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TECHNICAL CORRIGENDUM 1

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Information technology — Computer graphics and image processing — Image Processing and Interchange (IPI) — Functional specification —

Part 2:
Programmer's imaging kernel system application program interface

TECHNICAL CORRIGENDUM 1

Technologies de l'information — Infographie et traitement de l'image — Traitement de l'image et échange (IPI) — Spécification fonctionnelle —

Partie 2: Interface de programme d'application PIKS

RECTIFICATIF TECHNIQUE 1

Technical Corrigendum 1 to International Standard ISO/IEC 12087-2:1994 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology,* Subcommittee SC 24, *Computer graphics and image processing.*

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Page 63

Add the following note below Table 9:

For the Foundation profile, support 2 image resampling is limited to bilinear interpolation.

Page 90

Update the accumulator error codes: add 15; delete 12, 14, 24 and 44.

Page 98

Update the allocate_composite_identifier_array error codes: delete 12 and 14.

ICS 35.140 **Ref. No. ISO/IEC 12087-2:1994/Cor.1:1997(E)**

Descriptors: data processing, information interchange, graphic data processing, image processing, communication procedure, specifications, operating requirements.

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Page 99

Update the allocate_composite_identifier_list error codes: delete 12 and 14.

Page 104

Update the allocate_histogram error codes: delete 12 and 14.

Page 108

Update the allocate_image error codes: add 4, 16, 22, 42, 61 (for profiles < Scientific) and 101.

Page 110

Update the allocate_lut error codes: delete 12 and 14.

Page 112

Update the allocate_matrix error codes: add 101; delete 12, 14, 111 and 112.

Page 113

Replace remark with:

Remarks:

1. The array_size tuple contains parameters of the ND data type

2. The key_pixel tuple contains parameters of the SD data type

3. The scale factor shall be unity for BD, ND, RD and CD data type arrays

4. For SD data type arrays, the scale factor shall be used by implementations as an indirect means of specifying arrays with fractional elements. For example, in an implementation, an image could be convolved with an SD impulse response function array, and then be divided by the scale factor to achieve the equivalent of convolution with a fractional impulse response function array.

Page 114

Update the allocate_neighbourhood_array error codes: add 16, 22 and 42.

Page 116

Update the allocate_pixel_record error codes: add 16, 22 and 42.

Page 118

Update the allocate_roi error codes: add 1, 2, 3, 16, 22 and 42.

Page 120

Update the allocate_static_array error codes: add 16, 22 and 42.

Page 122

Update the allocate_tuple error codes: delete 12 and 14.

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Page 124

Update the allocate_value_bounds error codes: add 1, 101 and 102; delete 12 and 14.

Page 128

Update the alpha_blend_constant error codes: add 15 and 18.

Page 130

Update the alpha_blend_variable error codes: add 15, 18, 41, 45 and 47; delete 43.

Page 132

Update the array_to_lut error codes: delete 22, 42 and 121.

Page 134

Update the bind_match_point error codes: add 16, 22 and 42; delete 41.

Page 136

Update the bind_roi error codes: add 16 and 42; delete 41 and 43.

Page 139

Update the bit_shift error codes: add 15 and 18.

Page 144

Update the cartesian_to_polar error codes: add 15 and 45.

Page 160

Update the classifier_bayes error codes: add 15; delete 12, 14, 22, 42 and 48.

Page 164

Update the classifier_nearest_neighbour error codes: add 3 and 15; delete 12, 14, 22 and 42.

Page 165

Update the close_piks error codes: delete 302.

Page 170

Update the colour_conversion_linear error codes: add 15, 16, 18, 25 and 54.

Page 184

Update the colour_conversion_nonlinear error codes: add 15, 18 and 25.

Page 187

Update the colour_conversion_subtractive error codes: add 15, 25 and 104; delete 12 and 14.

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Page 191

Update the colour_lookup_interpolated error codes: add 15, 16 and 42; delete 25 and 101.

Page 193

In Nomenclature, replace the DST entry with:

DST(x,y,z,t,b) XxYxZxTxB destination image

Page 194

Update the complement and complement_roi error codes: add 15, 16, 18, 19, 24, 25 and 26; delete 21, 23 and 101.

Page 196

Update the complex_composition error codes: add 15, 18 and 25; delete 21 and 23.

Page 198

Update the complex_conjugate error codes: add 15, 18, 25 and 45; delete 21 and 23.

Page 200

Update the complex_decomposition error codes: add 15, 18 and 25; delete 21 and 23.

Page 202

Update the complex_magnitude error codes: add 15, 18 and 25; delete 21 and 23.

Page 204

Update the composite_identifier_array_equal error codes: add 22 and 28; delete 21 and 27.

Page 206

Update the composite_identifier_array_get error codes: add 16.

Page 214

Update the composite_identifier_list_get error codes: add 16.

Page 218

Update the composite_identifier_list_remove error codes: add 16.

Page 220

Update the composite_identifier_record_equal error codes: add 28; delete 27.

Page 222

Update the composite_identifier_record_get error codes: add 16.

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Page 226

Update the constant_predicate error codes: add 15 and 101.

Page 228

Update the convert_array_to_image error codes: add 16, 32 and 53; delete 42 and 43.

Page 229

In Objects, add BD to the SRC and DST data types as follows:

SRC data type:	BD, ND, SD, RD, CD
DST data type:	BD, ND, SD, RD, CD

Page 230

Replace remark 5 with:

5. Conversions from the CD to the BD, ND, SD and RD data types are not allowed.

Update the convert_image_datatype error codes: add 15 and 18; delete 41 and 43.

Page 232

Update the convert_image_to_array error codes: add 15, 31 and 40; delete 41 and 45.

Page 234

Update the convert_image_to_roi error codes: add 15 and 31; delete 44.

Page 236

Update the convert_roi_to_image error codes: add 16 and 32; delete 42.

Page 242

Update the convolve_2d error codes: add 15, 16, 22, 25, 42 and 43; delete 52.

Page 246

Update the convolve_5d error codes: add 15, 16, 18, 42 and 43; delete 52.

Page 247

Add the following remark.

3. For colour images, the band offset is zero and the band sizes are equal.

Page 249

Update the copy_window and copy_window_roi error codes: add 15, 16, 22, 26, 46 and 101; delete 41.

Page 251

In Parameters, move the data value parameters to the end of the parameter list.

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Page 252

Update the create_tuple error codes: add 24, 44 and 101; delete 22 and 42.

Page 255

Update the cross_correlation error codes: add 15 and 47; delete 12, 14, 24 and 44.

Page 257

Update the deallocate_data_object error codes: add 11 and 13.

Page 259

Replace remark with:

Remarks:

1. The parameter tuples contain parameters of the ND data type.
2. The sub-image does not inherit the ROI of the source image.
3. An ROI can be bound to a sub-image.

Page 260

In the definition, replace the DST equation with:

$$DST\,(x-x_0, y-y_0, z-z_0, t-t_0, b-b_0) = SRC(x,y,z,t,b)$$

Update the define_sub_image error codes: add 12, 14, 15, 16, 17, 22, 23, 42 and 45; delete 1 and 3.

Page 262

Update the difference_measures error codes: add 3, 15 and 43; delete 2.

Page 265

Update the diffuse error codes: add 15, 16, 18, 22, 42 and 43; delete 1.

Page 269

Update the dither error codes: add 15, 16, 18, 22, 42 and 43; delete 1.

Page 272

Update the draw_pixels and draw_pixels_roi error codes: add 23; delete 11, 12, 13 and 14.

Page 275

Update the dyadic_arithmetic error codes: add 15, 18, 23 and 43.

Page 279

Update the dyadic_complex error codes: add 15, 18, 23 and 45.

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Page 284

Update the dyadic_logical error codes: add 15, 18, 23 and 43.

Page 288

Update the dyadic_predicate error codes: add 15, 18 and 23.

Page 292

Update the edge_detection_orthogonal_gradient error codes: add 15, 16 and 18; delete 28.

Page 296

Update the edge_detection_second_derivative error codes: add 15, 16, 18 and 101.

Page 300

Update the edge_detection_template_gradient error codes: add 15, 16 and 18.

Page 302

Update the equal_predicate error codes: add 15 and 101.

Pages 305 and 306

Remove the overbars on H in the dilation equations.

Page 307

Update the erosion_dilation_boolean and erosion_dilation_boolean_roi error codes: add 15, 16, 18, 19 and 101; delete 41 and 43; reorder 3 and 2.

Page 313

Update the erosion_dilation_grey error codes: add 15, 16, 18, 43, 48 and 101.

Page 316

Update the error_function_scaling error codes: add 15, 18 and 45.

Page 321

Update the error_test error codes: delete 62 and 302.

Page 324

Update the export_histogram error codes: add 16; delete 24, 42 and 44.

Page 325

In Parameters, replace *data_type* with:

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data_type	destination data type option BI planar BI pixel interleaved NI Planar NI pixel interleaved SI planar SI pixel interleaved TI planar TI pixel interleaved RF planar RF pixel interleaved CF	SP	in

Page 326

Add remark 5 as follows:

5. The external data type option specifies whether colour images are stored in planar or pixel interleaved format.

Add the following after the current DST definition:

Image data exported from PIKS to an application is transferred as a one-dimensional array. This data is presented in planar or pixel interleaved form according to the following ordering.

Planar representation:	Pixel interleaved representation:
data(0,0,0,0,0),	data(0,0,0,0,0),
data(1,0,0,0,0),	data(1,0,0,0,0),
...,	...,
data(X,0,0,0,0),	data(B,0,0,0,0),
...,	...,
data(0,1,0,0,0),	data(0,1,0,0,0),
...,	...,
data(X,Y,0,0,0),	data(B,X,0,0,0),
...,	...,
data(0,0,1,0,0),	data(0,0,1,0,0),
...,	...,
data(X,Y,Z,0,0),	data(B,X,Y,0,0),
...,	...,
data(0,0,0,1,0),	data(0,0,0,1,0),
...,	...,
data(X,Y,Z,T,0),	data(B,X,Y,Z,0),
...,	...,
data(0,0,0,0,1),	data(0,0,0,0,1),
...,	...,
data(X,Y,Z,T,B)	data(B,X,Y,Z,T)

Page 327

Update the export_image error codes: add 15; delete 23, 41 and 43.

Page 330

Update the export_lut error codes: add 16; delete 24, 42 and 44.

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Page 332

Update the export_matrix error codes: add 16; delete 24, 42 and 44.

Page 334

Update the export_neighbourhood_array error codes: add 1, 16 and 101; delete 24, 42 and 44.

Page 336

Update the export_roi_array error codes: add 16; delete 24, 42 and 44.

Page 338

Update the export_static_array error codes: add 16; delete 24, 42 and 44.

Page 340

Update the export_tuple error codes: add 16; delete 24, 42 and 44.

Page 342

Update the export_value_bounds error codes: add 16; delete 24, 42 and 44.

Page 344

Update the extract_pixel_plane and extract_pixel_plane_roi error codes: add 12, 14, 15, 16, 18, 19 and 24; delete 11, 13, 23 and 41.

Page 347

Update the extrema error codes: add 15; delete 1, 12, 14, 24, 30, 44 and 50.

Page 350

Update the false_colour error codes: add 15, 16, 18 and 52.

Page 354

Update the fill_region error codes: add 15, 18, 45 and 101.

Page 357

Update the filter_butterworth error codes: add 16.

Page 360

Update the filter_gaussian error codes: add 16.

Page 363

Update the filter_inverse error codes: add 16.

Page 367

Update the filter_matched error codes: add 16 and 19; reorder 48 and 74.

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Page 371

Update the filter_wiener error codes: add 16 and 19.

Page 376

Update the filter_zonal error codes: add 16, 22 and 42.

Page 379

Update the filtering_homomorphic error codes: add 15, 16, 18, 43 and 45; delete 44.

Page 383

Update the filtering_linear error codes: add 15, 16, 18 and 45.

Page 388

Update the filtering_median error codes: add 15, 16 and 18.

Page 391

Update the filtering_pseudomedian error codes: add 15, 16, 18 and 43.

Page 396

Update the filtering_rank_order error codes: add 15, 16 and 18.

Page 399

Update the flip_spin_transpose and flip_spin_transpose_roi error codes: add 12, 14, 15, 16, 18, 19, 22, 24 and 26; delete 41 and 45.

Page 403

Update the gamma_correction error codes: add 15, 18 and 104; delete 103.

Page 406

Update the get_colour_pixel error codes: add 15; delete 62.

Page 408

Update the get_pixel and get_pixel_roi error codes: add 12, 14, 15 and 16; delete 11, 13 and 41.

Page 409

In Parameters, replace the jo and ko entries with:

jo	first index offset	SP	in
ko	second index offset	SP	in

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Replace remark with:

Remarks:

1. The data type of each array data value shall be of the same class as the source image.

2. If the array spatially extends over the J-K plane of the source image, the returned pixel values in the non-coincident region are set to zero for arithmetic data type images, and are set to FALSE for Boolean data type images.

Page 410

Update the get_pixel_array and get_pixel_array_roi error codes: add 15 and 16; delete 11, 12, 13, 14, 24, 41, 44, 62 and 112.

Page 412

Update the get_pixel_record and get_pixel_record_roi error codes: add 15 and 16; delete 11, 12, 13, 14, 24, 41, 44 and 62.

Page 416

Update the histogram_modification error codes: add 15 and 18.

Page 419

Update the histogram_scaling error codes: add 15 and 18.

Page 423

Update the histogram_shape_1d error codes: add 16; delete 24 and 44.

Page 428

Update the histogram_shape_2d error codes: add 16; delete 24 and 44.

Page 431

Update the histogram_1d error codes: add 15; delete 44.

Page 435

Update the histogram_2d error codes: add 15; delete 44.

Page 443

Update the hit_or_miss error and hit_or_miss_roi codes: add 12. 14, 15, 16, 18 and 19; delete 11, 13, 25, 41 and 43.

Page 448

Update the hough_transform error codes: add 15.

Page 451

Update the image_bar_chart error codes: add 16.

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Page 454

Update the image_constant error codes: add 16, 22, 23 and 42.

Page 456

Update the image_gaussian error codes: add 16, 22, 42 and 101.

Page 459

Update the image_grey_scale error codes: add 16, 22 and 42.

Page 462

Update the image_random_number error codes: add 16, 22, 23 and 42.

Page 464

Update the import_histogram error codes: add 16; delete 22, 42 and 44.

Page 465

In Parameters, replace the src_data_ type with:

src_data_type	source data type option BI planar BI pixel interleaved NI planar NI pixel interleaved SI planar SI pixel interleaved TI planar TI pixel interleaved RF planar RF pixel interleaved CF	SP	in

Page 466

Add remark 5 as follows:

5. The external data type option specifies whether colour images are stored in planar or pixel interleaved format.

Add the following after the current DST definition:

Image data exported from PIKS to an application is transferred as a one-dimensional array. This data is presented in planar or pixel interleaved form according to the following ordering.

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Planar representation:	Pixel interleaved representation:
data(0,0,0,0,0),	data(0,0,0,0,0),
data(1,0,0,0,0),	data(1,0,0,0,0),
...,	...,
data(X,0,0,0,0),	data(B,0,0,0,0),
...,	...,
data(0,1,0,0,0),	data(0,1,0,0,0),
...,	...,
data(X,Y,0,0,0),	data(B,X,0,0,0),
...,	...,
data(0,0,1,0,0),	data(0,0,1,0,0),
...,	...,
data(X,Y,Z,0,0),	data(B,X,Y,0,0),
...,	...,
data(0,0,0,1,0),	data(0,0,0,1,0),
...,	...,
data(X,Y,Z,T,0),	data(B,X,Y,Z,0),
...,	...,
data(0,0,0,0,1),	data(0,0,0,0,1),
...,	...,
data(X,Y,Z,T,B)	data(B,X,Y,Z,T)

Page 467

Update the import_image error codes: add 15; delete 41, 43 and 61.

Page 470

Update the import_lut error codes: delete 22 and 42.

Page 472

Update the import_matrix error codes: delete 22 and 42.

Page 474

Update the import_neighbourhood_array error codes: add 16.

Page 476

Update the import_roi_array error codes: add 16.

Page 478

Update the import_static_array error codes: add 16.

Page 479

Delete remark 2.

Page 480

Update the import_tuple error codes: delete 22, 42 and 44.

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Page 482

Update the import_value_bounds error codes: add 102; delete 22 and 42.

Page 485

Update the impulse_boxcar error codes: add 16, 22 and 42.

Page 489

Update the impulse_derivative_of_gaussian error codes: add 16, 22 and 42.

Page 493

Update the impulse_difference_of_gaussians error codes: add 16, 22 and 42.

Page 497

Update the impulse_elliptical error codes: add 16, 22 and 42.

Page 500

Update the impulse_gaussian error codes: add 16, 22 and 42.

Page 502

Update the impulse_laplàcian_of_gaussian error codes: add 16, 22 and 42.

Page 505

Update the impulse_pyramid error codes: add 16, 22 and 42.

Page 508

Update the impulse_rectangular error codes: add 16, 22 and 42; delete 111 and 112.

Page 511

Update the impulse_sinc error codes: add 16, 22 and 42.

Page 514

Update the input_object error codes: add 11; delete 1, 14, 42, 44 and 62.

Page 528

Add the following remark.

4. If a non-image data object parameter has not been set prior to an inquiry, an indication of this state is returned to the application.

Page 529

In the Lookup table, replace "table size" with "table entries".

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Page 530

In ROI elliptical, replace:

ellipse dimension	EP

with:

index manipulate 5-tuple	ID
ellipse dimension code	EP
2D	
3D	
4D	
5D	

In ROI polygon, insert the following between the array entries and polarity code lines:

index manipulate 5-tuple	ID

In ROI rectangular, insert the following between the end position 5-tuple and rectangle dimension code lines:

index manipulate 5-tuple	ID

Page 546

Update the insert_pixel_plane and insert_pixel_plane_roi error codes: add 15, 16, 18, 23 and 45; delete 21, 41 and 43.

Page 549

Update the label_objects error codes: add 16 and 18.

Page 553

Update the laws_texture_features error codes: add 15, 16 and 18.

Page 556

Update the level_slice error codes: add 15 and 18.

Page 561

Update the line_profile error codes: add 15, 16, 22, 42 and 62; delete 24 and 44.

Page 565

Update the lookup error codes: add 15, 16, 18, 21, 23, 52 and 53; delete 42 and 43.

Page 569

Update the lookup_interpolated error codes: add 15, 16, 18, 21, 23, 52; delete 42 and 43.

Page 573

Update the luminance_generation error codes: add 15, 18 and 43.

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Page 576

Update the markov_spectrum error codes: add 16, 22 and 42.

Page 578

Update the moments error codes: add 15.

Page 581

Update the monadic_arithmetic error codes: add 15, 18 and 43.

Page 585

Update the monadic_complex error codes: add 15, 18 and 45.

Page 590

Update the monadic_logical and monadic_logical_roi error codes: add 12, 14, 15, 16, 18, 19, 26, 42, 43 44 and 46; delete 11, 13, 25, 41 and 45.

Page 592

Add the following remarks:

4. The pixel stacker neighbourhood lies totally within the J-K pixel plane.

5. The first and last rows and columns of the destination image are set to FALSE.

Page 593

In the Morphic processor conceptual model, replace "Bit 1" with "MSB" and replace "Bit 9" with "LSB".

Update the morphic_processor and morphic_processor_roi error codes: add 15, 16, 18,19, 23, 24 and 26; delete 11, 13, 25, 41 and 43.

Page 600

Update the morphology and morphology_roi error codes: add 12, 14, 15, 16, 18, 19, 24 and 26; delete 11,13, 25, 41 and 43.

Page 609

Update the neighbour_count error codes: add 15,16 and 18.

Page 613

Update the noise_combination error codes: add 15 and 18.

Page 617

Update the open_close and open_close_roi error codes: add 15, 16, 18 and 19; delete 25, 41, 45 and 101.

Page 620

Update the open_piks error codes: add 62.

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Page 622

Update the outlier_removal error codes: add 15, 16 and 18.

Page 624

Update the output_object error codes: add 11, 13, 15, 16 and 62; delete 25, 26 and 46.

Page 628

Update the paint_pixels error codes: add 15, 16 and 18.

Page 632

Update the perimeter_code_generator error codes: add 15; delete 12, 14, 24 and 44.

Page 636

Update the polar_to_cartesian error codes: add 15 and 45.

Page 638

Update the power_law_scaling error codes: add 15.

Page 640

Update the pseudocolour error codes: add 15, 16, 18 and 52; delete 28 and 172.

Page 644

Update the put_pixel and put_pixel_roi error codes: add 12 and 14; delete 11, 13 and 43.

Page 645

In Parameters, replace the jo and ko entries with:

jo	first index offset	SP	in
ko	second index offset	SP	in

Add the following remark section:

Remark:

If the array spatially extends over the J-K plane of the source image, the pixel values of the non-coincident region are not recorded in the source image.

Page 646

Update the put_pixel_array and put_pixel_array_roi error codes: delete 11, 12, 13, 14, 22, 42 and 43.

Page 647

Replace the Name section with:

put_pixel_record put_pixel_record_roi

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Page 648

Update the put_pixel_record and put_pixel_record_roi error codes: delete 11, 12, 13, 14, 22, 42 and 43.

Page 652

Update the rescale and rescale_roi error codes: add 15, 16, 22, 24 and 42; delete 1, 11 and 13.

Page 655

Update the resize and resize_roi error codes: add 15, 16, 22, 24 and 42; delete 11 and 13.

Page 661

Update the roi_coordinate error codes: add 2 and 16; delete 44.

Page 664

Add the following remark.

6. The *index_manipulate* tuple contains parameters of the CS data type.

Page 666

Update the roi_elliptical error codes: add 16, 22 and 42; delete 44.

Page 667

Replace remark 4 with:

4. The *roi_size* tuple contains parameters of the ND data type.

Page 668

Add the following remark.

6. The *index_manipulate* tuple contains parameters of the CS data type.

Update the roi_polygon error codes: add 2 and 16; delete 44.

Page 670

In Nomenclature, make the following substitutions:

From:	To:
je > js	je ≥ js
ke > ks	ke ≥ ks
le > ls	le ≥ ls
me > ms	me ≥ ms
ne > ns	ne ≥ ns

Replace remark 3 as follows:

3. The *roi_size, start_position* and *end_position* tuples contain parameters of the ND data type.

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Add the following remark.

5. The *index_manipulate* tuple contains parameters of the CS data type.

Page 672

Update the roi_rectangular error codes: add 16, 22 and 42; delete 44.

Page 674

In remark 2, add the following to the beginning of the sentence: "In the 2D case, 'rotation...'".

Page 675

In the definition:, switch signs before all SIN functions, i.e. -SIN instead of SIN and SIN instead of -SIN.

Page 676

Update the rotate and rotate_roi error codes: add 12, 14, 15 and 16; delete 25, 41 and 45.

Page 678

Update the rubber_band_scaling error codes: add 15 and 43.

Page 682

Update the sequence_average error codes: add 1 and 3; delete 21.

Page 685

Update the sequence_karhunen_loeve error codes: add 15, 16 and 18.

Page 690

Update the sequence_running_measures error codes: add 12, 15, 16 and 23; delete 21, 25 and 173.

Page 697

In the definition, replace the first sentence with:

This mechanism performs the following functions only for attributes that are NULL:

Update the set_image_attributes error codes: add 4, 5, 12, 14, 16, 22, 42 and 101.

Page 701

Update the set_index_assignment error codes: delete 12, 14, 24 and 44.

Page 708

Update the shape_metrics error codes: add 15; delete 12, 14, 24 and 44.

Page 712

Update the spatial_moments_invariant error codes: add 15; delete 12 14 24 and 44.

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Page 716

Update the spatial_moments_scaled error codes: add 15; delete 12, 14, 24 and 44.

Page 719

Update the split_image error codes: add 15, 18 and 23.

Page 722

In the definition, replace:

$$\text{jd} \leq \text{j} \leq \text{MIN}\{ J_S - 1, J_M \}$$

$$\text{kd} \leq \text{k} \leq \text{MIN}\{ K_S - 1, K_M \}$$

with:

$$\text{jd} \leq \text{j} \leq \text{MIN}\{ J_D - 1, jd + J_M - 1 \}$$

$$\text{kd} \leq \text{k} \leq \text{MIN}\{ K_D - 1, kd + k_M - 1 \}$$

Update the subsample and subsample_roi error codes: add 15 and 16; delete 25, 41 and 45.

Page 723

Update the synchronize error codes: delete 302.

Page 727

Update the template_match error codes: add 15, 16 and 18; delete 12, 14, 24 and 43.

Page 731

Update the threshold error codes: add 15 and 18 error codes: delete 43.

Page 735

Update the transform_cosine error codes: add 15 and 18.

Page 740

Update the transform_fourier error codes: add 15 and 18.

Page 743

Update the transform_hadamard error codes: add 15 and 18.

Page 747

Update the transform_hartley error codes: add 15 and 18.

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Page 751

Update the translate and translate_roi error codes: add 12, 14, 15, 16, 18, 19, 22, 24 and 42; delete 11, 13, 25, 41 and 45.

Page 754

Update the unary_integer error codes: add 15 and 18.

Page 758

Update the unary_real error codes: add 15 and 18.

Page 759

In Parameters, replace the w1, w2 and bf parameter entries with the following:

w1	first weight factor	RP	in
w2	second weight factor	RP	in
bf	BIAS factor	RP	in

Page 761

Update the unsharp_mask error codes: add 15, 16 and 18.

Page 764

Update the value_bounds error codes: add 15, 18 and 43.

Page 769

In Parameters, substitute the *conditional* entry in the parameter listing with:

branch	logical flag for branch control	BP	in
return	logical flag for return control	BP	in

In the definition, replace the first sentence of the third paragraph with:

The conditional branch and return flags control the reaction to the conditional tests.

Page 781

In Objects:, replace the DST data type entry with:

DST data type	SD, RD

Page 782

Replace the equation for *D(j,k,l,m,n,)* with the following:

$$D(j,k,l,m,n) = [S(j,k,l,m,n) - A(j,k,l,m,n)] \left[\frac{(g)(v)}{(g)[V(j,k,l,m,n)] + v} \right] + [(p)(a) + (1 - p)[A(j,k,l,m,n)]]$$

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Page 783

Update the wallis_statistical_differencing error codes: add 15, 16 and 18.

Page 788

Update the warp_control_point and warp_control_point_roi error codes: add 15 and 16; delete 11, 12, 13, 14, 22, 28, 41, 42 and 45.

Page 790

Update the warp_lut and warp_lut_roi error codes: add 15 and 16; delete 11, 13, 25, 28, 41, 45 and 48.

Page 793

Update the warp_polynomial and warp_polynomial_roi error codes: add 1, 15 and 16; delete 11, 12, 13, 14, 22, 25, 28, 41, 42, 45 and 48.

Page 797

Update the windowing_function error codes: add 12, 16, 22 and 42.

Page 801

Update the window_level error codes: add 15 and 18.

Page 805

Update the window_statistics error codes: add 15 and 18.

Page 808

Update the z-merge error codes: add 15 and 18.

Page 811

Update the zoom and zoom_roi error codes: add 15, 16, 22 and 42; delete 1, 11, 13, 25, 41 and 45.

Page 816

Update the 3d_slice error codes: add 15 and 23; delete 25.

Pages 917-920

Add the following error codes to the corresponding location in the listing:

4
Cause: Incompatible attributes specified.
Reaction: Issue warning and continue execution.

5
Cause: Attempt to change existing attributes not accepted.
Reaction: Issue warning and continue execution.

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15
Cause: Source image does not contain data.
Reaction: Abort operation and issue warning.

16
Cause: Source non-image object does not contain data.
Reaction: Abort operation and issue warning.

17
Cause: Attempt to change image identifier of existing sub-image.
Reaction: Abort operation and issue warning.

18
Cause: Mismatch between source and destination image sizes.
Reaction: Abort operation and issue warning.

19
Cause: Mismatch between source and destination non-image sizes.
Reaction: Abort operation and issue warning.

31
Cause: Mismatch between source image and destination non-image structure.
Reaction: Abort operation and issue warning.

32
Cause: Mismatch between source non-image and destination image structure.
Reaction: Abort operation and issue warning.

40
Cause: Mismatch between source image and destination non-image data type.
Reaction: Abort operation and issue warning.

56
Cause: Mismatch between source image and destination image colour spaces.
Reaction: Abort operation and issue warning.

104
Cause: Source image contains pixel of negative amplitude.
Reaction: Abort operation and issue warning.

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INTERNATIONAL STANDARD

ISO/IEC 12087-2

First edition
1994-08-01

Information technology — Computer graphics and image processing — Image Processing and Interchange (IPI) — Functional specification —

Part 2:
Programmer's imaging kernel system application program interface

Technologies de l'information — Infographie et traitement de l'image — Traitement de l'image et échange (IPI) — Spécification fonctionnelle —

Partie 2: Interface de programme d'application PIKS

Reference number
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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

International Standard ISO/IEC 12087-2 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 24, *Computer graphics and image processing*.

ISO/IEC 12087 consists of the following parts, under the general title *Information technology — Computer graphics and image processing — Image processing and interchange (IPI) — Functional specification*:

— *Part 1: Common architecture for imaging*

— *Part 2: Programmer's imaging kernel system application program interface*

— *Part 3: Image Interchange Facility*

Annexes A, G, H and J form an integral part of this part of ISO/IEC 12087. Annexes B, C, D, E, F, K and L are for information only.

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Information technology — Computer graphics and image processing — Image Processing and Interchange (IPI) — Functional specification —

Part 2:
Programmer's imaging kernel system application program interface

1 Scope

This part of ISO/IEC 12087 establishes the specification of the application program interface (API), called the Programmer's Imaging Kernel System (PIKS). ISO/IEC 12087-1 establishes the conceptual and architectural definitions of the Common Architecture for Imaging (CAI). ISO/IEC 12087-3 establishes the specification of the Image Interchange Facility (IIF).

PIKS is intended to provide a rich set of both low-level and high-level services on image and image-derived data objects. These services can be used as building blocks for a broad range of common imaging applications.

A conscious effort has been made by the developers of PIKS to create a standard that does not favor any particular computing system. Implementations of PIKS should be possible on computing systems ranging in architecture from general purpose computers to specialised hardware accelerators, ranging in size from personal computers to mainframe supercomputers, and ranging in connectivity from stand-alone machines to distributed computing networks.

Where applicable, PIKS relies on other APIs and data format standards to provide capabilities that are not unique to imaging. The following lists contain a summary of technological capabilites provided by PIKS and not provided by PIKS. However, it should be noted that PIKS functionality may be useful as a pre-processor or co-processor for many of the technologies in the "Not provided by PIKS" list.

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Provided by PIKS

image analysis
image classification (basic)
image enhancement
image interchange between PIKS and an application
image interchange between PIKS and the IIF
image manipulation primitives
image processing data object generation tools (e.g., image filter functions)
image restoration
image visualization (basic)
standard colour models

Not provided by PIKS

audio
computer graphics
device control
image acquisition
image communication
image compression and decompression
image display
image transport between applications
image understanding
multimedia
pattern recognition
specific implementations
video
window systems

NOTE – The Image Interchange Facility of ISO/IEC 12087-3 specifies image compression and decompression functionality and image transport between applications and between an application and PIKS.

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2 Normative references

The following standards contain provisions which, through references in this text, constitute provisions of this part of the ISO/IEC 12087. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO/IEC 12087 are encouraged to investigate the possibility of applying the most recent standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO/IEC 12087-1:—[1)], *Information technology — Computer graphics and image processing — Image Processing and Interchange (IPI) — Functional specification — Part 1: Common Architecture for Imaging.*

ISO/IEC 12087-3:—[1)], *Information technology — Computer graphics and image processing — Image Processing and Interchange (IPI) — Functional specification — Part 3: Image Interchange Facility.*

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3 Symbols and abbreviations

The following are symbols and abbreviations utilized in this standard. The mathematical functions are defined in Annex A.

0D	zero-dimensional
1D	one-dimensional
2D	two-dimensional
3D	three-dimensional
4D	four-dimensional
5D	five-dimensional
ACOS	arc cosine function
AND	logical AND operator
API	Application Program Interface
ASIN	arc sine function
ASSIGN	index assignment function between image and operator input indices
ASN.1	abstract syntax notation one
ATAN	arc tangent function
ATAN2	arc tangent ratio function
b	spectral band index of an image
B	image spectral band size
BD	Boolean data type (PIKS internal)
BER	basic encoding rules
BI	external Boolean pixel data type
BITEXT	bit extraction function
BITINS	bit insertion function
BP	Boolean data type (PIKS parameter)
CAI	Common Architecture for Imaging
CAS	Hartley cas function
CCIR	Comite Consultatif International des Radiocommunications
CD	complex arithmetic data type (PIKS internal)
CF	external complex floating point pixel data type
CHAIN	chain data object
CHOICE	choice function

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CIE	Commission Internationale de l'Eclairage
COLR	colour image
CONJ	complex conjugate function
COS	cosine function
CP	complex arithmetic data type (PIKS parameter)
CS	character string data type
D	single operator output image
DET	determinant of matrix argument
DOB	destination non-image object
Dq	q-th operator output image, $1 \leq q \leq Q$
DST	single destination image
DSTq	q-th destination image, $1 \leq q \leq Q$
EBU	European Broadcasting Union
EP	enumerated parameter
ERF	Gaussian error function
EXP	exponential function
EXT	external data type
GEN	generic image
HIST	histogram data object
i	square root of minus one, $i = \sqrt{-1}$
ID	data object identifier (PIKS internal)
ID_ARRAY	composite image identifier array
ID_LIST	composite image identifier list
ID_RECORD	composite image identifier record
IEC	International Electrotechnical Commission
IEEE	Institute Electrical and Electronic Engineers
IIF	Image Interchange Facility
IMAG	imaginary part of complex number argument function
in	input parameter
IP	data object identifier (PIKS parameter)
IPI	Image Processing and Interchange
ISO	International Organisation for Standardisation

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j	first operator index
J	first operator index size
k	second operator index
K	second operator index size
l	third operator index
L	third operator index size
LIV	lowest integer value of argument function
LOG	base e natural logarithm function
LOOK	lookup table function
LUT	lookup table data object
m	fourth operator index
M	fourth operator index size
MATRIX	matrix data object
MAX	maximum of argument sequence function
MIN	minimum of argument sequence function
MOD	modulus function
MON	monochrome image
n	fifth operator index
N	fifth operator index size
NA	not applicable
NAND	logical NAND operator
NBHOOD_ARRAY	neighbourhood array data object
ND	non-negative integer data type (PIKS internal)
NI	external non-negative integer pixel data type
NIV	nearest integer value of argument function
NOR	logical NOR operator
NOT	logical NOT operator
NP	non-negative integer data type (PIKS parameter)
NTSC	National Television Systems Committee
NULL	null data type
OR	logical OR operator
out	output parameter

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PIKS	Programmer's Imaging Kernel System
PIXEL_RECORD	pixel record data object
POW	power law function of two arguments
RD	real arithmetic data type (PIKS internal)
REAL	real part of complex number argument function
REASSIGN	index reassignment function between operator output and image indices
RES_1	one-dimensional resampling function
RES_2	two-dimensional resampling function
RES_3	three-dimensional resampling function
RES_4	four-dimensional resampling function
RES_5	five-dimensional resampling function
RF	external real floating point pixel data type
ROI	Region-of-Interest
ROI_ARRAY	array Region-of-Interest data object
ROI_COORD	coordinate collection Region-of-Interest data object
ROI_ELLIP	elliptical Region-of-Interest data object
ROI_GEN	generic Region-of-Interest data object
ROI_POLY	polygon Region-of-Interest data object
ROI_RECT	rectangular Region-of-Interest data object
ROID	Region-of-interest of destination image
ROIDq	Region-of-interest of q-th destination image, $1 \leq q \leq Q$
ROIS	Region-of-interest of source image
ROISp	Region-of-interest of p-th source image, $1 \leq p \leq P$
RP	real arithmetic data type (PIKS parameter)
S	single operator input image
SD	signed integer data type (PIKS internal)
SI	signed integer number
SIN	sine function
SMPTE	Society of Motion Picture and Television Engineers
SOB	source non-image object
SORT	sort function
Sp	p-th operator input image, $1 \leq p \leq P$

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SP	signed integer data type (PIKS parameter)
SPE	spectral image
SRC	single source image
SRCp	p-th source image, $1 \leq p \leq P$
STATIC_ARRAY	static array data object
t	temporal index of an image
T	image temporal size
TAN	tangent function
TEM	temporal image
TC	temporal-color image
TI	two's complement fixed point integer number
TS	temporal-spectral image
TUPLE	tuple data object
VALUE_BOUNDS	value bounds collection data object
VOL	volume image
VC	volume-colour image
VREG	virtual register data object
VS	volume-spectral image
VT	volume-temporal image
VTC	volume-temporal-colour image
VTS	volume-temporal-spectral image
x	horizontal index (along rows) of an image
X	image horizontal size (image width)
XOR	exclusive OR operator
y	vertical index (along columns) of an image
Y	image vertical size (image height)
z	depth index of an image
Z	image depth size
$\cap$	boolean intersection symbol
$\cup$	boolean union symbol
$\overline{[.]}$	overbar indicates complement of boolean argument
$\lvert[.]\rvert$	vertical lines indicate magnitude of arithmetic argument

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$[.]^T$	superscript T indicates matrix transpose
+	plus or positive symbol
−	minus or negative symbol
×	multiply symbol
/	arithmetic divide symbol
÷	integer divide symbol
⊕	logical AND symbol
⊖	logical OR symbol
⊗	logical XOR symbol
⊛	convolution symbol
⊞	morphological dilation symbol
⊟	morphological erosion symbol
Σ	sequence summation symbol
Π	sequence product symbol
M	sequence maxima symbol
N	sequence minima symbol
∪	sequence union symbol
∩	sequence intersection symbol

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4 Programmer's Imaging Kernel System specification

This clause establishes the specification of the Programmer's Imaging Kernel System (PIKS) application program interface.

4.1 PIKS imaging model

Figure 1 describes the PIKS imaging model. The solid lines indicate data flow and the dashed lines indicate control flow. The PIKS application program interface consists of four major parts:

- data objects
- operators, tools, and utilities
- system mechanisms
- import and export

The PIKS data objects are specified in ISO/IEC 12087-1. They include both image and non-image data objects. The operators, tools, and utilities are functional elements that are used to process images or data objects extracted from images. The system mechanisms manage and control the processing. PIKS receives information from the application to invoke its system mechanisms, operators, tools, and utilities, and returns certain status and error information to the application. The import and export facility provides the means of accepting images and image-related data objects from an application, and for returning processed images and image-related data objects to the application. PIKS can transmit its internal data objects to an external facility through the Image Interchange Facility (IIF) specified in ISO/IEC 12087-3. Also, PIKS can receive data objects in its internal format, which have been supplied by the IIF. PIKS can operate independently of the IIF.

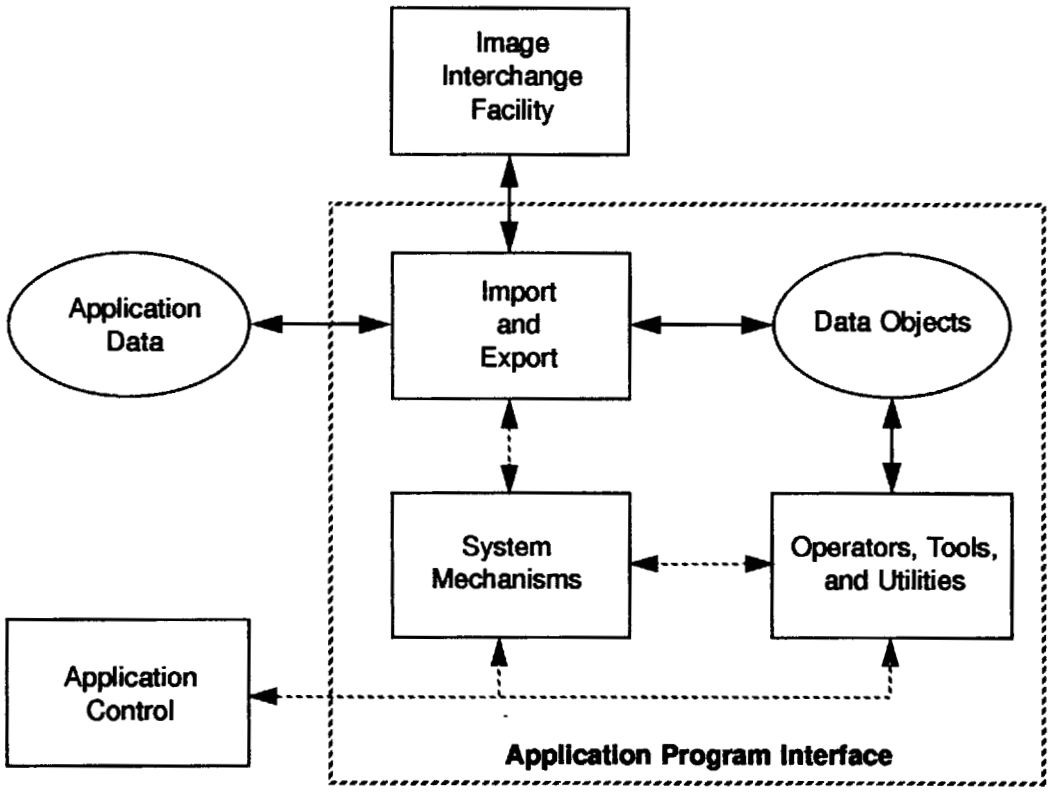

Figure 1 – PIKS imaging model

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4.1.1 Image data objects

ISO/IEC 12087-1 describes the image data objects supported by PIKS. This subclause summarizes this information and establishes notation used in this part of ISO/IEC 12087.

As specified in ISO/IEC 12087-1, PIKS supports a general five-dimensional image object with ordered indices

$$0 \leq x \leq X - 1$$

$$0 \leq y \leq Y - 1$$

$$0 \leq z \leq Z - 1$$

$$0 \leq t \leq T - 1$$

$$0 \leq b \leq B - 1$$

where x is the horizontal index, y is the vertical index, z is the depth index, t is the time index, and b is the band index. The characters X, Y, Z, T, B represent the maximum sizes of the image coordinates x, y, z, t, b, respectively.

NOTE – Some of the image dimensions may be unpopulated, e.g., for a monochrome image, Z = 1, T = 1 and B = 1.

A two-dimensional pixel array involving only two indices is called a pixel plane. A pixel plane involving the x-y indices is called a x-y pixel plane. Conceptually, a five-dimensional image object can be considered to be organized as a set of depth, time, and band x-y pixel planes.

NOTE – PIKS operators are able to access and process arbitrary pixel planes.

In this part of ISO/IEC 12087, a single source image is expressed notationally as a five-dimensional array

SRC(x, y, z, t, b)

and the p-th source image in a set of P images is expressed notationally as

SRCp(x, y, z, t, b)

where $1 \leq p \leq P$.

NOTE – In general, source images can be of different sizes.

In this part of ISO/IEC 12087, a single destination image is expressed notationally as a five-dimensional array

DST(x, y, z, t, b)

and the q-th destination image in a set of Q images is expressed notationally as

DSTq(x, y, z, t, b)

where $1 \leq q \leq Q$.

NOTE – In general, source and destination images can be of different sizes. However, some PIKS operators require that source and destination images be of the same size, e.g., the Fourier transform operator.

PIKS gives semantic meaning to certain dimensional subsets of a general five-dimensional image object. These are listed in Table 1. Definitions of these image objects are presented in ISO/IEC 12087-1.

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Table 1 – PIKS image objects

Semantic description	image indices	code
monochrome	x, y, 0, 0, 0	MON
volume	x, y, z, 0, 0	VOL
temporal	x, y, 0, t, 0	TEM
colour	x, y, 0, 0, b	COLR
spectral	x, y, 0, 0, b	SPE
volume-temporal	x, y, z, t, 0	VT
volume-colour	x, y, z, 0, b	VC
volume-spectral	x, y, z, 0, b	VS
temporal-colour	x, y, 0, t, b	TC
temporal-spectral	x, y, 0, t, b	TS
volume-temporal-colour	x, y, z, t, b	VTC
volume-temporal-spectral	x, y, z, t, b	VTS
generic	x, y, z, t, b	GEN

NOTE – The generic category represents images whose indices do not have any semantic meaning. For notational consistency, the generic image uses the same index notation as the semantic categories.

As specified in ISO/IEC 12087-1, PIKS supports the following abstract data types for the internal representation of image pixels.

Code	Data type
BD	Boolean
ND	non-negative integer
SD	signed integer
RD	real arithmetic
CD	complex arithmetic

All image pixels accessed by the x, y, z, t indices shall be of the same pixel data type. The pixel data type may differ between bands. An image whose pixels are of different data types across bands is called a heterogeneous band image.

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A PIKS implementation shall be free to provide any form of physical representation of the image pixel data types provided that the physical representation satisfies the abstract data type definitions, as specified in ISO/IEC 12087-1. The minimum levels of storage precision for the ND, SD, RD, and CD pixel types shall be

ND 8 bits per pixel

SD 16 bits per pixel

RD 32 bits per pixel

CD 32 bits per real component and per imaginary component per pixel

4.1.2 Non-image data objects

ISO/IEC 12087-1 describes the non-image data objects supported by PIKS. This subclause summarizes this information and establishes notation used in ISO/IEC 12087-2.

PIKS supports the following internal, non-image data objects, which are defined in ISO/IEC 12087-1:

Code	Name
CHAIN	chain
HIST	histogram
ID_ARRAY	composite identifier array
ID_LIST	composite identifier list
ID_RECORD	composite identifier record
LUT	lookup table
MATRIX	matrix
NBHOOD_ARRAY	neighbourhood array
PIXEL_RECORD	pixel record
ROI_ARRAY	region-of-interest, array
ROI_COORD	region-of-interest, coordinate collection
ROI_ELLIP	region-of-interest, elliptical
ROI_GEN	region-of-interest, generic
ROI_POLY	region-of-interest, polygon
ROI_RECT	region-of-interest, rectangular
STATIC_ARRAY	static array
TUPLE	tuple
VALUE_BOUNDS	value bounds collection
VREG	virtual register

Non-image data objects that are created by PIKS elements and returned directly to an application are not regarded as PIKS non-image data objects. The data structures of directly-returned non-image data objects are defined by the elements providing the return. Collectively, such data objects are called external data objects, and are referenced by the code EXT.

In this part of ISO/IEC 12087, a single source non-image data object is expressed notationally as SOB, and the p-th source non-image data object in a set of P objects is expressed as SOBp where $1 \leq p \leq P$. In this standard, single destination non-image data object is expressed notationally as DOB, and the q-th destination non-image data object in a set of Q objects is expressed as DOBq where $1 \leq q \leq Q$.

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4.1.3 Data object creation

PIKS source and destination data objects that are referenced by an operator, tool, or utility shall be allocated by a system management allocation mechanism, as described in 4.4, prior to the invocation of an operator, tool, or utility. There are three classes of allocated data objects:

Class A - identified with object attributes and data;

Class B - identified with object attributes only;

Class C - identified only

When an image is allocated, an identifier is assigned to the image data object by the PIKS implementation. The image allocation mechanism allows an application to specify certain image attributes, such as size, structure, and colour space, upon allocation, or to leave the attributes unspecified. When a class C data object is specified as a destination, many of the PIKS operators, tools, and utilities will supply the "missing" data object attributes.

NOTE – A PIKS implementation may reserve data storage for a Class B data object at the time that the data object is allocated, or the implementation may defer data storage reservation until the time that the data for a data object is first available.

4.2 PIKS operators, tools, data object repository, utilities, and system mechanisms

This subclause establishes the general specification of the PIKS operators, tools, data object repository, utilities, and system mechanisms.

4.2.1 Operators

PIKS operators are functional elements that perform manipulations of images or of data objects extracted from images in order to enhance images, restore images, or to assist in the extraction of information from images. Operators can be classified as being primitive or high-level operators. Primitive operators are a small set of low-level operators, fundamental to image processing, which can be used to implement high-level operators. Examples are image convolution and image histogram generation. High-level operators are operators of greater complexity. Examples are adaptive histogram equalization and Hough transform.

NOTE – There is no requirement in the PIKS specification that high-level operators shall be constructed from primitive operators.

Another form of operator classification is by functionality, e.g., operators that perform geometric manipulations such as rotate or operators that detect image edges. Table 2 contains a list of the PIKS operators arranged by functionality class. These operators are specified in clause 7.

Still another form of operator classification, as listed below, is by the types of source and destination objects supported by an operator.

Source	Destination
non-image	non-image
image	non-image
image	image

NOTE – PIKS does not provide any non-image to image operators. PIKS does provide several image generation tools.

Table 2 indicates the type of source and destination objects supported by each functional class of operators.

--`,,`-`-`,,`,,`,`,,`---

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PIKS operators that have an image as a source data object can also be classified by their neighbourhood processing dimensionality as defined below.

0D A zero-dimensional operator is one that operates on each pixel of a source image independently of its neighbouring pixels. An example is taking the logarithm of a spectral image.

1D A one-dimensional operator is one that operates on a group of pixels along one dimension of an image. An example is a one-dimensional moving window average along the rows of a monochrome image. Another example is a one-dimensional Fourier transform along the columns of a monochrome image.

2D A two-dimensional operator is one that operates on a group of pixels along two dimensions of an image. An example is erosion of a monochrome image with a two-dimensional morphological structuring element.

3D A three-dimensional operator is one that operates on a group of pixels along three dimensions of an image. An example is convolution of a volume image with a three-dimensional impulse response function array.

4D A four-dimensional operator is one that operates on a group of pixels along four dimensions of an image. An example is computation of the four-dimensional Fourier transform of a volume-temporal image.

5D A five-dimensional operator is one that operates on a group of pixels along five dimensions of an image. An example is computation of the extrema pixels of a five-dimensional image.

NOTES

1 – By this form of operator classification, the neighbourhood need not be compact. Also, the neighbourhood may contain all of the pixels along an image dimension.

2 – In subsequent clauses, an "rD" operator is called an operator of order r. The words "dimensional" and "dimension" are reserved, whenever possible, for image descriptors.

Annexes B to F contain alphabetical listings of PIKS elements with indications of the supported image structure, image data type, operator order, and element functionality.

4.2.2 Tools

PIKS tools are elements that create data objects to be used by PIKS operators. Examples are the generation of test images, the creation of impulse response function arrays, and the generation of Region-of-Interest objects.

Table 3 contains a list of PIKS tools. The PIKS tools are specified in clause 7.

4.2.3 Data object repository

Many data objects are routinely used by operators. An example is the set of Sobel edge detection horizontal and vertical edge gradient impulse response function arrays. PIKS provides a repository of commonly used data objects. Annex G contains a specification of the PIKS data object repository.

The data object repository contains three types of data:

impulse response function arrays
dither arrays
colour conversion matrices

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4.2.3.1 Impulse response function arrays

Impulse response function arrays in the data object repository are commonly-used instantiations of two-dimensional neighbourhood array data objects. In the repository, each array is specified according to the following general form:

$$\frac{1}{S}\begin{bmatrix} H(0,0) & H(1,0) & \ldots H(C-1,0) \\ \vdots & \vdots & \vdots \\ H(0,r) & H(1,r) & \ldots H(C-1,r) \\ \vdots & \vdots & \vdots \\ H(0,R-1) & H(1,R-1) & \ldots H(C-1,R-1) \end{bmatrix}$$

where S is a scale factor.

NOTES

1 – The impulse response function arrays are specified with signed integer scale factors and signed integer array terms. The physical storage data format is implementation dependent.

2 – The impulse response array indexing is the same as the indexing of a two-dimensional image array.

4.2.3.2 Dither arrays

Dither arrays in the data object repository are commonly-used instantiations of two-dimensional neighbourhood array data objects. In the repository, each dither array is specified according to the same general form as an impulse response function array.

4.2.3.3 Colour conversion matrices

Colour conversion matrices in the data object repository are commonly-used instantiations of matrix data objects. In the repository, each 3x3 matrix is specified according to the following general form:

$$\begin{bmatrix} T(1,1) & T(1,2) & T(1,3) \\ T(2,1) & T(2,2) & T(2,3) \\ T(3,1) & T(3,2) & T(3,3) \end{bmatrix}$$

All colour conversion matrices are specified for the transformation of an input column vector to an output column vector.

NOTES

1 – ISO/IEC 12087-1 defines the colour spaces and associated chromaticity coordinates and white points used to generate each colour conversion matrix.

2 – In order to minimize quantization error in colour component conversion, the colour conversion matrices are specified in terms of six decimal digits of precision, even though the original definitions specify fewer digits of precision.

3 – The colour conversion matrix names specify the proper input and output colour spaces for colour component conversion.

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4.2.4 Utilities

PIKS utilities are elements that perform basic mechanical image manipulation tasks such as extracting a pixel from an image and composing a volumetric image from a set of monochromatic images. Table 4 contains a list of PIKS utilities. These utilities are specified in clause 7.

4.2.5 System mechanisms

PIKS system mechanisms are elements that perform control and management tasks such as allocating data storage references for PIKS data objects, opening and closing PIKS sessions, error handling, and element chaining. Table 5 contains a list of PIKS mechanisms.

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Table 2 – PIKS operators listed by functional class

ANALYSIS OPERATORS

Class of image to non-image operators that extract numerical information from an image.

- accumulator
- difference measures
- extrema
- histogram, one-dimensional
- histogram, two-dimensional
- Hough transform
- line profile
- moments
- value bounds

CLASSIFICATION OPERATORS

Class of image to image operators that classifies each pixel of a multispectral image into one of a specified number of classes based upon the amplitudes of pixels across image bands.

- classifier, Bayes
- classifier, nearest neighbour

COLOUR OPERATORS

Class of image to image operators that convert a colour image from one colour space to another.

- colour conversion, linear
- colour conversion, nonlinear
- colour conversion, subtractive
- colour lookup, interpolated
- luminance generation

COMPLEX IMAGE OPERATORS

Class of image to image operators that perform basic manipulations of images in real and imaginary or magnitude and phase form.

- complex composition
- complex conjugate
- complex decomposition
- complex magnitude

CORRELATION OPERATORS

Class of image to non-image operators that compute a correlation array of a pair of images.

- cross-correlation
- template match

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Table 2 – PIKS operators listed by functional class *(continued)*

EDGE DETECTION OPERATORS

Class of image to image operators that detect the edge boundary of objects within an image.

edge detection, orthogonal gradient
edge detection, second derivative
edge detection, template gradient

ENHANCEMENT OPERATORS

Class of image to image operators that improve the visual appearance of an image or that convert an image to a form better suited for analysis by a human or a machine.

adaptive histogram equalization
false colour
histogram modification
outlier removal
pseudocolour
unsharp mask
Wallis statistical differencing

ENSEMBLE OPERATORS

Class of image to image operators that perform arithmetic (add, subtract, multiply), extremal (maximum, minimum), and logical (and, or) combination of a pair of images.

alpha blend, constant
alpha blend, variable
dyadic, arithmetic
dyadic, complex
dyadic, logical
dyadic, predicate
split image
Z merge

FEATURE EXTRACTION OPERATORS

Class of image to image operators that compute a set of image features at each pixel of an image.

label objects
Laws texture features
window statistics

FILTERING OPERATORS

Class of image to image operators that perform neighbourhood combinations of pixels directly or by Fourier transform domain processing.

convolve, five-dimensional
convolve, two-dimensional
filtering, homomorphic
filtering, linear

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Table 2 – PIKS operators listed by functional class *(continued)*

FILTERING OPERATORS (continued)

filtering, median
filtering, pseudomedian
filtering, rank order

GEOMETRIC OPERATORS

Class of image to image operators that perform geometric manipulations such as minification, magnification, rotation, and rubber sheet warping.

cartesian to polar
flip, spin, transpose
polar to cartesian
rescale
resize
rotate
subsample
translate
warp, control point
warp, lookup table
warp, polynomial
zoom

HISTOGRAM SHAPE OPERATORS

Class of non-image to non-image operators that generate shape measurements of a pixel amplitude histogram of an image.

histogram shape, one-dimensional
histogram shape, two-dimensional

MORPHOLOGICAL OPERATORS

Class of image to image operators that perform morphological operations such as erosion, dilation, and skeletonization on boolean and grey scale images.

erosion or dilation, Boolean
erosion or dilation, grey
fill region
hit or miss transformation
morphic processor
morphology
neighbour count
open and close

PIXEL MODIFICATION OPERATORS

Class of image to image operators that modify an image by pixel drawing or painting.

draw pixels
paint pixels

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Table 2 – PIKS operators listed by functional class *(continued)*

POINT OPERATORS

Class of image to image operators that perform point manipulation such as magnitude, logarithm, and threshold on a pixel-by-pixel basis.

bit shift
complement
error function scaling
gamma correction
histogram scaling
level slice
lookup
lookup, interpolated
monadic, arithmetic
monadic, complex
monadic, logical
noise combination
power law scaling
rubber band scaling
threshold
unary, integer
unary, real
window-level

PRESENTATION OPERATORS

Class of image to image operators that prepare an image for display.

diffuse
dither

SHAPE OPERATORS

Class of image to non-image operators that label objects and perform measurements of the shape of objects within an image.

perimeter code generator
shape metrics
spatial moments, invariant
spatial moments, scaled

UNITARY TRANSFORM OPERATORS

Class of image to image operators that perform multi-dimensional forward and inverse unitary transforms of an image.

transform, cosine
transform, Fourier
transform, Hadamard
transform, Hartley

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Table 2 – PIKS operators listed by functional class *(concluded)*

3D SPECIFIC OPERATORS

Class of image to image operators that perform manipulations of three-dimensional image data.

- sequence average
- sequence Karhunen-Loeve transform
- sequence running measures
- 3D slice

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Table 3 – PIKS tools listed by functional class

IMAGE GENERATION

Class of tools that create test images.

- image, bar chart
- image, constant
- image, Gaussian image
- image, grey scale image
- image, random number image

IMPULSE RESPONSE FUNCTION ARRAY GENERATION

Class of tools that create impulse response function neighbourhood array data objects.

- impulse, boxcar
- impulse, derivative of Gaussian
- impulse, difference of Gaussians
- impulse, elliptical
- impulse, Gaussian
- impulse, Laplacian of Gaussian
- impulse, pyramid
- impulse, rectangular
- impulse, sinc function

LOOKUP TABLE GENERATION

Class of tools that create entries of a lookup table data object.

- array to LUT

MATRIX GENERATION

Class of tools that create matrix data objects.

- colour conversion matrix

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Table 3 – PIKS tools listed by functional class *(concluded)*

REGION-OF-INTEREST GENERATION

Class of tools that create region-of-interest data objects from a mathematical description of the region-of-interest.

ROI, coordinate
ROI, elliptical
ROI, polygon
ROI, rectangular

STATIC ARRAY GENERATION

Class of tools that create filter transfer function, power spectrum, and windowing function static array data objects.

filter, Butterworth
filter, Gaussian
filter, inverse
filter, matched
filter, Wiener
filter, zonal
Markov process power spectrum
windowing function

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Table 4 – PIKS utilities listed by functional class

EXPORT FROM PIKS

Class of utilities that export image and non-image data objects from PIKS to an application or to the IIF.

export histogram
export image
export LUT
export matrix
export neighbourhood array
export ROI array
export static array
export tuple
export value bounds
get colour pixel
get pixel
get pixel array
get pixel record
output object

IMPORT TO PIKS

Class of utilities that import image and non-image data objects to PIKS from an application or from the IIF.

import histogram
import image
import LUT
import matrix
import neighbourhood array
import ROI array
import static array
import tuple
import value bounds
input object
put colour pixel
put pixel
put pixel array
put pixel record

INQUIRY

Class of utilities that return information to the application regarding PIKS data objects, status, and implementation.

inquire chain environment
inquire chain status
inquire elements
inquire image
inquire index assignment
inquire non-image object
inquire PIKS implementation
inquire PIKS status
inquire repository
inquire resampling

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Table 4 – PIKS utilities listed by functional class *(concluded)*

INTERNAL

Class of utilities that perform manipulation and conversion of PIKS internal image and non-image data objects.

constant predicate
convert array to image
convert image data type
convert image to array
convert image to ROI
convert ROI to image
copy window
create tuple
equal predicate
extract pixel plane
insert pixel plane

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Table 5 – PIKS system mechanisms listed by functional class

CHAINING

Class of system mechanisms that manage execution of PIKS elements inserted in chains.

- chain abort
- chain begin
- chain delete
- chain end
- chain execute
- chain reload

COMPOSITE IDENTIFIER MANAGEMENT

Class of system mechanisms that perform manipulation of image identifiers inserted in arrays, lists, and records.

- composite identifier array equal
- composite identifier array get
- composite identifier array put
- composite identifier list empty
- composite identifier list equal
- composite identifier list get
- composite identifier list insert
- composite identifier list remove
- composite identifier record equal
- composite identifier record get
- composite identifier record put

CONTROL

Class of system mechanisms that control the basic operational functionality of PIKS.

- abort asynchronous execution
- close PIKS
- close PIKS, emergency
- open PIKS
- synchronize

ERROR

Class of system mechanisms that provide means of reporting operational errors.

- error handler
- error logger
- error test

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Table 5 – PIKS system mechanisms listed by functional class *(concluded)*

SYSTEM MANAGEMENT

Class of system mechanisms that allocate, deallocate, bind, and set attributes of data objects and set global variables.

allocate chain
allocate composite identifier array
allocate composite identifier list
allocate composite identifier record
allocate histogram
allocate image
allocate lookup table
allocate matrix
allocate neighbourhood array
allocate pixel record
allocate ROI
allocate static array
allocate tuple
allocate value bounds collection
allocate virtual register
bind match point
bind ROI
deallocate data object
define sub image
return repository identifier
set globals
set image attributes
set index assignment

VIRTUAL REGISTER

Class of system mechanisms that manage the use of virtual registers.

vreg alter
vreg clear
vreg conditional
vreg copy
vreg create
vreg delete
vreg get
vreg set
vreg wait

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4.3 PIKS operator model

The PIKS operator model defines three possible transformations of PIKS data objects by a PIKS operator:

- non-image to non-image
- image to non-image
- image to image

Class A source data objects (identified with object attributes and data) shall exist prior to the invocation of an operator. Destination data objects may be Class A or Class B (identified with object attributes only). In the case of a Class A destination data object, the previously stored data will be overwritten unless there is inhibition invoked by a PIKS system mechanism, as described in 4.4.1. Some operators support Class C destination data objects (identified only) or Class B destination data objects with partial object attributes. Such operators shall supply the necessary object attributes. If the attributes of a source data object are mismatched to the attributes expected by an operator, or if the attributes of a destination data object are mismatched to the attributes expected by an operator, that operator shall generate an error indication at the time of execution.

4.3.1 Non-image to non-image operators

Figure 2 shows the PIKS operator model for the transformation of non-image data objects by an operator to produce other non-image data objects. An example of such a transformation is the generation of shape features from an image histogram. In this operator model, there is no explicit operator processing control; the transformation is completely defined by the specification of each operator, as presented in clause 7.

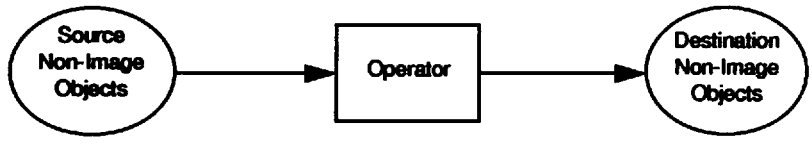

Figure 2 - PIKS operator model: non-image to non-image operators

4.3.2 Image to non-image operators

Figure 3 shows the PIKS operator model for the transformation of image data objects by an operator to produce non-image data objects. An example of such a transformation is the computation of the sum-squared difference between a pair of images. In this operator model, processing is subject to two control mechanisms: source match point translation and Region-of-Interest (ROI) source selection. As shown in Figure 3, source match point translation occurs first, followed by ROI source selection. This is followed by index assignment within the operator, as defined in Figure 5. These control mechanisms are defined in 4.4.2 and 4.4.3, respectively. The dashed line in Figure 3 indicates the transfer of control information. The dotted line indicates the binding of source ROI objects to source image objects.

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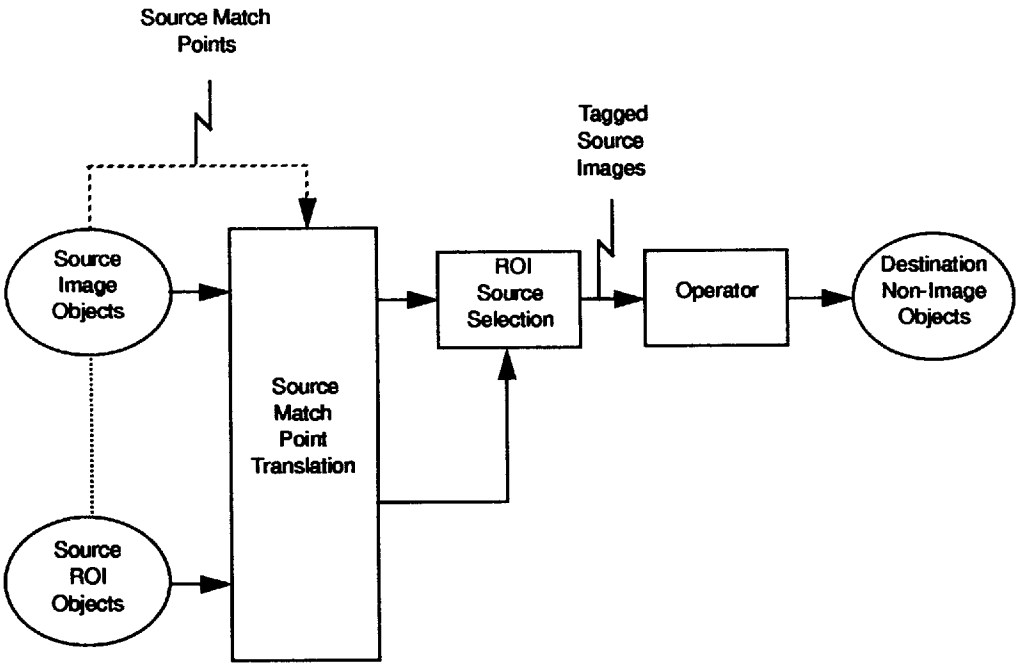

Figure 3 – PIKS operator model: image to non-image operators

NOTE – The concept of tagged source images is described in 4.4.2.

4.3.3 Image to image operators

Figure 4 shows the PIKS operator model for the transformation of image data objects by an operator to produce other image data objects. An example of such a transformation is the unsharp masking operator that enhances detail within an image. In this operator model, processing is subject to four control mechanisms: source match point translation, destination match point translation, ROI source selection, and ROI destination selection. As shown in Figure 4, source match point translation occurs first, followed by ROI source selection. This is followed by index assignment within the operator, as defined in Figure 5. The destination match point translation and ROI destination selection control mechanisms are defined in 4.4.2 and 4.4.3, respectively.

NOTE – Some PIKS operators are restricted to certain semantic types of image objects. For example, the colour processing operators are applicable only to colour images.

Certain PIKS operators are capable of accepting source images with pixels of non-negative, or signed integer data type, and automatically converting the source images to the real arithmetic data type for processing. The source promotion conversion process is implementation-dependent. The Element Functionality list associated with each PIKS operator indicates by "yes" or "no" if the operator supports source promotion.

4.3.4 Neighbourhood operators

Some PIKS operators, e. g., two-dimensional convolution and dilation, perform linear or nonlinear combinations of source image pixels within a neighbourhood of a reference source pixel to produce a single destination image pixel. For such operators, the neighbourhood is specified by a neighbourhood array non-image data object as defined in ISO/IEC 12087-1. Each neighbourhood array has an associated key pixel, which is, in general, a five-dimensional coordinate offset measured with respect to the origin of the neighbourhood array. In operation, the key pixel is sequentially translated over all

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source image pixels, the linear or nonlinear neighbourhood combination is computed for each reference source pixel, and the computed result is recorded at the destination pixel corresponding to the reference source pixel that lies "under" the key pixel. In general, if the neighbourhood extends beyond the boundary of the source image, the "missing" source pixel values are assumed to be of zero value for arithmetic combinations or of FALSE value for Boolean combinations. This is the default condition. Some operators override the default condition by specifying the boundary conditions differently. For example, the *convolve_2d* operator has an option for which the "missing" neighbourhood pixels are replaced by pixels obtained by reflections about the boundaries of pixels within the source image.

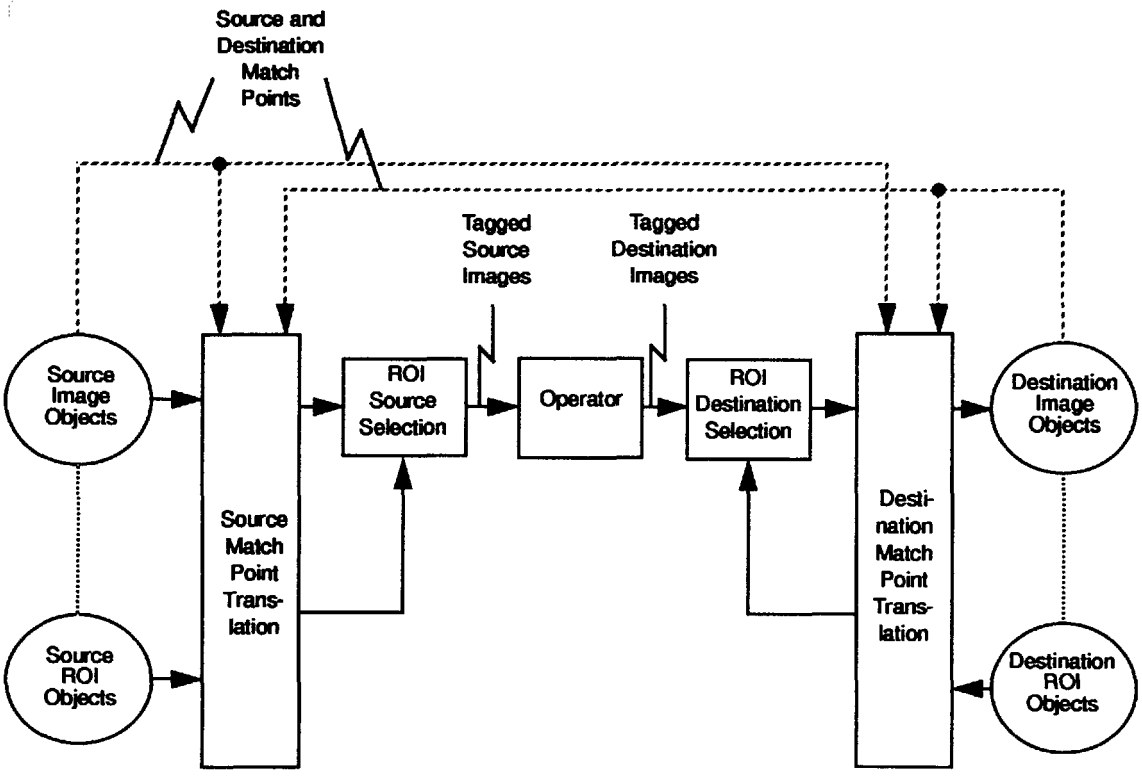

Figure 4 – PIKS operator model: image to image operators

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4.3.5 Operator index assignment

Some PIKS image to non-image and image to image operators shall have the capability of assigning operator indices to image indices. This capability permits operators that are inherently r-th order, where r > 0, to be applied to five-dimensional images in a flexible manner.

Figure 5 illustrates the PIKS image to non-image and image to image operator index assignment and reassignment process. There is a global index assignment 5-tuple, which relates the ordering of the five image indices (x, y, z, t, b) to five generic operator indices (j, k, l, m, n).

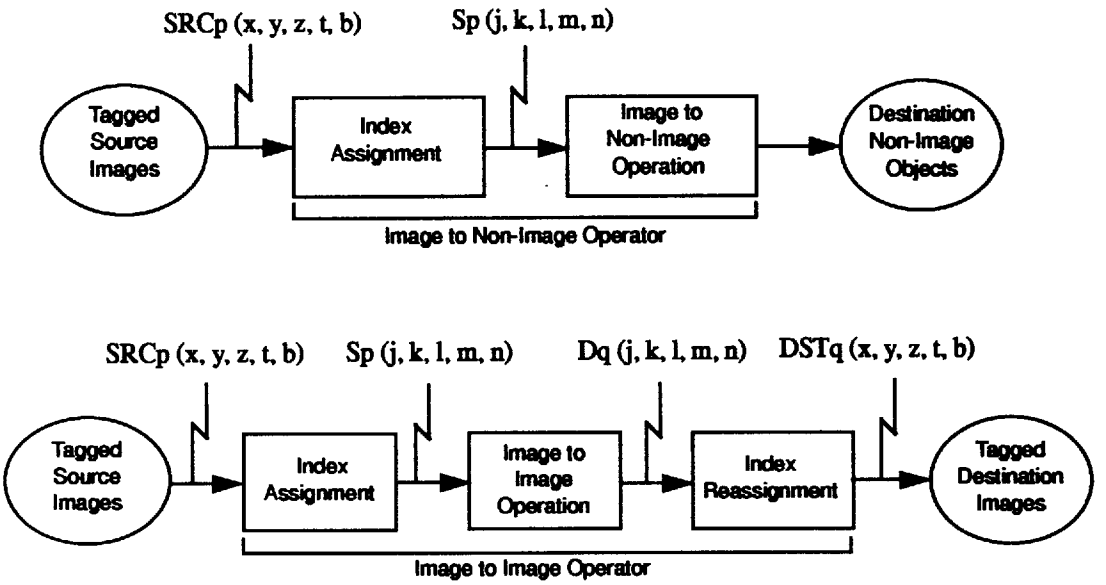

Figure 5 - Operator index assignment

Prior to the execution of an operator, each source image SRCp(x, y, z, t, b) is logically converted to an operator input image Sp(j, k, l, m, n) according to a global operator assignment specification table, generated by the *index_assignment* system management mechanism, as shown below.

Operator Index	Image Index
j	x or y or z or t or b
k	x or y or z or t or b
l	x or y or z or t or b
m	x or y or z or t or b
n	x or y or z or t or b

The character assignment [x, y, z, t, b] must be unique, i.e., if x is assigned to the j operator index, it cannot be assigned to any other operator index. Operator index assignment is not permitted for an rD operator if the band index is to be reassigned to one of the first r indices, and the source image does not have bands of the same data type.

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The assignment process defined above is expressed functionally as

$$Sp(j, k, l, m, n) = SRCp(ASSIGN\{x, y, z, t, b\})$$

The destination image index reassignment process from an operator output image Dq(j, k, l, m, n) to a destination image DSTq(x, y, z, t, b) is a direct inverse of the assignment process. The reassignment process is expressed functionally as

$$DSTq(x, y, z, t, b) = Dq(REASSIGN\{j, k, l, m, n\})$$

NOTE – The index assignment and index reassignment processes are described in the *index_assignment* system management mechanism described in clause 7.

As an example, consider a temporal source image SRC(x, y, 0, t, 0), which is input to a 3D convolution operator to perform image smoothing in x-y-t image space. The following index assignment table could be formed.

Operator Index	Image Index
j	x
k	y
l	t
m	z
n	b

For an rD operator, the assignment sequence of the (r+1)-st and higher indices is immaterial. In the example above, b could have been assigned to m, and z could have been assigned to n.

For most operators, if the operator is of order less than the image dimension, then the operator is executed independently over the pixel planes not directly involved in the operator. As an example, consider a temporal-colour source image SRC(x, y, 0, t, b), which is input to a 2D convolution operator to perform image smoothing in each x-y pixel plane. The following index assignment table could be formed.

Operator Index	Image Index
j	x
k	y
l	z
m	t
n	b

The 2D convolution operation will be executed for all T temporal planes and all B bands. A 2D operator need not be restricted to operate on the x-y pixel planes of a source image. It could, for example, operate on the t-x pixel planes of a temporal image by assignment of t to j and x to k.

NOTES

1 – A PIKS implementation may choose to physically reorder the indices of an image or choose to pass to an operator the index assignment information.

2 – The index assignment technique applies to some utilities and to some image generation and ROI generation tools.

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4.4 PIKS system mechanisms

This subclause describes the PIKS system mechanisms. These mechanisms are specified in clause 7.

4.4.1 Data object allocation

PIKS shall provide automatic memory management that permits an application to specify image and non-image data objects by object identifiers, and not be concerned with physical storage mechanisms. Image data object identifiers are created by the *allocate_image* system management mechanism. Non-image data object identifiers are created by an allocate system management mechanism corresponding to the non-image data object name. Image and non-image attribute information is accessed via the object identifier by inquiry mechanisms.

Any temporary images that may be required for storage of intermediate results in an implementation of a PIKS operator shall be automatically generated. A PIKS application does not have access to temporary images through PIKS.

PIKS does not specify the internal physical storage format of an implementation. PIKS implementations may choose to store images as conventional pixel planes, tiled planes, interleaved pixels, or any combination of storage means. The physical storage mechanism is hidden from the PIKS application.

Each PIKS implementation shall establish image size and capacity limits, and shall make this information available to the PIKS system inquire utility.

4.4.2 Match point control

Each PIKS image object has an associated match point coordinate set (x, y, z, t, b), which some PIKS operators utilize to control multi-dimensional translations of images prior to processing by an operator. Notes associated with each operator indicate if the operator is or is not subject to match point control. In order to simplify the mathematical definitions of the operators, they are expressed as if there were no match point control.

NOTE – Match points need not be integer valued.

The generic effect of match point control for an operator that creates a single destination image from a single source image is to independently translate each dimension of the source image such that its match point is aligned with the corresponding match point of the destination image prior to processing. This generic operation is mathematically defined as follows. Let

$$SRC(x, y, z, t, b) = X_S x Y_S x Z_S x T_S x B_S \text{ source image}$$

$$DST(x, y, z, t, b) = X_D x Y_D x Z_D x T_D x B_D \text{ destination image}$$

$$(x_{sm}, y_{sm}, z_{sm}, t_{sm}, b_{sm}) = \text{source match point}$$

$$(x_{dm}, y_{dm}, z_{dm}, t_{dm}, b_{dm}) = \text{destination match point}$$

$$O\{\cdot\} = \text{general operator}$$

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Then

$$DST(x, y, z, t, b) = O\{RESr\{SRC, x-x_{dm}+x_{sm}, y-y_{dm}+y_{sm}, z-z_{dm}+z_{sm}, t-t_{dm}+t_{sm}, b-b_{dm}+b_{sm}\}\}$$

for the destination image pixels x, y, z, t, b lying in the range

$$MAX\{0, x_{dm}-x_{sm}\} \leq x \leq MIN\{X_D-1, X_S-1+x_{dm}-x_{sm}\}$$

$$MAX\{0, y_{dm}-y_{sm}\} \leq y \leq MIN\{Y_D-1, Y_S-1+y_{dm}-y_{sm}\}$$

$$MAX\{0, z_{dm}-z_{sm}\} \leq z \leq MIN\{Z_D-1, Z_S-1+z_{dm}-z_{sm}\}$$

$$MAX\{0, t_{dm}-t_{sm}\} \leq t \leq MIN\{T_D-1, T_S-1+t_{dm}-t_{sm}\}$$

$$MAX\{0, b_{dm}-b_{sm}\} \leq b \leq MIN\{B_D-1, B_S-1+b_{dm}-b_{sm}\}$$

where RESr{.}, for $1 \leq r \leq 5$, denotes a resampling function, as defined in Annex H, whereby destination image pixels are generated from interpolated source image pixels.

The destination image DST(x, y, z, t, b) is only modified by operators within the bounds specified above. All other portions of the destination image remain unchanged if it is an existent Class A image. If the destination image is a Class B or Class C image (void of image data) prior to the operation, pixels in all other portions of the destination image are set to zero value if the destination image is an arithmetic data type or set to the FALSE state if the destination image is a boolean data type. As indicated by the generic definition, the source and destination images are aligned by their match points prior to an image operation. Match point alignment occurs prior to ROI control and image to operator index assignment.

The generic effect of match point control for an operator that creates multiple destination images from multiple source images is to translate each source image and each destination image, other than the first destination image, such that the match points of these images are aligned with the match point of the first destination image prior to processing. Figure 6 provides an example of match point translation for the subtraction of a pair of monochrome images. In the example, the difference region is shown cross-hatched.

A ROI that is bound to an image is spatially translated in register with the image to which it is bound. Each translated image and bound ROI control object is resampled according to the global resampling options specified in 4.4.8.

NOTE – The match point control mechanism can be used to extract a lower dimensional subset of an image for processing. For example, by properly choosing the source and destination match points, and by properly selecting the spatial size of the destination image, it is possible to process only a spatial window of each pixel plane of a source image.

4.4.3 ROI control

The PIKS region-of-interest (ROI) control mechanism shall adhere to the following definition.

NOTE – This ROI definition conceptually describes the semantics of the PIKS ROI functionality. There is no requirement that the functionality shall be implemented in the conceptual manner described.

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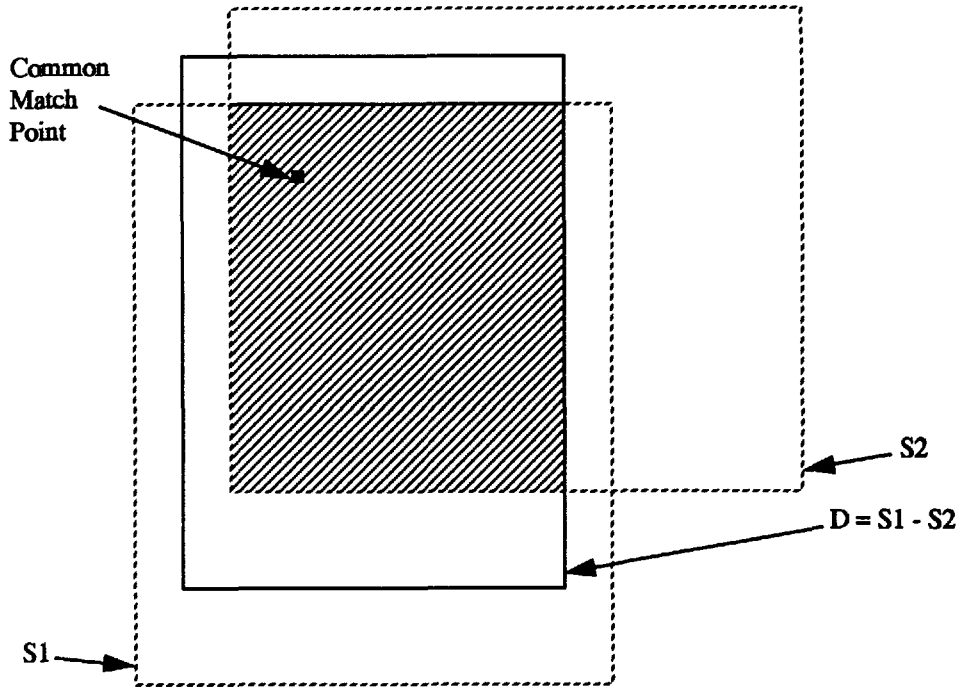

Figure 6 - Example of match point translation for image subtraction

Region-of-interest is a mechanism for controlling which pixels within an image will be processed by an operator, for specifying how they will be processed (for some, but not all operators), and for specifying how the processed pixels will be recorded in a destination image. Conceptually, a ROI control object is a Boolean-valued, five-dimensional array that is associated with each source and destination image. It is of the same size as its associated image, and is in spatial register with respect to the image origin. The ROI control object array assumes one of two logical states at each pixel. If a ROI pixel is in the logical TRUE state, the corresponding image pixel is said to be inside the ROI. Conversely, an image pixel is outside the ROI if its ROI pixel is in the logical FALSE state.

A ROI control object is created, conceptually, by a ROI binding mechanism that binds a ROI data object to an image. The ROI binding mechanism creates a ROI data object identifier reference in the image attribute list associated with each image. ROI data object creation and binding is described in 4.4.4.

If an image attribute list makes no reference to a ROI, a default ROI control object is assumed to exist and to be logically TRUE for each pixel of the image.

NOTE – The ROI control object defined in this clause is used as a means of explaining the operation of ROI control in the PIKS operator model. The ROI control object is not a standardized PIKS data object.

In the PIKS operator model, the source ROI control object is a selector that chooses which source pixels are to be processed. The destination ROI control object is a spatial selector that chooses which processed source pixels are to be recorded in a destination image. The selection operations are defined only at integer pixel coordinates, i.e., PIKS does not support subpixel ROI selection.

The image to operator index assignment operation specified in 4.3.4 applies to a ROI control object bound to an image as well as to the image itself. For example, if the y index of an image is associated with the first operator input index, then the y index of the associated ROI control object is also associated with the first operator input index.

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Figure 4 contains a diagram that conceptually describes the ROI operation in the PIKS operator model for image to image operators. In the special case of the processing of multiple source images by a point processing operator to produce a single destination image, let

$$SRCp(x, y, z, t, b) = \text{p-th source image for } 1 \leq p \leq P$$

$$DST(x, y, z, t, b) = \text{destination image}$$

$$P(x, y, z, t, b) = \text{operator output image without ROI control}$$

$$O(x, y, z, t, b) = \text{operator output image when ROI is invoked}$$

$$ROISp(x, y, z, t, b) = \text{p-th source ROI control object}$$

$$ROIS(x, y, z, t, b) = \text{composite source ROI control object}$$

$$ROID(x, y, z, t, b) = \text{destination ROI control object}$$

A composite source ROI control object, ROIS(x, y, z, t, b), is conceptually formed by taking the logical intersection of all of the source ROI control objects. Thus

$$ROIS(x, y, z, t, b) = ROIS1(x, y, z, t, b) \cap ROIS2(x, y, z, t, b) \cap \ldots \cap ROISP(x, y, z, t, b)$$

Conceptually, the composite source ROI control object tags each pixel in the source image as being inside or outside the ROI, and conceptually toggles a source control switch within the operator such that

$$O(x, y, z, t, b) = P(x, y, z, t, b)$$

if ROIS(x, y, z, t, b) is TRUE. There is no operator output if ROIS(x, y, z, t, b) is FALSE.

Conceptually, the destination ROI control object toggles a destination control switch such that

$$DST(x, y, z, t, b) = O(x, y, z, t, b)$$

if ROIS(x, y, z, t, b) is TRUE and if ROID(x, y, z, t, b) is TRUE. The destination image remains unchanged if ROID(x, y, z, t, b) is FALSE or if ROIS(x, y, z, t, b) is FALSE and ROID(x, y, z, t, b) is TRUE.

Figure 7 illustrates three cases of ROI functionality for point processing of a monochrome image. In Case 1, the destination ROI is logically TRUE over the full image extent, and the source ROI is TRUE over a rectangular region smaller than the full image. In this case, the destination image consists of the existing destination image with an insert of processed source pixels. For Case 2, the source ROI is of full extent, and the destination ROI is of a smaller rectangular extent. The resultant destination image consists of processed pixels inserted into the existing destination image. Functionally, the result is the same as for Case 1. The third case shows the destination image when the source and destination ROIs are overlapping rectangles smaller than the image extent. In this case, the processed pixels are recorded only in the overlap area of the source and destination ROIs.

The ROI concept extends to multiple destination images. Each destination image has a separately bound ROI control object, which independently controls recording of pixels in the corresponding destination image.

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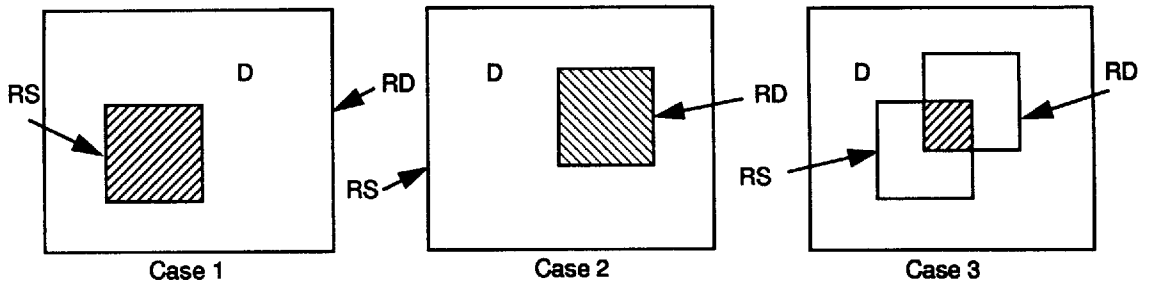

Figure 7 – Examples of ROI operation

The ROI concept applies to neighbourhood operators as well as point operators. Each neighbourhood processing object, such as an impulse response array or a morphological structuring element, has a predefined key pixel. If the key pixel lies within a source control ROI, the output pixel is formed by the neighbourhood operator even if any or all neighbourhood elements lie outside the ROI.

Some PIKS operators are under match point control. For such operators, the source and destination images and their registered ROI control objects are translated such that their match points are in alignment prior to ROI processing. Image processing operations are valid only in the intersection region of the translated source and destination images and their corresponding ROIs.

When a ROI control object is translated under match point control along with the image to which it is bound, the ROI resampling option invoked is applied to the ROI control object. For resampling, the ROI control object is conceptually treated as a bi-level image in which the TRUE state pixels are represented as value 1.0 and FALSE state pixels are represented as value 0.0. After the resampling interpolation operation is completed, the interpolated ROI control object is thresholded at a level of 0.5 for which the equal or above threshold value is set TRUE and the below threshold value is set FALSE. ROI resampling is defined mathematically in Annex H.

Some PIKS operators, such as the unitary transform operators, are not subject to ROI control because they are only defined over rectangular extent images. It is noted in the specification of an operator if it is or is not subject to ROI control.

In order to simplify the mathematical definition of the operators in clause 7, they are expressed as if there were no ROI control.

Some PIKS operators, e.g., rotate, can perform the same processing operation on a source ROI control object as on a source image. For such operators, the existing destination ROI control object can be replaced by the processed source ROI control object. The Element Functionality list associated with each PIKS element indicates by "yes" or "no" if the element supports ROI processing. The processing of a source ROI control object and subsequent replacement of the existing destination ROI control object can be suppressed by the *set_globals* system management mechanism described in 4.4.8.

NOTE – In PIKS, ROI control is only defined conceptually. Some implementations may choose to implement ROIs as physical bitmaps. Other implementations may choose to implement ROIs as physical coordinate lists or as run length code generators.

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4.4.4 ROI data object creation and manipulation

PIKS provides tools for generating ROI data objects from higher level specifications. Such supported specifications include:

Name	Code
array	ROI_ARRAY
coordinate collection	ROI_COORD
elliptical shape	ROI_ELLIP
polygonal shape	ROI_POLY
rectangular shape	ROI_RECT

These tools, together with the ROI binding mechanism, provide the capability to conceptually generate five-dimensional ROI control objects from lower dimensional descriptions by pixel plane extensions. For example, with the elliptical ROI generation tool, it is possible to generate a circular disk ROI in a spatial pixel plane, and then cause the disk to be conceptually replicated over the other pixel planes of a volume image to obtain a cylinder-shaped ROI. The specific functionality of the ROI tools is defined in clause 7.

Conceptually, a ROI data object is a Boolean-valued, five-dimensional array. The ROI data object array assumes one of two logical states (TRUE or FALSE) at each point in the array. Figure 8 presents an example of the spatial cross-section of an elliptical ROI data object. The TRUE state region is shown cross-hatched.

In ISO/IEC 12087-1, a ROI data object is expressed, notationally, as a five-dimensional array:

ROI(x, y, z, t, b)

The PIKS ROI data objects are specified in ISO/IEC 12087-1. Associated with each image is a key point 5-tuple (xk, yk, zk, tk, bk) consisting of five signed integers, which defines an offset of the ROI origin with respect to the image origin. When a ROI data object is bound to an image, conceptually, the ROI data object is translated in each orthogonal direction such that the origin of the ROI data object is aligned in five-dimensional space with the key point in the image to which the ROI data object is bound. The directional sense (left/right, up/down, etc.) is the same as an image translated by match point alignment. The ROI control object is conceptually formed by clipping the ROI data object to the extent of the image. If the ROI data object is not in the TRUE state at the geometric centre of a particular pixel of the image, the ROI control object is set FALSE at that pixel position. Figure 8 shows an example of the spatial relationship between an ROI data object and an image to which it is bound.

NOTE – The key point may lie outside the extent of the ROI data object and the image.

PIKS provides utilities for converting a Boolean image to a ROI array data object and for converting a ROI array data object to a Boolean image.

PIKS provides operators for the processing of ROI data objects. For example, a rectangular ROI data object can be resized to produce another rectangular-shaped ROI data object. Such operators can accept as a source ROI any of the ROI data object structures, e.g., ROI_ARRAY, ROI_RECT, etc., but the operator output is specified only as being a generic ROI structure. The ROI_GEN structure is implementation-dependent.

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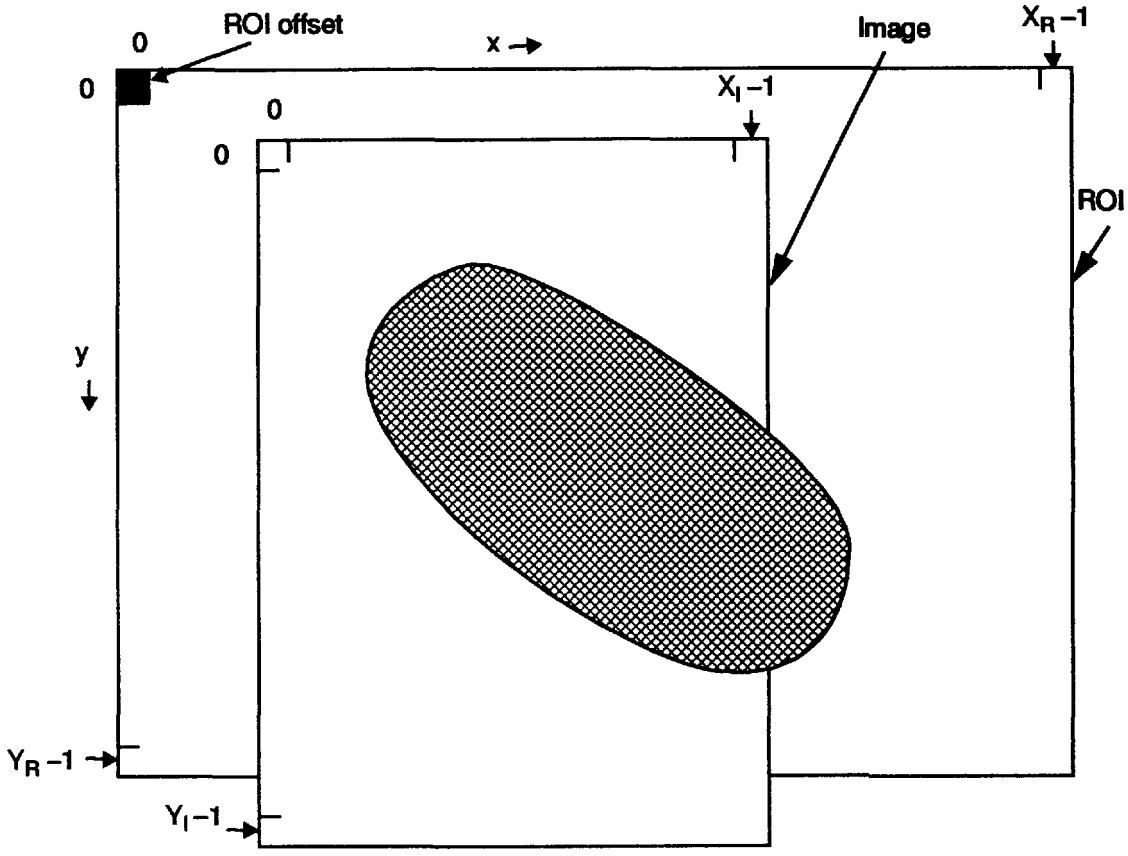

Figure 8 - Example of the relationship between a ROI and an image

4.4.5 Asynchronous control

PIKS provides two global modes in which certain of its elements (operators, tools, utilities, or mechanisms) may be executed: synchronous or asynchronous. The global PIKS mode is initially set to Synchronous by the *open_piks* mechanism and remains in that state until changed to Asynchronous by invocation of the *set_globals* mechanism. The Element Functionality list associated with each element indicates by "yes" or "no" if the element supports asynchronous execution.

The following control mechanisms relating to asynchronous execution are available:

set_asynchronous (via the *set_globals* mechanism)
set_synchronous (via the *set_globals* mechanism)
synchronize
abort_asynchronous_execution

When PIKS elements are executed synchronously, all processing and error reporting is completed before the implementation returns control to the calling application. This is the least sophisticated mode of operation, and shall be supported by all implementations.

Asynchronous execution permits implementations to use multiple processors or external accelerator devices to take advantage of possible parallel or distributed execution resources. It also allows for some optimization of the execution of sequences of PIKS elements because execution need not begin prior to returning to the application. The implementation may defer execution of a sequence of PIKS elements in

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order to combine consecutive PIKS elements into single macro operations or to execute a sequence of operations in a way that reduces loop control overhead, lessens the temporary storage space needed or better allocates available processing facilities to the deferred set of operations. The methods provided to enhance asynchronous operations are strictly internal to the implementation, outside the scope of this standard, and need not be visible to the application.

Asynchronous execution also permits the application to perform other activities, such as numerically intensive processing, the reading and writing of files, input/output operations, or other time consuming processing, while a PIKS implementation is performing the enqueued imaging operations.

The degree of optimization supplied in the asynchronous mode is strictly implementation-dependent. In fact, all conformance profiles allow an implementation to support the asynchronous mode with synchronous execution, without violating conformance to the standard. In this case, all operations in the asynchronous mode would actually be performed in the synchronous mode. An application may perform an *inquire_piks_implementation* to verify whether asynchronous operations are supported by a particular PIKS profile.

In the asynchronous mode, each PIKS element is added to the end of a queue of all pending asynchronous PIKS elements. This mechanism is referred to as the Asynchronous Execution Queue. The parameters associated with each enqueued PIKS element are also fetched and saved to prevent subsequent changes by the application from modifying the function to be performed. The queue keeps the elements in the same sequence that they were called by the application. Control may be immediately returned to the application, prior to initiation of execution, without any error checking or reporting. Although the timing of the error detection in parameters of asynchronous calls is implementation-dependent, the resulting error detection and error handling produce the standard-specified results via the PIKS error mechanisms.

A synchronization control mechanism, called *synchronize*, is provided to allow an application to request a wait until all pending asynchronous PIKS elements have been completed. While the synchronize function causes the application to wait, it does not affect the execution of asynchronous elements.

Some PIKS elements cause an implicit synchronization. For example, PIKS elements that must return a value of a non-PIKS data type to the application must wait until processing is completed before they can return a result, and then return control to the calling program. Most PIKS operations do not cause implicit synchronization. Because PIKS data types are referenced by identifiers — not values — their values are automatically updated by an asynchronous element, and are available to asynchronous elements invoked later. An invocation of the *set_globals* mechanism, when the synchronicity mode is set to SYNCHRONOUS, causes an implicit synchronization.

The *close_piks* mechanism does an implicit synchronization to assure that all operations have been completed prior to the closing actions.

Execution of the enqueued asynchronous operations is controlled by the specific scheduling mechanism provided by the implementation. It must begin and complete execution of all enqueued elements prior to giving a return to any explicit or implicit *synchronize* call. In most cases, PIKS elements will not be executed as fast as they can be added to the queue. In the event that the asynchronous execution control does complete all enqueued elements, it simply waits until additional elements are entered to the queue to resume asynchronous processing.

All PIKS elements which do not cause a synchronization prior to their execution are placed on the Asynchronous Execution Queue. This includes operations that simply change a global state, such as the resampling mode. This will ensure that all operations are executed in the order they were invoked, and that earlier operations properly affect later operations avoiding the side-effects that could be caused by changes in the global state during the execution of asynchronous elements invoked by prior calls.

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The only exceptions to the sequential execution rule are the inquiry operations, which always return their values immediately and which do not directly affect the execution of any element. An application is free to invoke an explicit synchronization prior to performing an inquiry element if it wishes to inquire state values or to affect virtual register values after all asynchronous elements have been executed.

The *abort_asynchronous_execution* mechanism is provided for the application to terminate all on-going asynchronous operations and to clear the Asynchronous Execution Queue. This procedure can be used to recover from serious error conditions or when the program or user changes the flow of processing.

While in 'synchronous' mode, invocation of the *synchronize* or *abort_asynchronous_execution* control elements is treated as a no-operation mechanism.

If Asynchronous is "yes" and the Asynchronous Mode is in effect, the element will not be immediately executed if another element is presently being executed. It will instead be put onto the Asynchronous Execution Queue and executed when it reaches the head of the queue.

NOTE – For implementations which do not support the Asynchronous Mode, operations are always executed synchronously, as if the Synchronous Mode was in effect.

If Asynchronous is "yes" and the Asynchronous Mode is not in effect, the element will not be put onto the Asynchronous Execution Queue, but will be executed immediately.

If Asynchronous is "no" the new element will not be put onto the Asynchronous Execution Queue even if Asynchronous Mode is in effect. Instead, the implicit synchronize mechanism is invoked, that is, execution of the new element will be deferred until all presently queued elements have been executed asynchronously; then the new element is executed. Exceptions to this operation are the *abort_asynchronous_execution* and *close_piks_emergency* mechanisms which are executed immediately upon being invoked.

4.4.6 Element chaining

PIKS provides a mechanism, known as chaining, for the assembly and controlled execution of a sequence of PIKS elements. Using this mechanism, an implementation can provide for the efficient execution of element sequences.

The primary objective of chaining is to facilitate the optimization of element sequences. This includes minimizing data storage requirements, eliminating unnecessary data flow, maximizing the use of hardware facilities, and condensing sequences of PIKS elements into single operations. Because entire sequences of PIKS elements can be analyzed as a whole, individual elements may be restructured (but not resequenced in any manner that changes the result of the computation) to suit the facilities available for their execution. The choice and extent of the optimization provided rests solely with each PIKS implementation; such optimizations shall not change the result of a computation.

Chains are constructed and stored within an implementation during the CHAIN_BUILD state. The stored chains may then be executed, and re-executed as many times as the application desires. When or if any optimization occurs is implementation-dependent.

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4.4.6.1 Chain construction

Once a chain identifier has been allocated by invoking the *allocate_chain* mechanism, a chain can be constructed, executed and manipulated using the following control mechanisms:

chain_abort
chain_begin
chain_delete
chain_end
chain_execute
chain_reload

The application starts a new chain definition by performing *chain_begin*, which sets PIKS to the CHAIN_BUILD state.

In the CHAIN_BUILD state, all subsequent PIKS calls for elements which support chaining will simply have their functions added to the chain, instead of being executed. The chain definition is completed when a *chain_end* is performed, returning the PIKS implementation to its previous state. While PIKS is in the CHAIN_BUILD state, new operators are not placed on the asynchronous execution queue, but operations already on the queue continue to be executed. There is an additional requirement that the building of chains must be performed outside of chaining. Although chains may execute chains, they cannot build chains. Not allowing an executing chain to build a chain avoids confusion about alterations of program synchronization.

NOTE – Image and non-image data objects are not overtly copied as a result of the invocation of any chaining mechanism.

Only one chain may be in the CHAIN_BUILD state at any time. Each chain must be completed (or closed) by invoking *chain_end* prior to starting another chain. Closing a chain is required prior to calling a non-chainable PIKS functional element, otherwise an error will be issued and the function will be ignored. Once closed, a chain may not be reopened, added to or modified, except as allowed by the *chain_reload* function, which is described below.

Not all PIKS elements can be included in a chain. The Element Functionality list associated with each element indicates by "yes" or "no" if an element is chainable without virtual registers. Virtual registers are defined in 4.4.7. Some PIKS elements can be included in chains if and only if their outputs are directed to virtual registers. Elements that require the use of virtual registers during chaining are denoted as "vreg" under the chainable designation.

Only PIKS elements can be included in a chain and not other functions supplied by a programming language. An implementation need not report invalid attempts to do so, though such attempts will probably result in invalid results.

Figure 9 illustrates a few exemplary chains supportable by PIKS. The linear chain consists of a simple sequence of PIKS elements. The multi-thread chain consists of several interrelated sequences, each containing PIKS elements. Each of the multi-thread chains may be executed in parallel to produce a common result. The use of virtual registers as chained elements allows synchronization. Single threaded chaining implementations produce the same result, by blocking on mutually required resources held in virtual registers.

Chain reconstruction continues until a *chain_end* is performed. PIKS then reverts to its previous state. Invoking *chain_end* causes the chain to be stored and optimization may occur within the implementation.

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A chain is executed by invoking *chain_execute*, with the chain identifier of a completed and closed chain. In asynchronous mode, the *chain_execute* element is put onto the Asynchronous Execution Queue and is treated in the same way as any other PIKS element in that queue.

4.4.6.2 Chain execution

A *chain_execute* element may form part of a chain. The chain identifier of the embedded *chain_execute* may reference an undefined chain identifier (one which has been allocated but not yet defined by a *chain_begin/chain_end* sequence) at the time it is entered into a chain. However, by the time a chain executes, any embedded chains must be defined; otherwise, an error will result. In synchronous mode, chain elements are executed in the order they are placed in the chain; embedded chains act as subroutines. In asynchronous mode, an implementation is free to reorder or execute PIKS elements in parallel as long as the result seen by the application is the same as if the chain were executed in synchronous mode.

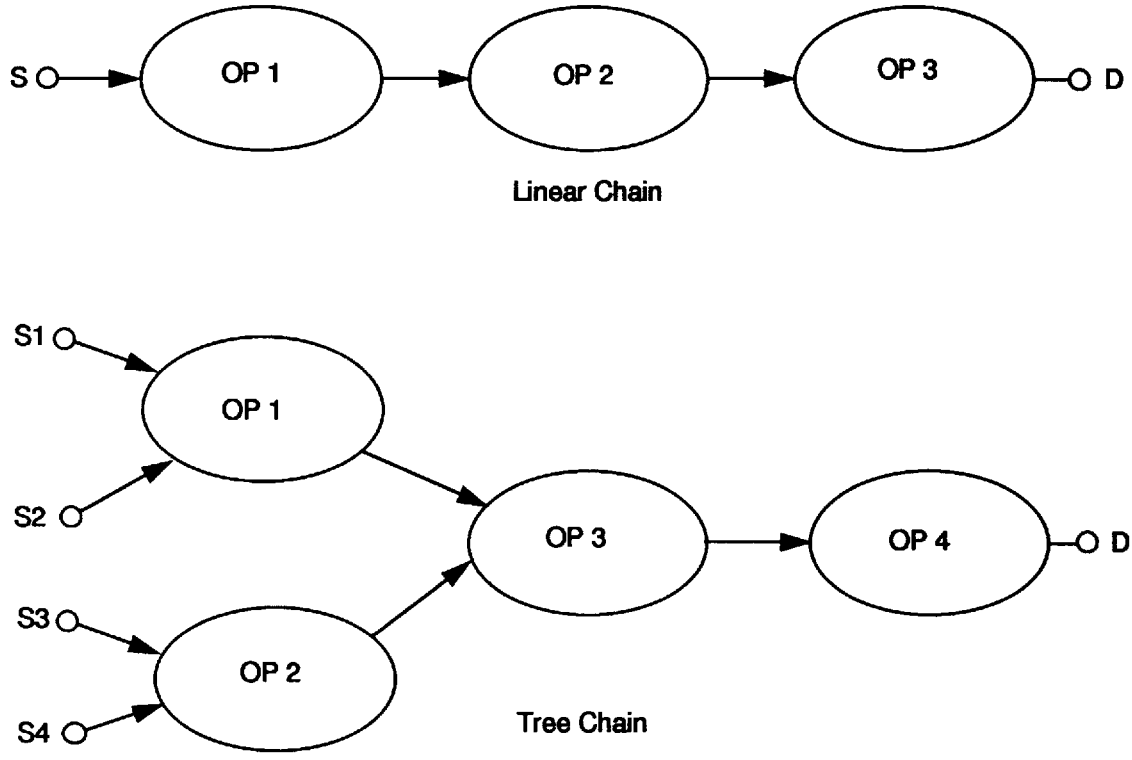

Figure 9 – Examples of PIKS element chains

The number of chains which may be nested or initiated from within other chains is not limited. However, the number of chains, and the total number of chain elements stored may be limited by an implementation. Likewise the number of simultaneous *chain_execute* threads supported by an implementation may be limited. Information on the implementation limitations for chaining are provided by the *inquire_piks_implementation* element. Regardless of the implementation of chaining, the results provided by a one-thread implementation shall be the same as that provided by an implementation having an unbounded number of threads, except for the time required to complete the execution of all elements.

More than one instance of a particular chain may be in execution at a time. Each will carry its own state. However, this opens up the possibility of multiple instances of the same chain simultaneously operating on the same image resources. It is the application's responsibility to assure that no particular chain is

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being executed more than once if that is not intended for purposes of recursion. It is likewise the application's responsibility to assure that the set of chains executed do not form an infinite loop, such as would occur if the set contains a circular definition, such as would be the case if chain A executes chain B and chain B executes chain A.

Chain execution may be either synchronous or asynchronous according to the global mode. In asynchronous mode, *chain_execute* may return to the application immediately. PIKS provides a mechanism for an application to determine the state of execution of a particular chain, using the *inquire_chain_status* mechanism.

During chain execution, PIKS elements use the parameters and data referenced at the time the chain was built. PIKS provides a means for any PIKS element embedded in a chain to reference new parameters or data after the chain build has been completed, and even after the chain has been executed. One method of changing data and/or parameter values is accomplished by using the *chain_reload* element prior to execution or re-execution of a completed chain. Another method is provided by the use of PIKS virtual registers as element parameters. This latter method is explained in detail in subsequent sections.

PIKS system mechanisms which allocate and deallocate PIKS data objects, such as images, may be chained. A PIKS data object which is allocated and deallocated within a chain can be considered a temporary data object whose value is not made available to the application. This provides a means of producing and controlling temporary data objects during chain execution.

The *chain_reload* mechanism allows chain elements to be modified. The mechanism *chain_reload* can access any element built into a chain by specifying the chain identifier and the position of the element in the chain. The first element in the chain is identified as element 1 and the n-th element as element n. To prevent excessive complications and possible behaviour problems, *chain_reload* mandates that the replacing element be exactly the same type (function name) as the replaced element. Only the parameters and data associated with the two elements may be different.

Additional chain elements may be reloaded by accessing them one at a time. The new values established by *chain_reload* will be used in all subsequent executions of the chain, or until the *chain_delete* mechanism destroys the entire stored chain. If extensive modifications are to be made to a chain, it may be easier for the application to invoke *chain_delete* to destroy the stored chain. Then a replacement chain may be built in the same fashion as originally performed, using the new variables.

Chain execution terminates when a fatal error occurs during the execution of any PIKS element in a chain. The PIKS Error Handler and Error Logger are invoked when an error is detected, just as is the case for non-chained elements. The *inquire_chain_status,* and other inquiry functions, can be used to query the various state parameters to determine the location and type of error that has occurred.

As described in 4.4.7, additional functionality is provided by the use of PIKS virtual registers to hold temporary results or to signal chain events. PIKS provides a method for specifying that any output parameter may be a temporary object, to be used only during the execution of a particular chain, and not to be returned directly to the application. These temporary objects are defined as the content of virtual registers, (VREGs). VREG values may also be used to hold parameters and data for chain-embedded PIKS elements. Because VREGs can contain any valid PIKS data type, these registers can also be used to communicate chain element outputs to other chains or to the application. Iteration, "test and branch," and "wait on completion" programming constructs are also provided. In addition to carrying either data or parameters, the VREGs allow the application to initiate a chain execution sequence to another chain execution or to signal the application. This two way communication may be used to signal progress and status or to alter the sequence of chain execution. One obvious use is to inform the application that data produced at some intermediate point in the chain is now valid. Details on the use of VREGs within any asynchronous or chained operation are provided in the next clause.

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The *chain_abort* mechanism allows an application to prematurely terminate execution of a particular chain. This is useful for error recovery, in response to unsatisfactory partial results obtained from virtual registers, or when the user signals that a change of process is desired. This mechanism only affects the chain to be aborted. Other dependent chains could end up in a blocked state as a result. It is possible to circumvent this hazard by specifying a *chain_abort* for all dependent chains; these aborts may even be contained in a chain set up explicitly for that purpose. Note also that the PIKS global *abort_asynchronous_execution* mechanism (rather than *chain_abort*) will kill any and all chains as well as any asynchronous operations, either on-going or waiting in the Asynchronous Execution Queue.

4.4.7 Virtual register control

PIKS provides a set of virtual registers, or VREGs, to support application control for chaining and asynchronous processing. The VREGs are specific for each of the valid PIKS data types and are bound to a particular data type when they are created. The use of virtual registers is primarily in the context of chaining control, but does not preclude other uses, such as in asynchronous communication and control within PIKS. Virtual registers may also be used in sequential, non-chained PIKS programs.

PIKS virtual registers are manipulated with the following mechanisms:

vreg_alter
vreg_clear
vreg_conditional
vreg_copy
vreg_create
vreg_get
vreg_set
vreg_wait

Virtual registers are provided for all PIKS data types and act as virtual storage locations within PIKS. There is a complete set of virtual registers for each of the PIKS data types. Appropriate virtual registers can be used as parameters for any PIKS functional element. This allows an application to specify operational results to be held in the context of the PIKS environment, alleviating the need for PIKS to return results to an application, and forcing a synchronization. Virtual registers can also be used to control program flow within chained operations by auditing the progress of asynchronous operations, and through multi-threaded synchronization and resource monitoring. Because of the special control nature of VREGs, an "immediate-mode" parameter is associated with each of them, allowing for instant or delayed execution under the asynchronous PIKS mode.

Virtual registers in PIKS have three associated fields: status flag, data type, and data value. The first field, a status flag, indicates whether the register has been "set," VREG_SET, or "cleared," VREG_CLEARED. The "*value*" contains a data value appropriate for the data type of register. Allocation of virtual registers is performed by the *allocate_vreg* mechanism, which supplies PIKS with the appropriate data type to associate with the VREG. A VREG identifier is returned to the application. If the status flag has not been set, the value field is not meaningful. VREGs are initially in the VREG_CLEARED state when they are created with an *allocate_vreg* mechanism. Only VREG operations which set a VREG can change the state to VREG_SET. A *vreg_clear* mechanism allows the VREG to be re-initialized to the VREG_CLEARED state. All associated data is considered meaningless as a result, but the virtual register itself is not destroyed, as it would be with a *vreg_delete*.

The use of VREGs depends on the application requirements to manipulate these symbolic variables. The flexibility achieved by symbolic, or token, specification of PIKS functional element parameters is especially useful in the context of element chaining. There are three main uses for VREGs in the context of chaining operations: communication, synchronization, and process control. Although the VREGs can be used outside of chaining, the remainder of this clause will primarily exemplify their use in chaining.

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4.4.7.1 Virtual registers for storage of PIKS temporary variables

Virtual registers may be used to store the temporary results of chained elements. Temporary results can be input to any chained element in one of two ways. First, by substituting an invocation of the *vreg_get* mechanism in the parameter list of the chained element at the position of the desired parameter, if and only if the VREG contains an internal identifier. Second, by substituting the VREG identifier itself in the parameter list of the chained element at the position of the desired parameter.

The VREG mechanisms allow an application to use internal PIKS variables as either input or output parameters. The output of a PIKS element can be returned in a virtual register and then used as an input parameter to another PIKS element. An important distinction between VREG variables and application variables is that VREGs are local to PIKS, and not returned to the application unless explicitly requested through a *vreg_get* mechanism. This means that the virtual register variables are insulated from inadvertant alteration by an application. A second difference is that virtual register variables allow for synchronization, unlike program variables. This feature, which can be very valuable for multi-chained asynchronous operations, is discussed in the next clause.

Virtual registers provide an alternative to the *chain_reload* mechanism because they allow for the alteration of chained element parameters, and therefore can be automatically altered prior to or during execution of a chain. Virtual registers allow chained elements to access previously computed results. It can be of significant advantage to use VREGs as an autonomous mechanism for chains to pass results without supervision and synchronization required from an application.

In addition to PIKS functional elements setting virtual registers as output parameters, an application or a chain can also set virtual registers with a *vreg_set* mechanism. The use of the *vreg_clear* mechanism allows either a chain or an application to re-initialize the virtual registers. The *vreg_copy* mechanism allows the contents of a virtual register to be replicated to other virtual registers. This can be useful for multiple chains sharing a partial result independently.

Persistence of virtual registers is for the duration of the PIKS_OPEN state, unless explicitly deleted using the *vreg_delete* mechanism.

4.4.7.2 Virtual registers for asynchronous control

One use of virtual registers is to coordinate synchronization on asynchronous PIKS operations. The completion of a PIKS event can be signaled by setting a virtual register to a value. This can be either explicit, with a call to *vreg_set*, or implicit, through use of a VREG as an output parameter of a PIKS chainable or asynchronous functional element. Synchronization can be achieved by having the application, or another chain, wait on the VREG_SET event using the *vreg_wait* mechanism. This call will block execution of the caller until the associated VREG is set to the value indicated in the *vreg_wait* call. The value waited on can be either specific to the VREG data type, or general to any value being set in the VREG.

When a VREG is an input parameter to a PIKS element in the asynchronous or chaining mode, an implicit "wait until VREG_SET" occurs. The *vreg_clear* mechanism resets the state of the virtual register to VREG_CLEARED, for further synchronization usage. The use of *vreg_set*, *vreg_wait*, and *vreg_clear* allows an application to control the synchronization of chains, which depend on other chains for input of computed variables or data objects.

4.4.7.3 Virtual registers for chain iteration and conditional execution

Additional control over chain operations is supplied by the *vreg_conditional* mechanism, which provides a "test and branch" chaining control mechanism. The *vreg_conditional* mechanism allows program

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specification of a condition to be met, which will cause a branch to another executable chain. The test is for the value of a virtual register to be within a specified value range; the branch can be taken on either a TRUE or a FALSE result. Additional specification of process control is provided by *vreg_conditional* and indicates whether the chain that executes the branch is to be returned to after completion of the branch. Multiple occurrences of the *vreg_conditional* mechanism within a chain, with different value ranges and conditions, can duplicate "if-else" and "case" program constructs. Iteration can be specified with the use of *vreg_alter* to change (by increment or decrement) the value of a virtual register, and then the *vreg_conditional* mechanism can be used to test the result and branch back to the beginning of the chain.

4.4.7.4 Virtual registers for auditing asynchronous state

The *vreg_get* mechanism allows the application to query the state of a virtual register. Thus, state information on the progress of asynchronous or chained processing can be obtained. Another use for *vreg_get* is to return temporary values at any stage within a chain. This feature can be used for a number of purposes. One purpose would be to use VREGs to indicate results of a particular stage in a chain selectively, especially for debugging purposes. Setting of virtual registers as outputs either within a chain or for asynchronous operations can also be used as an audit trail to indicate progress on operations. The *vreg_get* mechanism allows an application to inquire the data type, value, and status (VREG_SET or VREG_CLEARED) of a particular virtual register.

NOTES

1 – The use of chaining and virtual registers together can provide algorithmic specifications within PIKS. Such programming extensions, however, must be constructed out of existing PIKS functional elements. Thus, chaining, as an extension mechanism, is limited to macro capabilities on top of PIKS functional capabilities.

2 – PIKS does not specify process priority or interrupt mechanisms to allow program control over asynchronous execution. Therefore, when using chaining and virtual registers, it is important to specify inter-process dependencies in unambiguous ways, which do not assume anything beyond the implicit sequence of operations within a single chain. Race conditions, non-terminal iteration, conflicting processing states, and other programming defects may result from improper usage of these chaining mechanisms. The *chain_abort* mechanism can insulate an application from some of these malignancies, but ultimately it is the responsibility of the application to insure programming integrity.

4.4.8 Global element control

PIKS shall provide mechanisms for global operator control within the operator model. The operator control functions are:

ENGAGE ROI CONTROL – This is a switch mechanism that engages the standard ROI control functionality of the operator model when the switch is ON. When the switch is OFF, the ROI control functionality is disabled.

ENGAGE ROI PROCESSING – This is a switch mechanism that engages the processing of ROI control objects by certain operators when the switch is ON. When the switch is OFF, a source ROI control object is not modified by an operator.

ENGAGE MATCH POINT – This is a switch mechanism that engages the match point functionality of the operator model when the switch is ON. When the switch is OFF, the match point functionality is disabled.

ENGAGE INDEX ASSIGNMENT – This is a switch mechanism that engages the index assignment and reassignment functionality of the operator model when the switch is ON. When the switch is OFF, the index assignment and reassignment functionality is disabled.

ENGAGE ASYNCHRONOUS – This is a switch mechanism that engages asynchronous operation when the switch is ON. When the switch is OFF, operation becomes synchronous.

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IMAGE RESAMPLE SELECT – This is an option selector that specifies which resampling function will be used in image resampling when match point translation or relevant operator processing is performed in the operator model.

ROI RESAMPLE SELECT – This is an option selector that specifies which resampling function will be used in ROI resampling when match point translation or relevant operator processing is performed in the operator model.

The image and ROI global resampling options are:

1 support 1 constant (nearest neighbour)
2 support 2 linear
3 support 2 lookup table
4 support 4 truncated sinc
5 support 4 cubic B-spline
6 support 4 cubic convolution
7 support 4 Lagrangian
8 support 4 lookup table
9 support 8 truncated sinc
10 support 8 lookup table

Additions to the global resampling options are possible through the extension method described in 5.6.

The ENGAGE ROI CONTROL switch overrides any image attribute references to bound ROIs. When the switch is OFF, the operator model acts in the same manner as it would if all bound ROIs were TRUE at all pixels.

The ENGAGE MATCH POINT switch overrides any image attribute references to match points. When the switch is OFF, the operator model acts in the same manner as it would if all match points were set to the origin.

The ENGAGE INDEX ASSIGNMENT switch overrides any image attribute references to an index assignment table. When the switch is OFF, the operator model acts as if: x was assigned to j; y was assigned to k; z was assigned to l; t was assigned to m; and b was assigned to n.

Operators that provide resample options shall override the global resampling option.

Clause 7 contains specifications of the global operator control mechanisms. Annex H defines the global resampling options.

4.4.9 Composite image management

This clause specifies aggregation and deaggregation image object composition mechanisms. They are higher-level adjuncts to basic PIKS image objects. The purpose of these mechanisms is to provide an application with a means of handling ensembles of related images. These mechanisms permit the composition and decomposition of aggregates of images, such as lists, arrays, and records of images, whose pixels are BD, ND, SD, RD, CD data types, as defined in ISO/IEC 12087-1. These image aggregates are directly specialized from the compound image data types defined in ISO/IEC 12087-1 to comply with the five-dimensional memory model underlying the PIKS architecture. They provide for storage and retrieval of image identifiers.

NOTE – PIKS does not provide operators that perform operations directly on composite images. However, PIKS does provide operators that perform operations on PIKS image objects that are referenced by identifiers in composite image aggregates.

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There are three types of composite image identifier objects:

- composite image identifier arrays
- composite image identifier lists
- composite image identifier records

The following clauses describe each of these types of composite image objects.

4.4.9.1 Composite image identifier arrays

Composite image arrays are one-dimensional, fixed-length arrays of image identifiers, which provide references to PIKS image objects that have been created using PIKS system management mechanisms. The individual composite image identifier array elements can be accessed by a non-negative integer index. Prior to any access, composite image identifier arrays are created by invoking the mechanism

allocate_composite_identifier_array

which creates an array of image identifiers, all of which are initialised to NULL value upon creation. For storage, image identifiers can be arbitrarily accessed by index by using the mechanism

composite_identifier_array_put

For retrieval, the corresponding mechanism is

composite_identifier_array_get

The equality of two composite image arrays may be tested by a composite image mechanism

composite_identifier_array_equal

which determines if both composite image identifier arrays store identical sequences of image identifiers.

If no longer needed, composite image identifier arrays can be explicitly deleted by invoking the general system management mechanism

deallocate_data_object

Clause 7 specifies the composite image identifier array mechanisms.

The code for a composite image identifier array data object is ID_ARRAY.

4.4.9.2 Composite image identifier lists

Composite image identifier lists are sequences of image identifiers, which provide references to PIKS image objects. The ordering of a list is imposed by the order in which list elements have been appended to the tail of the list. Prior to any access, composite image identifier lists are created by invoking the mechanism

allocate_composite_identifier_list

Upon creation, the list is empty. Image identifiers can be inserted in a composite image identifier list by the mechanism

composite_identifier_list_insert

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Image identifiers can be removed from the tail of a composite image list by the mechanism

composite_identifier_list_remove

Individual images referenced by their identifiers in a composite image identifier list can be accessed by moving an internal list pointer through relations between the list elements. These relations are defined by the order in which images have been inserted in the composite image identifier list. The image identifiers can be retrieved by the mechanism.

composite_identifier_list_get

The following mechanism determines if a composite image identifier list is empty.

composite_identifier_list_empty

The equality of two composite image identifier lists may be tested by a composite image mechanism

composite_identifier_list_equal

which determines if both lists contain identical sequences of image identifiers.

If no longer needed, composite image identifier lists can be explicitly deleted by invoking the general mechanism

deallocate_data_object

Clause 7 specifies the composite image identifier list mechanisms.

The code for a composite image identifier list data object is ID_LIST.

4.4.9.3 Composite image identifier records

Composite image records are records of image identifiers, which provide references to PIKS image objects. A composite image identifier record is an aggregate of named attributes, which provides access by name to the PIKS image identifiers it stores. Prior to using a composite image identifier record, it is created by invoking the mechanism

allocate_composite_identifier_record

which specifies character string attribute names of the components of the record. All access to image identifiers stored in the composite image identifier record shall be by these attribute names.

An image identifier can be stored in an image identifier record by invoking the mechanism

composite_identifier_record_put

It can be retrieved by the mechanism

composite_identifier_record_get

The equality of two composite image identifier records may be tested by a composite image mechanism

composite_identifier_record_equal

which determines if both records contain identical names

If no longer needed, composite image identifier records can be explicitly deleted by invoking the general mechanism

deallocate_data_object

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Clause 7 specifies the composite image identifier record mechanisms.

The code for a composite image identifier record data object is ID_RECORD.

NOTES

1 – Composite image identifier arrays, lists, and records provide an efficient means of manipulating large ensembles of related physical images. Physical images can be "virtually stored" between several image identifier arrays, lists, and records, without duplicating bulk pixel data, by copying the respective image identifiers.

2 – Many of the composite identifier array, list, and record mechanisms can be used to store non-image object identifiers. It is the responsibility of the application to insure consistency between these mechanisms and other PIKS elements.

4.4.10 PIKS error handling

For each PIKS element, error situations are specified, any of which will cause the PIKS error handling function to be called. Every PIKS implementation shall support this form of error checking. The error handling function provides an interface between PIKS and an application. The error handling function, if provided by an application, may interpret the information about the error and may store data in a data area for subsequent interpretation by the application after returning from the PIKS element that caused the error.

NOTE – Inquiry utilities do not generate error indications.

The PIKS error handling strategy is derived from the following error classification:

I. errors resulting in a precisely defined reaction

II. errors resulting in an attempt to save the results of previous operations

III. errors that cause unpredictable results, including the loss of information

PIKS recognizes three situations in which errors are detected:

A. error detected in PIKS functions

B. error detected in functions called from PIKS (driver functions, operating system functions)

C. error detected in other areas of the application program

If errors are detected outside PIKS (situation C), either the application may regain control over the execution, or program execution will be terminated abnormally. In the latter case, results are unpredictable (class III), and, in the worst situation, all processed image information produced thus far may be lost. However, if the application obtains control, it may attempt to close PIKS properly, or at least attempt an emergency closure by calling the *close_piks_emergency* mechanism. Similarly, if an error occurs in the element called by PIKS, and control is not returned properly to PIKS, the effects will be unpredictable.

Finally, all errors that are listed explicitly as part of the definition of PIKS elements belong to class I. Either these errors are detected within PIKS itself (situation A), or an element called from PIKS has returned control to the corresponding PIKS element with appropriate error information (situation B). In all of the these class I cases, PIKS calls the *error_handler* mechanism. If a PIKS element is invoked with more than one error condition applicable, at least the first error is reported.

The application may either provide its own error handling function, or may use the one provided as part of PIKS. Any error handling function accepts the following information from PIKS.

identification of the error condition

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identification of the PIKS element that called the error handling function

error file

The error handling function provided by PIKS calls for an *error_logger* mechanism using the same set of parameters. The latter performs the following actions:

writes an error message and PIKS element identification on the error file

returns to the calling element

This two-stage calling of error functions allows the application to supply its own error handling function while still having access to services provided by the error logging function. The following is an example of an error handling function supplied by an application:

```
ERROR HANDLER (error number, identification of PIKS element, indication of
    asynchronous or synchronous state, identification of chain if one exists, error file);
    Interpret PIKS element and error identification in order to select the following cases:
CASE 'special treatment':
    Interpret error parameters as passed from PIKS;
    Store information for the application in application-supplied data area;
    Return to calling PIKS element
CASE 'standard treatment':
    Call error logging function with all of the above parameters;
     Return to calling PIKS element
END
```

A PIKS application may suppress transfer of control to the *error_handler* mechanism by setting the 'error reporting mode' in the PIKS error state list to OFF. The default value for the 'error' reporting mode is ON.

All PIKS elements take these steps after detecting an error condition:

set error state to ON

call *error_handler* function with appropriate parameters

set error state to OFF

do built-in error reaction

At least one error detected is reported.

An error handling function, supplied by an application, has access to the set of PIKS state variables. However, no modification of PIKS state is possible during error handling. Only the *error_logger*, *close_piks_emergency*, and PIKS inquiry mechanisms may be called by the error handling function, which is supplied by the application. This is achieved by setting the error state to ON prior to calling the error handling function from PIKS, and by setting the error state to OFF afterwards.

Error numbers for errors originating in PIKS elements can be found in clause 7 under each PIKS element. Annex J contains a compilation of PIKS error codes. The following errors numbers are reserved:

Negative error numbers are reserved for implementation errors.

Unused error number less than 2000 are reserved for future standardization.

Error numbers 2000 to 3999 are reserved for language bindings.

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Error numbers greater than or equal to 4000 are reserved for registration.

Error numbers are registered in the ISO International Register of Graphical Items, which is maintained by the Registration Authority. When an error has been approved by ISO, the error number will be assigned by the Registration Authority.

When multiple errors are possible for a PIKS element, the order in which they are listed in clause 7 is the order in which an implementation should test for and report any error conditions.

4.4.11 PIKS operational states

PIKS functions in a number of operational states. Each state supports certain allowable capability as well as certain restrictions. These states are designed to provide integrity and protection for both PIKS and applications using PIKS.

Figure 10 shows the relationship of the PIKS operational states.

In some instances, PIKS will change back and forth among states, as in the case of ERROR, EXECUTE_CHAIN, and BUILD_CHAIN, which interleave with PIKS_OPEN.

Individual PIKS elements declare the PIKS state or states that allow their execution. If an element is invoked when PIKS is in any state other than an allowed state, an error will result.

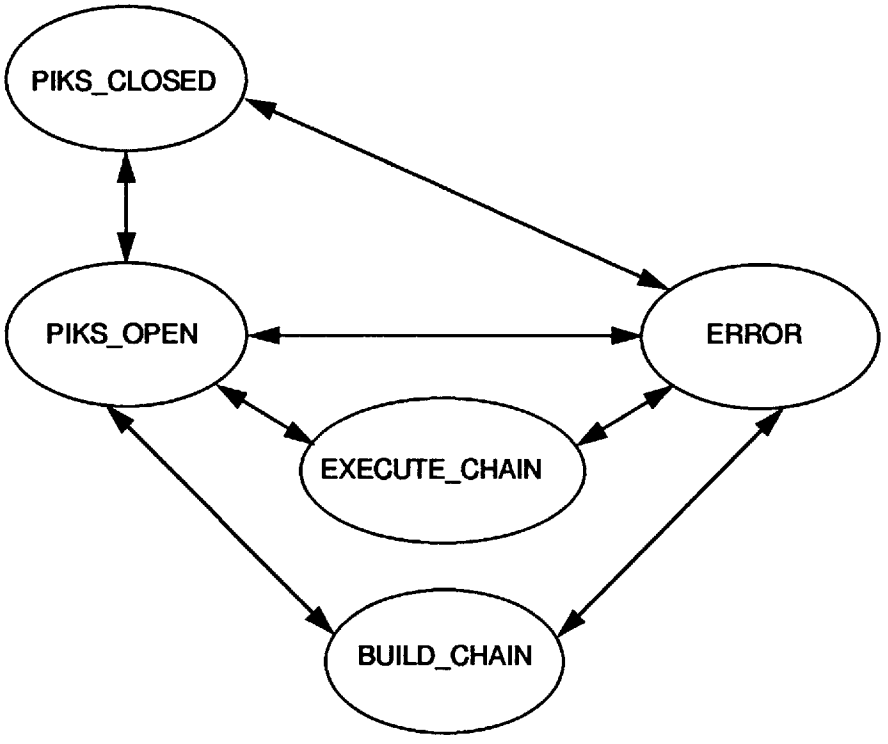

Figure 10 - PIKS operational state diagram

A description of the various PIKS states follows.

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State: ERROR

This state is entered when an error occurs during the execution of a PIKS element.

State: PIKS_CLOSED

This state is in effect prior to successful execution of the *open_piks* mechanism and following a successful invocation of the *close_piks* or *close_piks_emergency* mechanisms. In this state, it is permissible that PIKS global storage (including state tables) have not yet been allocated, and that no default values or other values has been established. Therefore, execution of any inquiry system management mechanism will result in an 'inquiry data not available' response. Execution of any PIKS element, other than an inquiry or *open_piks* mechanism, will result in an error.

State: PIKS_OPEN

This state is established after successful execution of the *open_piks* mechanism after all internal tables have been established and have been given either default values or other values. The only elements that cannot be executed in this state are the *open_piks* and *chain_end* mechanisms. A successful execution of the *close_piks* mechanism puts PIKS back into the PIKS_CLOSED state.

State: BUILD_CHAIN

In this state, the operation code and parameters of all elements invoked are put onto a specified chain prior to returning control to the application. The parameters of the elements of the chain may not have been fully examined for validity, but they may have undergone a preliminary analysis for correctness.

The BUILD_CHAIN state is entered from the PIKS_OPEN state by execution of the *chain_begin* mechanism. The BUILD_CHAIN state is terminated, returning back to the PIKS_OPEN state, by execution of the *chain_end* mechanism. Once completed, the chain may be executed by invoking the *chain_execute* mechanism.

The specification for each PIKS element indicates whether it can be chained. Any PIKS element, which may be invoked in the PIKS_OPEN state, may be invoked in the BUILD_CHAIN state provided that it is identified as chainable.

If an error is detected during the building of a chain, the ERROR HANDLER will be invoked. PIKS will be put into the ERROR state, and the condition will be handled prior to the normal return to the application.

State: EXECUTE_CHAIN

This PIKS state is in effect when the PIKS elements, which are part of a chain, are being interpreted and executed. The EXECUTE_CHAIN state is entered when the *chain_execute* mechanism is invoked. When the *chain_execute* mechanism returns control to the application, the state returns to PIKS_OPEN. Normally, PIKS elements are invoked by an application in the PIKS_OPEN state. When these elements are executed as part of a chain, PIKS is placed into the EXECUTE_CHAIN state in order to make more information available if an error occurs.

When an error occurs, the current PIKS state is reported as part of the error information. If the error state is EXECUTE_CHAIN, the application can then inquire about additional information, such as which chain and which chain element caused the error.

PIKS allows PIKS elements and chains to be executed asynchronously. In addition,

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implementations may provide multiple execution threads to provide high performance PIKS environments. There are no PIKS facilities for multi-thread process handling, and the presence of such threads is apparent only in improved performance. However, if an error occurs during the execution of a PIKS element by an asynchronous control thread, some PIKS condition needs to be reported. Thus, if an error occurs during the asynchronous execution of a PIKS element, then one of two conditions is reported as the error state. These two conditions are: ASYNCHRONOUS_EXECUTION and ASYNCHRONOUS_EXECUTE_CHAIN. The error condition is ASYNCHRONOUS_EXECUTE_CHAIN if the PIKS element that caused the error is part of a chain; if the PIKS element was placed on the Asynchronous Execution Queue individually and not as part of a chain, then the condition reported as the error state is ASYNCHRONOUS_EXECUTION.

4.5 PIKS utilities

This clause describes the general properties of PIKS utilities. These utilities are specified in clause 7.

4.5.1 Inquiry

PIKS provides a class of inquiry functions whose purpose is to supply information to the application about the operational status of PIKS internal functionality. Inquiry utilities do not return errors. If an inquiry utility is unable to ascertain the requested information, a data validity flag is set to indicate "data unavailable."

4.5.2 Import and export

PIKS provides capabilities to import and export image and non-image data objects between PIKS and an application and between PIKS and the Image Interchange Facility. Figure 11 describes the flow of data objects between PIKS and the application and between PIKS and the IIF.

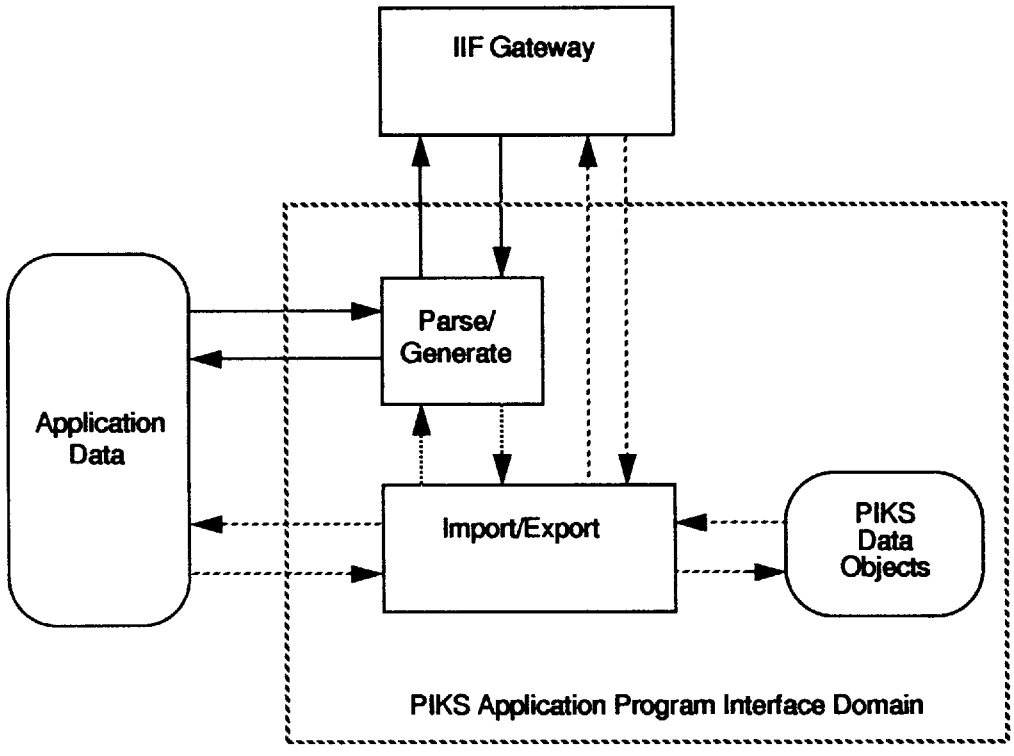

Figure 11 – PIKS interface to the IIF gateway and an application

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NOTES

1 – The storage environment for data objects in an application is not specified by the IPI standard. However, PIKS specifies a set of physical data types that it is capable of importing and exporting.

2 – ISO/IEC 12087-2 does not specify the physical storage environment of data objects that exist within the PIKS domain. PIKS data objects are only defined abstractly, as specified in ISO/IEC 12087-1.

3 – ISO/IEC 12087-3 specifies the environment for data object representation within the Image Interchange Facility.

Figure 11 shows pairs of data paths between PIKS and an application and between PIKS and the IIF Gateway. The solid lines indicate the interchange of data according to the specification of the IIF data format whose syntax is expressed in the ASN.1 notation, as specified in ISO/IEC 12087-3. The dashed lines indicate the interchange of data according to an implementation-specific data format. The PIKS import and export facility is responsible for accepting data in either format and performing appropriate data type conversions.

An ASN.1 syntax format data stream accepted from an application or the IIF is parsed by the PIKS Parse/Generate facility and supplied to the PIKS Import/Export facility for conversion to the internal PIKS data object representation. Similarly, PIKS data objects that are to be transferred to the application or to the IIF via a data stream, which is encoded according to the ASN.1 Basic Encoding Rules (BER), are converted from the PIKS internal data object representation. The data stream is generated by the PIKS Parse/Generate facility. ISO/IEC 12087-3 specifies the utilities for ASN.1 parsing and generating of PIKS data objects.

The dashed line data pathways between PIKS and the application and between PIKS and the IIF are not specified by this part of ISO/IEC 12087. An implementation is free to provide any physical means of data interchange of PIKS data objects.

NOTES

1 – The purpose of the ASN.1 data stream pathways is to provide a means of standardized data transportability between PIKS and an application or PIKS and the IIF.

2 – The purpose of the non-standardized pathways is to permit implementations of PIKS and the IIF by a single implementor to achieve more efficient data interchange by avoiding the parsing and generating functions.

PIKS does not specify image compression or decompression capabilities, nor does PIKS specify any image data object representations for the storage of compressed images. PIKS implementations may choose to accept compressed image data across the implementation-specific data pathway and store such data in compressed form. Such implementations must decompress the image data prior to processing by PIKS elements.

4.5.2.1 Data object import and export utilities

Table 4 lists the PIKS data object import and export utilities. Specifications of the utilities are presented in Clause 7. These import and export utilities apply to the interchange of data objects via the ASN.1 data stream or the implementation-specific data path. The source and destination data object identifiers distinguish which data path that is to be utilized. ISO/IEC 12087-3 specifies the parse and generate utilities that must be used in conjunction with the PIKS import and export utilities to create a data interchange of PIKS data objects via an ASN.1 data stream.

4.5.2.2 PIKS to application data type conversion

Figure 12 describes the PIKS to application interface for data interchange for an implementation-specific data pathway.

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PIKS supports a limited number of physical data types that may exist within an application domain or within the PIKS domain. Such data types represent both input and output parameters of PIKS elements and image and non-image data that are interchanged between PIKS and the application.

PIKS provides notational differentiation between most of the elementary abstract data types used entirely within the PIKS domain (PIKS internal), those that are used to convey parameter data between PIKS and the application (PIKS parameter), and those that are used to convey pixel data between PIKS and the application (external physical image). Table 6 lists the codes for the PIKS abstract data types. The abstract data types are defined in ISO/IEC 12087-1. PIKS internal and parameter data types are of the same class if they refer to the same basic data type. For example, RP and RD data types are of the same class, but RP and SD data types are of different classes.

NOTE – The notational distinction between PIKS and inter-PIKS data types makes it possible for implementations to provide different physical representations and different precisions for the same class of data types. For example, in a PIKS element calling syntax, a real arithmetic data parameter RP might be represented as a floating point number, while RD data type pixels in a physical processor might be represented as two's complement, fixed point integers.

The external physical data types supported by PIKS for the import and export of image data are listed in Table 7. PIKS internal pixel data types and external pixel data types are of the same class if they refer to the same basic data type. For example, ND and NI data types are of the same class, but SI and ND data types are of different classes.

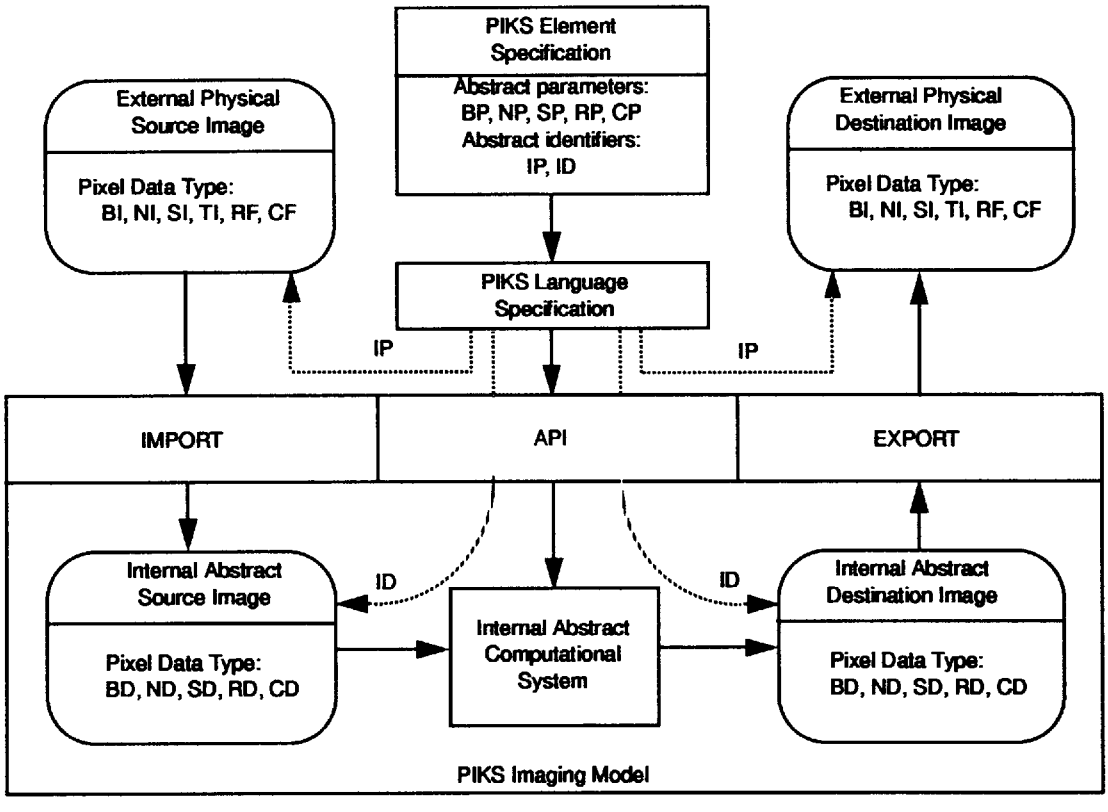

Figure 12 – PIKS to application interface

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NOTES

1 – The precision of internal and external physical image arithmetic data types need not be the same.

2 – An implementation may utilize more than one data length (precision) in the various usages of the data types shown in Figure 12.

The conversion procedures between the PIKS external physical arithmetic data types and the PIKS internal physical arithmetic data types are implementation-dependent. The conversion procedures provide for certain changes between physical data types. For example, a signed integer image can be converted to a floating point image as part of the import process.

NOTE - ISO/IEC 12087-1 uses the characters BC, NC, SC, RC, CC to denote general abstract data types. The PIKS data types shown in Figure 12 and defined in Tables 6 and 7 are specific delineations of the ISO/IEC 12087-1 data types.

Table 6 - PIKS data type codes

Data Type	PIKS Internal Code	PIKS Parameter Code
Boolean	BD	BP
non-negative integer	ND	NP
signed integer	SD	SP
real arithmetic	RD	RP
complex arithmetic	CD	CP
character string	CS	CS
data object identifier	ID	IP
enumerated	NA	EP
null	NULL	NULL

Table 7 - External physical data types supported by PIKS

Data Type	Physical Code
Boolean	BI
non-negative integer	NI
signed integer	SI
fixed point integer	TI
real floating point	RF
complex floating point	CF

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5 PIKS conformance and extension methods

ISO/IEC 12087-1 establishes the concept of conformance profiles. PIKS provides three profile levels: a foundation level, an application level, and a full level. This clause specifies the functionality of the PIKS profiles. This clause also specifies PIKS extension methods.

5.1 Foundation profile

The PIKS foundation profile specifies a minimally conformant level of PIKS functional capability. It is a functional subset of any and all other profiles.

5.2 Application profiles

There is provision, within the definition of profiles in ISO/IEC 12087-1, for PIKS to specify a set of application-specific profiles. Each application profile shall contain all of the functionality of the foundation profile plus additional functionality pertinent to certain imaging applications. Application profiles may overlap in terms of functionality.

PIKS specifies two application profiles called PIKS Technical and PIKS Scientific. They are intended to serve the general technical and scientific imaging markets.

NOTE – Additional application profiles can be registered.

5.3 Full profile

The full profile, called PIKS Full, is the conformance profile that specifies the full set of functional capabilities for all functionalities specified in this standard.

5.4 IIF capability profiles

All PIKS profiles may be augumented by inclusion of data interchange capabilities between PIKS and the Image Interchange Facility (IIF), as specified in ISO/IEC 12087-3. Such profiles are denoted as

Foundation – IIF capable

Technical – IIF capable

Scientific – IIF capable

Full – IIF capable

The suffix "IIF capable" indicates that a PIKS implementation is capable of supporting the interchange of PIKS data objects between PIKS and the IIF according to the specification of the IIF data format whose syntax is expressed in the ASN.1 notation, as specified in ISO/IEC 12087-3.

5.5 PIKS profile definitions

The data types of PIKS non-image data objects supported by the Foundation profile are listed in Table 8. All other profiles support the full range of data types, as specified in ISO/IEC 12087-1.

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Table 9 lists the functional features of each PIKS conformance profile. The number of PIKS elements (operators, tools, utilities, and system mechanisms) supported by each profile is presented in Table 10. Table 11 specifies which elements are in each profile.

The elements type code of Table 11 is as follows:

O	operator
T	tool
U	utility
M	mechanism

Annex L contains alphabetical listings of the PIKS elements by profile.

NOTE – Table 1 defines the image structure codes referenced in Table 8. Table 6 defines the data type codes referenced in Table 9.

Table 8 – Data types of PIKS non-image data objects supported in the Foundation profile

	Data Type			
Object	**BD**	**ND**	**SD**	**RD**
HIST		X		
LUT	X	X	X	
MATRIX		X	X	X
NBHOOD_ARRAY	X	X	X	X
ROI	X			
TUPLE	X	X	X	X

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Table 9 – PIKS conformance profiles

Feature	Foundation	Technical	Scientific	Full
Image data type				
BD	X	X	X	X
ND	X	X	X	X
SD	X	X	X	X
RD		X	X	X
CD		X	X	X
Image structure				
MON	X	X	X	X
VOL		X	X	X
TEM		X	X	X
COLR	X	X	X	X
SPE		X	X	X
VT		X	X	X
VC		X	X	X
VS		X	X	X
TC		X	X	X
TS		X	X	X
VTC		X	X	X
VTS		X	X	X
GEN		X	X	X
Control				
index assignment		X	X	X
match point		integer	sub pixel	sub pixel
image resampling	support 1, 2	support 1, 2, 4	support 1, 2, 4, 8	support 1, 2, 4, 8
ROI resampling	support 1	support 1, 2, 4	support 1, 2, 4, 8	support 1, 2, 4, 8
ROI control	2D ROI_RECT	all ROIs	all ROIs	all ROIs
ROI process			X	X
heterogeneous bands			X	X
composite image			X	X
chaining				X
asynchronous			X	X
virtual registers				X
Repository	X	X	X	X

"X" indicates that a particular feature is in a profile.

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Table 10 – Number of operators, tools, utilities, mechanisms, and total elements in each profile

	Foundation	Technical	Scientific	Full
Operators	37	84	126	126
Tools	5	15	28	28
Utilities	37	54	56	58
Mechanisms	17	21	38	54
Total elements	96	174	248	266

	Foundation-IIF	Technical-IIF	Scientific-IIF	Full-IIF
Operators	37	84	126	126
Tools	5	15	28	28
Utilities	37	54	56	58
Mechanisms	19	23	40	56
Total elements	98	176	250	268

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Table 11 PIKS elements in each profile

No.	Element	Type	Foundation	Technical	Scientific	Full
1	abort_asynchronous_execution	M			X	X
2	accumulator	O	X	X	X	X
3	adaptive_histogram_equalization	O			X	X
4	allocate_chain	M				X
5	allocate_composite_identifier_array	M			X	X
6	allocate_composite_identifier_list	M			X	X
7	allocate_composite_identifier_record	M			X	X
8	allocate_histogram	M	X	X	X	X
9	allocate_image	M	X	X	X	X
10	allocate_lookup_table	M	X	X	X	X
11	allocate_matrix	M	X	X	X	X
12	allocate_neighbourhood_array	M	X	X	X	X
13	allocate_pixel_record	M		X	X	X
14	allocate_roi	M	X	X	X	X
15	allocate_static_array	M		X	X	X
16	allocate_tuple	M	X	X	X	X
17	allocate_value_bounds	M			X	X
18	allocate_vreg	M				X
19	alpha_blend_constant	O	X	X	X	X
20	alpha_blend_variable	O		X	X	X
21	array_to_lut	T	X	X	X	X
22	bind_match_point	M		X	X	X
23	bind_roi	M	X	X	X	X
24	bit_shift	O	X	X	X	X
25	cartesian_to_polar	O			X	X
26	chain_abort	M				X
27	chain_begin	M				X
28	chain_delete	M				X
29	chain_end	M				X
30	chain_execute	M				X

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Table 11 PIKS elements in each profile *(continued)*

No.	Element	Type	Foundation	Technical	Scientific	Full
31	chain_reload	M				X
32	classifier_bayes	O			X	X
33	classifier_nearest_neighbour	O			X	X
34	close_piks	M	X	X	X	X
35	close_piks_emergency	M	X	X	X	X
36	colour_conversion_linear	O	X	X	X	X
37	colour_conversion_matrix	T	X	X	X	X
38	colour_conversion_nonlinear	O		X	X	X
39	colour_conversion_subtractive	O	X	X	X	X
40	colour_lookup_interpolated	O		X	X	X
41	complement	O	X	X	X	X
42	complement_roi	O		X	X	X
43	complex_composition	O		X	X	X
44	complex_conjugate	O		X	X	X
45	complex_decomposition	O		X	X	X
46	complex_magnitude	O		X	X	X
47	composite_identifier_array_equal	M			X	X
48	composite_identifier_array_get	M			X	X
49	composite_identifier_array_put	M			X	X
50	composite_identifier_list_empty	M			X	X
51	composite_identifier_list_equal	M			X	X
52	composite_identifier_list_get	M			X	X
53	composite_identifier_list_insert	M			X	X
54	composite_identifier_list_remove	M			X	X
55	composite_identifier_record_equal	M			X	X
56	composite_identifier_record_get	M			X	X
57	composite_identifier_record_put	M			X	X
58	constant_predicate	U		X	X	X
59	convert_array_to_image	U	X	X	X	X
60	convert_image_datatype	U	X	X	X	X

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Table 11 PIKS elements in each profile *(continued)*

No.	Element	Type	Foundation	Technical	Scientific	Full
61	convert_image_to_array	U	X	X	X	X
62	convert_image_to_roi	U		X	X	X
63	convert_roi_to_image	U	X	X	X	X
64	convolve_2d	O	X	X	X	X
65	convolve_5d	O		X	X	X
66	copy_window	U	X	X	X	X
67	copy_window_roi	U		X	X	X
68	create_tuple	U	X	X	X	X
69	cross_correlation	O			X	X
70	deallocate_data_object	M	X	X	X	X
71	define_sub_image	M	X	X	X	X
72	difference_measures	O		X	X	X
73	diffuse	O	X	X	X	X
74	dither	O	X	X	X	X
75	draw_pixels	O	X	X	X	X
76	draw_pixels_roi	O		X	X	X
77	dyadic_arithmetic	O	X	X	X	X
78	dyadic_complex	O		X	X	X
79	dyadic_logical	O	X	X	X	X
80	dyadic_logical_roi	O		X	X	X
81	dyadic_predicate	O	X	X	X	X
82	edge_detection_orthogonal_gradient	O			X	X
83	edge_detection_second_derivative	O			X	X
84	edge_detection_template_gradient	O			X	X
85	equal_predicate	U		X	X	X
86	erosion_dilation_boolean	O		X	X	X
87	erosion_dilation_boolean_roi	O		X	X	X
88	erosion_dilation_grey	O		X	X	X
89	error_function_scaling	O			X	X
90	error_handler	M	X	X	X	X

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Table 11 PIKS elements in each profile *(continued)*

No.	Element	Type	Foundation	Technical	Scientific	Full
91	error_logger	M	X	X	X	X
92	error_test	M	X	X	X	X
93	export_histogram	U	X	X	X	X
94	export_image	U	X	X	X	X
95	export_lut	U	X	X	X	X
96	export_matrix	U	X	X	X	X
97	export_neighbourhood_array	U	X	X	X	X
98	export_roi_array	U		X	X	X
99	export_static_array	U		X	X	X
100	export_tuple	U	X	X	X	X
101	export_value_bounds	U			X	X
102	extract_pixel_plane	U	X	X	X	X
103	extract_pixel_plane_roi	U		X	X	X
104	extrema	O	X	X	X	X
105	false_colour	O			X	X
106	fill_region	O		X	X	X
107	fill_region_roi	O		X	X	X
108	filter_butterworth	T		X	X	X
109	filter_gaussian	T		X	X	X
110	filter_inverse	T			X	X
111	filter_matched	T			X	X
112	filter_wiener	T			X	X
113	filter_zonal	T		X	X	X
114	filtering_homomorphic	O			X	X
115	filtering_linear	O		X	X	X
116	filtering_median	O		X	X	X
117	filtering_pseudomedian	O			X	X
118	filtering_rank_order	O			X	X
119	flip_spin_transpose	O	X	X	X	X
120	flip_spin_transpose_roi	O	X	X	X	X

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Table 11 PIKS elements in each profile *(continued)*

No.	Element	Type	Foundation	Technical	Scientific	Full
121	gamma_correction	O		X	X	X
122	get_colour_pixel	U	X	X	X	X
123	get_pixel	U	X	X	X	X
124	get_pixel_roi	U	X	X	X	X
125	get_pixel_array	U	X	X	X	X
126	get_pixel_array_roi	U	X	X	X	X
127	get_pixel_record	U		X	X	X
128	get_pixel_record_roi	U		X	X	X
129	histogram_modification	O			X	X
130	histogram_scaling	O			X	X
131	histogram_shape_1d	O			X	X
132	histogram_shape_2d	O			X	X
133	histogram_1d	O	X	X	X	X
134	histogram_2d	O			X	X
135	hit_or_miss	O		X	X	X
136	hit_or_miss_roi	O		X	X	X
137	hough_transform	O			X	X
138	image_bar_chart	T		X	X	X
139	image_constant	T	X	X	X	X
140	image_gaussian	T			X	X
141	image_grey_scale	T		X	X	X
142	image_random_number	T			X	X
143	import_histogram	U	X	X	X	X
144	import_image	U	X	X	X	X
145	import_lut	U	X	X	X	X
146	import_matrix	U	X	X	X	X
147	import_neighbourhood_array	U	X	X	X	X
148	import_roi_array	U		X	X	X
149	import_static_array	U		X	X	X
150	import_tuple	U	X	X	X	X

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Table 11 PIKS elements in each profile *(continued)*

No.	Element	Type	Foundation	Technical	Scientific	Full
151	import_value_bounds	U			X	X
152	impulse_boxcar	T			X	X
153	impulse_derivative_of_gaussian	T			X	X
154	impulse_difference_of_gaussians	T			X	X
155	impulse_elliptical	T		X	X	X
156	impulse_gaussian	T		X	X	X
157	impulse_laplacian_of_gaussian	T			X	X
158	impulse_pyramid	T			X	X
159	impulse_rectangular	T	X	X	X	X
160	impulse_sinc	T			X	X
161	input_object (Full — IIF only)	U	X	X	X	X
162	inquire_chain_environment	U				X
163	inquire_chain_status	U				X
164	inquire_elements	U	X	X	X	X
165	inquire_image	U	X	X	X	X
166	inquire_index_assignment	U		X	X	X
167	inquire_non_image_object	U	X	X	X	X
168	inquire_piks_implementation	U	X	X	X	X
169	inquire_piks_status	U	X	X	X	X
170	inquire_repository	U	X	X	X	X
171	inquire_resampling	U	X	X	X	X
172	insert_pixel_plane	U	X	X	X	X
173	insert_pixel_plane_roi	U		X	X	X
174	label_objects	O			X	X
175	laws_texture_features	O			X	X
176	level_slice	O			X	X
177	line_profile	O			X	X
178	lookup	O	X	X	X	X
179	lookup_interpolated	O		X	X	X
180	luminance_generation	O	X	X	X	X

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Table 11 PIKS elements in each profile *(continued)*

No.	Element	Type	Foundation	Technical	Scientific	Full
181	markov_spectrum	T			X	X
182	moments	O	X	X	X	X
183	monadic_arithmetic	O	X	X	X	X
184	monadic_complex	O		X	X	X
185	monadic_logical	O	X	X	X	X
186	monadic_logical_roi	O		X	X	X
187	morphic_processor	O	X	X	X	X
188	morphic_processor_roi	O		X	X	X
189	morphology	O		X	X	X
190	morphology_roi	O		X	X	X
191	neighbour_count	O			X	X
192	noise_combination	O			X	X
193	open_close	O			X	X
194	open_close_roi	O			X	X
195	open_piks	M	X	X	X	X
196	outlier_removal	O		X	X	X
197	output_object (Full — IIF only)	U	X	X	X	X
198	paint_pixels	O		X	X	X
199	perimeter_code_generator	O			X	X
200	polar_to_cartesian	O			X	X
201	power_law_scaling	O		X	X	X
202	pseudocolour	O		X	X	X
203	put_colour_pixel	U	X	X	X	X
204	put_pixel	U	X	X	X	X
205	put_pixel_roi	U		X	X	X
206	put_pixel_array	U	X	X	X	X
207	put_pixel_array_roi	U		X	X	X
208	put_pixel_record	U		X	X	X
209	put_pixel_record_roi	U		X	X	X
210	rescale	O	X	X	X	X

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Table 11 PIKS elements in each profile *(continued)*

No.	Element	Type	Foundation	Technical	Scientific	Full
211	rescale_roi	O	X	X	X	X
212	resize	O	X	X	X	X
213	resize_roi	O	X	X	X	X
214	return_repository_id	M	X	X	X	X
215	roi_coordinate	T		X	X	X
216	roi_elliptical	T		X	X	X
217	roi_polygon	T		X	X	X
218	roi_rectangular	T	X	X	X	X
219	rotate	O	X	X	X	X
220	rotate_roi	O		X	X	X
221	rubber_band_scaling	O			X	X
222	sequence_average	O			X	X
223	sequence_karhunen_loeve	O			X	X
224	sequence_running_measures	O			X	X
225	set_globals	M	X	X	X	X
226	set_image_attributes	M	X	X	X	X
227	set_index_assignment	M		X	X	X
228	shape_metrics	O			X	X
229	spatial_moments_invariant	O			X	X
230	spatial_moments_scaled	O			X	X
231	split_image	O	X	X	X	X
232	subsample	O	X	X	X	X
233	subsample_roi	O		X	X	X
234	synchronize	M			X	X
235	template_match	O			X	X
236	threshold	O	X	X	X	X
237	transform_cosine	O		X	X	X
238	transform_fourier	O		X	X	X
239	transform_hadamard	O			X	X
240	transform_hartley	O			X	X

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Table 11 PIKS elements in each profile *(concluded)*

No.	Element	Type	Foundation	Technical	Scientific	Full
241	translate	O	X	X	X	X
242	translate_roi	O	X	X	X	X
243	unary_integer	O	X	X	X	X
244	unary_real	O		X	X	X
245	unsharp_mask	O		X	X	X
246	value_bounds	O			X	X
247	vreg_alter	M				X
248	vreg_clear	M				X
249	vreg_conditional	M				X
250	vreg_copy	M				X
251	vreg_delete	M				X
252	vreg_get	M				X
253	vreg_set	M				X
254	vreg_wait	M				X
255	wallis_statistical_differencing	O		X	X	X
256	warp_control_point	O		X	X	X
257	warp_control_point_roi	O		X	X	X
258	warp_lut	O		X	X	X
259	warp_lut_roi	O		X	X	X
260	warp_polynomial	O		X	X	X
261	warp_polynomial_roi	O		X	X	X
262	windowing_function	T			X	X
263	window_level	O	X	X	X	X
264	window_statistics	O			X	X
265	z_merge	O		X	X	X
266	zoom	O	X	X	X	X
267	zoom_roi	O	X	X	X	X
268	3d_slice	O			X	X

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5.6 Extension methods

PIKS provides two methods to extend the functionality of the base standard. With the first method, which is in accordance with the ISO IS 9973 Procedures for Registration of Graphical Items, PIKS elements (operators, tools, utilities, system mechanisms), data object repository entries, and resampling options may be registered when such added functionality has been approved by ISO. The second method permits the addition of private non-standard elements, data object entries, and resampling options to a standard PIKS implementation.

Each element provided as an extension shall be specified with an element template, as described in clause 6. The element's parameter list may contain source images, destination images, non-image data objects, and element data parameters. Element functionality (index assignment, match point control, ROI support, chaining, and asynchronous operation) shall be specified for each added element. Data object repository entries may be added to each of the three data object repository classes: impulse response function arrays, dither arrays, and colour conversion matrices. Additions may be made to the base set of resampling options. Additions may be made to the list of error codes.

Every element, data object repository entry, and resampling option is assigned a number. The elements, data object repository entries, and resampling options of the base standard are numbered sequentially starting at 1. Extended functionality that has been approved by ISO shall be assigned positive numbers starting at a number one higher than the highest in the existing standard for each class of extended functionality. Negative numbers are reserved for each class of implementation-specific extended functionality with private non-standard elements.

Some PIKS elements provide options for the selection of specific functionality. Options that are not capable of extension are specified by an enumerated data parameter, EP. Options that may be extended are specified by a signed integer parameter, SP. Each extended option that has been approved by ISO shall be assigned a positive number starting at a number one higher than the highest in the existing standard for the option. Negative numbers are reserved for implementation-specific options.

PIKS inquiry utilities provide a means of accessing the available elements, data object repository entries, resampling options, and profile level supported by a PIKS implementation.

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6 PIKS element specification template

This clause defines the general functionality of all PIKS elements: operators, tools, utilities, and mechanisms, which are specified in clause 7. The following pages of this clause contain a template, in italics, of the information provided for each element. An example, in standard font, is given for the image rotation operator.

Remarks:

1. Many of the element specifications in clause 7 utilize tuple data objects to convey parameter information to other PIKS data objects. It is not a requirement that these tuples be incorporated in the data structures of the PIKS data objects.
2. Error code 302 shall be reported for all PIKS elements, other than inquiry mechanisms, if that element is invoked and PIKS is not in the PIKS_OPEN state.

NOTES

1 – For notational simplicity, the mathematical expressions that define operators involving images assume that all images are of the same size except for operators that inherently change the size of destination images with respect to source images, e.g., the *rescale* operator.

2 – For notational simplicity, the mathematical expressions that define operators involving images assume that the match point translation and ROI control mechanisms are not invoked.

3 – The PIKS specification references some parameters of mixed data type. A PIKS binding may choose to represent such parameters by individual entries for each data type or by the union of the mixed data types.

4 – The PIKS specification references some arrays whose elements are of mixed data type. A PIKS binding may choose to represent such arrays as a collection of sub-arrays of homogeneous data type.

5 – The PIKS specification references some external arrays. A PIKS implementation may choose to represent their data structures in an implementation-dependent manner.

Annex A provides definitions of mathematical functions utilized in the PIKS functional element definitions.

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Element specification template and example

ELEMENT CLASSIFICATION

GEOMETRIC OPERATOR

ELEMENT TITLE

ROTATE

Description:

Brief non-mathematical description of the functionality of an element.

Performs two-dimensional or three-dimensional rotation of an image about a point.

Name:

Abbreviation of element name appropriate for a language binding entry point. The second entry, if it exists, is the abbreviation for the element version that provides manipulation of a ROI as well as an image.

rotate rotate_roi

Parameters:

List of parameters necessary to specify source images, destination images, non-image data objects, and element data parameters. The input/output column specifies if a data object or data parameter is a data input or a data output to an element. The order of presentation is: source images, destination images, source non-image data objects, destination non-image objects, parameters and tuples, options.

name	*description*	*data type*	*input/ output*
SRC	source image	ID	in
DST	destination image	ID	out
js	first index source rotation centre	RP	in
ks	second index source rotation centre	RP	in
ls	third index source rotation centre	RP, NULL	in
rjk	j-k plane rotation angle	RP	in
rjl	j-l plane rotation angle	RP	in
rkl	k-l plane rotation angle	RP, NULL	in
option	rotation option 2D rotation 3D rotation	SP	in

Objects:

Specification of element source images, destination images, and non-image data objects in terms of their structure, data type, and dimension. The second set of entries, if they exist, are the specifications for the element version that provide manipulation of a ROI as well as an image.

SRC structure:	any	any ROI
DST structure:	same as SRC structure	ROI_GEN
SRC data type:	BD, ND, SD, RD, CD	BD
DST data type:	same as SRC data type	BD

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Element functionality:

Information regarding the general functionality of each element. The index assignment, match point control, ROI control, ROI processing, ROI manipulation, source promotion, and heterogeneous bands designations apply only to PIKS elements that manipulate images. The second set of entries, if they exist, specify the element functionality for the element version that provides manipulation of a ROI as well as an image.

Index assignment:	yes	no
Match point:	yes	no
ROI control:	yes	no
ROI processing:	yes	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Index assignment "yes" indicates that the element supports the capability of assigning the semantic indices of an image to the indices of an operator when the global mode has been set to INDEX_ASSIGN_ON.

Match point "yes" indicates that the element supports the capability of translating source and destination images to a common five-dimensional coordinate prior to processing when the global mode has been set to MATCH_POINT_ON.

ROI control "yes" indicates that the element supports region-of-interest control of source pixel selection and destination pixel recording when the global mode has been set to ROI_CONTROL_ON.

ROI processing "yes" indicates that the element supports the capability of processing the source ROI as well as the source image and replacing the destination image ROI with the processed source ROI when the global mode has been set to ROI_PROCESS_ON. For the rotate operator, the source ROI is rotated according to the same parameters as the source image and substituted for the previous destination image ROI.

Source promotion "yes" indicates the element is capable of converting non-negative integer or signed integer images to internal real arithmetic data type form prior to processing.

Heterogeneous bands "yes" indicates that the element is capable of processing source images whose pixel data types may differ from band to band. Within a band all pixels are of the same data type.

Chainable element "yes" indicates that the element is capable of being inserted into a chain.

Chainable element "vreg" indicates that the element is capable of being inserted in a chain if the value returned by the element is stored in a virtual register.

Asynchronous "yes" indicates that the element is capable of being computed asynchronously when the global mode has been set to ASYNCH_ON.

Remarks:

Information regarding element utilization and its limitations.

1. For geometric operators, all pixels are assumed to be of unit dimension. The geometric origin along a coordinate direction is at the centre of the pixel with index value zero. The geometric bounds of an origin pixel are – 0.5 to 0.5.
2. Rotation angles are positive for counterclockwise rotation about a vector emanating toward positive

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infinity from the rotation centre of a rotation plane.

3. Rotation angles are measured in radians.
4. The order of rotation is rjk, followed by rjl, followed by rkl.
5. The rotation centre coordinates need not be integer valued.
6. Geometric resampling is performed according to the global resampling option selected by the *set_globals* utility.
7. Source image pixels outside the index range of the source image are assumed to have value zero for ND, SD, RD, or CD data type images and are assumed to be of FALSE value for BD data type images.

Nomenclature:

Mathematical nomenclature used in the mathematical definition of an element.

SRC(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ source image
DST(x, y, z, t, b)	$X_D x Y_D x Z_D x T_D x B_D$ destination image
S(j, k, l, m, n)	$J_S x K_S x L_S x M_S x N_S$ operator input image
D(j, k, l, m, n)	$J_D x K_D x L_D x M_D x N_D$ operator output image
js	first index source rotation centre
ks	second index source rotation centre
ls	third index source rotation centre
rjk	j-k plane rotation angle
rjl	j-l plane rotation angle
rkl	k-l plane rotation angle

Definition:

Definition of PIKS element. A mathematical definition is provided whenever possible. Algorithmic or textual descriptions are provided for some complicated elements.

Index assignment is applicable to some PIKS elements. For such elements, there is an implied index assignment from (x, y, z, t, b) image space to (j, k, l, m, n) operator space prior to element execution, and an inverse index reassignment from (j, k, l, m, n) space to (x, y, z, t, b) space after element execution.

2D mode:

The 2D *rotate* operator is based upon a two-stage algorithm. In the first stage, a reverse address calculation is made whereby (j', k') source coordinates of the rotation transformation are calculated for integer values of the destination coordinates (j, k) for all l, m, n. In general, the (j', k') coordinates are not integer valued. The second stage of the algorithm entails resampling of the source image to evaluate the destination image at integer coordinates. The following figure defines the relationship between the source and destination images. The 2D *rotate* operator is defined as follows.

For all l, m, n

$$D(j, k, l, m, n) = RES_2\{S, j', k', l, m, n\}$$

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where j' and k' are components of the vector space transformation

$$\begin{bmatrix} j' \\ k' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & js \\ 0 & 1 & ks \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \text{COS}\{rjk\} & \text{SIN}\{rjk\} & 0 \\ -\text{SIN}\{rjk\} & \text{COS}\{rjk\} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -js \\ 0 & 1 & -ks \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} j \\ k \\ 1 \end{bmatrix}$$

3D mode:

The 3D *rotate* operator is based upon separable application of the 2D *rotate* operator to the j-k, j-l, and k-l planes. The 3D *rotate* operator is defined as follows.

For all m, n

$$D(j, k, l, m, n) = \text{RES}_3\{S, j', k', l', m, n\}$$

where j', k', and l' are components of the vector space transformation

$$\begin{bmatrix} j' \\ k' \\ l' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & js \\ 0 & 1 & 0 & ks \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \text{COS}\{rjk\} & \text{SIN}\{rjk\} & 0 & 0 \\ -\text{SIN}\{rjk\} & \text{COS}\{rjk\} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & -js \\ 0 & 1 & 0 & -ks \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\times \begin{bmatrix} 1 & 0 & 0 & js \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & ls \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \text{COS}\{rjl\} & 0 & -\text{SIN}\{rjl\} & 0 \\ 0 & 1 & 0 & 0 \\ \text{SIN}\{rjl\} & 0 & \text{COS}\{rjl\} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & -js \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & -ls \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\times \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & ks \\ 0 & 0 & 1 & ls \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \text{COS}\{rkl\} & \text{SIN}\{rkl\} & 0 \\ 0 & -\text{SIN}\{rkl\} & \text{COS}\{rkl\} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & -ks \\ 0 & 0 & 1 & -ls \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} j \\ k \\ 1 \\ 1 \end{bmatrix}$$

PIKS mathematical functions, such as RES3{.}, are defined in Annex A.

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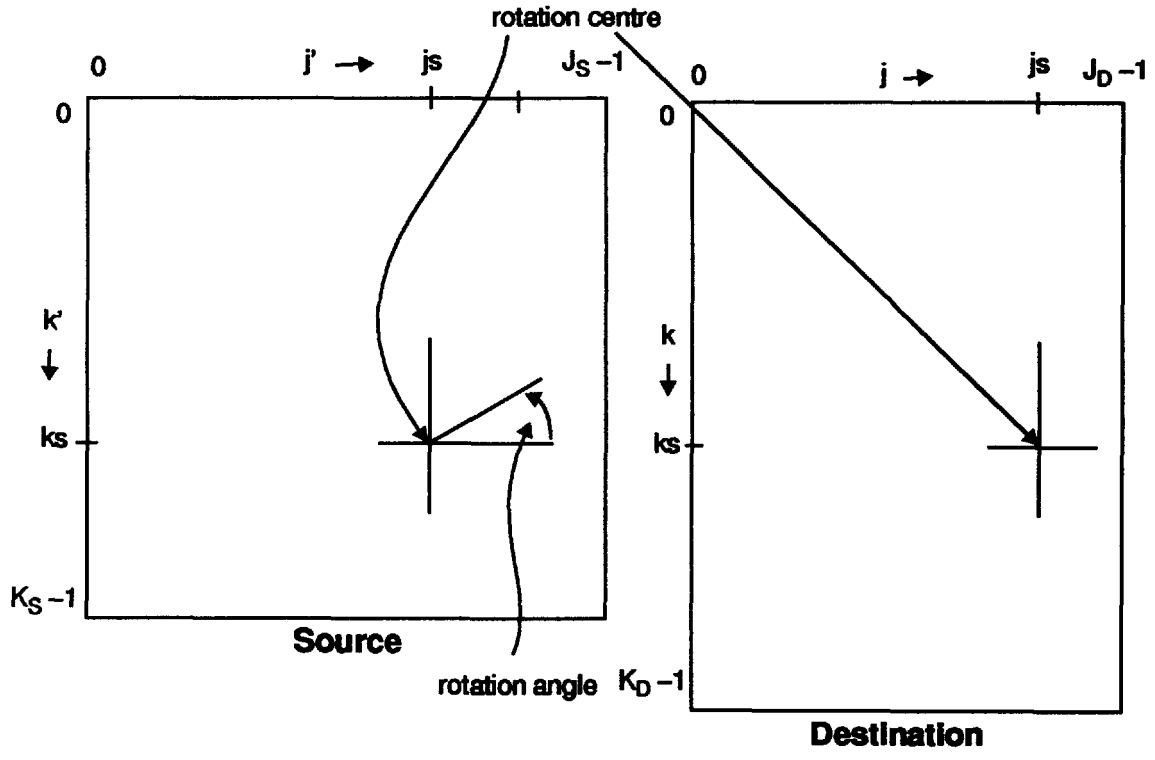

2D rotation example

Profile:

Lowest level conformance profile.

Foundation	rotate
Technical	rotate_roi

Error codes:

List of error codes to be returned to an application by an element.

001
011
013
025
041
045
061
101

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7 PIKS element specifications

This clause presents the functional specification of all PIKS elements. The specifications are presented in alphabetical order based upon the name of each element.

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CONTROL MECHANISM **ABORT ASYNCHRONOUS EXECUTION**

Description:

Terminates any ongoing or pending asynchronous operations.

Name:

abort_asynchronous_execution

Parameters:

none

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Definition:

This control mechanism terminates any operation started in the asynchronous mode. The queue for asynchronous execution is cleared.

Profile:

Scientific

Error codes:

302

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ANALYSIS OPERATOR **ACCUMULATOR**

Description:

Accumulates amplitudes of pixels of an image.

Name:

accumulator

Parameters:

SRC	source image	ID	in
DOB	sum of pixels array object	IP	out
mode	accumulation mode	EP	in
	zero		
	one		
	two		
	three		
	four		

Objects:

SRC structure:	any image
DOB structure:	EXT
SRC data type:	ND, SD, RD
DOB data type:	RP
DOB dimension:	0D, 1D, 2D, 3D, 4D

Element functionality:

Index assignment:	yes
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	no
Asynchronous:	no

Remark:

The accumulation mode options, zero, one, etc., correspond to the dimensionality of the accumulator array.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
S(j, k, l, m, n)	JxKxLxMxN operator input image
a(k, l, m, n)	sum of pixels in k-th, l-th, m-th, n-th planes - 4D array
a(l, m, n)	sum of pixels in l-th, m-th, n-th planes - 3D array
a(m, n)	sum of pixels in m-th, n-th planes - 2D array
a(n)	sum of pixels in n-th plane - 1D array
a	sum of pixels in image - 0D array

Definition:

Accumulation mode zero:

$$a = \sum_{j=0}^{J-1} \sum_{k=0}^{K-1} \sum_{l=0}^{L-1} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} S(j, k, l, m, n)$$

Accumulation mode one:

$$a(n) = \sum_{j=0}^{J-1} \sum_{k=0}^{K-1} \sum_{l=0}^{L-1} \sum_{m=0}^{M-1} S(j, k, l, m, n)$$

Accumulation mode two:

$$a(m, n) = \sum_{j=0}^{J-1} \sum_{k=0}^{K-1} \sum_{l=0}^{L-1} S(j, k, l, m, n)$$

Accumulation mode three:

$$a(l, m, n) = \sum_{j=0}^{J-1} \sum_{k=0}^{K-1} S(j, k, l, m, n)$$

Accumulation mode four:

$$a(k, l, m, n) = \sum_{j=0}^{J-1} S(j, k, l, m, n)$$

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The external sum of pixels arrays are defined as follows:

0D array:

a

1D array:

a(1)
a(2)
.
.
a(N)

2D arrays:

a(1, 1)
a(2, 1)
.
.
a(M, 1)
a(1, 2)
.
.
a(M, N)

3D array:

a(1, 1, 1)
a(2, 1, 1)
.
.
a(L, M, N)

4D array:

a(1, 1, 1, 1)
a(2, 1, 1, 1)
.
.
a(K, 1, 1, 1)
a(1, 2, 1, 1)
.
.
a(K, L, M, N)

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Profile:

Foundation

Error codes:

001
002
011
012
013
014
024
041
044
061
062

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ENHANCEMENT OPERATOR **ADAPTIVE HISTOGRAM EQUALIZATION**

Description:

Performs image contrast stretching of each pixel in a pixel plane by a nonlinear point transformation using a lookup table transformation. The transformation function is the cumulative histogram within a moving window over the pixel plane.

Name:

adaptive_histogram_equalization

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
R	number of histogram reference points per index	NP	in
W	window size	NP	in
off	number of lookup table source offset entries	NP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD
DST data type:	same as SRC data type

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j,k, l, m, n)	JxKxLxMxN operator output image
R	number of histogram reference points along rows and columns, $R > 0$
W	window size, positive odd integer
off	number of lookup table source offset entries, $off \geq 0$
E	number of lookup table entries, $E \geq 2$
j_p	first index histogram reference coordinate, $0 \leq p \leq R-1$
k_q	second index histogram reference coordinate, $0 \leq q \leq R-1$
$H_{p,q}(e)$	histogram of WxW window centred at j_p, k_q
$g_{p,q}(f)$	transformation function for reference coordinate j_p, k_q

Definition:

For all l, m, n, perform the following computational steps.

Step 1:

Determine the location of histogram reference points and the histogram window size.

The histogram reference points are placed uniformly across the j-k plane at coordinates

$$j_0 = \mathrm{LIV}\left\{ \frac{J}{R} \right\}$$

$$j_p = j_0 + \mathrm{LIV}\left\{ \frac{J(p+0.5)}{R} \right\} \qquad \text{for } 0 \leq p \leq R-1$$

$$k_0 = \mathrm{LIV}\left\{ \frac{K}{R} \right\}$$

$$k_q = k_0 + \mathrm{LIV}\left\{ \frac{K(q+0.5)}{R} \right\} \qquad \text{for } 0 \leq q \leq R-1$$

Step 2:

Compute the histogram $H_{p,q}(e)$, for $0 \leq e \leq E-1$ over a WxW window centred at each reference pixel, j_p, k_p of each j-k pixel plane, as described by the *histogram_1d* operator.

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Step 3:

Compute the transformation function, $g_{p,q}(f)$, which is a function of each normalized cumulative histogram.

For $0 \leq f \leq E-1$

$$g_{p,q}(f) = \frac{(E-1)\,[C_{p,q}(f)]}{\sum_{d=0}^{E-1} C_{p,q}(d)}$$

where

$$C_{p,q}(f) = \sum_{e=0}^{f} H_{p,q}(e)$$

Step 4:

Compute the transformation function at each pixel by bilinear interpolation of the transformation functions at the four nearest reference points.

For all j, k and for $0 \leq f \leq E-1$

$$g(f) = (u)(v)\,[g_{p,q}(f)] + (u)(1-v)\,[g_{p+1,q}(f)] + (1-u)(v)\,[g_{p,q+1}(f)]$$

$$+ (1-u)(1-v)\,[g_{p+1,q+1}(f)]$$

where

$$u = \frac{j-j_p}{j_{p+1}-j_p}$$

$$v = \frac{k-k_q}{k_{q+1}-k_q}$$

In the boundary region of the image, some of the reference points in the interpolation for g(f) shall be replaced by pixels on the boundary. For example, in the upper left corner of the pixel plane, pixels at coordinates (0, 0), (j_0, 0), (0, k_0), and (j_0, k_0) are utilized in the interpolation equation.

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Step 5:

For all j, k, store the transformation function g(f) in a E entry lookup table, called table, and perform the lookup table transformation.

$$D(j, k, l, m, n) = LOOK\{S(j, k, l, m, n), off, 0, table\}$$

Profile:

Scientific

Error codes:

001
011
013
025
041
045
061
101

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Description:

Allocates a reference to a chain object.

Name:

allocate_chain

Parameters:

DOB	chain object	ID	out

Object:

DOB structure: CHAIN

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	yes

Definition:

This mechanism returns an object identifier to the application.

Profile:

Full

Error codes:

012
014

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SYSTEM MANAGEMENT MECHANISM ALLOCATE COMPOSITE IDENTIFIER ARRAY

Description:

Allocates a reference to a composite identifier array object.

Name:

allocate_composite_identifier_array

Parameters:

DOB	composite identifier array object	ID	out
length	array length	NP	in

Object:

DOB structure: ID_ARRAY

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneus bands:	NA
Chainable element:	vreg
Asynchronous:	yes

Nomenclature:

E	array length, $E \geq 1$

Definition:

This mechanism returns an object identifier to the application. This identifier shall be used for all access by index to the newly created composite image array. All elements of the composite image array are initialised as NULL values. The index values range from 0 to E – 1.

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Profile:

Scientific

Error codes:

001
012
014
101

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SYSTEM MANAGEMENT MECHANISM **ALLOCATE COMPOSITE IDENTIFIER LIST**

Description:

Allocates a reference to a composite identifier list object.

Name:

allocate_composite_identifier_list

Parameter:

DOB	composite identifier list object	ID	out

Object:

DOB structure: ID_LIST

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	yes

Definition:

This mechanism creates an empty composite image list and returns an object identifier to the application. This identifier shall be used for all access to the newly created composite image list.

Profile:

Scientific

Error codes:

012
014

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SYSTEM MANAGEMENT MECHANISM ALLOCATE COMPOSITE IDENTIFIER RECORD

Description:

Allocates a reference to a composite identifier record object.

Name:

allocate_composite_identifier_record

Parameters:

DOB	composite identifier record object	ID	out
R	record length	NP	in
att_name	collection of attribute names	IP	in

Object:

DOB structure: ID_RECORD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	yes

Remark:

The parameter tuple contains parameters of the CS data type.

Nomenclature:

R record length, $R \geq 1$

Definition:

This mechanism returns an object identifier to the application. This identifier shall be used for all access to the newly created composite image record. The R attribute names shall be used for all access by name to the composite image record. All entries of the composite image record are initialised to NULL values.

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The record contains the following entries.

entry	*associated identifier*
attribute name 1	ID 1
attribute name 2	ID 2
.	.
.	.
.	.
attribute name R	ID R

The data type of the attribute name is a character string, CS.

Profile:

Scientific

Error codes:

001
101
166

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Description:

Allocates a reference to a histogram object and creates its attributes.

Name:

allocate_histogram

Parameters:

DOB	histogram object	ID	out
histogram_size	histogram size	NP, NULL	in
lower_bound	lower amplitude bound	RP, NULL	in
upper_bound	upper amplitude bound	RP, NULL	in

Object:

DOB structure:	HIST
DOB data type:	ND

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	yes

Nomenclature:

E	histogram size, $E \geq 1$
A	lower amplitude bound
B	upper amplitude bound, $B > A$

Definition:

This mechanism returns an object identifier to the application and creates the object attributes if they are specified as parameters.

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Profile:

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Error codes:

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014
101
102

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Description:

Allocates a reference to an image object and creates metric and colour descriptor information in its attributes.

Name:

allocate_image

Parameters:

DST	destination image	ID	out
image_size	image size tuple	ID, NULL	in
band_data_type	band data type tuple	ID, NULL	in
band_precision	band precision tuple	ID, NULL	in
X_o	X tristimulus value white point	RP, NULL	in
Y_o	Y tristimulus value white point	RP, NULL	in
Z_o	Z tristimulus value white point	RP, NULL	in
structure	image structure option	SP, NULL	in
	MON		
	VOL		
	TEM		
	COLR		
	SPE		
	VT		
	VC		
	VS		
	TC		
	TS		
	VTC		
	VTS		
	GEN		
colour	colour space option	SP, NULL	in
	unspecified		
	non-standard RGB		
	linear CCIR illuminant D65 RGB		
	linear CIE illuminant E RGB		
	linear EBU illuminant C RGB		
	linear EBU illuminant D65 RGB		
	linear NTSC illuminant C RGB		
	linear NTSC illuminant D65 RGB		
	linear SMPTE illuminant D65 RGB		
	gamma CCIR illuminant D65 RGB		
	gamma EBU illuminant C RGB		
	gamma EBU illuminant D65 RGB		
	gamma NTSC illuminant C RGB		
	gamma NTSC illuminant D65 RGB		
	gamma SMPTE illuminant D65 RGB		
	luminance/chrominance EBU illuminant C YUV		

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luminance/chrominance EBU illuminant D65 YUV
luminance/chrominance NTSC illuminant C YIQ
luminance/chrominance NTSC illuminant D65 YIQ
luminance/chrominance SMPTE illuminant D65 YCbCr
CIE XYZ
CIE UVW
CIE Yxy
CIE Yuv
CIE L*a*b*
CIE L*u*v*
IHS
CMY
CMYK

Object:

DST structure:	as specified
DST data type:	as specified

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	yes

Remarks:

1. The tuples can be created by the *create_tuple* utility.
2. Each image attribute may be specified as NULL. In each instance, the attribute will be set when the image data is created by a PIKS element.
3. The band_precision_tuple of the channel descriptor attribute may be set as a request for a certain precision for arithmetic data types. PIKS implementations are not required to grant such requests.
4. The *bind_roi* mechanism provides identifiers to a ROI object and to a ROI offset tuple, which overrides the NULL default states for these items.
5. The *bind_match_point* mechanism provides an identifier to a match point tuple, which overrides the NULL state for this item.

Nomenclature:

DST(x, y, z, t, b)	XxYxZxTxB destination image

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Definition:

This mechanism performs the following functions:

returns an object identifier to the application;

generates image structure and colour space information in the image attribute list;

creates PIKS image size and image data type tuples and binds them to the image object using the specified PIKS indicators;

creates default states for the control descriptor information of the image attribute list.

The control descriptor default states are:

Entry name	*State*	*Action*
ROI identifier	NULL	ROI control object TRUE for all pixels values
ROI offset	NULL	zero value offsets
match point	NULL	zero value match point

The image size tuple is defined as follows:

5
ND
X size value
Y size value
Z size value
T size value
B size value

The band data type tuple is defined as follows:

B value
SD
band 1 code
band 2 code
.
.
.
band B code

where the band data type codes are:

BD	Boolean
ND	non-negative integer
SD	signed integer
RD	real arithmetic
CD	complex arithmetic

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The band precision tuple is defined as follows:

B value
ND
band 1 value
band 2 value
.
.
.
band B value

Profile:

Foundation

Error codes:

001
003
012
014

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SYSTEM MANAGEMENT MECHANISM **ALLOCATE LOOKUP TABLE**

Description:

Allocates a reference to a lookup table object and creates its attributes.

Name:

allocate_lookup_table

Parameters:

DOB	lookup table object	ID	out
table_entries	lookup table entries	NP, NULL	in
table_bands	lookup table bands	NP, NULL	in
input_data_type	input table data type option	SP, NULL	in
	ND		
	SD		
output_data_type	output table data type option	SP, NULL	in
	BD		
	ND		
	SD		
	RD		
	CD		

Object:

DOB structure:	LUT
DOB data type:	as specified

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	yes

Nomenclature:

E	table entries, $E \geq 1$
B	table bands, $B \geq 1$

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Definition:

This mechanism returns an object identifier to the application and creates the object attributes if they are specified as parameters.

Profile:

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Error codes:

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012
014
101

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Description:

Allocates a reference to a matrix array object and creates its attributes.

Name:

allocate_matrix

Parameters:

DOB	matrix object	ID	out
col_size	matrix column size	NP, NULL	in
row_size	matrix row size	NP, NULL	in
data_type	data type option ND SD RD CD	SP, NULL	in

Object:

DOB structure:	MATRIX
DOB data type:	as specified

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Hetrogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	yes

Nomenclature:

R	row size, positive integer, $R \geq 1$
C	column size, positive integer, $C \geq 1$

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Definition:

This mechanism returns an object identifier to the application and creates the object attributes if they are specified as parameters.

Profile:

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Error codes:

001
003
012
014
111
112

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SYSTEM MANAGEMENT MECHANISM — ALLOCATE NEIGHBOURHOOD ARRAY

Description:

Allocates a reference to a neighbourhood array object and creates its attributes.

Name:

allocate_neighbourhood_array

Parameters:

DOB	neighbourhood array object	ID	out
array_size	array size 5-tuple	ID, NULL	in
key_pixel	key pixel 5-tuple	ID, NULL	in
scale_factor	scale factor	SP, NULL	in
label	semantic label option	SP, NULL	in
	generic		
	dither		
	impulse response		
	mask		
	structuring element		
data_type	data type option	SP, NULL	in
	BD		
	ND		
	SD		
	RD		
	CD		

Object:

DOB structure:	NBHOOD_ARRAY
DOB data type:	as specified

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	yes

Remark:

The parameter tuples contain parameters of the ND data type.

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Nomenclature:

J	first index size, $J \geq 1$
K	second index size, $K \geq 1$
L	third index size, $L \geq 1$
M	fourth index size, $M \geq 1$
N	fifth index size, $N \geq 1$

Definition:

This mechanism returns an object identifier to the application and creates the object attributes if they are specified as parameters.

Profile:

Foundation

Error codes:

001
003
012
014
101

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SYSTEM MANAGEMENT MECHANISM **ALLOCATE PIXEL RECORD**

Description:

Allocates a reference to a pixel record object.

Name:

allocate_pixel_record

Parameters:

DOB	pixel record	ID	out
B	record length	NP, NULL	in
band_type	band data type B-tuple	ID	in

Object:

DOB structure: PIXEL_RECORD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	yes

Remark:

The parameter tuple contains parameters of the SD data type.

Nomenclature:

B record length, $B \geq 1$

Definition:

This mechanism returns an object identifier to the application and creates the object attributes.

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Profile:

Technical

Error codes:

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012
014
101

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Description:

Allocates a reference to a ROI object and creates its attributes.

Name:

allocate_roi

Parameters:

DOB	ROI object	ID	out
array_size	virtual array size 5-tuple	ID,NULL	in
roi_option	ROI structure option	SP,NULL	in
	ROI array		
	ROI coordinate		
	ROI elliptical		
	ROI generic		
	ROI polygon		
	ROI rectangular		
polarity_option	ROI polarity option	EP,NULL	
	set TRUE		
	set FALSE		

Object:

DOB structure:	ROI_ARRAY, ROI_COORD, ROI_ELLIP, ROI_GEN, ROI_POLY, ROI_RECT
DOB data type:	BD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	yes

Remark:

The parameter tuple contains parameters of the ND data type.

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Nomenclature:

J	first index size, $J \geq 1$
K	second index size, $K \geq 1$
L	third index size, $L \geq 1$
M	fourth index size, $M \geq 1$
N	fifth index size, $N \geq 1$

Definition:

This mechanism returns an object identifier to the application and creates the object attributes if they are specified as parameters.

Profile:

Foundation

Error codes:

012
014
101

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SYSTEM MANAGEMENT MECHANISM **ALLOCATE STATIC ARRAY**

Description:

Allocates a reference to a static array object and creates its attributes.

Name:

allocate_static_array

Parameters:

DOB	static array object	ID	out
array_size	array size 5-tuple	ID, NULL	in
label	semantic label	SP, NULL	in
	generic		
	power spectrum		
	transfer function		
	windowing function		
data_type	data type option	SP, NULL	in
	BD		
	ND		
	SD		
	RD		
	CD		

Object:

DOB structure:	STATIC_ARRAY
DOB data type:	as specified

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	yes

Remark:

The parameter tuple contains parameters of the ND data type.

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Nomenclature:

J	first index size, $J \geq 1$
K	second index size, $K \geq 1$
L	third index size, $L \geq 1$
M	fourth index size, $M \geq 1$
N	fifth index size, $N \geq 1$

Definition:

This mechanism returns an object identifier to the application and creates the object attributes if they are specified as parameters.

Profile:

Technical

Error codes:

001
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101

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Description:

Allocates a reference to a tuple object and creates its attributes.

Name:

allocate_tuple

Parameters:

DOB	tuple object	ID	out
entries	number of tuple entries	NP, NULL	in
data_type	data type option	SP, NULL	in
	BD		
	ND		
	SD		
	RD		
	CD		
	CS		

Object:

DOB structure:	TUPLE
DOB data type:	as specified

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	yes

Nomenclature:

E	number of tuple entries, $E \geq 1$

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Definition:

This mechanism returns an object identifier to the application and creates the object attributes if they are specified as parameters.

Profile:

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001
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SYSTEM MANAGEMENT MECHANISM **ALLOCATE VALUE BOUNDS COLLECTION**

Description:

Allocates a reference to a value bounds collection object and creates its attributes.

Name:

allocate_value_bounds

Parameters:

DOB	value bounds object	ID	out
size	collection size	NP	in
lower	lower amplitude bound	NP, SP, RP	in
upper	upper amplitude bound	NP, SP, RP	in
data_type	pixel data type NP SP RP	SP	in

Object:

DOB structure:	VALUE_BOUNDS
DOB data type:	See *value_bounds* operator.

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable elements	vreg
Asynchronous:	yes

Definition:

This mechanism returns an object identifier to the application.

Profile:

Scientific

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SYSTEM MANAGEMENT MECHANISM

ALLOCATE VIRTUAL REGISTER

Description:

Allocates a virtual register object and creates its attributes.

Name:

allocate_vreg

Parameters:

DOB	virtual register object	ID	out
mode	immediate mode flag	BP	in
type	data type	SP	in
	ID		
	IP		
	BP		
	NP		
	SP		
	RP		
	CP		
	CS		

Object:

DOB structure: VREG

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	yes

Definition:

This mechanism returns an object identifier to the application and creates the object attributes. The virtual register is specified according to the enumerated PIKS data type. Valid values for the VREG will correspond to the virtual register's data type. The VREG is initialized to VREG_CLEARED, the value field is not meaningful until set.

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Profile:

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Error code:

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014

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ENSEMBLE OPERATOR **ALPHA BLEND, CONSTANT**

Description:

Performs an alpha blending combination of a pair of images using a constant alpha blend factor.

Name:

alpha_blend_constant

Parameters:

SRC1	first source image	ID	in
SRC2	second source image	ID	in
DST	destination image	ID	out
a	alpha factor	RP	in

Objects:

SRC1 structure:	any image
SRC2 structure:	same as SRC1 structure
DST structure:	same as SRC1 structure
SRC1 data type:	ND, SD, RD
SRC2 data type:	same as SRC1 data type
DST data type:	same as SRC1 data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC1(x, y, z, t, b)	XxYxZxTxB first source image
SRC2(x, y, z, t, b)	XxYxZxTxB second source image
DST(x, y, x , y, b)	XxYxZxTxB destination image
S1(x, y, z, t, b)	XxYxZxTxB first operator input image
S2(x, y, z, t, b)	XxYxZxTxB second operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
a	alpha blend factor, $0 \leq a \leq 1$

Definition:

For all x, y, z, t, b

$$D(x, y, z, t, b) = (a)[S1(x, y, z, t, b)] + (1 - a)[S2(x, y, z, t, b)]$$

Profile:

Foundation

Error codes:

001
011
013
025
027
041
045
047
061
101

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ENSEMBLE OPERATOR **ALPHA BLEND VARIABLE**

Description:

Performs an alpha blending combination of a pair of images using variable alpha blend factors.

Name:

alpha_blend_variable

Parameters:

SRC1	first source image (operand)	ID	in
SRC2	second source image (operand)	ID	in
SRC3	third source image (first alpha blend factor)	ID	in
SRC4	fourth source image (second alpha blend factor)	ID	in
DST	destination image	ID	out

Objects:

SRC1 structure:	any image
SRC2 structure:	same as SRC1 structure
SRC3 structure:	same as SRC1 structure
SRC4 structure:	same as SRC1 structure
DST structure:	same as SRC1 structure
SRC1 data type:	ND, SD, RD
SRC2 data type:	same as SRC1 data type
SRC3 data type:	RD
SRC4 data type:	RD
DST data type:	same as SRC1 data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. SRC1 and SRC2 must be of the same data type.
2. SRC3 and SRC4 must be of the RD data type.
3. DST must be of the same data type as SRC1 and SRC2.

Nomenclature:

SRC1(x, y, z, t, b)	XxYxZxTxB first source image
SRC2(x, y, z, t, b)	XxYxZxTxB second source image
SRC3(x, y, z, t, b)	XxYxZxTxB third source image
SRC4(x, y, z, t, b)	XxYxZxTxB fourth source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S1(x, y, z, t, b)	XxYxZxTxB first operator input image
S2(x, y, z, t, b)	XxYxZxTxB second operator input image
S3(x, y, z, t, b)	XxYxZxTxB third operator input image, $0 \leq S3(x, y, z, t, b) \leq 1$
S4(x, y, z, t, b)	XxYxZxTxB fourth operator input image, $0 \leq S4(x, y, z, t, b) \leq 1$
D(x, y, z, t, b)	XxYxZxTxB operator output image

Definition:

Source images S1 and S2 are blended together using source images S3 and S4 as the index-dependent alpha blending factors.

$$D(x, y, z, t, b) = [S3(x, y, z, t, b)]\,[S1(x, y, z, t, b)] + [S4(x, y, z, t, b)]\,[S2(x, y, z, t, b)]$$

Profile:

Technical

Error codes:

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027
041
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061

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LOOKUP TABLE GENERATION TOOL **ARRAY TO LUT**

Description:

Inserts an external array of values into a lookup table at a specified index offset.

Name:

array_to_lut

Parameters:

DOB	lookup table object	ID	in, out
SOB	lookup table value array object	IP	in
eo	lookup table entry offset	NP	in
bo	lookup table band offset	NP	in
C	number of array columns	NP	in
R	number of array rows	NP	in

Objects:

DOB structure:	LUT
SOB structure:	EXT
DOB data type:	BD, ND, SD, RD, CD
SOB data type:	BP, NP, SP, RP, CP

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

The array data type shall be of the same data type class as the lookup table.

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Nomenclature:

T(b, e)	lookup table array, $0 \leq b \leq B-1, 0 \leq e \leq E-1$
eo	lookup table entry offset, $0 \leq eo \leq E-1$
bo	lookup table band offset, $0 \leq bo \leq B-1$
A(c, r)	array value, $0 \leq c \leq C-1, 0 \leq r \leq R-1$
R	number of array rows, $R \geq 1$
C	number of array columns, $C \geq 1$

Definition:

The value array is sequentially inserted into the lookup table starting at the index offset value.

For $0 \leq r \leq R-1$ and $0 \leq c \leq C-1$

$$T(bo + c, eo + r) = A(c, r)$$

The external value array is defined as follows:

A(0, 0)	A(1, 0)	...	A(C–1, 0)
.			
.			
A(0, r)	A(1, r)	...	A(C–1, r)
.			
.			
A(0, R–1)	A(1, R–1)	...	A(C–1, R–1)

Profile:

Foundation

Error codes:

001
012
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Description:

Binds a match point tuple to an image.

Name:

bind_match_point

Parameters:

SRC	source image	ID	in, out
match_point	match point 5-tuple	ID	in

Object:

SRC structure:	any image
SRC data type:	BD, ND, SD, RD, CD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	yes
Chainable element:	yes
Asynchronous:	yes

Remark:

The parameter tuple contains parameters of the RD data type.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
xm	match point x index
ym	match point y index
zm	match point z index
tm	match point t index
bm	match point b index

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Definition:

The match point binding mechanism relates the match point identifier in the source image attribute list to the match point identifier in the parameter list.

The match point tuple is defined as follows:

5
RD
x index match point value
y index match point value
z index match point value
t index match point value
b index match point value

Profile:

Technical

Error codes:

011
012
013
014
041

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SYSTEM MANAGEMENT MECHANISM **BIND ROI**

Description:

Binds a ROI object and a ROI offset tuple to an image.

Name:

bind_roi

Parameters:

SRC	source image	ID	in, out
SOB	region-of-interest object	ID, NULL	in
roi_offset	ROI offset 5-tuple	ID, NULL	in

Objects:

SRC structure:	any image
SOB structure:	ROI
SRC data type:	BD, ND, SD, RD, CD
SOB data type:	BD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	yes
Chainable element:	yes
Asynchronous:	yes

Remark:

The parameter tuple contains parameters of the SD data type.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
xo	ROI offset x index
yo	ROI offset y index
zo	ROI offset z index
to	ROI offset t index
bo	ROI offset b index

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Definition:

The ROI binding mechanism relates the ROI object identifier in the source image attribute list to the identifier of the ROI in the parameter list, and relates the ROI offset identifier in the source image attribute list to the ROI offset identifier in the parameter list. The physical or logical mapping of the ROI data object to the virtual ROI control object within the PIKS operator model is implementation dependent and transparent to an application.

If the *bind_roi* mechanism is invoked on an image that has an ROI presently bound to it, the present ROI is replaced by the SOB identified ROI.

If the roi_offset parameter is NULL, the ROI offset value is set to zero along each coordinate index.

If the SOB identifier is NULL and the SRC image has an ROI presently bound to it, the present ROI is re-bound to the image at the specified ROI offset value.

The ROI offset tuple is defined as follows:

5
SD
x index ROI offset value
y index ROI offset value
z index ROI offset value
t index ROI offset value
b index ROI offset value

Profile:

Foundation

Error codes:

011
012
013
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022
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043

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POINT OPERATOR **BIT SHIFT**

Description:

Performs bit shifting of an integer data type pixel image.

Name:

bit_shift

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
nb	number of bits to be shifted	NP	in
option	bit shift option left overflow shift right overflow shift left barrel shift right barrel shift left arithmetic shift right arithmetic shift	SP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD
DST data type:	same as SRC data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The "left" bit of a SD integer is its sign bit.
2. The "left" bit of a ND integer is its most significant bit.
3. The "right" bit of a ND or SD integer is its least significant bit.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
nb	number of bits to be shifted, integer

Definition:

For all x, y, z, t, b

$$D(x, y, z, t, b) = \mathcal{T}\{S(x, y, z, t, b)\}$$

where the point transformation $\mathcal{T}\{.\}$ is defined as follows.

Left overflow shift:

Bits of integer pixel are translated left by nb bit positions. Missing bits on the right are filled with zeros. Example for an 8-bit integer pixel and nb = 3:

input:	01011011
output:	11011000

Right overflow shift:

Bits of integer pixel are translated right by nb bit positions. Missing bits on the left are filled with zeros. Example for an 8-bit integer pixel and nb = 3:

input:	01011011
output:	00001011

Left barrel shift:

Bits of integer pixel are translated left by nb bit positions. Missing bits on the right are filled with overflow bits from the left. Example for an 8-bit integer pixel and nb = 3:

input:	01011011
output:	11011010

Right barrel shift:

Bits of integer pixel are translated right by nb bit positions. Missing bits on the left are filled with overflow bits from the right. Example for an 8-bit integer pixel and nb = 3:

input:	01011011
output:	01101011

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Left arithmetic shift, ND:

Bits of integer pixel are translated left by nb bit positions. Missing bits on the right are filled with zeros. Example for an 8-bit integer pixel and nb = 3:

input:	01011011
output:	11011000

Left arithmetic shift, SD:

Bits of integer pixel are translated left by nb bit positions. Missing bits on the right are filled with zeros. Example for an 8-bit integer pixel and nb = 3:

input:	11111011
output:	11011000

Right arithmetic shift, ND:

Bits of integer pixel are translated right by nb bit positions. Missing bits on the left are filled with zeros. Example for an 8-bit integer pixel and nb = 3:

input:	01011011
output:	00001011

Right arithmetic shift, SD:

Bits of integer pixel are translated right by nb bit positions. Missing bits on the left are filled with the sign bit. Example for an 8-bit integer pixel and nb = 3:

input	11011011
output	11111011

Profile:

Foundation

Error codes:

001
003
011
013
025
041
045
061

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GEOMETRIC OPERATOR

CARTESIAN TO POLAR

Description:

Performs conversion of a pixel plane in cartesian coordinates to a pixel plane in polar coordinates.

Name:

cartesian_to_polar

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
rho_min	minimum value of rho	RP	in
rho_max	maximum value of rho	RP	in
theta_min	minimum value of theta	RP	in
theta_max	maximum value of theta	RP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	RD

Element functionality:

Index assignment:	yes
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ source image
DST(x, y, z, t, b)	$X_D x Y_D x Z_D x T_D x B_D$ destination image
S(j, k, l, m, n)	$J_S x K_S x L_S x M_S x N_S$ operator input image
D(j, k, l, m, n)	$J_D x K_D x L_D x M_D x N_D$ operator output image
ρ_{min}	minimum value of rho, $0 < \rho_{min} < \rho_{max}$
ρ_{max}	maximum value of rho, $\rho_{min} < \rho_{max} \leq [(J_S)^2 + (K_S)^2]^{1/2}$
Θ_{min}	minimum value of theta, $0 < \Theta_{min} < \Theta_{max}$
Θ_{max}	maximum value of theta, $\Theta_{min} < \Theta_{max} \leq \pi/2$

Definition:

The cartesian to polar conversion involves two processing stages. In the first stage, for all l, m, n, an inverse address calculation is made whereby (j', k') source image coordinates are computed according to polar to cartesian conversion equations based upon the destination image coordinates (j, k). In general, the (j', k') coordinates are not integer valued. The second stage of the algorithm entails two-dimensional resampling of the source image to evaluate the destination image at integer coordinates.

As shown in the figure, for all j, k, l, m, n

$$D(j, k, l, m, n) = RES_2\{S, j', k', l, m, n\}$$

where

$$j' = [\rho(j)]COS\{\Theta(k)\}$$

$$k' = [\rho(j)]SIN\{\Theta(k)\}$$

and

$$\rho(j) = \frac{j[\rho_{max} - \rho_{min}]}{J_D - 1} + \rho_{min}$$

$$\Theta(k) = \frac{k[\Theta_{max} - \Theta_{min}]}{K_D - 1} + \Theta_{min}$$

$$L_D = L_S$$

$$M_D = M_S$$

$$N_D = N_S$$

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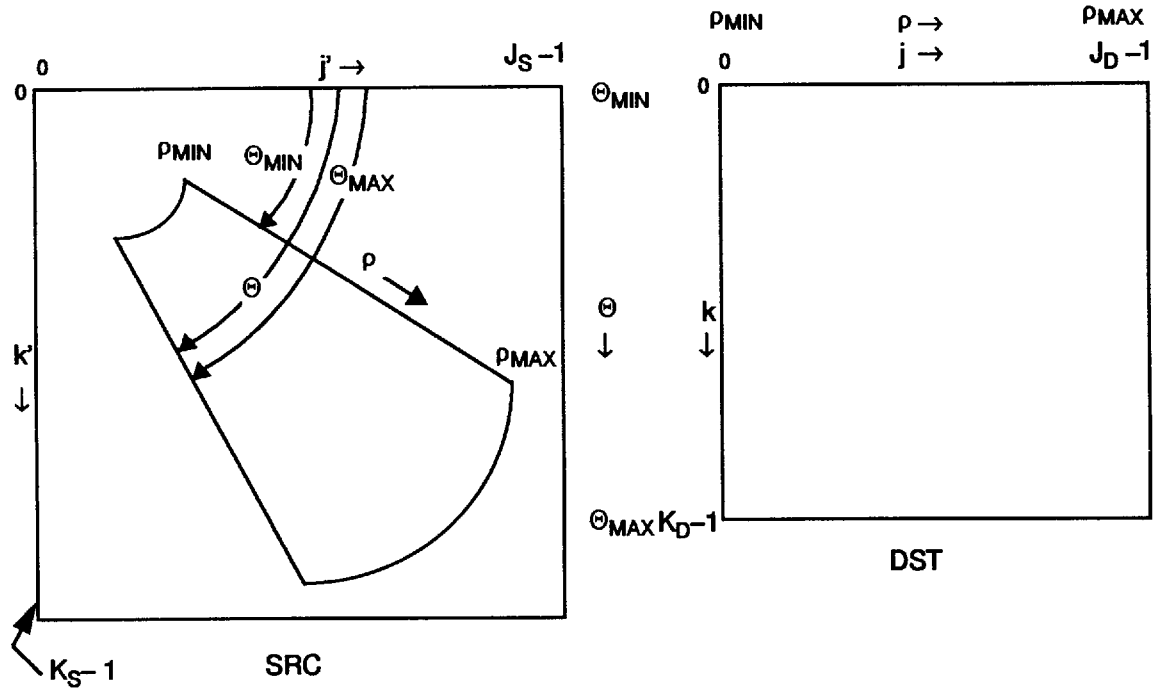

Relationship between source and destination images

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cartesian_to_polar

Profile:

Scientific

Error codes:

001
011
013
025
041
043
061
101
102

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CHAINING MECHANISM

CHAIN ABORT

Description:

Terminates the execution of a currently executing chain.

Name:

chain_abort

Parameters:

SOB	chain identifier	ID	in

Object:

SOB structure: CHAIN

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

This control mechanism terminates the execution of a specific chain, as defined by the chain identifier, if that particular chain is currently executing. If that particular chain is not currently executing, an error condition will result.

Profile:

Full

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Error codes:

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209

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CHAINING MECHANISM **CHAIN BEGIN**

Description:

Begins the definition of a chain.

Name:

chain_begin

Parameters:

SOB	chain object	ID	in

Object:

SOB structure:	CHAIN

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remarks:

1. The mechanisms *chain_execute* and *chain_delete* may not be initiated upon the specified chain identifier until the CHAIN_BUILD state has been exited by invoking *chain_end*.
2. Invocation of *chain_begin* is not allowed in the CHAIN_BUILD state.
3. An error will be generated if a non-chainable element is involved when PIKS is in the CHAIN_BUILD state.

Definition:

This control mechanism initiates the definition of a chain. It sets the PIKS state to CHAIN_BUILD so that all subsequent chainable PIKS operations, along with their bound parameters and data, are built into a chain structure. The building of a chain continues until a *chain_end* is encountered. It is then possible to execute the operations contained in the defined chain.

New, unique chain identifiers are produced by the *allocate_chain* mechanism.

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chain_begin

Profile:

Full

Error codes:

012
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062
202
210
211
212

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CHAINING MECHANISM **CHAIN DELETE**

Description:

Deletes all references to a chain.

Name:

chain_delete

Parameters:

SOB	chain object	ID	in

Object:

SOB structure: CHAIN

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

The chain, which is referenced by its identifier, is deleted.

Profile:

Full

Error codes:

012
014
022
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207
217

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CHAINING MECHANISM **CHAIN END**

Description:

Ends the definition of a chain.

Name:

chain_end

Parameters:

SOB	chain object	ID	in

Object:

SOB structure: CHAIN

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Definition:

This mechanism ends the definition of a chain and terminates the CHAIN_BUILD state.

Profile:

Full

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211

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CHAINING MECHANISM **CHAIN EXECUTE**

Description:

Initiates execution of an existing chain.

Name:

chain_execute

Parameters:

SOB	chain object	ID	in

Object:

SOB structure: CHAIN

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

This control mechanism initiates the execution of a chain and sets the CHAIN_EXECUTE state.

PIKS elements, which have been assembled into the chain structure during the CHAIN_BUILD state, will be performed one at a time in sequence. Chain execution may be performed either synchronously or asynchronously depending upon the setting of the global PIKS synchronous mode.

If the state CHAIN_BUILD is in effect when this mechanism is invoked, the *chain_execute* element will be added to the chain structure being built. If the state is not in CHAIN_BUILD, the *chain_execute* mechanism is executed according to the rules applied for synchronous or asynchronous element executution, whichever state then exists.

During chain execution, an implementation may reorder or execute the elements in parallel as long as the result of the execution is the same as if the chain elements were executed in sequence. The implementation is responsible for detecting such data dependencies that might restrict any reordering or parallel execution.

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Profile:

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012
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206

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CHAINING MECHANISM

CHAIN RELOAD

Description:

Reloads parameters and referenced data for a single PIKS element that has been built into a chain.

Name:

chain_reload

Parameters:

SOB	chain object	ID	in
operation	selector	NP	in
arguments	arguments parameters	IP	in

Object:

SOB structure: CHAIN

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

The arguments parameter identifies a collection of parameters corresponding to the number of parameters of the element to be reloaded.

Definition:

This control mechanism allows the application to reload parameters and data involved with a particular PIKS element which has previously been built into a chain. During the initial build, the parameters and data were bound to each element, and will stay bound for all subsequent execution of the chain unless a *chain_reload* is performed upon the particular element. The particular chain to be selected is specified by the chain identifier and the element within that chain is defined by the selector. The first element, number 1, is the first chainable PIKS element following *chain_begin*. Subsequent chainable PIKS elements preceding the *chain_end* element will be numbered 2, 3, 4,..., n. This allows the application to select any element in any chain as the object of the *chain_reload* element.

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The element selected by the chain identifier and selected parameters must be the same PIKS element as originally created for that element during the initial building of the chain, otherwise, an error will result; only the parameters may be changed. The newly specified parameters are bound to the specified element in the chain.

Profile:

Full

Error codes:

001
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213
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216

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CLASSIFICATION OPERATOR

CLASSIFIER, BAYES

Description:

Performs Bayes quadratic Gaussian classification of a spectral image.

Name:

classifier_bayes

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB1	class a priori probability array object	IP	in
SOB2	class mean vector array object	IP	in
SOB3	class covariance matrix array object	IP	in
class_size	number of classes	NP	in

Objects:

SRC structure:	SPE
DST structure:	MON
SOB1 structure:	EXT
SOB2 structure:	EXT
SOB3 structure:	EXT
SRC data type:	ND, SD, RD
DST data type:	SD
SOB1 data type:	RP
SOB2 data type:	RP
SOB3 data type:	RP

Element functionality:

Index assignment:	no
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC(x, y, z, t, b)	XxYx1x1xB source image
DST(x, y, z, t, b)	XxYx1x1x1 destination image
S(x, y, z, t, b)	XxYx1x1xB operator input image
D(x, y, z, t, b)	XxYx1x1x1 operator output image
I	number of classes, $I \geq 2$
P_i	a priori probability of class i, $1 \leq i \leq I$
m_i	Bx1 mean vector of class i
S_i	BxB covariance matrix of class i
h_i	discriminant function of class i
u	Bx1 across band observation vector

Definition:

For all j, k, form an observation vector u of B components across the bands of the source image,

$$u^T = [S(x, y, 0, 0, 0),...,S(x, y, 0, 0, b),...,S(x, y, 0, 0, B-1)]$$

and compute a set of discriminant function values, h_i, for $1 \leq i \leq I$

$$h_i = b_i - (0.5)(u - m_i)^T(S_i)^{-1}(u - m_i)$$

where

$$b_i = LOG\{P_i\} - (0.5)LOG\{DET\{S_i\}\}$$

If for $1 \leq i \leq I$, if either

$$h_r > h_i$$

or

$$h_r = h_i \text{ and } r < i$$

then set

$$D(x, y, 0, 0, 0) = r$$

The external class a priori probability value array is defined as follows:

value 1
value 2
.
.
value I

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The external I class mean vector arrays are defined as follows:

value 1 }
value 2 }
. } class 1
. }
value B }

.
.
.

value 1 }
value 2 }
. } class I
. }
value B }

The external I class covariance matrix arrays are defined as follows:

value 1, 1 }
value 2, 1 }
. }
. }
value B, 1 }
value 1, 2 } class 1
value 2, 2 }
. }
. }
value B, B }

.
.
.

value 1, 1 }
value 2, 1 }
. }
. }
value B, 1 }
value 1, 2 } class I
value 2, 2 }
. }
. }
value B, B }

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Profile:

Scientific

Error Codes:

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011
012
013
014
021
022
023
041
042
043
048
061
101

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CLASSIFICATION OPERATOR **CLASSIFIER, NEAREST NEIGHBOUR**

Description:

Performs nearest neighbour classification of a spectral image.

Name:

classifier_nearest_neighbour

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	training pattern set array object	IP	in
class_size	number of classes	NP	in
pattern_size	number of patterns per class	NP	in
distance	distance measure option	SP	in
	Euclidean		
	city block		

Objects:

SRC structure:	SPE
DST structure:	MON
SOB structure:	EXT
SRC data type:	ND, SD, RD
DST data type:	ND
SOB data type:	RP

Element functionality:

Index assignment:	no
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC(x, y, z, t, b)	XxYx1x1xB source image
DST(x, y, z, t, b)	XxYx1x1x1 destination image
S(x, y, z, t, b)	XxYx1x1xB operator input image
D(x, y, z, t, b)	XxYx1x1x1 operator output image
I	number of classes, $I \geq 2$
h_i	discriminant function of class i
u	Bx1 across band observation vector
v	Bx1 across band pattern vector
D(u, v)	distance function
$w_i(p)$	p-th pattern vector of training pattern set, $1 \leq p \leq P$ of class i
P	number of pattern vectors per class in each training set, $P \geq 1$

Definition:

For all x, y, form an observation vector **u** of B components across the bands of the source image where

$$\mathbf{u}^T = [S(x, y, 0, 0, 0),....,S(x, y, 0, 0, b),....,S(x, y, 0, 0, B-1)]$$

For each class i, compute an index r_i for $1 \leq i \leq I$ such that the distance function

$$D[\mathbf{u}, \mathbf{w}_i(r_i)]$$

is a minimum where $\mathbf{w}_i(p)$ is the p-th pattern vector of the training pattern set.

The Euclidean distance measure between the observation vector **u** and the pattern vector **v** is

$$D[\mathbf{u}, \mathbf{v}] = \sum_{b=0}^{B-1} [u(b) - v(b)]^2$$

The city block distance measure between the observation vector **u** and the pattern vector **v** is

$$D[\mathbf{u}, \mathbf{v}] = \sum_{b=0}^{B-1} |u(b) - v(b)|$$

The discriminant function for each class is

$$h_i = -D[\mathbf{u}, \mathbf{w}_i(r_i)]$$

If for $1 \leq i \leq I$

$$h_s \geq h_i$$

then set

$$D(x, y, 0, 0, 0) = s$$

If more than one class, s, has a maximum value of h_s, the value of D(x, y, 0, 0, 0) will be of the maxima chosen in an implementation dependent manner.

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The external training pattern set array is defined as follows:

value 1, 1
value 2, 1
.
.
.
value B, 1
.
. } class 1
.
value 1, P
value 2, P
.
.
.
value B, P

.
.
.
.

value 1, 1
value 2, 1
.
.
.
value B, 1
.
. } class I
.
value 1, P
value 2, P
.
.
.
value B, P

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Profile:

Scientific

Error Codes:

001
011
012
013
014
021
022
023
041
042
043
061
101

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CONTROL MECHANISM

CLOSE PIKS

Description:

Performs closure of a PIKS session.

Name:

close_piks

Parameters:

None

Objects:

None

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Definition:

This control mechanism performs an implicit synchronize to ensure that all executing and asynchronous queued operations are completed, PIKS functionality is terminated, and control is returned to the appplication. All previously allocated PIKS objects are deallocated.

Profile:

Foundation

Error codes:

062
302
304

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CONTROL MECHANISM **CLOSE PIKS, EMERGENCY**

Description:

Performs an emergency closure of a PIKS session.

Name:

close_piks_emergency

Parameters:

None

Objects:

None

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Definition:

This mechanism terminates a PIKS session when a fatal error occurs. No synchronization is performed. On-going PIKS element execution is aborted, the asynchronous execution queue is cleared, and PIKS shutdown actions are performed. When PIKS is closed, control is returned to the application. All previously allocated PIKS objects are deallocated.

Profile:

Foundation

Error codes:

062
304

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COLOUR OPERATOR **COLOUR CONVERSION, LINEAR**

Description:

Performs linear inter-band colour conversion of a trichromatic colour image between colour spaces.

Name:

colour_conversion_linear

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	colour conversion matrix object	ID, NULL	in

Objects:

SRC structure:	COLR, VC, TC, VTC
DST structure:	same as SRC structure
SOB structure:	MATRIX
SRC data type:	SD, RD
DST data type:	same as SRC data type
SOB data type:	SD, RD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. Colour conversions within "video" colour spaces, e.g., RGB to and from YIQ, assume gamma corrected (point nonlinear) RGB components.
2. Colour conversions within "colourimetry" colour spaces and between video and colourimetry colour spaces, e.g., CIE RGB to and from XYZ, assume point linear RGB colour components.
3. The *colour_conversion_linear* operator does not perform point transformations that gamma correct linear components or that linearize gamma corrected components.
4. The PIKS data object repository contains a collection of 3x3 transformation matrices between

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common colour spaces.

5. If the SOB parameter is NULL, the appropriate transformation matrix in the data object repository will be used, based upon the source and destination image colour space codes.
6. If a matrix from the data object repository is selected, the appropriate colour space image attribute information is entered in the attribute list of the destination image.
7. The *import_matrix* utility and the *colour_conversion_matrix* tool can be used to create a 3x3 transformation matrix.
8. The tables on the following pages specify the identifiers of the colour conversion matrices in the data object repository.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
M(c, r)	3x3 transformation matrix

Definition:

For all x, y, z, t,

$$\begin{bmatrix} D(x,y,z,t,0) \\ D(x,y,z,t,1) \\ D(x,y,z,t,2) \end{bmatrix} = \begin{bmatrix} M(0,0) & M(1,0) & M(2,0) \\ M(0,1) & M(1,1) & M(2,1) \\ M(0,2) & M(1,2) & M(2,2) \end{bmatrix} \begin{bmatrix} S(x,y,z,t,0) \\ S(x,y,z,t,1) \\ S(x,y,z,t,2) \end{bmatrix}$$

Profile:

Foundation

Error codes:

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	CCIR D65 RGB	CIE E RGB	EBU C RGB	EBU D65 RGB	NTSC C RGB	NTSC D65 RGB	SMPTE D65 RGB	UVW	XYZ
CCIR D65 RGB	X	1	2	3	4	5	6	7	8
CIE E RGB	9	X	10	11	12	13	14	15	16
EBU C RGB	17	18	X	19	20	21	22	23	24
EBU D65 RGB	25	26	27	X	28	29	30	31	32
NTSC C RGB	33	34	35	36	X	37	38	39	40
NTSC D65 RGB	41	42	43	44	45	X	46	47	48
SMPTE D65 RGB	49	50	51	52	53	54	X	55	56
UVW	57	58	59	60	61	62	63	X	64
XYZ	65	66	67	68	69	70	71	72	X

Point linear colour conversion matrices — colourimetric match

	CCIR D65 RGB	CIE E RGB	EBU C RGB	EBU D65 RGB	NTSC C RGB	NTSC D65 RGB	SMPTE D65 RGB
CCIR D65 RGB	X	73	74	X	75	X	X
CIE E RGB	76	X	77	78	79	80	81
EBU C RGB	82	83	X	84	X	85	86
EBU D65 RGB	X	87	88	X	89	X	X
NTSC C RGB	90	91	X	92	X	93	94
NTSC D65 RGB	X	95	96	X	97	X	X
SMPTE D65 RGB	X	98	99	X	100	X	X

Point linear colour conversion matrices — appearance match

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	EBU C RGB	EBU D65 RGB	NTSC C RGB	NTSC D65 RGB	SMPTE D65 RGB	EBU C YUV	EBU D65 YUV	NTSC C YIQ	NTSC D65 YIQ	SMPTE D65 YCbCr
EBU C RGB	X	X	X	X	X	101	X	X	X	X
EBU D65 RGB	X	X	X	X	X	X	102	X	X	X
NTSC C RGB	X	X	X	X	X	X	X	103	X	X
NTSC D65 RGB	X	X	X	X	X	X	X	X	104	X
SMPTE D65 RGB	X	X	X	X	X	X	X	X	X	105
EBU C YUV	106	X	X	X	X	X	X	X	X	X
EBU D65 YUV	X	107	X	X	X	X	X	X	X	X
NTSC C YIQ	X	X	108	X	X	X	X	X	X	X
NTSC D65 YIQ	X	X	X	109	X	X	X	X	X	X
SMPTE D65 YCbCr	X	X	X	X	110	X	X	X	X	X

Point non-linear colour conversion matrices — RGB/luminance-chrominance conversion

	C	D50	D65	E
C	X	111	112	113
D50	114	X	115	116
D65	117	118	X	119
E	120	121	122	X

Von Kries colour conversion matrices — XYZ to XYZ white point conversion

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MATRIX GENERATION TOOL **COLOUR CONVERSION MATRIX**

Description:

Generates 3x3 colour conversion matrices for conversion between XYZ and RGB colour spaces.

Name:

colour_conversion_matrix

Parameters:

DOB1	XYZ to RGB conversion matrix object	ID	out
DOB2	RGB to XYZ conversion matrix object	ID	out
xR	red primary x chromaticity coordinate	RP	in
yR	red primary y chromaticity coordinate	RP	in
xG	green primary x chromaticity coordinate	RP	in
yG	green primary y chromaticity coordinate	RP	in
xB	blue primary x chromaticity coordinate	RP	in
yB	blue primary y chromaticity coordinate	RP	in
xW	white reference x chromaticity coordinate	RP	in
yW	white reference y chromaticity coordinate	RP	in

Objects:

DOB1 structure:	MATRIX
DOB2 structure:	MATRIX
DOB1 data type:	RD
DOB2 data type:	RD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

xR	red primary x chromaticity coordinate
yR	red primary y chromaticity coordinate
zR	red primary z chromaticity coordinate
xG	green primary x chromaticity coordinate
yG	green primary y chromaticity coordinate
zG	green primary z chromaticity coordinate
xB	blue primary x chromaticity coordinate
yB	blue primary y chromaticity coordinate
zB	blue primary z chromaticity coordinate
xW	white reference x chromaticity coordinate
yW	white reference y chromaticity coordinate
zW	white reference z chromaticity coordinate
M(p, q)	RGB to XYZ conversion matrix, p = 1, 2, 3, q = 1, 2, 3
N(p, q)	XYZ to RGB conversion matrix, p = 1, 2, 3, q = 1, 2, 3

Definition:

Step 1:

Compute the colourimetric weighting coefficients, a(i), for i = 1, 2, 3.

$$\begin{bmatrix} a(1) \\ a(2) \\ a(3) \end{bmatrix} = \begin{bmatrix} xR & xG & xB \\ yR & yG & yB \\ zR & zG & zB \end{bmatrix}^{-1} \begin{bmatrix} xW/yW \\ 1 \\ zW/yW \end{bmatrix}$$

where

$$zR = 1 - xR - yR$$

$$zG = 1 - xG - yG$$

$$zB = 1 - xB - yB$$

$$zW = 1 - xW - yW$$

Step 2:

Compute the RGB to XYZ conversion matrix.

$$\begin{bmatrix} M(1,1) & M(1,2) & M(1,3) \\ M(2,1) & M(2,2) & M(2,3) \\ M(3,1) & M(3,2) & M(3,3) \end{bmatrix} = \begin{bmatrix} xR & xG & xB \\ yR & yG & yB \\ zR & zG & zB \end{bmatrix} \begin{bmatrix} a(1) & 0 & 0 \\ 0 & a(2) & 0 \\ 0 & 0 & a(3) \end{bmatrix}$$

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Step 3:

Compute the XYZ to RGB conversion matrix.

$$\begin{bmatrix} N(1,1) & N(1,2) & N(1,3) \\ N(2,1) & N(2,2) & N(2,3) \\ N(3,1) & N(3,2) & N(3,3) \end{bmatrix} = \begin{bmatrix} M(1,1) & M(1,2) & M(1,3) \\ M(2,1) & M(2,2) & M(2,3) \\ M(3,1) & M(3,2) & M(3,3) \end{bmatrix}^{-1}$$

Profile:

Foundation

Error codes:

001
012
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030
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050

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COLOUR OPERATOR **COLOUR CONVERSION, NONLINEAR**

Description:

Performs nonlinear intra-band colour conversion of a trichromatic colour image between RGB and nonlinear colour spaces.

Name:

colour_conversion_nonlinear

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
Xo	X tristimulus value white point	RP, NULL	in
Yo	Y tristimulus value white point	RP, NULL	in
Zo	Z tristimulus value white point	RP, NULL	in
RGB	RGB colour option	SP	in
	uncalibrated		
	CIE spectral		
	linear NTSC		
	linear EBU		
	linear SMPTE		
	linear CCIR		
input	input option	SP	in
	RGB		
	IHS		
	Yxy		
	Yuv		
	L*a*b*		
	L*u*v*		
output	output option	SP	in
	RGB		
	IHS		
	Yxy		
	Yuv		
	L*a*b*		
	L*u*v*		

Objects:

SRC structure:	COLR, VC, TC, VTC
DST structure:	same as SRC structure
SRC data type:	RD
DST data type:	RD

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Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The conversion between RGB and IHS colour spaces is only defined for uncalibrated RGB.
2. The transformation between RGB and Yxy, Yuv, L*a*b*, or L*u*v* is only defined for calibrated, point linear RGB.
3. The following are commonly specified white reference point tristimulus values in the XYZ coordinate system.

	X_o	Y_o	Z_o
Illuminant A	1.0985	1.0000	0.3558
Illuminant C	0.981	1.000	1.182
Illuminant E	1.000	1.000	1.000
D50	0.96422	1.00000	0.82521
D65	0.950	1.000	1.089

4. The RGB and three nonlinear colour components, e.g., Yxy, are assumed to be stored in bands 0, 1, and 2, respectively, of source and destination images.
5. The linear matrix transformations between the RGB and XYZ or UVW colour spaces are defined in the data object repository.
6. The appropriate colour space image attribute information is entered in the image attribute list of the destination image if the entry is NULL.
7. If the white point tristimulus value parameters are set to NULL, the white point information is taken from the attribute list of the source image.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, x, y, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
X_o	X tristimulus white point
Y_o	Y tristimulus white point
Z_o	Z tristimulus white point

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Definition:

For all x, y, z, t

$$D(x, y, z, t, 0) = \mathcal{T}_0\{S(x, y, z, t, 0), S(x, y, z, t, 1), S(x, y, z, t, 2)\}$$

$$D(x, y, z, t, 1) = \mathcal{T}_1\{S(x, y, z, t, 0), S(x, y, z, t, 1), S(x, y, z, t, 2)\}$$

$$D(x, y, z, t, 2) = \mathcal{T}_2\{S(x, y, z, t, 0), S(x, y, z, t, 1), S(x, y, z, t, 2)\}$$

where the general transformation functions $\mathcal{T}_0\{.\}$, $\mathcal{T}_1\{.\}$, and $\mathcal{T}_2\{.\}$ are defined below for RGB to nonlinear colour spaces and for nonlinear colour spaces to RGB. Conversions between two nonlinear colour spaces are defined as a conversion from the input colour space to RGB followed by converson from RGB to the output colour space. An implementation may perform such conversions directly.

RGB to IHS:

Step 1:

$$\begin{bmatrix} I \\ V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \\ \frac{-1}{\sqrt{6}} & \frac{-1}{\sqrt{6}} & \frac{2}{\sqrt{6}} \\ \frac{1}{\sqrt{6}} & \frac{-1}{\sqrt{6}} & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Step 2:

$$H = \text{ATAN2}\ \{V_2, V_1\}$$

$$S = [(V_1)^2 + (V_2)^2]^{1/2}$$

IHS to RGB:

Step 1:

$$V_1 = (S)\text{COS}\{H\}$$

$$V_2 = (S)\text{SIN}\{H\}$$

Step 2:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & \frac{-\sqrt{6}}{6} & \frac{\sqrt{6}}{2} \\ 1 & \frac{-\sqrt{6}}{6} & \frac{-\sqrt{6}}{2} \\ 1 & \frac{\sqrt{6}}{3} & 0 \end{bmatrix} \begin{bmatrix} I \\ V_1 \\ V_2 \end{bmatrix}$$

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RGB to Yxy:

Step 1:

RGB to XYZ matrix transformation

Step 2:

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

Yxy to RGB:

Step 1:

$$X = Y\left[\frac{x}{y}\right]$$

$$Z = Y\left[\frac{1-x-y}{y}\right]$$

Step 2:

XYZ to RGB matrix transformation

RGB to Yuv:

Step 1:

RGB to UVW matrix transformation

Step 2:

$$Y = V$$

$$u = \frac{U}{U+V+W}$$

$$v = \frac{V}{U+V+W}$$

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Yuv to RGB:

Step 1:

$$U = Y\left[\frac{u}{v}\right]$$

$$V = Y$$

$$W = Y\left[\frac{1-u-v}{v}\right]$$

Step 2:

UVW to RGB matrix transformation

RGB to L*a*b*

Step 1:

RGB to XYZ matrix transformation

Step 2:

$$L^* = 116\left[\frac{Y}{Y_o}\right]^{1/3} - 16 \qquad \frac{Y}{Y_o} > 0.008856$$

$$L^* = 903.3\left[\frac{Y}{Y_o}\right] \qquad 0.0 \le \frac{Y}{Y_o} \le 0.008856$$

$$a^* = 500\left[f\left\{\frac{X}{X_o}\right\} - f\left\{\frac{Y}{Y_o}\right\}\right]$$

$$b^* = 200\left[f\left\{\frac{Y}{Y_o}\right\} - f\left\{\frac{Z}{Z_o}\right\}\right]$$

where

$$f\{w\} = (w)^{1/3} \qquad w > 0.008856$$

$$f\{w\} = 7.787\,(w) + \frac{16}{116} \qquad 0 \le w \le 0.008856$$

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L*a*b to RGB

Step 1:

$$Y = Y_o\left[g\left\{\frac{L^* + 16}{116}\right\}\right]$$

$$X = X_o\left[g\left\{f\left\{\frac{Y}{Y_o}\right\} + \frac{a^*}{500}\right\}\right]$$

$$Z = Z_o\left[g\left\{f\left\{\frac{Y}{Y_o}\right\} - \frac{b^*}{200}\right\}\right]$$

where

$$g\{w\} = (w)^3 \qquad w > 0.20689$$

$$g\{w\} = 0.1284\,(w - \frac{16}{116}) \qquad 0 \leq w \leq 0.20689$$

Step 2:

XYZ to RGB matrix transformation

RGB to L*u*v:

Step 1:

RGB to XYZ matrix transformation

Step 2:

$$u' = \frac{4X}{X + 15Y + 3Z}$$

$$v' = \frac{9Y}{X + 15Y + 3Z}$$

$$u'_o = \frac{4X_o}{X_o + 15Y_o + 3Z_o}$$

$$v'_o = \frac{9Y_o}{X_0 + 15Y_o + 3Z_o}$$

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Step 3:

$$L^* = 116\left[\frac{Y}{Y_o}\right]^{1/3} - 16 \qquad \frac{Y}{Y_o} > 0.008856$$

$$L^* = 903.3\left[\frac{Y}{Y_o}\right] \qquad 0.0 \le \frac{Y}{Y_o} \le 0.008856$$

$$u^* = 13L^*\,(u' - u'_o)$$

$$v^* = 13L^*\,(v' - v'_o)$$

L*u*v* to RGB:

Step 1:

$$u'_o = \frac{4X_o}{X_o + 15Y_o + 3Z_o}$$

$$v'_o = \frac{9Y_o}{X_o + 15Y_o + 3Z_o}$$

$$u' = \frac{u^*}{13L^*} + u'_o$$

$$v' = \frac{v^*}{13L^*} + v'_o$$

$$Y = Y_o\left[\frac{L^* + 16}{116}\right]^3 \qquad L^* > 8.0$$

$$Y = \frac{(Y_o)(L^*)}{903.3} \qquad 0.0 \le L^* \le 8.0$$

$$X = Y\left[\frac{9u'}{4v'}\right]$$

$$Z = Y\left[\frac{12 - 3u' - 20v'}{4v'}\right]$$

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Step 2:

XYZ to RGB matrix transformation

Profile:

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Error codes:

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COLOUR OPERATOR **COLOUR CONVERSION, SUBTRACTIVE**

Description:

Performs a conversion of a colour image between additive uncalibrated RGB and subtractive uncalibrated CMY or CMYK colour spaces.

Name:

colour_conversion_subtractive

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
f	blackness factor	RP, NULL	in
IM	maximum integer size	NP, NULL	in
method_info	method data	IP, NULL	in
direction_option	direction option	SP	in
	RGB to CMY		
	RGB to CMYK		
	CMY to RGB		
	CMYK to RGB		
method_option	method option	SP	in
	simple		
	implementation dependent		

Objects:

SRC structure:	COLR, VC, TC, VTC
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. The red, green, and blue colour components are assumed to be stored in bands 0, 1, and 2, respectively, of an image.
2. The cyan, magenta, yellow, and black colour components are assumed to be stored in bands 0, 1, 2 and 3, respectively, of an image.
3. The appropriate colour space image attribute information is entered in the image attribute list of the destination image if the entry is NULL.
4. This operator provides a simple conversion method or access to a non-standardized, implementation-dependent conversion method.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image, $S(x, y, z, t, b) \geq 0$
D(x, y, z, t, b)	XxYxZxTxB operator output image, $D(x, y, z, t, b) \geq 0$
f	blackness factor, $0 \leq f \leq 1$
IM	maximum integer size
v	maximum tristimulus value

Definition:

Simple method option:

For all x, y, z, t

RGB to CMY conversion:

$$D(x, y, z, t, 0) = v - S(x, y, z, t, 0)$$

$$D(x, y, z, t, 1) = v - S(x, y, z, t, 1)$$

$$D(x, y, z, t, 2) = v - S(x, y, z, t, 2)$$

RGB to CMYK conversion:

$$D(x, y, z, t, 3) = (f)MIN\{v - S(x, y, z, t, 0), v - S(x, y, z, t, 1), v - S(x, y, z, t, 2)\}$$

$$D(x, y, z, t, 0) = v - S(x, y, z, t, 0) - D(x, y, z, t, 3)$$

$$D(x, y, z, t, 1) = v - S(x, y, z, t, 1) - D(x, y, z, t, 3)$$

$$D(x, y, z, t, 2) = v - S(x, y, z, t, 2) - D(x, y, z, t, 3)$$

CMY to RGB conversion:

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CMY to RGB conversion:

$$D(x, y, z, t, 0) = v - S(x, y, z, t, 0)$$

$$D(x, y, z, t, 1) = v - S(x, y, z, t, 1)$$

$$D(x, y, z, t, 2) = v - S(x, y, z, t, 2)$$

CMYK to RGB conversion:

$$D(x, y, z, t, 0) = v - S(x, y, z, t, 0) - D(x, y, z, t, 3)$$

$$D(x, y, z, t, 1) = v - S(x, y, z, t, 1) - D(x, y, z, t, 3)$$

$$D(x, y, z, t, 2) = v - S(x, y, z, t, 2) - D(x, y, z, t, 3)$$

where for a ND or SD integer data type

$$v = IM$$

and for a RD data type

$$v = 1$$

Implementation-dependent method:

The method_info identifier provides access to all parameters required for the implementation-dependent conversion method.

Profile:

Foundation

Error codes:

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COLOUR OPERATOR **COLOUR LOOKUP, INTERPOLATED**

Description:

Performs interpolated lookup table manipulation of a colour image.

Name:

colour_lookup_interpolated

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	lookup table object	ID	in
num_cells	number of cells tuple	ID	in
size_cells	size of cells tuple	ID	in
size_array	array dimension tuple	ID	in

Objects:

Source structure:	COLR, VC, TC, VTC
Destination structure:	GEN
SOB structure:	LUT
SRC data type:	ND, SD, RD
Destination data type:	same as SOB data type
SOB data type:	ND, SD, RD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	yes
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The contents of a lookup table can be filled by a lookup table tool.
2. The *num_cells* and *size_array* tuples each contain B_s elements of the ND data type.
3. The *size_cells* tuple contains B_s elements of the RD data type.
4. The lookup table effectively contains a B_s-dimensional table for each output band. The table stores the output pixel values at the corners of the cells of a B_s-dimensional array of cells of n(0) by n(1)

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by... by $n(B_s-1)$ cells. Thus, there are

$$\prod_{i=0}^{B_s-1} [n(i)+1]$$

pixel values per output band included in the lookup table.

5. The elements contained in the *size_array* tuple represent the physical sizes of the dimensions of the B_s-dimensional lookup table of which the first n(i) + 1 in each dimension i are used. Thus

$$N(i) \geq n(i) + 1$$

The size of the lookup table must be at least

$$\prod_{i=0}^{B_s-1} N(i)$$

Nomenclature:

SRC(x, y, z, t, b)	$XxYxZxTxB_S$ source image
DST(x, y, z, t, b)	$XxYxZxTxB_D$ destination image
S(x, y, z, t, b)	$XxYxZxTxB_S$ operator input image
D(x, y, z, t, b)	$XxYxZxTxB_D$ operator output image
SOB	lookup table identifier
n(b)	number of lookup table bins in the b-th dimension
s(b)	size of cells in the b-th dimension
N(b)	array dimension in the b-th dimension, $N(b) \geq n(b) + 1$
p	integer position within the lookup table

Definition:

This operator provides linear interpolation within a nD block of a lookup table. The nD table may have different sizes in the n dimensions and the sizes are not constrained to be powers of two. The operator allows the size of the cells to be real numbers.

For all x, y, z, t, b, where $0 \leq b < B_s$, let

$$c(b) = \frac{S(x, y, z, t, b)}{s(b)}$$

$$i(b) = LIV\{c(b)\}$$

$$f(b) = c(b) - i(b)$$

$$p(b) = \prod_{q=b+1}^{B_s-1} N(q) \qquad \text{with } p(B_s-1) = 1$$

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$$m = \sum_{q=0}^{B_s - 1} [i(q)]\,[p(q)]$$

For each band, b_{OUT}, the destination image can then be expressed as

$$D(x, y, z, t, b_{OUT}) = V(m, B_s, b_{OUT})$$

where for any q,

$$V(q, 0, b_{OUT}) = LOOK\{q, 0, b_{OUT}, SOB\}$$

and for $0 \leq b < B_s$ and any q,

$$V(q, b + 1, b_{OUT}) = [1 - f(b)]\,[V(q, b, b_{OUT})] + [f(b)]\,[V(q + p(b), b, b_{OUT})]$$

The pixel value of the destination image is undefined if

$$c(b) < 0 \text{ or } c(b) > n(b) \text{ for } 0 \leq b < B_s$$

Profile:

Technical

Error codes:

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POINT OPERATOR **COMPLEMENT**

Description:

Performs logical complement of a Boolean or integer image.

Name:

complement	complement_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SRC data type:	BD, ND, SD	BD
DST data type:	same as SRC data type	BD

Element functionality:

Index assignment:	no	no
Match point:	yes	no
ROI control:	yes	no
ROI processing:	yes	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxS destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
s(p)	p-th bit of integer pixel of operator input image
d(p)	p-th bit of integer pixel of operator output image
bs	number of source bits per pixel, $bs \geq 1$
p	integer bit index $0 \leq p \leq bs - 1$

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Definition:

For all x, y, z, t, b

Boolean complement:

$$D(x, y, z, t, b) = \overline{S(x, y, z, t, b)}$$

Integer complement:

For $0 \leq p \leq bs - 1$

$$s(p) = \text{BITEXT}\{S(x, y, z, t, b), p\}$$

$$d(p) = \overline{s(p)}$$

$$D(x, y, z, t, b) = \text{BITINS}\{D(x, y, z, t, b), d(p), p\}$$

Profile:

Foundation	complement
Technical	complement_roi

Error codes:

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COMPLEX OPERATOR **COMPLEX COMPOSITION**

Description:

Performs conversion of a pair of real arithmetic data type images containing the real and imaginary or magnitude and phase parts of a complex image into a complex data type image.

Name:

complex_composition

Parameters:

SRC1	first source image	ID	in
SRC2	second source image	ID	in
DST	destination image	ID	out
option	conversion option	EP	in
	real/imaginary to complex		
	magnitude/phase to complex		

Objects:

SRC1 structure:	any image
SRC2 structure:	same as SRC1 structure
DST structure:	same as SRC1 structure
SRC1 data type:	RD
SRC2 data type:	RD
DST data type:	CD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

Phase data is represented in units of radians.

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Nomenclature:

SRC1(x, y, z, t, b)	XxYxZxTxB first source image
SRC2(x, y, z, t, b)	XxYxZxTxB second source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S1(x, y, z, t, b)	XxYxZxTxB first operator input image
S2(x, y, z, t, b)	XxYxZxTxB second operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image

Definition:

Real/imaginary to complex conversion:

$$REAL\{D(x, y, z, t, b)\} = S1(x, y, z, t, b)$$

$$IMAG\{D(x, y, z, t, b)\} = S2(x, y, z, t, b)$$

Magnitude/phase to complex conversion:

$$REAL\{D(x, y, z, t, b)\} = [S1(x, y, z, t, b)][COS\{S2(x, y, z, t, b)\}]$$

$$IMAG\{D(x, y, z, t, b)\} = [S1(x, y, z, t, b)][SIN\{S2(x, y, z, t, b)\}]$$

Profile:

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Error codes:

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COMPLEX OPERATOR **COMPLEX CONJUGATE**

Description:

Computes complex conjugate of a complex image.

Name:

complex_conjugate

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	CD
DST data type:	CD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image

Definition:

$$REAL\{D(x, y, z, t, b)\} = REAL\{S(x, y, z, t, b)\}$$

$$IMAG\{D(x, y, z, t, b)\} = -IMAG\{S(x, y, z, t, b)\}$$

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COMPLEX OPERATOR

COMPLEX DECOMPOSITION

Description:

Performs conversion of a complex data type image into a pair of real arithmetic data type images containing the real and imaginary or magnitude and phase parts of the complex image.

Name:

complex_decomposition

Parameters:

SRC	source image	ID	in
DST1	first destination image	ID	out
DST2	second destination image	ID	out
option	conversion option	EP	in
	complex to real/imaginary		
	complex to magnitude/phase		

Objects:

SRC structure:	any image
DST1 structure:	same as SRC structure
DST2 structure:	same as SRC structure
SRC data type:	CD
DST1 data type:	RD
DST2 data type:	RD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

Phase data is represented in units of radians.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST1(x, y, z, t, b)	XxYxZxTxB first destination image
DST2(x, y, z, t, b)	XxYxZxTxB second destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D1(x, y, z, t, b)	XxYxZxTxB first operator output image
D2(x, y, z, t, b)	XxYxZxTxB second operator output image

Definition:

Complex to real/imaginary conversion:

$$D1(x, y, z, t, b) = REAL\{S(x, y, z, t, b)\}$$

$$D2(x, y, z, t, b) = IMAG\{S(x, y, z, t, b)\}$$

Complex to magnitude/phase conversion:

$$D1(x, y, z, t, b) = [[REAL\{S(x, y, z, t, b)\}]^2 + [IMAG\{S(x, y, z, t, b)\}]^2]^{1/2}$$

$$D2(x, y, z, t, b) = ATAN2\{IMAG\{S(x, y, z, t, b)\}, REAL\{S(x, y, z, t, b)\}\}$$

Profile:

Technical

Error codes:

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COMPLEX OPERATOR **COMPLEX MAGNITUDE**

Description:

Computes magnitude or magnitude squared of a complex image.

Name:

complex_magnitude

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
option	magnitude option	EP	in
	magnitude		
	magnitude squared		

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	CD
DST data type:	RD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image

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Definition:

Magnitude:

$$D(x, y, z, t, b) = [[REAL\{S(x, y, z, t, b)\}]^2 + [IMAG\{S(x, y, z, t, b)\}]^2]^{1/2}$$

Magnitude squared:

$$D(x, y, z, t, b) = [REAL\{S(x, y, z, t, b)\}]^2 + [IMAG\{S(x, y, z, t, b)\}]^2$$

Profile:

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COMPOSITE IDENTIFIER MECHANISM **COMPOSITE IDENTIFIER ARRAY EQUAL**

Description:

Checks the equality of two composite identifier arrays.

Name:

composite_identifier_array_equal

Parameters:

SOB1	first composite identifier array object	ID	in
SOB2	second composite identifier array object	ID	in
flag	equality flag	BP	out

Object:

SOB1 structure:	ID_ARRAY
SOB2 structue:	ID_ARRAY

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	no

Definition:

This mechanism returns a Boolean value TRUE if the identifiers at corresponding indices in the two composite identifier arrays are identical for all indices; otherwise a Boolean flag value FALSE is returned.

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Description:

Gets an image identifier from a composite identifier array at a specified index value.

Name:

composite_identifier_array_get

Parameters:

DST	destination image	ID	out
SOB	composite identifier array object	ID	in
index	index value	NP	in

Objects:

DST structure:	any
SOB structure:	ID_ARRAY

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Nomenclature:

E	array length, $E \geq 1$
e	index value, $0 \leq e \leq E - 1$

Definition:

This mechanism returns an image identifier at index e of an existing composite identifier array.

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Profile:

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COMPOSITE IDENTIFIER MECHANISM **COMPOSITE IDENTIFIER ARRAY PUT**

Description:

Puts an image identifier into a composite identifier array at a specified index value.

Name:

composite_identifier_array_put

Parameters:

SRC	source image	ID	in
SOB	composite identifier array object	ID	in
index	index value	NP	in

Objects:

SRC structure:	any
SOB structure:	ID_ARRAY

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Nomenclature:

E	array length, $E \geq 1$
e	index value, $0 \leq e \leq E - 1$

Definition:

This mechanism enters an image identifier at index e of an existing composite identifier array.

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Profile:

Scientific

Error codes:

001
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012
013
014
022
101

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COMPOSITE IDENTIFIER MECHANISM **COMPOSITE IDENTIFIER LIST EMPTY**

Description:

Determines if a composite identifier list is empty.

Name:

composite_identifier_list_empty

Parameters:

SOB	composite identifier list object	ID	in
flag	empty flag	BP	out

Object:

SOB structure: ID_LIST

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	no

Definition:

This mechanism returns a Boolean value TRUE if the composite identifier list is empty; otherwise a Boolean flag value FALSE is returned.

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COMPOSITE IDENTIFIER MECHANISM **COMPOSITE IDENTIFIER LIST EQUAL**

Description:

Checks the equality of two composite identifier lists.

Name:

composite_identifier_list_equal

Parameters:

SOB1	first composite identifier list object	ID	in
SOB2	second composite identifier list object	ID	in
flag	equality flag	BP	out

Object:

SOB1 structure:	ID_LIST
SOB2 structure:	ID_LIST

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	no

Definition:

This mechanism returns a Boolean value TRUE if the identifiers at corresponding positions in the two composite identifier lists are identical for all positions; otherwise a Boolean flag value FALSE is returned.

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COMPOSITE IDENTIFIER MECHANISM **COMPOSITE IDENTIFIER LIST GET**

Description:

Returns the identifier at a specified pointer position in a composite identifier list.

Name:

composite_identifier_list_get

Parameters:

DST	destination image	ID	out
SOB	composite identifier list object	ID	in
option	list pointer option	SP	in
	current position		
	predecessor position		
	successor position		
	head position		
	tail position		

Objects:

DST structure:	any
SOB structure:	ID_LIST

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

When the *allocate_composite_identifier* mechanism is invoked, the pointer is initialized to the head of the list.

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Definition:

This mechanism returns an identifier at a specifed pointer position in an existing composite identifier list.

Current position option:

The pointer is not moved. The identifier at the pointer position is returned.

Predecessor position option:

The pointer is moved to the next list entry closer to the head of the list if it is not presently at the head of the list. If the initial pointer position is not the head of the list, the identifier at the new pointer position is returned. If the initial pointer position is the head of the list, a NULL value is returned.

Successor position option:

The pointer is moved to the next list entry closer to the tail of the list if it is not presently at the tail of the list. If the initial pointer position is not the tail of the list, the identifier at the new pointer position is returned. If the initial pointer position is the tail of the list, a NULL value is returned.

Head position option:

The pointer is moved to the head of the list. The identifier at the head of the list is returned.

Tail position option:

The pointer is moved to the tail of the list. The identifier at the tail of the list is returned.

Profile:

Scientific

Error codes:

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COMPOSITE IDENTIFIER MECHANISM **COMPOSITE IDENTIFIER LIST INSERT**

Description:

Inserts an image identifier at a specified position in a composite identifier list.

Name:

composite_identifier_list_insert

Parameters:

SRC	source image	ID	in
SOB	composite identifier list object	ID	in
option	list pointer option before current position after current position	SP	in

Object:

SRC structure:	any
SOB structure:	ID_LIST

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

This mechanism inserts an image identifier at a specified position in an existing composite identifier list.

Before current position option:

The position of the pointer is not moved. The image identifier is inserted before the position of the pointer. The pointer is not moved.

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After current position option:

The position of the pointer is not moved. The image identifier is inserted after the position of the pointer. The pointer is moved to the next list entry closer to the tail of the list.

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COMPOSITE IDENTIFIER MECHANISM **COMPOSITE IDENTIFIER LIST REMOVE**

Description:

Removes an identifier from the current pointer position in a composite identifier list.

Name:

composite_identifier_list_remove

Parameters:

SOB	composite identifier list object	ID	in

Object:

SOB structure: ID_LIST

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

This mechanism removes the identifier at the current pointer position from the composite identifier list.

The pointer remains unchanged except when the identifier removed is at the tail of the existing identifier list. After the tail identifier has been removed from the identifier list, the pointer is moved to the tail of the revised list.

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composite_identifier_list_remove

Profile:

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COMPOSITE IDENTIFIER MECHANISM **COMPOSITE IDENTIFIER RECORD EQUAL**

Description:

Checks the equality of two composite identifier records.

Name:

composite_identifier_record_equal

Parameters:

SOB1	first composite identifier record object	ID	in
SOB2	second composite identifier record object	ID	in
flag	equality flag	BP	out

Objects:

SOB1 structure:	ID_RECORD
SOB2 structure:	ID_RECORD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	no

Definition:

This mechanism returns a Boolean value TRUE if the identifiers at coresponding positions in the two composite identifier records are identical for two positions; otherwise, a Boolean flag value FALSE is returned.

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COMPOSITE IDENTIFIER MECHANISM COMPOSITE IDENTIFIER RECORD GET

Description:

Gets an identifier from a composite identifier record as specified by an attribute name.

Name:

composite_identifier_record_get

Parameters:

DST	destination image	ID	out
SOB	composite identifier record object	ID	in
att_name	attribute name	CS	in

Objects:

SOB structure:	ID_RECORD
DST structure:	any

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

This mechanism returns an identifier specified by an attribute name from an existing composite identifier record.

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Profile:

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Error codes:

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Description:

Puts an image identifier into a composite identifier record as specified by an attribute name.

Name:

composite_identifier_record_put

Parameters:

SRC	source image	ID	in
SOB	composite identifier record object	ID	in
att_name	attribute name	CS	in

Objects:

SRC structure:	any
SOB structure:	ID_RECORD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

This mechanism enters an image identifier in an existing composite identifier record at the position specified by an attribute name.

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INTERNAL UTILITY

CONSTANT PREDICATE

Description:

Determines if all pixels in an image are equal to a constant within a specified tolerance.

Name:

constant_predicate

Parameters:

SRC	source image	ID	in
pv	pixel value	RP	in
pt	pixel tolerance	RP	in
flag	predicate flag	BP	out

Object:

SRC structure:	any
SRC data type:	ND, SD, RD

Element functionality:

Index assignment:	no
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	vreg
Asynchronous:	no

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
pv	pixel value
pt	pixel tolerance, $pt \geq 0$
flag	predicate flag

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constant_predicate

Definition:

The flag is set TRUE if all pixels are equal within the tolerance value. Otherwise, the flag is set FALSE.

Set

flag = TRUE

For all x, y, z, t, b, if

|SRC(x, y, z, t, b) - pvl| > pt

then

flag = FALSE

Profile:

Technical

Error codes:

001
011
041

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INTERNAL UTILITY **CONVERT ARRAY TO IMAGE**

Description:

Converts a matrix, neighbourhood, or static array object to a monochrome image.

Name:

convert_array_to_image

Parameters:

DST	destination image	ID	out
SOB	array object	ID	in

Objects:

DST structure:	MON
SOB structure:	MATRIX, NBHOOD_ARRAY, STATIC_ARRAY
DST data type:	same as SOB data type
SOB data type:	BD, ND, SD, RD, CD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

The image attributes are created by the *allocate_image* system management mechanism.

Nomenclature:

A(x, y)	XxY array
DST(x, y, z, t, b)	XxYx1x1x1 destination image

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Definition:

For all x, y

DST(x, y, 0, 0, 0) = A(x, y)

Profile:

Foundation

Error code:

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043

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INTERNAL UTILITY **CONVERT IMAGE DATA TYPE**

Description:

Converts a PIKS image from one arithmetic data type to another.

Name:

convert_image_datatype

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD, CD
DST data type:	ND, SD, RD, CD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	yes
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The image band data types are specified by the band data type tuples, which are bound to the source and destination images upon their allocation or by the *set_image_attributes* mechanism.
2. The *convert_image_datatype* utility provides a means for converting an image between the same data types, but different internal precisions or different internal representations.
3. PIKS implementations may use the pixel precision image attribute as a hint of the pixel precision desired by an application.
4. The conversion process is implementation dependent.

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5. Conversions from the CD to the ND, SD, and RD data types are not allowed.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image

Definition:

For all x, y, z, t, b

$$DST(x, y, z, t, b) = SRC(x, y, z, t, b)$$

Profile:

Foundation

Error codes:

011
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025
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043

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INTERNAL UTILITY **CONVERT IMAGE TO ARRAY**

Description:

Converts a monochrome image to a matrix, neighourhood, or static array object.

Name:

convert_image_to_array

Parameters:

SRC	source image	ID	in
DOB	array object	ID	out

Objects:

SRC structure:	MON
DOB structure:	MATRIX, NBHOOD_ARRAY, STATIC_ARRAY
SRC data type:	BD, ND, SD, RD, CD
DOB data type:	same as SRC data type

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

The array data object attributes are created by the *allocate_matrix*, *allocate_neighbourhood_array*, or *allocate_static_array* system management mechanisms.

Nomenclature:

SRC(x, y, z, t, b)	XxYx1x1x1 source image
A(x, y)	XxY array

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Definition:

For all x, y

A(x, y) = SRC(x, y, 0, 0, 0)

Profile:

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INTERNAL UTILITY **CONVERT IMAGE TO ROI**

Description:

Converts an image to a ROI object.

Name:

convert_image_to_roi

Parameters:

SRC	source image	ID	in
DOB	ROI object	ID	out

Objects:

SRC structure:	any image
DOB structure:	ROI_ARRAY
SRC data type:	BD
DOB data type:	BD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

The ROI data object attributes are created by the *allocate_roi* system management mechanism.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
ROI(x, y, z, t, b)	XxYxZxTxB ROI

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convert_image_to_roi

Definition:

For all x, y, z, t, b

$$ROI(x, y, z, t, b) = SRC(x, y, z, t, b)$$

Profile:

Technical

Error codes:

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INTERNAL UTILITY **CONVERT ROI TO IMAGE**

Description:

Converts a ROI object to an image.

Name:

convert_roi_to_image

Parameters:

DST	destination image	ID	out
SOB	ROI object	ID	in

Objects:

DST structure:	any image
SOB structure:	any ROI
DST data type:	BD
SOB data type:	BD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

The image attributes are created by the *allocate_image* system management mechanism.

Nomenclature:

ROI(x, y, z, t, b)	XxYxZxTxB ROI
DST(x, y, z, t, b)	XxYxZxTxB destination image

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Definition:

For all x, y, z, t, b

DST(x, y, z, t, b) = ROI(x, y, z, t, b)

Profile:

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FILTERING OPERATOR **CONVOLVE, 2D**

Description:

Performs two-dimensional convolution with a general impulse response function array for several image boundary conditions.

Name:

convolve_2d

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	impulse response array object	ID	in
convolution	convolution option upper left corner justified enclosed array key pixel, zero exterior key pixel, reflected exterior	SP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB structure:	NBHOOD_ARRAY
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type
SOB data type:	SD, RD
SOB dimension:	2D

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. The PIKS data object repository contains a set of fixed size impulse response arrays.
2. Variable size impulse response arrays can be generated by PIKS tools.
3. One-dimensional convolution can be achieved with this operator by specifying an impulse response array with only a single row or column.
4. The impulse response array data type shall be SD if the source image data type is ND or SD.
5. The impulse response array data type shall be RD if the source image data type is RD.

Nomenclature:

SRC(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ source image
DST(x, y, z, t, b)	$X_D x Y_D x Z_D x T_D x B_D$ destination image
S(j, k, l, m, n)	$J_S x K_S x L_S x M_S x N_S$ operator input image
D(j, k, l, m, n)	$J_D x K_D x L_D x M_D x N_D$ operator output image
H(j, k)	$J_H x K_H$ impulse response function array
(j_k, k_k)	key pixel coordinate

The key pixel coordinate is referenced to the origin of the impulse response function array. It is not restricted to be within the bounds of the impulse response function array, i.e., j_k can be negative or larger than J_H.

Definition:

Upper left corner justified mode:

The 2D impulse response function array is rotated 180 degrees and translated with respect to the j-k pixel plane of the source image. A destination pixel is computed for all spatial intersections of the array and the source image. The destination image j-k pixel plane is indexed from its upper left corner. The destination image j-k plane is larger than the source image j-k plane.

For all l, m, n, and for

$$0 \le j \le J_D - 1$$

$$0 \le k \le k_D - 1$$

$$D(j,k,l,m,n) = \sum_{j'} \sum_{k'} S(j',k',l,m,n)\, H(j-j',k-k')$$

The summation limits are

$$MAX\{0, j - J_H + 1\} \le j' \le MIN\{J_S - 1, j\}$$

$$MAX\{0, k - K_H + 1\} \le k' \le MIN\{K_S - 1, k\}$$

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The pixel plane sizes are

$$J_D = J_S + J_H - 1$$

$$K_D = K_S + K_H - 1$$

$$L_D = L_S$$

$$M_D = M_S$$

$$N_D = N_S$$

Enclosed impulse response array mode:

The 2D impulse response function array is rotated 180 degrees and translated with respect to the j-k pixel plane of the source image. A destination pixel is computed whenever all elements of the array lie within the bounds of the source image; all other destination pixels are set to zero. The destination image size is the same as the source image size.

For all l, m, n, and for

$$j_c \le j \le J - 1 - j_c \quad \text{if } J_H \text{ is odd}$$

$$j_c - 1 \le j \le J - 1 - j_c \quad \text{if } J_H \text{ is even}$$

$$k_c \le k \le K - 1 - k_c \quad \text{if } K_H \text{ is odd}$$

$$k_c - 1 \le k \le K - 1 - k_c \quad \text{if } K_H \text{ is even}$$

$$D(j, k, l, m, n) = \sum_{j'} \sum_{k'} S(j', k', l, m, n)\, H(j - j' + j_c, k - k' + k_c)$$

For all l, m, n, and for

$$j < j_c \quad \text{or} \quad j > J - 1 - j_c \quad \text{if } J_H \text{ is odd}$$

$$j < j_c - 1 \quad \text{or} \quad j > J - 1 - j_c \quad \text{if } J_H \text{ is even}$$

$$k < k_c \quad \text{or} \quad k > K - 1 - k_c \quad \text{if } K_H \text{ is odd}$$

$$k < k_c - 1 \quad \text{or} \quad k > K - 1 - k_c \quad \text{if } K_H \text{ is even}$$

$$D(j, k, l, m, n) = 0$$

where

$$j_c = \frac{J_H - 1}{2} \quad \text{if } J_H \text{ is odd}$$

$$j_c = \frac{J_H}{2} \quad \text{if } J_H \text{ is even}$$

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$$k_c = \frac{K_H - 1}{2} \qquad \text{if } K_H \text{ is odd}$$

$$k_c = \frac{K_H}{2} \qquad \text{if } K_H \text{ is even}$$

The summation limits are

$$\text{MAX}\{0, j-j_c\} \le j' \le \text{MIN}\{J-1, j+j_c\} \qquad \text{if } J_H \text{ is odd}$$

$$\text{MAX}\{0, j-j_c+1\} \le j' \le \text{MIN}\{J-1, j+j_c\} \qquad \text{if } J_H \text{ is even}$$

$$\text{MAX}\{0, k-k_c\} \le k' \le \text{MIN}\{K-1, k+k_c\} \qquad \text{if } K_H \text{ is odd}$$

$$\text{MAX}\{0, k-k_c+1\} \le k' \le \text{MIN}\{K-1, k+k_c\} \qquad \text{if } K_H \text{ is even}$$

The pixel plane sizes are

$$J_D = J_S = J$$

$$K_D = K_S = K$$

$$L_D = L_S = L$$

$$M_D = M_S = M$$

$$N_D = N_S = N$$

Key pixel, zero exterior mode:

The 2D impulse response function array is rotated 180 degrees and translated with respect to the j-k pixel plane of the source image. A destination pixel is computed whenever the key pixel of the array is over a source pixel. The destination image size is the same as the source image size. Source pixels outside the j-k plane boundary are assumed to be zero valued.

For all l, m, n, and for

$$\text{MAX}\{0, -j_k\} \le j \le \text{MIN}\{J-1, J-1+j_k\}$$

$$\text{MAX}\{0, -k_k\} \le k \le \text{MIN}\{K-1, K-1+k_k\}$$

$$D(j, k, l, m, n) = \sum_{j'} \sum_{k'} S(j', k', l, m, n)\, H(j - j' + j_{k'}, k - k' + k_k)$$

For all l, m, n, and for

$$j < \text{MAX}\{0, -j_k\} \quad \text{or} \quad j > \text{MIN}\{J-1, J-1+j_k\}$$

$$k < \text{MAX}\{0, -k_k\} \quad \text{or} \quad k > \text{MIN}\{K-1, K-1+k_k\}$$

$$D(j, k, l, m, n) = 0$$

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The summation limits are

$$MAX\{0, j-J_H+j_k+1\} \leq j' \leq MIN\{J-1, j+j_k\}$$

$$MAX\{0, k-K_H+k_k+1\} \leq k' \leq MIN\{K-1, k+k_k\}$$

The pixel plane sizes are

$$J_D = J_S = J$$

$$K_D = K_S = K$$

$$L_D = L_S = L$$

$$M_D = M_S = M$$

$$N_D = N_S = N$$

Key pixel, reflected exterior mode:

The 2D impulse response function array is rotated 180 degrees and translated with respect to the j-k pixel plane of the source image. A destination pixel is computed whenever the key pixel of the impulse response array is over a source pixel. The destination image size is the same as the source image size. Source pixels outside the j-k pixel plane boundary are assumed to be reflections of source pixels about each boundary, i.e., the source image is assumed to be reflected about its left, right, top, and bottom sides.

For all l, m, n, and for

$$0 \leq j \leq J-1$$

$$0 \leq k \leq K-1$$

$$D(j, k, l, m, n) = \sum_{j''} \sum_{k''} S(j'', k'', l, m, n)\, H(j - j'' + j_k, k - k'' + k_k)$$

where

$$j'' = 1 - j' \qquad j' < 0 \qquad k'' = 1 - k' \qquad k' < 0$$

$$j'' = j' \qquad 0 \leq j' \leq J-1 \qquad k'' = k' \qquad 0 \leq k' \leq K-1$$

$$j'' = 2(J-1) - j' \qquad j' > J-1 \qquad k'' = 2(K-1) - k' \qquad k' > K-1$$

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The summation limits are

$$MAX\{0, j-J_H+j_k+1\} \leq j' \leq MIN\{J-1, j+j_k\}$$

$$MAX\{0, k-K_H+k_k+1\} \leq k' \leq MIN\{K-1, k+k_k\}$$

The pixel plane sizes are

$$J_D = J_S = J$$

$$K_D = K_S = K$$

$$L_D = L_S = L$$

$$M_D = M_S = M$$

$$N_D = N_S = N$$

Profile:

Foundation

Error codes:

001
003
011
012
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014
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FILTERING OPERATOR **CONVOLVE, 5D**

Description:

Performs five-dimensional convolution with a general impulse response function array for an enclosed array image boundary condition.

Name:

convolve_5d

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	impulse response array object	ID	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB structure:	NBHOOD_ARRAY
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type
SOB data type:	SD, RD
SOB dimension:	5D

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. Convolution of dimension lower than five can be achieved with this operator by specifying an impulse response array with unpopulated dimensions.
2. The impulse response array data type shall be SD if the source image data type is ND or SD.
3. The impulse response array data type shall be RD if the source image data type is RD.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
H(j, k, l, m, n)	J_HxK_HxL_HxM_HxN_H impulse response function array

Definition:

A destination pixel is computed whenever all elements of the impulse response array lie within the bounds of the image; all other destination pixels are set to zero. The destination image size is the same as the source image size.

For

$$j_c \le j \le J-1-j_c \quad \text{if } J_H \text{ is odd}$$
$$j_c-1 \le j \le J-1-j_c \quad \text{if } J_H \text{ is even}$$
$$k_c \le k \le K-1-k_c \quad \text{if } K_H \text{ is odd}$$
$$k_c-1 \le k \le K-1-k_c \quad \text{if } K_H \text{ is even}$$
$$l_c \le l \le L-1-l_c \quad \text{if } L_H \text{ is odd}$$
$$l_c-1 \le l \le L-1-l_c \quad \text{if } L_H \text{ is even}$$
$$m_c \le m \le M-1-m_c \quad \text{if } M_H \text{ is odd}$$
$$m_c-1 \le m \le M-1-m_c \quad \text{if } M_H \text{ is even}$$
$$n_c \le n \le N-1-n_c \quad \text{if } N_H \text{ is odd}$$
$$n_c-1 \le n \le N-1-n_c \quad \text{if } N_H \text{ is even}$$

$$D(j,k,l,m,n) = \sum_{j'}\sum_{k'}\sum_{l'}\sum_{m'}\sum_{n'} S(j',k',l',m',n') \times H(j-j'+j_c, k-k'+k_c, l-l'+l_c, m-m'+m_c, n-n'+n_c)$$

For

$$j < j_c \text{ or } j > J-1-j_c \quad \text{if } J_H \text{ is odd}$$
$$j < j_c-1 \text{ or } j > J-1-j_c \quad \text{if } J_H \text{ is even}$$
$$k < k_c \text{ or } k > K-1-k_c \quad \text{if } K_H \text{ is odd}$$
$$k < k_c-1 \text{ or } k > K-1-k_c \quad \text{if } K_H \text{ is even}$$
$$l < l_c \text{ or } l > L-1-l_c \quad \text{if } L_H \text{ is odd}$$
$$l < l_c-1 \text{ or } l > L-1-l_c \quad \text{if } L_H \text{ is even}$$
$$m < m_c \text{ or } m > M-1-m_c \quad \text{if } M_H \text{ is odd}$$
$$m < m_c-1 \text{ or } m > M-1-m_c \quad \text{if } M_H \text{ is even}$$

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$n < n_c$ or $n > N - 1 - n_c$ if N_H is odd

$n < n_c - 1$ or $n > N - 1 - n_c$ if N_H is even

$D(j, k, l, m, n) = 0$

where

$$j_c = \frac{J_H - 1}{2}$$ if J_H is odd

$$j_c = \frac{J_H}{2}$$ if J_H is even

$$k_c = \frac{K_H - 1}{2}$$ if K_H is odd

$$k_c = \frac{K_H}{2}$$ if K_H is even

$$l_c = \frac{L_H - 1}{2}$$ if L_H is odd

$$l_c = \frac{L_H}{2}$$ if L_H is even

$$m_c = \frac{M_H - 1}{2}$$ if M_H is odd

$$m_c = \frac{M_H}{2}$$ if M_H is even

$$n_c = \frac{N_H - 1}{2}$$ if N_H is odd

$$n_c = \frac{N_H}{2}$$ if N_H is even

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The summation limits are

$$\text{MAX}\{0, j-j_c\} \le j' \le \text{MIN}\{J-1, j+j_c\} \quad \text{if } J_H \text{ is odd}$$

$$\text{MAX}\{0, j-j_c+1\} \le j' \le \text{MIN}\{J-1, j+j_c\} \quad \text{if } J_H \text{ is even}$$

$$\text{MAX}\{0, k-k_c\} \le k' \le \text{MIN}\{K-1, k+k_c\} \quad \text{if } K_H \text{ is odd}$$

$$\text{MAX}\{0, k-k_c+1\} \le k' \le \text{MIN}\{K-1, k+k_c\} \quad \text{if } K_H \text{ is even}$$

$$\text{MAX}\{0, l-l_c\} \le l' \le \text{MIN}\{L-1, l+l_c\} \quad \text{if } L_H \text{ is odd}$$

$$\text{MAX}\{0, l-l_c+1\} \le l' \le \text{MIN}\{L-1, l+l_c\} \quad \text{if } L_H \text{ is even}$$

$$\text{MAX}\{0, m-m_c\} \le m' \le \text{MIN}\{M-1, m+m_c\} \quad \text{if } M_H \text{ is odd}$$

$$\text{MAX}\{0, m-m_c+1\} \le m' \le \text{MIN}\{M-1, m+m_c\} \quad \text{if } M_H \text{ is even}$$

$$\text{MAX}\{0, n-n_c\} \le n' \le \text{MIN}\{N-1, n+n_c\} \quad \text{if } N_H \text{ is odd}$$

$$\text{MAX}\{0, n-n_c+1\} \le k' \le \text{MIN}\{N-1, n+n_c\} \quad \text{if } N_H \text{ is even}$$

Profile:

Scientific

Error codes:

011
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INTERNAL UTILITY **COPY WINDOW**

Description:

Copies a multi-dimensional rectangular-shaped window from a source image into a destination image.

Name:

copy_window copy_window_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
src_off	source index offset 5-tuple	ID	in
dst_off	destination index offset 5-tuple	ID	in
win	window size 5-tuple	ID	in

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SRC data type:	BD, ND, SD, RD, CD	BD
DST data type:	same as SRC data type	BD

Element functionality:

Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Remarks:

1. The *src_off* and *dst_off* parameter tuples contain parameters of the SD data type.
2. The *win* tuple contains parameters of the ND data type.

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Nomenclature:

SRC(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ source image
DST(x, y, z, t, b)	$X_D x Y_D x Z_D x T_D x B_D$ destination image
S(j, k, l, m, n)	$J_S x K_S x L_S x M_S x N_S$ utility input image
D(j, k, l, m, n)	$J_D x K_D x L_D x M_D x N_D$ utility output image
js	first index source offset
ks	second index source offset
ls	third index source offset
ms	fourth index source offset
ns	fifth index source offset
jd	first index destination offset
kd	second index destination offset
ld	third index destination offset
md	fourth index destination offset
nd	fifth index destination offset
jw	first index window size, jw > 0
kw	second index window size, kw > 0
lw	third index window size, lw > 0
mw	fourth index window size, mw > 0
nw	fifth index window size, nw > 0

Definition:

For all j_D, k_D, l_D, m_D, n_D

$$D(j_D, k_D, l_D, m_D, n_D) = S(j_S, k_S, l_S, m_S, n_S)$$

where

$$j_S = j_D + js - jd$$

$$k_S = k_D + ks - kd$$

$$l_S = l_D + ls - ld$$

$$m_S = m_D + ms - md$$

$$n_S = n_D + ns - nd$$

over the source index ranges

$$js \le j_S \le J_S - 1$$

$$ks \le k_S \le K_S - 1$$

$$ls \le l_S \le L_S - 1$$

$$ms \le m_S \le M_S - 1$$

$$ns \le n_S \le N_S - 1$$

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and over the destination index ranges

$$jd \leq j_D \leq \text{MIN}\{J_D - 1, j_D + jw - 1\}$$

$$kd \leq k_D \leq \text{MIN}\{K_D - 1, k_D + kw - 1\}$$

$$ld \leq l_D \leq \text{MIN}\{L_D - 1, l_D + lw - 1\}$$

$$md \leq m_D \leq \text{MIN}\{M_D - 1, m_D + mw - 1\}$$

$$nd \leq n_D \leq \text{MIN}\{N_D - 1, n_D + nw - 1\}$$

Otherwise, the destination image is left unchanged.

Profile:

Foundation	copy_window
Technical	copy_window_roi

Error codes:

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INTERNAL UTILITY

CREATE TUPLE

Description:

Creates a tuple data object.

Name:

create_tuple

Parameters:

DOB	tuple data object	ID	out
E	tuple size	NP	in
value_1	first data value	BP,NP,SP,RP,CP,CS	in
value_2	second data value	BP,NP,SP,RP,CP,CS	in
.	.	.	.
.	.	.	.
value_E	last data value	BP,NP,SP,RP,CP,CS	in
data_type	data type option BD ND SD RD CD CS	SP	in

Object:

DOB structure:	TUPLE
DOB data type:	BD, ND, SD, RD, CD, CS

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

The data type of each value shall correspond to the data type option.

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create_tuple

Nomenclature:

E	number of tuple entries, $E \geq 1$

Definition:

The E-tuple has the following data structure:

E
CHOICE{BD, ND, SD, RD, CD, CS}
value_1
value_2
.
.
value_E

Profile:

Foundation

Error code:

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CORRELATION OPERATOR **CROSS CORRELATION**

Description:

Computes the cross-correlation function array of a pixel plane of a pair of images.

Name:

cross_correlation

Parameters:

SRC1	first source image	ID	in
SRC2	second source image	ID	in
DOB	cross-correlation array object	ID	out
lv	third index value	NP	in
mv	fourth index value	NP	in
nv	fifth index value	NP	in
C	number of array columns	NP	in
R	number of array rows	NP	in

Objects:

SRC1 structure:	any image
SRC2 structure:	same as SRC1 structure
DOB structure:	STATIC_ARRAY
SRC1 data type:	ND, SD, RD
SRC2 data type:	same as SRC1 data type
DOB data type:	RD

Element functionality:

Index assignment:	yes
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC1(x, y, z, t, b)	XxYxZxTxB first source image
SRC2(x, y, z, t, b)	XxYxZxTxB second source image
S1(j, k, l, m, n)	JxKxLxMxN first operator input image
S2(j, k, l, m, n)	JxKxLxMxN second operator input image
A(c, r)	CxR cross-correlation array
C	number of array columns, positive odd integer
R	number of array rows, positive odd integer
lv	third index value, $lv \geq 0$
mv	fourth index value, $mv \geq 0$
nv	fifth index value, $nv \geq 0$

Definition:

For

$$0 \leq r \leq R-1$$

$$0 \leq c \leq C-1$$

$$A(c,r) = \frac{\sum_j \sum_k S1(j,k,lv,mv,nv)\, S2(j-c+c_c, k-r+r_c, lv, mv, nv)}{\left[\sum_j \sum_k [S1(j,k,lv,mv,nv)]^2\right]^{1/2} \left[\sum_j \sum_k [S2(j-c+c_c, k-r+r_c, lv, mv, nv)]^2\right]^{1/2}}$$

where

$$c_c = \frac{C+1}{2}$$

$$r_c = \frac{R+1}{2}$$

and the summation limits are

$$MAX\{0, c-c_c\} \leq j \leq MIN\{J-1, J-1+c-c_c\}$$

$$MAX\{0, r-r_c\} \leq k \leq MIN\{K-1, K-1+r-r_c\}$$

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Profile:

Scientific

Error codes:

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SYSTEM MANAGEMENT MECHANISM **DEALLOCATE DATA OBJECT**

Description:

Deallocates physical storage associated with an image or non-image data object and destroys its attribute list.

Name:

deallocate_data_object

Parameter:

object	data object	ID	in

Object:

Object structure:	any object
Object data type:	as specified

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

This mechanism removes reservation of physical memory for the referenced data object and destroys its associated attributes.

Profile:

Foundation

Error codes:

012
014

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Description:

Creates a reference to a sub-image.

Name:

define_sub_image

Parameters:

SRC	source image	ID	in
DST	destination sub band image	ID	out
offset_tuple	index offset 5-tuple	ID	in
size_tuple	sub image size 5-tuple	ID	in

Objects:

SRC structure:	any image
DST structure:	GEN
SRC data type:	BD, ND, SD, RD, CD
DST data type:	same as SRC data type

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

The parameter tuples contain parameters of the ND data type.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	$X_w x Y_w x Z_w x T_w x B_w$ destination image
x_o	x index offset, $0 \leq x_o \leq X-1$
y_o	y index offset, $0 \leq y_o \leq Y-1$
z_o	z index offset, $0 \leq z_o \leq Z-1$
t_o	t index offset, $0 \leq t_o \leq T-1$

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b_o	b index offset, $0 \leq b_o \leq B - 1$
X_w	x index sub-image size, $X_w > 0$
Y_w	y index sub-image size, $Y_w > 0$
Z_w	z index sub-image size, $Z_w > 0$
T_w	t index sub-image size, $T_w > 0$
B_w	b index sub-image size, $B_w > 0$

Definition:

This mechanism creates an identifier to a sub-image of a source image. This sub-image can be used as a source or destination image to other PIKS elements that utilize source and destination images. Any modification to pixels of a sub-image results in the same modification to the corresponding pixels of the source image from which the sub-image was derived.

The sub-image is defined as

$$DST(x, y, z, t, b) = SRC(x-x_o, y-y_o, z-z_o, t-t_o, b-b_o)$$

for

$$x_o \leq x \leq x_o + X_w$$

$$y_o \leq y \leq y_o + Y_w$$

$$z_o \leq z \leq z_o + Z_w$$

$$t_o \leq t \leq t_o + T_w$$

$$b_o \leq b \leq x_o + B_w$$

An error is reported if

$$x_o + X_w > X$$

$$y_o + Y_w > Y$$

$$z_o + Z_w > Z$$

$$t_o + T_w > T$$

$$b_o + B_w > B$$

Profile:

Foundation

Error codes:

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003
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013

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ANALYSIS OPERATOR **DIFFERENCE MEASURES**

Description:

Computes squared difference measures between a pair of images.

Name:

difference_measures

Parameters:

SRC1	first source image	ID	in
SRC2	second source image	ID	in
dv	distance measure value	RP	out
measure	measure option squared difference normalized squared difference	SP	in

Objects:

SRC1 structure:	any image
SRC2 structure:	same as SRC1 structure
SRC1 data type:	SD, RD
SRC2 data type:	same as SRC1 data type

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	vreg
Asynchronous:	no

Nomenclature:

SRC1(x, y, z, t, b)	XxYxZxTxB first source image
SRC2(x, y, z, t, b)	XxYxZxTxB second source image
S1(j, k, l, m, n)	JxKxLxMxN first operator input image
S2(j, k, l, m, n)	JxKxLxMxN second operator input image
dv	difference measure

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Definition:

Squared error:

For all j, k, l, m, n

$$dv = \frac{1}{JKLMN} \sum_{j=0}^{J-1} \sum_{k=0}^{K-1} \sum_{l=0}^{L-1} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} [S1(j,k,l,m,n) - S2(j,k,l,m,n)]^2$$

Normalized squared error:

For all j, k, l, m, n

$$dv = \frac{\sum_{j=0}^{J-1} \sum_{k=0}^{K-1} \sum_{l=0}^{L-1} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} [S1(j,k,l,m,n) - S2(j,k,l,m,n)]^2}{\sum_{j=0}^{J-1} \sum_{k=0}^{K-1} \sum_{l=0}^{L-1} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} [S1(j,k,l,m,n)]^2}$$

Profile:

Technical

Error codes:

001
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PRESENTATION OPERATOR **DIFFUSE**

Description:

Performs error diffusion halftoning on an image using the Floyd-Steinberg method to reduce the number of amplitude levels per pixel.

Name:

diffuse

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
level	destination amplitude level B-tuple	ID	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure, with B = 1
SRC data type:	ND
DST data type:	ND

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

The parameter tuple contains parameters of the ND data type.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image, SRC(x, y, z, t, b) $\geq$ 0
DST(x, y, z, t, b)	XxYxZxTxB destination image, DST(x, y, z, t, b) $\geq$ 0
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
E(x, y, z, t, b)	diffusion image
R	maximum value of implementation ND data type, R $\geq$ 1
V(b)	number of destination amplitude levels of b-th pixel plane, 1 $\leq$ V(b) $\leq$ R; V(b) is the b-th data element of the B-tuple.
Q(b)	source quantization scale factor of b-th pixel plane
C(b)	stride value of b-th pixel plane

Definition:

The *diffuse* operator converts the integer range of pixels in the pixel planes corresponding to the b-th index of a source image to a single pixel plane destination image with a virtual number, V(b), of amplitude levels per pixel plane. This is accomplished by scaling source pixels and spatially distributing the roundoff error to neighbouring pixels based upon the Floyd-Steinberg error diffusion method.

The factor, Q(b), quantizes the source image so that it only contains the requested number of quantization levels. The product of Q(b) and S(x, y, z, t, b) is truncated to its maximum quantization level. The value C(b) denotes the stride increment in output value required to give the next higher value of the b-th pixel plane.

If the source image has multiple pixel planes corresponding to the b-th index, i.e., B > 1, the destination image must be passed through a B-dimensional pseudocolour lookup table for display presentation. The pseudocolour operator can be used to perform this function if the source image is an RGB colour image.

Let

$$C(0) = 1$$

and for b > 0

$$C(b) = [V(b-1)]\,[V(b-2)] \ldots [V(0)]$$

For all b

$$Q(b) = \frac{R}{V(b)}$$

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For all x, y, z, t, b,

$$E(x, y, z, t, b) = \frac{7}{16} \text{ MOD } \{S(x-1, y, z, t, b), Q(b)\}$$

$$+ \frac{3}{16} \text{ MOD } \{S(x+1, y-1, z, t, b), Q(b)\}$$

$$+ \frac{5}{16} \text{ MOD } \{S(x, y-1, z, t, b), Q(b)\}$$

$$+ \frac{1}{16} \text{ MOD } \{S(x-1, y-1, z, t, b), Q(b)\}$$

Then

$$D(x, y, z, t, 0) = \sum_{b=0}^{B-1} [C(b)] [\text{LIV } \{S(x, y, z, t, b)/Q(b)\}$$

$$+ \text{ LIV } \{ [2] [E(x, y, z, t, b)]/Q(b)\}$$

Profile:

Foundation

Error codes:

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PRESENTATION OPERATOR **DITHER**

Description:

Performs ordered dither halftoning on an image to reduce the number of amplitude levels per pixel.

Name:

dither

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	dither array object	ID	in
level	destination amplitude level B-tuple	ID	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure, with B = 1
SOB structure:	NBHOOD_ARRAY
SRC data type:	ND
DST data type:	same as SRC data type
SOB data type:	RD
SOB dimension:	2D

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. The parameter tuple contains parameters of the ND data type.
2. The data object repository contains the following dither arrays:

DITHER_2x2	2x2 dither array
DITHER_4x4	4x4 dither array
DITHER_8x8	8x8 dither array
DITHER_16x16	16x16 dither array

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image, SRC(x, y, z, t, b) $\geq$ 0
DST(x, y, z, t, b)	XxYxZxTxB destination image, DST(x, y, z, t, b) $\geq$ 0
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
A(c, r)	WxW dither array, 0.0 $\leq$ A(c, r) $\leq$ 1.0
W	dither array size
R	maximum value of implementation ND data type, R $\geq$ 1
V(b)	number of destination amplitude levels of b-th pixel plane, 1 $\leq$ V(b) $\leq$ R; V(b) is the b-th data element of the B-tuple.
Q(b)	source quantization scale factor of b-th pixel plane
C(b)	stride value of b-th pixel plane

Definition:

The *dither* operator converts the integer range of pixels in the spectral pixel planes corresponding to the b-th index of a source image to a single pixel plane destination image with a virtual number, V(b), of amplitude levels per pixel plane. This is accomplished by scaling source pixels and spatially distributing the roundoff error to neighbouring pixels based upon a dither array, A(c, r).

The factor, Q(b), quantizes the source image so that it only contains the requested number of quantization levels. The product of Q(b) and S(x, y, z, t, b) is truncated to its maximum quantization level. The value C(b) denotes the stride increment in output value required to give the next higher value of the b-th pixel plane.

If the source image has multiple pixel planes corresponding to the b-th index, i.e., B > 1, the destination image must be passed through a B-dimensional pseudocolour lookup table for display presentation. The pseudocolour operator can be used to perform this function if the source image is an RGB colour image.

For all x, y, z, t, set

$$D(x, y, z, t, 0) = 0$$

For all x, y, z, t, b, if

$$MOD\{S(x, y, z, t, b), Q(b)\} > [Q(b)]\,[A(MOD\{x, W\}, MOD\{y, W\})]$$

then

$$D(x, y, z, t, 0) = D(x, y, z, t, 0) + [C(b)]\,[1 + LIV\{[S(x, y, z, t, b)]\,[Q(b)]\}]$$

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else

$$D(x, y, z, t, 0) = D(x, y, z, t, 0) + [C(b)]\,[LIV\{[S(x, y, z, t, b)] / Q(b)\}]$$

where

$$Q(b) = \frac{R}{V(b)}$$

$$C(b) = [V(b-1)]\,[V(b-2)] \ldots [V(0)]$$

with

$$C(0) = 1$$

Profile:

Foundation

Error codes:

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PIXEL MODIFICATION OPERATOR **DRAW PIXELS**

Description:

Inserts pixels specified by an external collection into an image.

Name:

draw_pixels	draw_pixels_roi

Parameters:

SOB	pixel collection object	IP	in
DST	destination image	ID	in, out
E	number of array entries	NP	in

Objects:

SOB structure:	EXT	EXT
DST structure:	any image	ROI_ARRAY
SOB data type:	see remark	see remark
DST data type:	BD, ND, SD, RD, CD	BD

Element functionality:

Index assignment:	no	no
Match point:	no	no
ROI control:	yes	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Remarks:

1. If a pixel coordinate set is repeated in the collection, the previous pixel value is overwritten by the later pixel value.
2. The SOB data type is ND for pixel coordinates and the same as the DST for pixel values.

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Nomenclature:

DST(x, y, z, t, b)	XxYxZxTxB destination image
pv(e)	e-th pixel value, $o \leq e \leq E - 1$
xv(e)	e-th horizontal index value, $0 \leq e \leq E - 1$
yv(e)	e-th vertical index value, $0 \leq e \leq E - 1$
zv(e)	e-th depth index value, $0 \leq e \leq E - 1$
tv(e)	e-th temporal index value, $0 \leq e \leq E - 1$
bv(e)	e-th band index value, $0 \leq e \leq E - 1$
E	number of entries in collection, $E > 0$

Definition:

Each pixel value in the collection is recorded in the destination image at the corresponding 5D coordinate with respect to the origin of the destination image.

For all $0 \leq e \leq E - 1$

DST[xv(e), yv(e), zv(e), tv(e), bv(e)] = pv(e)

Otherwise, the destination image is left unchanged.

The external pixel collection is defined as follows:

xv(0)	yv(0)	zv(0)	tv(0)	bv(0)	pv(0)
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
xv(e)	yv(e)	zv(e)	tv(e)	bv(e)	pv(e)
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
xv(E-1)	yv(E-1)	zv(E-1)	tv(E-1)	bv(E-1)	pv(E-1)

Profile:

Foundation	draw_pixels
Technical	draw_pixels_roi

Error codes:

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ENSEMBLE OPERATOR **DYADIC, ARITHMETIC**

Description:

Performs dyadic arithmetic combination of a pair of integer or real images.

Name:

dyadic_arithmetic

Parameters:

SRC1	first source image	ID	in
SRC2	second source image	ID	in
DST	destination image	ID	out
option	combination option	SP	in
	absolute value difference		
	addition		
	addition, scaled		
	arc tangent ratio		
	division		
	maximum		
	minimum		
	multiplication		
	subtraction		
	subtraction, scaled		

Objects:

SRC1 structure:	any image
SRC2 structure:	same as SRC1 structure
DST structure:	same as SRC1 structure
SRC1 data type:	ND, SD, RD
SRC2 data type:	same as SRC1 data type
DST data type:	same as SRC1 data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. Result of division by zero is implementation dependent.
2. The source images must be of the same data type.

Nomenclature:

SRC1(x, y, z, t, b)	XxYxZxTxB first source image
SRC2(x, y, z, t, b)	XxYxZxTxB second source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S1(x, y, z, t, b)	XxYxZxTxB first operator input image
S2(x, y, z, t, b)	XxYxZxTxB second operator input image
D(x, y, z, t, b)	XxYxZxTxB operator input image

Definition:

For all x, y, z, t, b

Absolute value difference:

$$D(x, y, z, t, b) = S1(x, y, z, t, b) - S2(x, y, z, t, b) \quad \text{if } S1(x, y, z, t, b) \geq S2(x, y, z, t, b)$$

$$D(x, y, z, t, b) = S2(x, y, z, t, b) - S1(x, y, z, t, b) \quad \text{if } S1(x, y, z, t, b) < S2(x, y, z, t, b)$$

Addition:

$$D(x, y, z, t, b) = S1(x, y, z, t, b) + S2(x, y, z, t, b)$$

Addition, scaled:

$$D(x, y, z, t, b) = \frac{S1(x, y, z, t, b) + S2(x, y, z, t, b)}{2}$$

Arc tangent ratio:

$$D(x, y, z, t, b) = \text{ATAN2}\{S1(x, y, z, t, b), S2(x, y, z, t, b)\}$$

Division:

$$D(x, y, z, t, b) = \frac{S1(x, y, z, t, b)}{S2(x, y, z, t, b)}$$

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Maximum:

$D(x, y, z, t, b) = S1(x, y, z, t, b)$ if $S1(x, y, z, t, b) \geq S2(x, y, z, t, b)$

$D(x, y, z, t, b) = S2(x, y, z, t, b)$ if $S1(x, y, z, t, b) < S2(x, y, z, t, b)$

Minimum:

$D(x, y, z, t, b) = S2(x, y, z, t, b)$ if $S1(x, y, z, t, b) \geq S2(x, y, z, t, b)$

$D(x, y, z, t, b) = S1(x, y, z, t, b)$ if $S1(x, y, z, t, b) < S2(x, y, z, t, b)$

Multiplication:

$$D(x, y, z, t, b) = [S1(x, y, z, t, b)] \times [S2(x, y, z, t, b)]$$

Subtraction:

$$D(x, y, z, t, b) = S1(x, y, z, t, b) - S2(x, y, z, t, b)$$

Subtraction, scaled:

$$D(x, y, z, t, b) = \frac{S1(x, y, z, t, b) - S2(x, y, z, t, b)}{2}$$

Profile:

Foundation

Error codes:

001
003
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ENSEMBLE OPERATOR **DYADIC, COMPLEX**

Description:

Performs dyadic arithmetic combination of a pair of complex images.

Name:

dyadic_complex

Parameters:

SRC1	first source image	ID	in
SRC2	second source image	ID	in
DST	destination image	ID	out
option	combination option	SP	in
	addition		
	division		
	multiply		
	subtraction		

Objects:

SRC1 structure:	any image
SRC1 structure:	same as SRC1 structure
DST structure:	same as SRC1 structure
SRC1 data type:	CD
SRC2 data type:	CD
DST data type:	CD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

Result of division by zero is implementation dependent.

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Nomenclature:

SRC1 (x, y, z, t, b)	XxYxZxTxB first source image
SRC2 (x, y, z, t, b)	XxYxZxTxB second source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S1(x, y, z, t, b)	XxYxZxTxB first operator input image
S2(x, y, z, t, b)	XxYxZxTxB second operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image

Definition:

For all x, y, z, t, b

Addition:

$$REAL\{D(x, y, z, t, b)\} = REAL\{S1(x, y, z, t, b))\} + REAL\{S2(x, y, z, t, b)\}$$

$$IMAG\{D(x, y, z, t, b)\} = IMAG\{S1(x, y, z, t, b)\} + IMAG\{S2(x, y, z, t, b)\}$$

Division of S1 by S2:

$$REAL\{D(x, y, z, t, b)\} =$$

$$\frac{[REAL\{S1(x, y, z, t, b)\}][REAL\{S2(x, y, z, t, b)\}] + [IMAG\{S1(x, y, z, t, b)\}][IMAG\{S2(x, y, z, t, b)\}]}{[REAL\{S2(x, y, z, t, b)\}]^2 + [IMAG\{S2(x, y, z, t, b)\}]^2}$$

$$IMAG\{D(x, y, z, t, b)\} =$$

$$\frac{[IMAG\{S1(x, y, z, t, b)\}][REAL\{S2(x, y, z, t, b)\}] - [REAL\{S1(x, y, z, t, b)\}][IMAG\{S2(x, y, z, t, b)\}]}{[REAL\{S2(x, y, z, t, b)\}]^2 + [IMAG\{S2(x, y, z, t, b)\}]^2}$$

Multiplication:

$$REAL\{D(x, y, z, t, b)\} =$$

$$[REAL\{S1(x, y, z, t, b)\}][REAL\{S2(x, y, z, t, b)\}] - [IMAG\{S1(x, y, z, t, b)\}][IMAG\{S2(x, y, z, t, b)\}]$$

$$IMAG\{D(x, y, z, t, b)\} =$$

$$[REAL\{S1(x, y, z, t, b)\}][IMAG\{S2(x, y, z, t, b)\}] + [IMAG\{S1(x, y, z, t, b)\}][REAL\{S2(x, y, z, t, b)\}]$$

Subtraction of S2 from S1:

$$REAL\{D(x, y, z, t, b)\} = REAL\{S1(x, y, z, t, b)\} - REAL\{S2(x, y, z, t, b)\}$$

$$IMAG\{D(x, y, z, t, b)\} = IMAG\{S1(x, y, z, t, b)\} - IMAG\{S2(x, y, z, t, b)\}$$

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Profile:

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ENSEMBLE OPERATOR **DYADIC, LOGICAL**

Description:

Performs dyadic logical combination of a pair of Boolean or integer images.

Name:

dyadic_logical dyadic_logical_roi

Parameters:

SRC1	first source image	ID	in
SRC2	second source image	ID	in
DST	destination image	ID	out
option	combination option	SP	in
	bitwise AND		
	bitwise NAND		
	bitwise NOR		
	bitwise OR		
	bitwise XOR		
	Boolean intersection		
	Boolean union		

Objects:

SRC1 structure:	any image	any ROI
SRC2 structure:	same as SRC1 structure	ROI_GEN
DST structure:	same as SRC1 structure	ROI_GEN
SRC1 data type:	BD, ND, SD	BD
SRC2 data type:	same as SRC1 data type	BD
DST data type:	same as SRC1 data type	BD

Element functionality:

Index assignment:	no	no
Match point:	yes	no
ROI control:	yes	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

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Remark:

Bitwise operations apply to ND or SD data type images; Boolean operations apply to BD data type images.

Nomenclature:

SRC1 (x, y, z, t, b)	XxYxZxTxB first source image
SRC2 (x, y, z, t, b)	XxYxZxTxB second source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S1(x, y, z, t, b)	XxYxZxTxB first operator input image
S2(x, y, z, t, b)	XxYxZxTxB second operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
$s_1(p)$	p-th bit of integer pixel of first operator input image
$s_2(p)$	p-th bit of integer pixel of second operator input image
d(p)	p-th bit of integer pixel of operator output image
bs	number of source bits per pixel, $bs \geq 1$
p	integer bit index, $0 \leq p \leq bs - 1$

Definition:

For all x, y, z, t, b

Bitwise AND:

For $0 \leq p \leq bs - 1$

$s_1(p) = BITEXT\{S1(x, y, z, t, b), p\}$

$s_2(p) = BITEXT\{S2(x, y, z, t, b), p\}$

$d(p) = [s_1(p)] \oplus [s_2(p)]$

$D(x, y, z, t, b) = BITINS\{D(x, y, z, t, b), d(p), p\}$

Bitwise NAND:

For $0 \leq p \leq bs - 1$

$s_1(p) = BITEXT\{S1(x, y, z, t, b), p\}$

$s_2(p) = BITEXT\{S2(x, y, z, t, b), p\}$

$d(p) = \overline{[s_1(p)] \oplus [s_2(p)]}$

$D(x, y, z, t, b) = BITINS\{D(x, y, z, t, b), d(p), p\}$

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Bitwise NOR:

For $0 \leq p \leq bs - 1$

$s_1(p) = BITEXT\{S1(x, y, z, t, b), p\}$

$s_2(p) = BITEXT\{S2(x, y, z, t, b), p\}$

$d(p) = \overline{[s_1(p)] \ominus [s_2(p)]}$

$D(x, y, z, t, b) = BITINS\{D(x, y, z, t, b), d(p), p\}$

Bitwise OR:

For $0 \leq p \leq bs - 1$

$s_1(p) = BITEXT\{S1(x, y, z, t, b), p\}$

$s_2(p) = BITEXT\{S2(x, y, z, t, b), p\}$

$d(p) = [s_1(p)] \ominus [s_2(p)]$

$D(x, y, z, t, b) = BITINS\{D(x, y, z, t, b), d(p), p\}$

Bitwise XOR:

For $0 \leq p \leq bs - 1$

$s_1(p) = BITEXT\{S1(x, y, z, t, b), p\}$

$s_2(p) = BITEXT\{S2(x, y, z, t, b), p\}$

$d(p) = [s_1(p)] \otimes [s_2(p)]$

$D(x, y, z, t, b) = BITINS\{D(x, y, z, t, b), d(p), p\}$

Boolean intersection:

$D(x, y, z, t, b) = [S1(x, y, z, t, b)] \cap [S2(x, y, z, t, b)]$

Boolean union:

$D(x, y, z, t, b) = [S1(x, y, z, t, b)] \cup [S2(x, y, z, t, b)]$

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Profile:

Foundation	dyadic_logical
Technical	dyadic_logical_roi

Error codes:

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POINT OPERATOR **DYADIC, PREDICATE**

Description:

Performs dyadic predicate combination of a pair of integer or real images.

Name:

dyadic_predicate

Parameters:

SRC1	first source image	ID	in
SRC2	second source image	ID	in
DST	destination image	ID	out
option	predicate combination option	SP	in
	greater than		
	greater than or equal to		
	less than		
	less than or equal to		
	equal to		
	not equal to		

Objects:

SRC1 structure:	any image
SCR2 structure:	same as SRC1 structure
DST structure:	same as SRC1 structure
SRC1 data type:	ND, SD, RD
SRC2 data type:	same as SRC1 data type
DST data type:	BD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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dyadic_predicate

Nomenclature:

SRC1 (x, y, z, t, b)	XxYxZxTxB first source image
SRC2 (x, y, z, t, b)	XxYxZxTxB second source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S1(x, y, z, t, b)	XxYxZxTxB first operator input image
S2(x, y, z, t, b)	XxYxZxTxB second operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image

Definition:

For all x, y, z, t, b

Greater than option:

If

$S1(x, y, z, t, b) > S2(x, y, z, t, b)$

then

$D(x, y, z, t, b) = TRUE$

otherwise

$D(x, y, z, t, b) = FALSE$

Greater than or equal to option:

If

$S1(x, y, z, t, b) \geq S2(x, y, z, t, b)$

then

$D(x, y, z, t, b) = TRUE$

otherwise

$D(x, y, z, t, b) = FALSE$

Less than option:

If

$S1(x, y, z, t, b) < S2(x, y, z, t, b)$

then

$D(x, y, z, t, b) = TRUE$

otherwise

$D(x, y, z, t, b) = FALSE$

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Less than or equal to option:

If

$$S1(x, y, z, t, b) \leq S2(x, y, z, t, b)$$

then

$$D(x, y, z, t, b) = TRUE$$

otherwise

$$D(x, y, z, t, b) = FALSE$$

Equal to option:

If

$$S1(x, y, z, t, b) = S2(x, y, z, t, b)$$

then

$$D(x, y, z, t, b) = TRUE$$

otherwise

$$D(x, y, z, t, b) = FALSE$$

Not equal to option:

If

$$S1(x, y, z, t, b) \neq S2(x, y, z, t, b)$$

then

$$D(x, y, z, t, b) = TRUE$$

otherwise

$$D(x, y, z, t, b) = FALSE$$

Profile:

Foundation

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EDGE DETECTION OPERATOR **EDGE DETECTION, ORTHOGONAL GRADIENT**

Description:

Performs edge detection based upon the formation of the spatial orthogonal gradient of a pixel plane.

Name:

edge_detection_orthogonal_gradient

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB1	horizontal gradient impulse array object	ID	in
SOB2	vertical gradient impulse array object	ID	in
th	threshold value	NP, SP, RP	in
bt	below threshold output value	BP,RP	in
at	above threshold output value	BP,RP	in
edge	edge detection option edge gradient thresholded edge gradient edge angle quantized edge angle	SP	in
horizontal_rotate	horizontal impulse rotation option no reflection reflection	EP	in
vertical_rotate	vertical impulse rotation option no reflection reflection	EP	in
data_type	destination data type option BD RD	SP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB1 structure:	NBHOOD_ARRAY
SOB2 structure:	NBHOOD_ARRAY
SRC data type:	ND, SD, RD
DST data type:	BD, RD
SOB1 data type:	RD
SOB2 data type:	RD
SOB1 dimension:	2D
SOB2 dimension:	2D

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Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The parameters "at" and "bt" shall be of the same data type class as the destination image.
2. The parameter "th" shall be of the same data type class as the source image.
3. The data object repository contains the following gradient impulse response arrays:

   BOXCAR_5x5_HORIZONTAL

   BOXCAR_5x5_VERTICAL

   FREI_CHEN_HORIZONTAL

   FREI_CHEN_VERTICAL

   PIXEL_DIFFERENCE_HORIZONTAL

   PIXEL_DIFFERENCE_VERTICAL

   PREWITT_HORIZONTAL

   PREWITT_VERTICAL

   ROBERTS_HORIZONTAL

   ROBERTS_VERTICAL

   SEPARATED_PIXEL_DIFFERENCE_HORIZONTAL

   SEPARATED_PIXEL_DIFFERENCE_VERTICAL

   SOBEL_HORIZONTAL

   SOBEL_VERTICAL

   TRUNCATED_PYRAMID_5x5_HORIZONTAL

   TRUNCATED_PYRAMID_5x5_VERTICAL

4. PIKS tools can be used to generate the following orthogonal gradient impulse response arrays:

   boxcar
   derivative of Gaussian
   pyramid

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5. The horizontal and vertical gradient impulse response functions can be reflected, by option, prior to computation of the gradients. No reflection of the horizontal gradient impulse response array results in a positive gradient if an edge increases in amplitude as the j index increases. No reflection of the vertical gradient impulse response array results in a positive gradient if an edge increases in amplitude as the k index decreases.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
$H_H(j, k)$	$J_H x K_H$ horizontal gradient impulse response array
$H_V(j, k)$	$J_V x K_V$ horizontal gradient impulse response array
th	threshold value
bt	below threshold output value
at	above threshold output value
$G_H(j, k, l, m, n)$	JxKxLxMxN horizontal edge gradient
$G_V(j, k, l, m, n)$	JxKxLxMxN vertical edge gradient
G(j, k, l, m, n)	JxKxLxMxN spatial edge gradient, $G(j, k, l, m, n) \geq 0$
A(j, k, l, m, n)	JxKxLxMxN spatial edge angle, $-\pi \leq A(j, k, l, m, n) \leq \pi$

Definition:

Edge gradient:

Each j-k pixel plane undergoes two-dimensional convolution with a horizontal and a vertical gradient generation impulse response array to generate horizontal and vertical edge gradients, which are then combined to form the spatial edge gradient.

For all j, k, l, m, n

$$D(j, k, l, m, n) = G(j, k, l, m, n)$$

where

$$G(j, k, l, m, n) = [[G_H(j, k, l, m, n)]^2 + [G_V(j, k, l, m, n)]^2]^{1/2}$$

$$G_H(j, k, l, m, n) = S(j, k, l, m, n) \circledast H_H(j, k)$$

$$G_V(j, k, l, m, n) = S(j, k, l, m, n) \circledast H_V(j, k)$$

and $\circledast$ denotes two-dimensional, enclosed array mode convolution as defined by the *convolve_2d* operator.

Thresholded edge gradient:

The spatial edge gradient is generated as above, and then thresholded.

For all j, k, l, m, n

$$D(j, k, l, m, n) = bt \quad \text{if } G(j, k, l, m, n) < th$$

$$D(j, k, l, m, n) = at \quad \text{if } G(j, k, l, m, n) \geq th$$

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Edge angle:

The horizontal and vertical edge gradients are generated as in the Edge Gradient option, and the arc tangent of their ratio is computed to create the edge orientation angle.

For all j, k, l, m, n

$$D(j, k, l, m, n) = A(j, k, l, m, n)$$

where

$$A(j, k, l, m, n) = ATAN2\{G_V(j, k, l, m, n), G_H(j, k, l, m, n)\}$$

Quantized edge angle:

The edge angle is generated as in the Edge Angle option, and then quantized to an integer that represents one of eight compass directions if the edge gradient is above a threshold.

For all j, k, l, m, n

$$D(j, k, l, m, n) = 0 \qquad \text{if } G(j, k, l, m, n) < th$$

$$D(j, k, l, m, n) = p \qquad \text{if } G(j, k, l, m, n) \geq th$$

where $1 \leq p \leq 8$ is an integer that satisfies the inequality

$$\frac{(p-1)\pi}{4} - \frac{\pi}{8} \leq A(j, k, l, m, n) < \frac{p\pi}{4} - \frac{\pi}{8}$$

Profile:

Scientific

Error codes:

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EDGE DETECTION OPERATOR **EDGE DETECTION, SECOND DERIVATIVE**

Description:

Performs edge detection based upon the formation of the spatial second derivative of a pixel plane.

Name:

edge_detection_second_derivative

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	second derivative impulse array object	ID	in
bt	no zero crossing output value	BP,RP	in
at	zero crossing output value	BP,RP	in
edge	edge detection option edge gradient thresholded edge gradient quantized edge angle	SP	in
data_type	destination data type option BD RD	SP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB structure:	NBHOOD_ARRAY
SRC data type:	ND, SD, RD
DST data type:	BD, RD
SOB data type:	RD
SOB dimension:	2D

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. The parameters "at" and "bt" shall be of the same data type class as the destination image.
2. The data object repository contains the following second derivative impulse response arrays:

   LAPLACIAN_1

   LAPLACIAN_2

   LAPLACIAN_3

3. PIKS tools can be used to generate the following second derivative impulse response arrays:

   difference of Gaussians

   Laplacian of Gaussian

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
G(j, k, l, m, n)	JxKxLxMxN spatial second derivative
H(j, k)	J_HxK_H second derivative impulse response array
bt	no zero crossing output value
at	zero crossing output value

Definition:

Edge gradient:

Each j-k pixel plane undergoes two-dimensional convolution with a second derivative impulse response array to generate a spatial second derivative.

For all j, k, l, m, n

$$D(j, k, l, m, n) = G(j, k, l, m, n)$$

where

$$G(j, k, l, m, n) = S(j, k, l, m, n) \circledast H(j, k)$$

and $\circledast$ denotes two-dimensional, enclosed array mode convolution as defined by the *convolve_2d* operator.

Thresholded edge gradient:

The spatial second derivative is generated as in the Edge Gradient option, and examined in a 3x3 pixel window about each pixel to determine if a zero crossing has occurred from a negative value to a positive value second derivative or from a positive value to a negative value. The following figure defines the zero crossing patterns that result in a zero crossing detection.

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For all j, k, l, m, n

D(j, k, l, m, n) = bt if no zero crossing exists

D(j, k, l, m, n) = at if a zero crossing exists

Quantized edge angle:

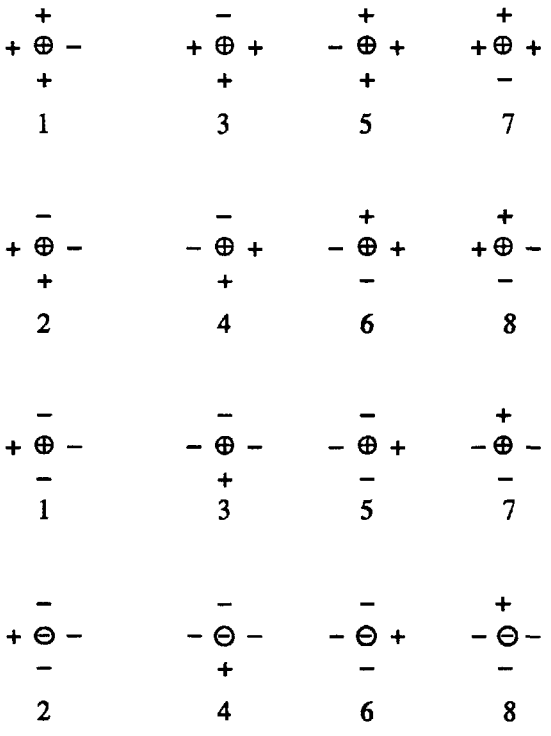
The spatial second derivative is generated as in the Edge Gradient option. The integer value of the zero crossing pattern in the following figure represents the edge angle.

For all j, k, l, m, n

D(j, k, l, m, n) = 0 if no zero crossing exists

D(j, k, l, m, n) = p if a zero crossing exists

where $1 \leq p \leq 8$ is an integer corresponding to the zero crossing pattern.



Zero crossing patterns

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Profile:

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EDGE DETECTION OPERATOR **EDGE DETECTION, TEMPLATE GRADIENT**

Description:

Performs edge detection based upon the formation of the template gradient of a pixel plane.

Name:

edge_detection_template_gradient

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	template gradient impulse array object set	ID	in
P	number of template gradient arrays	NP	in
th	threshold value	NP, SP, RP	in
bt	below threshold output value	BP,RP	in
at	above threshold output value	BP,RP	in
edge	edge detection option edge gradient thresholded edge gradient quantized edge angle	SP	in
data_type	destination data type option BD RD	SP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB structure:	ID_ARRAY
SRC data type:	ND, SD, RD
DST data type:	BD, RD
SOB data type:	RD
SOB dimension:	2D

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. The parameters "at" and bt" shall be of the same data type class as the destination image.
2. The parameter "th" shall be of the same data type class as the source image.
3. The template gradient impulse array object set is a set of NBHOOD_ARRAY data objects.
4. The identifier to the template gradient set individually identifies each array of the set.
5. The data object repository contains the following template gradient impulse response arrays:

compass gradient set:

COMPASS_E
COMPASS_NE
COMPASS_N
COMPASS_NW
COMPASS_W
COMPASS_SW
COMPASS_S
COMPASS_SE

Kirsch set:

KIRSCH_E
KIRSCH_NE
KIRSCH_N
KIRSCH_NW
KIRSCH_W
KIRSCH_SW
KIRSCH_S
KIRSCH_SE

Roberts 3-level set:

ROBERTS_3_LEVEL_E
ROBERTS_3_LEVEL_NE
ROBERTS_3_LEVEL_N
ROBERTS_3_LEVEL_NW
ROBERTS_3_LEVEL_W
ROBERTS_3_LEVEL_SW
ROBERTS_3_LEVEL_S
ROBERTS_3_LEVEL_SE

Roberts 5-level set:

ROBERTS_5_LEVEL_E
ROBERTS_5_LEVEL_NE
ROBERTS_5_LEVEL_N
ROBERTS_5_LEVEL_NW
ROBERTS_5_LEVEL_W
ROBERTS_5_LEVEL_SW
ROBERTS_5_LEVEL_S
ROBERTS_5_LEVEL_SE

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Nevatia-Babu set:

NEVATIA_0
NEVATIA_30
NEVATIA_60
NEVATIA_90
NEVATIA_120
NEVATIA_150
NEVATIA_180
NEVATIA_210
NEVATIA_240
NEVATIA_270
NEVATIA_300
NEVATIA_330

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
$G_p(j, k, l, m, n)$	JxKxLxMxN p-th template edge gradient, $1 \leq p \leq P$
G(j, k, l, m, n)	JxKxLxMxN spatial edge gradient, $G(j, k, l, m, n) \geq 0$
P	number of template gradient arrays, $P > 0$
$H_p(j, k)$	$J_H x K_H$ p-th template gradient impulse response array
th	threshold value
bt	below threshold output value
at	above threshold output value

Definition:

Edge gradient:

Each j-k pixel plane undergoes two-dimensional convolution with a set of directional template gradient impulse response arrays to generate template gradients in P equi-spaced directions. The edge template gradient is the largest magnitude directional gradient at each pixel.

For all j, k, l, m, n

$$D(j, k, l, m, n) = G(j, k, l, m, n)$$

where

$$G(j, k, l, m, n) = MAX\{|G_1(j, k, l, m, n)|, \ldots |G_p(j, k, l, m, n)|, \ldots |G_P(j, k, l, m, n)|\}$$

$$G_p(j, k, l, m, n) = S(j, k, l, m, n) \circledast H_p(j, k)$$

and $\circledast$ denotes two-dimensional, enclosed array mode convolution as defined by the *convolve_2d* operator, and P denotes the number of template gradients.

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Thresholded edge gradient:

The spatial edge gradient is generated as in the Edge Gradient option, and then thresholded.

For all j, k, l, m, n

$D(j, k, l, m, n) = bt$ if $G(j, k, l, m, n) < th$

$D(j, k, l, m, n) = at$ if $G(j, k, l, m, n) \geq th$

Quantized edge angle:

The template edge gradients are generated as in the Edge Gradient option. The integer value of the maximum template gradient represents the edge angle.

For all j, k, l, m, n

$D(j, k, l, m, n) = 0$ if $G(j, k, l, m, n) < th$

$D(j, k, l, m, n) = p$ if $G(j, k, l, m, n) \geq th$

where $1 \leq p \leq P$ is an integer corresponding to the maximum template gradient.

Profile:

Scientific

Error codes:

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INTERNAL UTILITY **EQUAL PREDICATE**

Description:

Determines if all pixels at corresponding indices of a pair of images are equal within a specified tolerance.

Name:

equal_predicate

Parameters:

SRC1	first source image	ID	in
SRC2	second source image	ID	in
pt	pixel tolerance	RP	in
flag	predicate flag	BP	out

Objects:

SRC1 structure:	any image
SRC2 structure:	same as SRC1 structure
SRC1 data type:	ND, SD, RD
SRC2 data type:	same as SRC1 data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	vreg
Asynchronous:	no

Nomenclature:

SRC1(x, y, z, t, b)	XxYxZxTxB first source image
SRC2(x, y, z, t, b)	XxYxZxTxB second source image
pt	pixel tolerance, $pt \geq 0$
flag	predicate flag

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equal_predicate

Definition:

The flag is set TRUE if all pixels are equal within the tolerance value. Otherwise, the flag is set FALSE.

Set

flag = TRUE

For all x, y, z, t, b if

$$|SRC1(x, y, z, t, b) - SRC2(x, y, z, t, b)| > pt$$

then

flag = FALSE

Profile:

Technical

Error codes:

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MORPHOLOGICAL OPERATOR **EROSION OR DILATION, BOOLEAN**

Description:

Performs erosion or dilation on a Boolean image with a rectangular structuring element array.

Name:

erosion_dilation_boolean erosion_dilation_boolean_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	structuring element array object	ID	in
iterations	number of iterations	NP	in
operation	operation option	EP	in
	erosion		
	dilation		
processing	processing option	SP	in
	enclosed array, non-rotated s.e.		
	enclosed array, rotated s.e.		
	key pixel, non-rotated s.e.		
	key pixel, rotated s.e.		

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SOB structure:	NBHOOD_ARRAY	NBHOOD_ARRAY
SRC data type:	BD	BD
SOB data type:	BD	BD
DST data type:	BD	BD
SOB dimension:	2D	2D

Element functionality:

Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	yes	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

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Remark:

If the parameter "iterations" is set to a positive integer value greater than zero, the operation is repeated "iterations" number of times. If the parameter "iterations" is set to zero, the source image is copied to the destination image without modification.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
H(j, k)	J_HxK_H structuring element array
(j_k, k_k)	key pixel coordinate

Definition:

Enclosed structuring element array mode:

The 2D structuring element array is translated with respect to the j-k pixel plane of the source image. A destination pixel is computed whenever all elements of the array lie within the bounds of the source image; all other destination pixels are set to FALSE. The destination image size is the same as the source image size.

For all l, m, n, and for

$$j_c \le j \le J - 1 - j_c \quad \text{if } J_H \text{ is odd}$$

$$j_c - 1 \le j \le J - 1 - j_c \quad \text{if } J_H \text{ is even}$$

$$k_c \le k \le K - 1 - k_c \quad \text{if } K_H \text{ is odd}$$

$$k_c - 1 \le k \le K - 1 - k_c \quad \text{if } K_H \text{ is even}$$

Erosion, non-rotated structuring element:

$$D(j, k, l, m, n) = \bigcap_{j'} \bigcap_{k'} S(j', k', l, m, n) \cup \bar{H}(j' - j + j_c, k' - k + k_c)$$

Erosion, rotated structuring element:

$$D(j, k, l, m, n) = \bigcap_{j'} \bigcap_{k'} S(j', k', l, m, n) \cup \bar{H}(j - j' + j_c, k - k' + k_c)$$

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Dilation, non-rotated structuring element:

$$D(j,k,l,m,n) = \bigcup_{j'} \bigcup_{k'} S(j',k',l,m,n) \cap \bar{H}(j'-j+j_c, k'-k+k_c)$$

Dilation, rotated structuring element:

$$D(j,k,l,m,n) = \bigcup_{j'} \bigcup_{k'} S(j',k',l,m,n) \cap \bar{H}(j-j'+j_c, k-k'+k_c)$$

For all l, m, n and for

$j < j_c$	or	$j > J-1-j_c$	if J_H is odd
$j < j_c-1$	or	$j > J-1-j_c$	if J_H is even
$k < k_c$	or	$k > K-1-k_c$	if K_H is odd
$k < k_c-1$	or	$k > K-1-k_c$	if K_H is even

$D(j, k, l, m, n) = \text{FALSE}$

where

$$j_c = \frac{J_H - 1}{2} \quad \text{if } J_H \text{ is odd}$$

$$j_c = \frac{J_H}{2} \quad \text{if } J_H \text{ is even}$$

$$k_c = \frac{K_H - 1}{2} \quad \text{if } K_H \text{ is odd}$$

$$k_c = \frac{K_H}{2} \quad \text{if } K_H \text{ is even}$$

The intersection and union function limits are

$MAX\{0, j-j_c\} \le j' \le MIN\{J-1, j+j_c\}$		if J_H is odd
$MAX\{0, j-j_c+1\} \le j' \le MIN\{J-1, j+j_c\}$		if J_H is even
$MAX\{0, k-k_c\} \le k' \le MIN\{K-1, k+k_c\}$		if K_H is odd
$MAX\{0, k-k_c+1\} \le k' \le MIN\{K-1, k+k_c\}$		if K_H is even

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Key pixel, zero exterior mode:

The 2D structuring element array is translated with respect to the j-k pixel plane of the source image. A destination pixel is computed whenever the key pixel of the array is over a source pixel. The destination image size is the same as the source image size. Source pixels outside the j-k pixel plane are assumed to be FALSE valued.

For all l, m, n, and for

$$MAX\{0, -j_k\} \le j \le MIN\{J-1, J-1+j_k\}$$

$$MAX\{0, -k_k\} \le k \le MIN\{K-1, K-1+k_k\}$$

Erosion, non-rotated structuring element:

$$D(j,k,l,m,n) = \bigcap_{j'} \bigcap_{k'} S(j',k',l,m,n) \cup \bar{H}(j'-j+j_k, k'-k+k_k)$$

Erosion, rotated structuring element:

$$D(j,k,l,m,n) = \bigcap_{j'} \bigcap_{k'} S(j',k',l,m,n) \cup \bar{H}(j-j'+j_k, k-k'+k_k)$$

Dilation, non-rotated structuring element:

$$D(j,k,l,m,n) = \bigcup_{j'} \bigcup_{k'} S(j',k',l,m,n) \cap \bar{H}(j'-j+j_k, k'-k+k_k)$$

Dilation, rotated structuring element:

$$D(j,k,l,m,n) = \bigcup_{j'} \bigcup_{k'} S(j',k',l,m,n) \cap \bar{H}(j-j'+j_k, k-k'+k_k)$$

For all l, m, n, and for

$$j < MAX\{0, -j_k\} \text{ or } j > MIN\{J-1, J-1+j_k\}$$

$$k < MAX\{0, -k_k\} \text{ or } k > MIN\{K-1, K-1+j_k\}$$

$$D(j,k,l,m,n) = FALSE$$

The intersection and union function limits are

$$MAX\{0, j-J_H+j_k+1\} \le j' \le MIN\{J-1, j+j_k\}$$

$$MAX\{0, k-K_H+k_k+1\} \le k' \le MIN\{K-1, k+k_k\}$$

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Profile:

Technical	erosion_dilation_boolean
Technical	erosion_dilation_boolean_roi

Error codes:

001
003
002
011
012
013
014
022
025
041
042
043
061

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MORPHOLOGICAL OPERATOR **EROSION OR DILATION, GREY**

Description:

Performs erosion or dilation on a grey scale image with a rectangular structuring element array.

Name:

erosion_dilation_grey

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB1	structuring element array object	ID	in
SOB2	mask array object	ID	in
iterations	number of iterations	NP	in
operation	operation option	EP	in
	erosion		
	dilation		
processing	processing option	SP	in
	enclosed array, non-rotated s.e.		
	enclosed array, rotated s.e.		
	key pixel, rotated s.e.		
	key pixel, non-rotated s.e.		

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB1 structure:	NBHOOD_ARRAY
SOB2 structure:	NBHOOD_ARRAY
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type
SOB1 data type:	same as SRC data type
SOB2 data type:	BD
SOB1 dimension:	2D
SOB2 dimension:	2D

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Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. If the "iterations" parameter is set to a positive integer value greater than zero, the operation is repeated "iterations" number of times. The "iterations" parameter must be greater than zero.
2. The mask array must be of the same size as the structuring element array.
3. The mask array must contain at least one TRUE state element.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	XxYxZxTxB operator input image
D(j, k, l, m, n)	XxYxZxTxB operator output image
H(j, k)	J_HxK_H structuring element array
V(j, k)	J_HxK_H mask array
(j_k, k_k)	key pixel coordinate

Definition:

Enclosed structuring element array mode:

The 2D structuring element array is translated with respect to the j-k pixel plane of the source image. A destination pixel is computed whenever all elements of the array lie within the bounds of the source image; all other destination pixels are set to zero. The destination image size is the same as the source image size.

For all l, m, n and for

$$j_c \le j \le J - 1 - j_c \quad \text{if } J_H \text{ is odd}$$

$$j_c - 1 \le j \le J - 1 - j_c \quad \text{if } J_H \text{ is even}$$

$$k_c \le k \le K - 1 - k_c \quad \text{if } K_H \text{ is odd}$$

$$k_c - 1 \le k \le K - 1 - k_c \quad \text{if } K_H \text{ is even}$$

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Erosion, non-rotated structuring element:

$$D(j, k, l, m, n) = \bigwedge_{j'} \bigwedge_{k'} [S(j', k', l, m, n) - H(j' - j + j_c, k' - k + k_c)]$$

Erosion, rotated structuring element:

$$D(j, k, l, m, n) = \bigwedge_{j'} \bigwedge_{k'} [S(j', k', l, m, n) - H(j - j' + j_c, k - k' + k_c)]$$

Dilation, non-rotated structuring element:

$$D(j, k, l, m, n) = \bigvee_{j'} \bigvee_{k'} [S(j', k', l, m, n) + H(j' - j + j_c, k' - k + k_c)]$$

Dilation, rotated structuring element:

$$D(j, k, l, m, n) = \bigvee_{j'} \bigvee_{k'} [S(j', k', l, m, n) + H(j - j' + j_c, k - k' + k_c)]$$

For all l, m, n and for

$j < j_c$	or	$j > J - 1 - j_c$	if J_H is odd
$j < j_c - 1$	or	$j > J - 1 - j_c$	if J_H is even
$k < k_c$	or	$k > K - 1 - k_c$	if K_H is odd
$k < k_c - 1$	or	$k > K - 1 - k_c$	if K_H is even

$$D(j, k, l, m, n) = 0$$

where

$$j_c = \frac{J_H - 1}{2} \quad \text{if } J_H \text{ is odd}$$

$$j_c = \frac{J_H}{2} \quad \text{if } J_H \text{ is even}$$

$$k_c = \frac{K_H - 1}{2} \quad \text{if } K_H \text{ is odd}$$

$$k_c = \frac{K_H}{2} \quad \text{if } K_H \text{ is even}$$

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The minima and maxima function limits are

$$\text{MAX}\{0, j - j_c\} \le j' \le \text{MIN}\{J - 1, j + j_c\} \quad \text{if } J_H \text{ is odd}$$

$$\text{MAX}\{0, j - j_c + 1\} \le j' \le \text{MIN}\{J-1, j + j_c\} \quad \text{if } J_H \text{ is even}$$

$$\text{MAX}\{0, k - k_c\} \le k' \le \text{MIN}\{K-1, k + k_c\} \quad \text{if } K_H \text{ is odd}$$

$$\text{MAX}\{0, k - k_c + 1\} \le k' \le \text{MIN}\{K-1, k + k_c\} \quad \text{if } K_H \text{ is even}$$

Source pixels are included in the minima and maxima computations for a non-rotated structuring element if and only if

$$V(j' - j + j_c, k' - k + k_c) = \text{TRUE}$$

or for a rotated structuring element if and only if

$$V(j - j' + j_c, k - k' + k_c) = \text{TRUE}$$

Key pixel, zero exterior mode:

The 2D structuring element array is translated with respect to the j-k pixel plane of the source image. A destination pixel is computed whenever the key pixel of the array is over a source pixel. The destination image size is the same as the source image size. Source pixels outside the j-k pixel plane are assumed to be zero valued.

For all l, m, n and for

$$\text{MAX}\{0, -j_k\} \le j \le \text{MIN}\{J - 1, J - 1 + j_k\}$$

$$\text{MAX}\{0, -k_k\} \le k \le \text{MIN}\{K - 1, K - 1 + k_k\}$$

Erosion, non-rotated structuring element:

$$D(j, k, l, m, n) = \bigwedge_{j'} \bigwedge_{k'} [S(j', k', l, m, n) - H(j' - j + j_k, k' - k + k_k)]$$

Erosion, rotated structuring element:

$$D(j, k, l, m, n) = \bigwedge_{j'} \bigwedge_{k'} [S(j', k', l, m, n) - H(j - j' + j_k, k - k' + k_k)]$$

Dilation, non-rotated structuring element:

$$D(j, k, l, m, n) = \bigvee_{j'} \bigvee_{k'} [S(j', k', l, m, n) + H(j' - j + j_k, k' - k + k_k)]$$

Dilation, rotated structuring element:

$$D(j, k, l, m, n) = \bigvee_{j'} \bigvee_{k'} [S(j', k', l, m, n) + H(j - j' + j_k, k - k' + k_k)]$$

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For all l, m, n and for

$$j < MAX\{0, -j_k\} \text{ or } j > MIN\{J - 1, J - 1 + j_k\}$$

$$k < MAX\{0, -k_k\} \text{ or } k > MIN\{K - 1, K - 1 + k_k\}$$

$$D(j, k, l, m, n) = 0$$

The minima and maxima function limits are

$$MAX\{0, j - J_H + j_k + 1\} \leq j' \leq MIN\{J - 1, j + j_k\}$$

$$MAX\{0, k - K_H + k_k + 1\} \leq k' \leq MIN\{K - 1, k + k_k\}$$

Source pixels are included in the minima and maxima computations for a non-rotated structuring element if and only if

$$V(j' - j + j_c, k' - k + k_c) = TRUE$$

or for a rotated structuring element if and only if

$$V(j - j' + j_c, k - k' + k_c) = TRUE$$

Profile:

Technical

Error codes:

001
002
003
011
012
013
014
022
025
028
041
042
045
052
061

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POINT OPERATOR **ERROR FUNCTION SCALING**

Description:

Performs Gaussian error function amplitude scaling of an image.

Name:

error_function_scaling

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
s	Gaussian spread factor	RP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	RD
DST data type:	RD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	JxKxLxMxN operator input image
D(x, y, z, t, b)	JxKxLxMxN operator output image
s	Gaussian spread factor, $s > 0$

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Definition:

For all x, y, z, t, b

$$D(x, y, z, t, b) = \frac{ERF\left\{\frac{S(x, y, z, t, b) - 0.5}{s\sqrt{2}}\right\} + ERF\left\{\frac{0.5}{s\sqrt{2}}\right\}}{(2)\,ERF\left\{\frac{0.5}{s\sqrt{2}}\right\}}$$

Profile:

Scientific

Error codes:

001
011
013
025
041
043
061
101

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ERROR MECHANISM **ERROR HANDLER**

Description:

Handles error conditions detected by a PIKS element during execution.

Name:

error_handler

Parameters:

error_number	error identifier code	SP	in
element_id	identification of PIKS element detecting error	SP	in
chain_id	identification of chain detecting error	ID, NULL	in
error_file	error file specification	IP	in
synchronicity	synchronicity state option synchronous asynchronous	EP	in

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remark:

See *open_piks* mechanism for a description of the error_file parameter.

Definition:

This mechanism handles all errors detected by PIKS elements. Upon entry, it sets the PIKS Error Substate, which prohibits the execution of all image related elements until the Error Substate has been reset by completion of this mechanism.

The parameter *synchronicity* indicates that asynchronous or synchronous execution state was in effect when the error was detected. The parameter *chain_id* indicates the chain identifier if a chain was executing when the error condition was detected, otherwise, indicates NULL. If a chain identity is indicated, then the chain element identifier locates the chain elements detecting the error.

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PIKS Error Substate prohibits modification of any PIKS state table value. In PIKS Error Substate, only the following PIKS mechanisms may be invoked:

an inquiry mechanism
error_logger
close_piks_emergency

The *error_handler* mechanism:

- Calls the *error_logger* mechanism to provide information about the error condition, and then returns to the *error_handler* mechanism. The same parameter values input to the *error_handler* mechanism are passed through to the *error_logger* mechanism.
- Resets the PIKS Error Substate.
- Performs a predetermined action, which depends upon the severity of the particular error condition.

The predetermined actions, chosen by the error number, are:

- Set error_file identifier to NULL.
- Return to the calling PIKS element to resume execution as if no error had occurred (error_file parameter set to 0).
- Enter *error_handler* to perform designated error reaction (such as cleaning up inprocess and incomplete operations of the element detecting the error) if it is capable of doing so, before returning to the application.
- Abort operation, invoke *close_piks_emergency*, and terminate the application (without returning to the calling element).

An application may elect to replace the PIKS *error_handler* mechanism with its own special error handler, however it must support the defined error handling concepts to maintain conformance with the standard.

Profile:

Foundation

Error codes:

001
002
012
014
062

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Description:

Logs detected error conditions.

Name:

error_logger

Parameters:

error_number	error identifier code	SP	in
element_id	identification of PIKS element detecting error	SP	in
chain_id	identification of chain detecting error	ID, NULL	in
error_file	error file specification	IP	in
synchronicity	synchronicity state synchronous asynchronous	EP	in

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remark:

See the *open_piks* mechanism for a description of the error_file parameter.

Definition:

This mechanism logs all errors detected by PIKS elements. It is called by the *error_handler* mechanism in Error Substate.

The PIKS *error_logger* mechanism:

- Logs the appropriate error message (chosen by the error number) on the designated error logging device.
- Returns to the calling element to complete the error handling.

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An application may elect to replace the PIKS *error_logger* mechanism with its own special error logger, however it must support the defined error handling concepts to maintain conformance with this standard. The application's error logger may use any inquiry function to obtain information about the nature of the error or PIKS status for presentation to the application.

Profile:

Foundation

Error codes:

001
002
012
014
062

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ERROR MECHANISM **ERROR TEST**

Description:

Tests for any occurence of a detected error condition since the last error_test mechanism was invoked.

Name:

error_test

Parameter:

error_flag	error flag no error error	BP	out

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	vreg
Asynchronous:	no

Definition:

This mechanism tests an error flag which is set by the PIKS *error_handler* mechanism when any error is detected by a PIKS element. This mechanism always returns to the calling element with the previous value of the error_flag after resetting it to the 'no error' state.

The error flag is set FALSE if there is no error. The error flag is set TRUE if there is an error.

Profile:

Foundation

Error codes:

062
302

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EXPORT UTILITY

EXPORT HISTOGRAM

Description:

Exports a histogram object to an application.

Name:

export_histogram

Parameters:

SOB	histogram object	ID	in
DOB	external data value array object	IP	out

Objects:

SOB structure:	HIST
DOB structure:	EXT
SOB data type:	ND
DOB data type:	NP

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remark:

The data type of each external data value shall be of the same class as the object.

Nomenclature:

E	table size, $E \geq 1$

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Definition:

The external array is defined as follows:

value 1
value 2
.
.
value E

Profile:

Foundation

Error codes:

012
014
022
024
042
044
062

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EXPORT UTILITY **EXPORT IMAGE**

Description:

Exports a PIKS image to an application and converts the image into the external data type.

Name:

export_image

Parameters:

SRC	internal source image	ID	in
DST	external destination image	IP	out
bd	number of bits of destination pixel	NP	in
data_type	destination data type option BI NI SI TI RF CF	SP	in

Objects:

SRC structure:	any image
DST structure:	EXT
SRC data type:	BD, ND, SD, RD, CD
DST data type:	BI, NI, SI, TI, RF, CF

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

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Remarks:

1. The image attribute list associated with the source image contains the image size specification and source bits per pixel specification.
2. All bands of an external source image shall be of the same data type.
3. The data type conversion is implementation dependent.
4. The following are allowable data type conversions upon export:

	Destination					
SRC	BI	NI	SI	TI	RF	CF
BD	X					
ND		X	X	X	X	X
SD			X	X	X	X
RD			X	X	X	X
CD					X	X

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
bd	number of destination image bits per pixel, $bd \geq 1$

Definition:

For all x, y, z, t, b

$$DST(x, y, z, t, b) = SRC(x, y, z, t, b)$$

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Profile:

Foundation

Error codes:

001
003
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023
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043
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101

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EXPORT UTILITY **EXPORT LOOKUP TABLE**

Description:

Exports a lookup table object to an application.

Name:

export_lut

Parameters:

SOB	lookup table object	ID	in
DOB	external data value array object	IP	out

Objects:

SOB structure:	LUT
DOB structure:	EXT
SOB data type:	BD, ND, SD, RD, CD
DOB data type:	BP, NP, SP, RP, CP

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remark:

The data type of each external data value shall be of the same class as the object.

Nomenclature:

E	table entries, $E \geq 1$
B	table bands, $B \geq 1$

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Definition:

The external array is defined as follows:

value 1, 1
value 2, 1
.
.
value E, 1
value 1, 2
.
.
value E, B

Profile:

Foundation

Error codes:

012
014
022
024
042
044
062

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Description:

Exports a matrix object to an application.

Name:

export_matrix

Parameters:

SOB	matrix object	ID	in
DOB	external data value array object	IP	out

Objects:

SOB structure:	MATRIX
DOB structure:	EXT
SOB data type:	ND, SD, RD, CD
DOB data type:	NP, SP, RP, CP

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remark:

The data type of each external data value shall be of the same class as the object.

Nomenclature:

R	row size, $R \geq 1$
C	column size, $C \geq 1$

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Definition:

The external array is defined as follows:

value 1, 1
value 2, 1
.
.
value C, 1
value 1, 2
.
.
value C, R

Profile:

Foundation

Error codes:

012
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022
024
042
044
062

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EXPORT UTILITY **EXPORT NEIGHBOURHOOD ARRAY**

Description:

Exports a neighbourhood array object to an application.

Name:

export_neighbourhood_array

Parameters:

SOB	neighbourhood array object	ID	in
DOB	external data value array object	IP	out
S	scale factor	SP	out

Objects:

SOB structure:	NBHOOD_ARRAY
DOB structure:	EXT
SOB data type:	BD, ND, SD, RD, CD
DOB data type:	BP, NP, SP, RP, CP

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remarks:

1. The data type of each external data value shall be of the same class as the object.
2. The scale factors for the BD, ND, RD, and CD data types are unity.

Nomenclature:

J	first index size, $J > 1$
K	second index size, $K \geq 1$
L	third index size, $L \geq 1$
M	fourth index size, $M \geq 1$
N	fifth index size, $N \geq 1$

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Definition:

The external array is defined as follows:

value 1, 1, 1, 1, 1
value 2, 1, 1, 1, 1
.
.
value J, 1, 1, 1, 1
value 1, 2, 1, 1, 1
value 2, 2, 1, 1, 1
.
.
value J, K, L, M, N

Profile:

Foundation

Error codes:

012
014
022
024
042
044
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EXPORT UTILITY **EXPORT ROI ARRAY**

Description:

Exports a ROI array data object to an application.

Name:

export_roi_array

Parameters:

SOB	ROI array object	ID	in
DOB	external data value array object	IP	out

Objects:

SOB structure:	ROI
DOB structure:	EXT
SOB data type:	BD
DOB data type:	BP

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remark:

The data type of each external value shall be of the same class as the object.

Nomenclature:

J	first index size, $J \geq 1$
K	second index size, $K \geq 1$
L	third index size, $L \geq 1$
M	fourth index size, $M \geq 1$
N	fifth index size, $N \geq 1$

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Definition:

The external array is defined as follows:

value 1, 1, 1, 1, 1
value 2, 1, 1, 1, 1
.
.
value J, 1, 1, 1, 1
value 1, 2, 1, 1, 1
value 2, 2, 1, 1, 1
.
.
value J, K, L, M, N

Profile:

Foundation

Error codes:

012
014
022
024
042
044
062

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EXPORT UTILITY **EXPORT STATIC ARRAY**

Description:

Exports static array object to an application.

Name:

export_static_array

Parameters:

SOB	static array object	ID	in
DOB	external data value object	IP	out

Objects:

SOB structure:	STATIC_ARRAY
DOB structure:	EXT
SOB data type:	BD, ND, SD, RD, CD
DOB data type:	BP, NP, SP, RP, CP

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remark:

The data type of each external data value shall be of the same class as the object.

Nomenclature:

J	first index size, $J \geq 1$
K	second index size, $K \geq 1$
L	third index size, $L \geq 1$
M	fourth index size, $M \geq 1$
N	fifth index size, $N \geq 1$

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Definition:

The external array is defined as follows:

value 1, 1, 1, 1, 1
value 2, 1, 1, 1, 1
.
.
value J, 1, 1, 1, 1
value 1, 2, 1, 1, 1
value 2, 2, 1, 1, 1
.
.
value J, K, L, M, N

Profile:

Technical

Error codes:

012
014
022
024
042
044
062

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EXPORT UTILITY **EXPORT TUPLE**

Description:

Exports a tuple object to an application.

Name:

export_tuple

Parameters:

SOB	tuple object	ID	in
DOB	external data value array object	IP	out

Objects:

SOB structure:	TUPLE
DOB structure:	EXT
SOB data type:	BD, ND, SD, RD, CD, CS
DOB data type:	BP, NP, SP, RP, CP, CS

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remark:

The data type of each external data value shall be of the same class as the object.

Nomenclature:

E	tuple size, $E \geq 1$

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Definition:

The external array is defined as follows:

value 1
value 2
.
.
value E

Profile:

Foundation

Error codes:

012
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022
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042
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EXPORT UTILITY **EXPORT VALUE BOUNDS**

Description:

Exports a value bounds collection object to an application.

Name:

export_value_bounds

Parameters:

SOB	value bounds collection object	ID	in
DOB	external data value array object	IP	out

Objects:

SOB structure:	VALUE_BOUNDS
DOB structure:	EXT
SOB data type:	ND, SD, RD
DOB data type:	NP, SP, RP

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remarks:

1. The data type of each external data value shall be of the same class as the object.
2. The image indices x(e), y(e), z(e), t(e), b(e) are of the ND data type; the pixel amplitude value S[x(e), y(e), z(e), t(e), b(e)] is of the ND, SD, or RD data type.

Nomenclature:

E	number of collection entries, $E \geq 1$

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export_value_bounds

Definition:

The external collection is defined as follows:

x(0)
y(0)
z(0)
t(0)
b(0)
S[x(0), y(0), z(0), t(0), b(0)]
.
.
.

x(E–1)
y(E–1)
z(E–1)
t(E–1)
b(E–1)
S[x(E–1), y(E–1), z(E–1), t(E–1), b(E–1)]

Profile:

Scientific

Error codes:

012
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042
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INTERNAL UTILITY **EXTRACT PIXEL PLANE**

Description:

Extracts a monochrome image from a multi-plane image.

Name:

extract_pixel_plane	extract_pixel_plane_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
zv	depth index value	NP	in
tv	temporal index value	NP	in
bv	band index value	NP	in

Objects:

SRC structure:	any image	any ROI
DST structure:	MON	ROI_GEN
SRC data type:	BD, ND, SD, RD, CD	BD
DST data type:	same as SRC data type	BD

Element functionality:

Index assignment:	no	no
Match point:	yes	no
ROI control:	yes	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	yes	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxlxlxl destination image
zv	depth index value, $zv \geq 0$
tv	temporal index value, $tv \geq 0$
bv	band index value, $bv \geq 0$

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Definition:

The *extract_pixel_plane* utility extracts a monochrome image from a specifed pixel plane of a multi-plane image.

For all x, y

DST(x, y, 0, 0, 0) = SRC(x, y, zv, tv, bv)

Profile:

Foundation	extract_pixel_plane
Technical	extract_pixel_plane_roi

Error codes:

001
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ANALYSIS OPERATOR **EXTREMA**

Description:

Detects the smallest and largest pixels of an image and records their values in an external array.

Name:

extrema

Parameters:

SRC	source image	ID	in
DOB1	minima extrema pixel array object	IP	out
DOB2	maxima extrema pixel array object	IP	out
mode	extrema mode	EP	in
	zero		
	one		
	two		
	three		
	four		

Objects:

SRC structure:	any image
DOB1 structure:	EXT
DOB2 structure:	EXT
SRC data type:	ND, SD, RD
DOB1 data type:	RP
DOB2 data type:	RP

Element functionality:

Index assignment:	yes
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	no
Asynchronous:	no

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Nomenclature:

SRC(x,y,z,t,b)	XxYxZxTxB source image
S(j,k,l,m,n)	JxKxLxMxN operator input image
(j_{min},k,l,m,n)	coordinate of smallest amplitude pixel, mode zero
(j_{max},k,l,m,n)	coordinate of largest amplitude pixel, mode zero
(j_{min},k_{min},l,m,n)	coordinate of smallest amplitude pixel, mode one
(j_{max},k_{max},l,m,n)	coordinate of largest amplitude pixel, mode one
$(j_{min},k_{min},l_{min},m,n)$	coordinate of smallest amplitude pixel, mode two
$(j_{max},k_{max},l_{max},m,n)$	coordinate of largest amplitude pixel, mode two
$(j_{min},k_{min},l_{min},m_{min},n)$	coordinate of smallest amplitude pixel, mode three
$(j_{max},k_{max},l_{max},m_{max},n)$	coordinate of largest amplitude pixel, mode three
$(j_{min},k_{min},l_{min},m_{min},n_{min})$	coordinate of smallest amplitude pixel, mode four
$(j_{max},k_{max},l_{max},m_{max},n_{max})$	coordinate of largest amplitude pixel, mode four

Definition:

The source image is searched for the smallest and largest amplitude pixels, and the following minima and maxima arrays are created.

Extrema mode zero:

$S(j_{min}, k_{min}, l_{min}, m_{min}, n_{min})$ $S(j_{max}, k_{max}, l_{max}, m_{max}, n_{max})$

Extrema mode one:

$S(j_{min}, k_{min}, l_{min}, m_{min}, 0)$ $S(j_{max}, k_{max}, l_{max}, m_{max}, 0)$

$\vdots$ $\vdots$

$S(j_{min}, k_{min}, l_{min}, m_{min}, N-1)$ $S(j_{max}, k_{max}, l_{max}, m_{max}, N-1)$

Extrema mode two:

$S(j_{min}, k_{min}, l_{min}, 0, 0)$ $S(j_{max}, k_{max}, l_{max}, 0, 0)$

$\vdots$ $\vdots$

$S(j_{min}, k_{min}, l_{min}, M-1, N-1)$ $S(j_{max}, k_{max}, l_{max}, M-1, N-1)$

Extrema mode three:

$S(j_{min}, k_{min}, 0, 0, 0)$ $S(j_{max}, k_{max}, 0, 0, 0)$

$\vdots$ $\vdots$

$S(j_{min}, k_{min}, L-1, M-1, N-1)$ $S(j_{max}, k_{max}, 0, 0, 0)$

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Extrema mode four:

$S(j_{min}, 0, 0, 0, 0)$ ... $S(j_{min}, K-1, L-1, M-1, N-1)$

$S(j_{max}, 0, 0, 0, 0)$ ... $S(j_{max}, K-1, L-1, M-1, N-1)$

Profile:

Foundation

Error codes:

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ENHANCEMENT OPERATOR **FALSE COLOUR**

Description:

Creates a multispectral or colour image from a multispectral or colour image by a linear transformation across bands.

Name:

false_colour

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	colour conversion matrix object	ID	in

Objects:

SRC structure:	COLR, SPE, VC, VS, TC, TS, VTC, VTS
DST structure:	COLR, SPE, VC, VS, TC, TS, VTC, VTS
SOB structure:	MATRIX
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type
SOB data type:	same as SRC data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

A common utilization of this operator is to transform from a multispectral image of many bands to a trichromatic colour image.

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Nomenclature:

SRC(x, y, z, t, b)	$XxYxZxTxB_S$ source image
DST(x, y, z, t, b)	$XxYxZxTxB_D$ destination image
S(x, y, z, t, b)	$XxYxZxTxB_S$ operator input image
D(x, y, z, t, b)	$XxYxZxTxB_D$ operator output image
M(r, c)	RxC transformation matrix

Definition:

For all x, y, z, t,

$$\begin{bmatrix} D(x,y,z,t,0) \\ D(x,y,z,t,1) \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ D(x,y,z,t,R-1) \end{bmatrix} = \begin{bmatrix} M(0,0) & M(1,0) & \ldots M(C-1,0) \\ M(0,1) & M(1,1) & \ldots M(C-1,1) \\ \cdot & & \\ \cdot & & \\ \cdot & & \\ \cdot & & \\ M(0,R-1) & M(1,R-1) & \ldots M(R-1,C-1) \end{bmatrix} \begin{bmatrix} S(x,y,z,t,0) \\ S(x,y,z,t,1) \\ S(x,y,z,t,2) \\ \cdot \\ \cdot \\ \cdot \\ S(x,y,z,t,C-1) \end{bmatrix}$$

where

$C = B_S$
$R = B_D$

Profile:

Scientific

Error codes:

011
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MORPHOLOGICAL OPERATOR — FILL REGION

Description:

Performs filling of a region, defined by a contour, in a pixel plane of a Boolean image whereby FALSE state pixels within the region are set to the TRUE state, and pixels outside the region are left unchanged.

Name:

fill_region fill_region_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
js	first index value of seed pixel within contour	NP	in
ks	second index value of seed pixel within contour	NP	in
lv	third index value	NP	in
mv	fourth index value	NP	in
nv	fifth index value	NP	in

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SRC data type:	BD	BD
DST data type:	BD	BD

Element functionality:

Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Remark:

The seed pixel must be in the Boolean FALSE state.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
js	first index value of seed pixel
ks	second index value of seed pixel
lv	third index value
mv	fourth index value
nv	fifth index value

Definition:

A contour is a set of eight connected TRUE state pixels. Typically, contours are closed, but they need not be.

A seed pixel is an application-supplied coordinate from which the region filling process originates.

A span is a contigous set of FALSE state pixels along a row between a pair of right and left contour pixels.

The contour is eight-connected; the background is four-connected.

Basic algorithm:

Step 1:

Copy the specified j-k pixel plane of the source image to the corresponding destination image pixel plane.

Step 2:

If the seed pixel is in the TRUE state, declare an error.

Step 3:

Convert the seed pixel and all contiguous FALSE state pixels along the span to the TRUE state.

Step 4:

Examine the row above the just-filled span, and record the pixel addresses of the rightmost pixels of each span in a top address stack.

--`,,`-`-`,,`,,`,`,,`---

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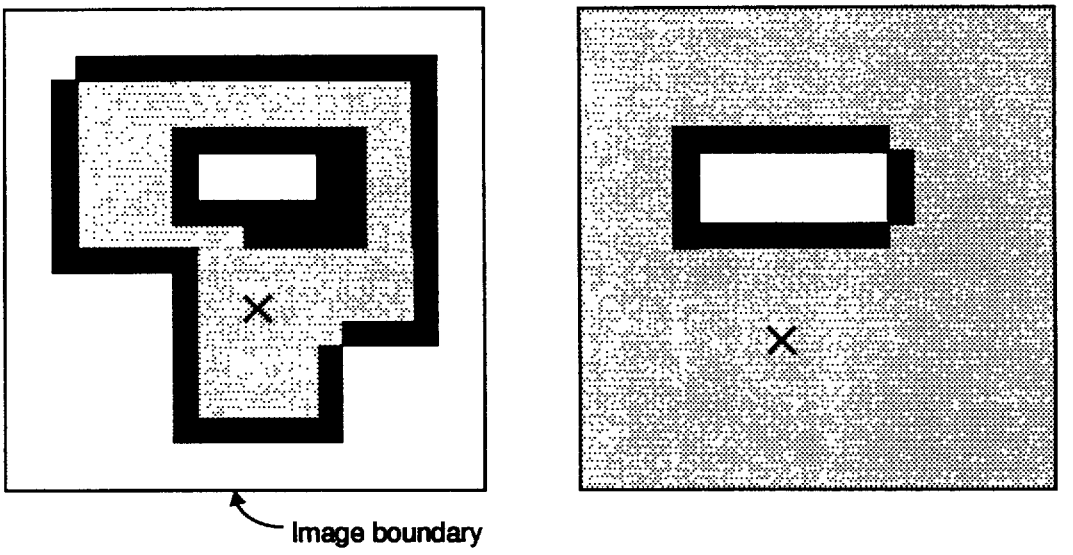
Step 5:

Examine the row below the just-filled span and record the pixel addresses of the rightmost pixels of each span in a bottom address stack.

Step 6:

Using the addresses in the stacks as seed pixels, fill each span until the addresses for a row are depleted. Move to the next rows until the contour is filled.

The following figure indicates the region filling result for several contours. The "X" indicates the position of the seed pixel.



Region filling

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Profile:

Technical	fill_region
Technical	fill_region_roi

Error codes:

001
011
013
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131

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Description:

Generates a Butterworth filter two-dimensional transfer function static array data object.

Name:

filter_butterworth

Parameters:

DOB	filter transfer function array object	ID	out
array_size	array size 5-tuple	ID	in
d	filter order	RP	in
cs	cutoff frequency	RP	in
option	filter type option low-pass high-pass	SP	in

Objects:

DOB structure:	STATIC_ARRAY
DOB data type:	CD
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The transfer function origin is at (0,0) in correspondence to the standard definition of the discrete Fourier transform.
2. The parameter tuple contains parameters of the ND data type.
3. The first element of the *array_size* 5-tuple is the number of array columns. The second element is the number of array rows. All other elements, if they exist, are ignored.

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Nomenclature:

A(c, r)	CxR transfer function array
C	number of array columns, positive even integer
R	number of array rows, positive even integer
d	filter order, d > 0
cs	cutoff frequency, 0 < cs < MIN{1+C/2, 1+R/2}

Definition:

For

$$0 \le c \le C-1$$

$$0 \le r \le R-1$$

$$A(c,r) = \mathcal{H}(c,r) \qquad 0 \le c \le C/2 \text{ and } 0 \le r \le R/2$$

$$A(c,r) = \mathcal{H}(C-c,r) \qquad 1+C/2 \le c \le C-1 \text{ and } 0 \le r \le R/2$$

$$A(c,r) = \mathcal{H}(c,R-r) \qquad 0 \le c \le C/2 \text{ and } 1+R/2 \le r \le R-1$$

$$A(c,r) = \mathcal{H}(C-c,R-r) \qquad 1+C/2 \le c \le C-1 \text{ and } 1+R/2 \le r \le R-1$$

where for a Butterworth low-pass filter

$$H(c,r) = \frac{1}{1+\left[\frac{[r^2+c^2]^{1/2}}{cs}\right]^{2d}} \qquad 0 \le c \le C/2 \text{ and } 0 \le r \le R/2$$

and for a Butterworth high-pass filter

$$\mathcal{H}(0,0) = 1$$

$$\mathcal{H}(c,r) = \frac{1}{1+\left[\frac{cs}{[r^2+c^2]^{1/2}}\right]^{2d}} \qquad 0 \le c \le C/2 \text{ and } 0 \le r \le R/2, \text{ but } r \text{ and } c \ne 0$$

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Profile:

Technical

Error codes:

001
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Description:

Generates a Gaussian-shaped filter two-dimensional transfer function static array data object.

Name:

filter_gaussian

Parameters:

DOB	filter transfer function array object	ID	out
array_size	array size 5-tuple	ID	in
cs	column index spread factor	RP	in
rs	row index spread factor	RP	in

Objects:

DOB structure:	STATIC_ARRAY
DOB data type:	CD
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The transfer function origin is at (0,0) in correspondence to the standard definition of the discrete Fourier transform.
2. The parameter tuple contains parameters of the ND data type.
3. The first element of the *array_size* 5-tuple is the number of array columns. The second element is the number of array rows. All other elements, if they exist, are ignored.

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Nomenclature:

A(c, r)	CxR transfer function array
C	number of array columns, positive even integer
R	number of array rows, positive even integer
cs	column index spread factor, cs > 0
rs	row index spread factor, rs > 0

Definition:

For

$$0 \le c \le C - 1$$

$$0 \le r < R - 1$$

$$A(c, r) = \mathcal{H}(c, r) \qquad 0 \le c \le C/2 \text{ and } 0 \le r \le R/2$$

$$A(c, r) = \mathcal{H}(C-c, r) \qquad 1 + C/2 \le c \le C - 1 \text{ and } 0 \le r \le R/2$$

$$A(c, r) = \mathcal{H}(c, R-r) \qquad 0 \le c \le C/2 \text{ and } 1 + R/2 \le r \le R - 1$$

$$A(c, r) = \mathcal{H}(C-c, R-r) \qquad 1 + C/2 \le c \le C - 1 \text{ and } 1 + R/2 \le r \le R - 1$$

where

$$\mathcal{H}(c, r) = \mathrm{EXP}\{-1/2\,[[(cs)(c)]^2 + [(rs)(r)]^2]\} \qquad 0 \le c \le C/2 \text{ and } 0 \le r \le R/2$$

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STATIC ARRAY GENERATION TOOL

FILTER, INVERSE

Description:

Generates an inverse filter two-dimensional transfer function static array data object.

Name:

filter_inverse

Parameters:

SOB	image blur transfer function array object	ID	in
DOB	filter transfer function array object	ID	out
array_size	array size 5-tuple	ID	in
CK	column index cutoff frequency	NP	in
RK	row index cutoff frequency	NP	in

Objects:

SOB structure:	STATIC_ARRAY
DOB structure:	STATIC_ARRAY
SOB data type:	CD
DOB data type:	CD
SOB dimension:	2D
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The transfer function origin is at (0,0) in correspondence to the standard definition of the discrete Fourier transform.
2. The parameter tuple contains parameters of the ND data type.
3. The first element of the *array_size* 5-tuple is the number of array columns. The second element is the number of array rows. All other elements, if they exist, are ignored.

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Nomenclature:

A(c, r)	CxR inverse filter transfer function array
$\mathcal{H}$(c, r)	CxR blur transfer function array
C	number of array columns, positive even integer
R	number of array rows, positive even integer
CK	column index cutoff frequency, CK < 1 + C/2
RK	row index cutoff frequency, RK < 1 + R/2

Definition:

For

$$0 \le c \le C-1$$

$$0 \le r \le R-1$$

$$A(c,r) = \frac{1}{\mathcal{H}(c,r)} \qquad 0 \le c \le CK-1 \text{ and } 0 \le r \le RK-1$$

$$A(c,r) = \frac{1}{\mathcal{H}(C-c,r)} \qquad C+1-CK \le c \le C-1 \text{ and } 0 \le r \le RK-1$$

$$A(c,r) = \frac{1}{\mathcal{H}(c,R-r)} \qquad 0 \le c \le CK-1 \text{ and } R+1-RK \le r \le R-1$$

$$A(c,r) = \frac{1}{\mathcal{H}(C-c,R-r)} \qquad C+1-CK \le c \le C-1 \text{ and } R+1-RK \le r \le R-1$$

$$A(c,r) = 0 \qquad \text{otherwise}$$

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Profile:

Scientific

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Description:

Generates a matched filter two-dimensional transfer function static array data object.

Name:

filter_matched

Parameters:

SOB1	reference image Fourier transform array object	ID	in
SOB2	noise power spectrum array object	ID	in
DOB	filter transfer function array object	ID	out
array_size	array size 5-tuple	ID	in
co	column index offset	NP	in
ro	row index offset	NP	in

Objects:

SOB1 structure:	STATIC_ARRAY
SOB2 structure:	STATIC_ARRAY
DOB structure:	STATIC_ARRAY
SOB1 data type:	CD
SOB2 data type:	CD
DOB data type:	CD
SOB1 dimension:	2D
SOB2 dimension:	2D
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. The transfer function origin is at (0,0) in correspondence to the standard definition of the discrete Fourier transform.
2. The parameter tuple contains parameters of the ND data type.
3. The first element of the *array_size* 5-tuple is the number of array columns. The second element is the number of array rows. All other elements, if they exist, are ignored.

Nomenclature:

$A(c, r)$	CxR inverse filter transfer function array
C	number of array columns, positive even integer
R	number of array rows, positive even integer
$\mathcal{F}(c, r)$	CxR reference image Fourier transform array
$\mathcal{W}_N(c, r)$	CxR noise power spectrum array
co	column index offset, $co \geq 0$
ro	row index offset, $ro \geq 0$

Definition:

The matched filter transfer function array is the ratio of the complex conjugate of the two-dimensional Fourier transform of a reference image to a noise power spectrum. The ratio is multiplied by an exponential weighting factor that determines the location of the match peak energy in a j-k pixel plane upon linear filtering of an observed image with the matched filter.

For

$$0 \leq c \leq C-1$$

$$0 \leq r \leq R-1$$

$$A(c,r) = \mathcal{H}_M(c,r) \qquad 0 \leq c \leq C/2 \text{ and } 0 \leq r \leq R/2$$

$$A(c,r) = \mathcal{H}_M(C-c,r) \qquad 1+C/2 \leq c \leq C-1 \text{ and } 0 \leq r \leq R/2$$

$$A(c,r) = \mathcal{H}_M(c,R-r) \qquad 0 \leq c \leq C/2 \text{ and } 1+R/2 \leq r \leq R-1$$

$$A(c,r) = \mathcal{H}_M(C-c,R-r) \qquad 1+C/2 \leq c \leq C-1 \text{ and } 1+R/2 \leq r \leq R-1$$

where

$$\mathcal{H}_M(c,r) = \frac{[\text{CONJ}\{\mathcal{F}(c,r)\}][\text{EXP}\{-2\pi i[(c)(co)/C+(r)(ro)/R]\}]}{\mathcal{W}_N(c,r)}$$

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STATIC ARRAY GENERATION TOOL

FILTER, WIENER

Description:

Generates a Wiener filter two-dimensional transfer function static array data object.

Name:

filter_wiener

Parameters:

SOB1	image blur transfer function array object	ID	in
SOB2	image power spectrum array object	ID	in
SOB3	noise power spectrum array object	ID	in
DOB	filter transfer function array object	ID	out
array_size	array size 5-tuple	ID	in

Objects:

SOB1 structure:	STATIC_ARRAY
SOB2 structure:	STATIC_ARRAY
SOB3 structure:	STATIC_ARRAY
DST structure:	STATIC_ARRAY
SOB1 data type:	CD
SOB2 data type:	CD
SOB3 data type:	CD
DST data type:	CD
SOB1 dimension:	2D
SOB2 dimension:	2D
SOB3 dimension:	2D
DST dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Hetrogeneous bands:	NA
Chainable elements:	yes
Asynchronous:	yes

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Remarks:

1. The transfer function origin is at (0,0) in correspondence to the standard definition of the discrete Fourier transform.
2. The parameter tuple contains parameters of the ND data type.
3. The first element of the *array_size* 5-tuple is the number of array columns. The second element is the number of array rows. All other elements, if they exist, are ignored.

Nomenclature:

$A(c, r)$	CxR Wiener filter transfer function array
C	number of array columns, positive even integer
R	number of array rows, positive even integer
$\mathcal{H}_B(c, r)$	CxR blur transfer function array
$\mathcal{W}_I(c, r)$	CxR image power spectrum array
$\mathcal{W}_N(c, r)$	CxR noise power spectrum array

Definition:

For

$$0 \le c \le C-1$$

$$0 \le r \le R-1$$

$$A(c, r) = \mathcal{H}_W(c, r) \qquad 0 \le c \le C/2 \text{ and } 0 \le r \le R/2$$

$$A(c, r) = \mathcal{H}_W(C-c, r) \qquad 1 + C/2 \le c \le C-1 \text{ and } 0 \le r \le R/2$$

$$A(c, r) = \mathcal{H}_W(c, R-r) \qquad 0 \le c \le C/2 \text{ and } 1 + R/2 \le r \le R-1$$

$$A(c, r) = \mathcal{H}_W(C-c, R-r) \qquad 1 + C/2 \le c \le C-1 \text{ and } 1 + R/2 \le r \le R-1$$

where

$$\mathcal{H}_W(c, r) = \frac{\text{CONJ}\{\mathcal{H}_B(c, r)\}\,\mathcal{W}_I(c, r)}{|\mathcal{H}_B(c, r)|^2 \mathcal{W}_I(c, r) + \mathcal{W}_N(c, r)}$$

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STATIC ARRAY GENERATION TOOL FILTER, ZONAL

Description:

Generates a zonal filter two-dimensional transfer function static array data object.

Name:

filter_zonal

Parameters:

DOB	transfer function array object	ID	out
array_size	array size 5-tuple	ID	in
CK	column index cutoff frequency	NP	in
RK	row index cutoff frequency	NP	in
option	filter type option	SP	in
	low-pass filter		
	high-pass filter with d.c. term		
	high-pass filter without d.c. term		

Object:

DOB structure:	STATIC_ARRAY
DOB data type:	CD
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The transfer function origin is at (0,0) in correspondence to the standard definition of the discrete Fourier transform.
2. The parameter tuple contains parameters of the ND data type.
3. The first element of the *array_size* 5-tuple is the number of array columns. The second element is the number of array rows. All other elements, if they exist, are ignored.

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Nomenclature:

A(c, r)	CxR transfer function array
C	number of array columns, positive even integer
R	number of array rows, positive even integer
CK	column index cutoff frequency, $CK \leq 1 + C/2$
RK	row index cutoff frequency, $RK \leq 1 + R/2$

Definition:

For

$0 \leq c \leq C - 1$

$0 \leq r \leq R - 1$

Zonal low-pass filter:

$A(c, r) = 1$	$0 \leq c \leq CK - 1$ and $0 \leq r \leq RK - 1$
$A(c, r) = 1$	$C + 1 - CK \leq c \leq C - 1$ and $0 \leq r \leq RK - 1$
$A(c, r) = 1$	$0 \leq c \leq CK - 1$ and $R + 1 - RK \leq r \leq R - 1$
$A(c, r) = 1$	$C + 1 - CK \leq c \leq C - 1$ and $R + 1 - RK \leq r \leq R - 1$
$A(c, r) = 0$	otherwise

Zonal high-pass filter with d.c. term:

$A(0,0) = 1$	
$A(c, r) = 0$	$0 \leq c \leq CK - 1$ and $0 < r \leq RK - 1$ but c and r = 0
$A(c, r) = 0$	$C + 1 - CK \leq c \leq C - 1$ and $0 \leq r \leq RK - 1$
$A(c, r) = 0$	$0 \leq c \leq CK - 1$ and $R + 1 - RK \leq r \leq R - 1$
$A(c, r) = 0$	$C + 1 - CK \leq c \leq C - 1$ and $R + 1 - RK \leq r \leq R - 1$
$A(c, r) = 1$	otherwise

Zonal high-pass filter without d.c. term:

$A(c, r) = 0$	$0 \leq c \leq CK - 1$ and $0 \leq r \leq RK - 1$
$A(c, r) = 0$	$C + 1 - CK \leq c \leq C - 1$ and $0 \leq r \leq RK - 1$
$A(c, r) = 0$	$0 \leq c \leq CK - 1$ and $R + 1 - RK \leq r \leq R - 1$
$A(c, r) = 0$	$C + 1 - CK \leq c \leq C - 1$ and $R + 1 - RK \leq r \leq R - 1$
$A(c, r) = 1$	otherwise

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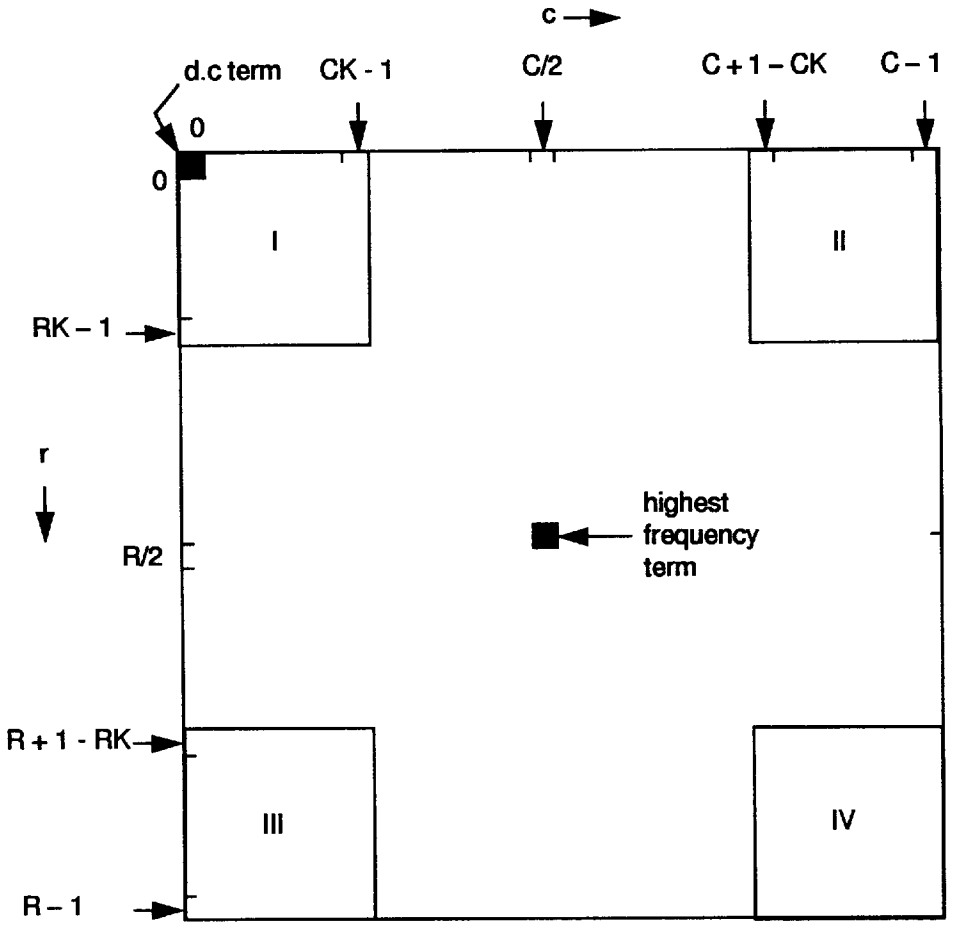

Zonal filter zones

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FILTERING OPERATOR

FILTERING, HOMOMORPHIC

Description:

Performs two-dimensional homomorphic filtering on an image using Fourier domain processing.

Name:

filtering_homomorphic

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB1	windowing function array object	ID	in
SOB2	filter transfer function array object	ID	in

Objects:

SRC structure:	any
DST structure:	same as SRC structure
SOB1 structure:	STATIC_ARRAY
SOB2 structure:	STATIC_ARRAY
SRC data type:	ND, SD, RD
DST data type:	RD
SOB1 data type:	RD
SOB2 data type:	CD
SOB1 dimension:	2D
SOB2 dimension:	2D

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. PIKS tools can be used to generate filter transfer function arrays such as the Butterworth filter or Wiener filter.
2. The *windowing_function* tool can be used to generate windowing function arrays such as the Hanning window.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image, SRC(x, y, z, t, b) > 0
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
W(j, k)	JxK windowing function array
H(j, k)	JxK transfer function array

Definition:

For j, k, l, m, n

Step 1: Form product of source image and windowing function.

$$D_1(j, k, l, m, n) = [W(j, k)] \times [S(j, k, l, m, n)]$$

Step 2: Take logarithm of each pixel of windowed source image.

$$D_2(j, k, l, m, n) = LOG\{D_1(j, k, l, m, n)\}$$

Step 3: Perform 2D Fourier transform of logarithm image.

$$D_3(j, k, l, m, n) = \frac{1}{\sqrt{JK}} \sum_{j'=0}^{J-1} \sum_{k'=0}^{K-1} D_2(j', k', l, m, n)\, EXP\{-2\pi i [jj'/J + kk'/K]\}$$

Step 4: Form product of Fourier transform and transfer function array.

$$D_4(j, k, l, m, n) = D_3(j, k, l, m, n)] \times [H(j, k)]$$

Step 5: Perform inverse 2D Fourier transform.

$$D(j, k, l, m, n) = \frac{1}{\sqrt{JK}} \sum_{j'=0}^{J-1} \sum_{k'=0}^{K-1} D_4(j', k', l, m, n)\, EXP\{2\pi i [jj'/J + kk'/K]\}$$

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FILTERING OPERATOR **FILTERING, LINEAR**

Description:

Performs two-dimensional linear filtering on an image using Fourier domain processing.

Name:

filtering_linear

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB1	window function array object	ID	in
SOB2	filter transfer function array object	ID	in

Objects:

SRC structure:	any
DST structure:	same as SRC structure
SOB1 structure:	STATIC_ARRAY
SOB2 structure:	STATIC_ARRAY
SRC data type:	ND, SD, RD
DST data type:	RD
SOB1 data type:	RD
SOB2 data type:	CD
SOB1 dimension:	2D
SOB2 dimension:	2D

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. PIKS tools can be used to generate filter transfer function arrays such as the Butterworth filter or the Wiener filter.
2. The *windowing_function* tool can be used to generate windowing function arrays such as the Hanning window.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
H(j, k)	JxK filter transfer function array
W(j, k)	JxK windowing function array

Definition:

For all j, k, l, m, n

Step 1: Form product of source image and window function.

$$D_1(j, k, l, m, n) = [W(j, k)] \times [S(j, k, l, m, n)]$$

Step 2: Perform 2D Fourier transform of windowed source image.

$$D_2(j, k, l, m, n) = \frac{1}{\sqrt{JK}} \sum_{j'=0}^{J-1} \sum_{k'=0}^{K-1} D_1(j', k', l, m, n) \, EXP\{-2\pi i [jj'/J + kk'/K]\}$$

Step 3: Form product of Fourier transform and transfer function array.

$$D_3(j, k, l, m, n) = [D_2(j, k, l, m, n)] \times [H(j, k)]$$

Step 4: Perform inverse 2D Fourier transform.

$$D(j, k, l, m, n) = \frac{1}{\sqrt{JK}} \sum_{j'=0}^{J-1} \sum_{k'=0}^{K-1} D_3(j', k', l, m, n) \, EXP\{2\pi i [jj'/J + kk'/K]\}$$

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FILTERING OPERATOR **FILTERING, MEDIAN**

Description:

Computes median of pixel planes of an image within a moving window mask.

Name:

filtering_median

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	mask array object	ID	in
option	processing option	SP	in
	enclosed array		
	key pixel		

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB structure:	NBHOOD_ARRAY
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type
SOB data type:	BD
SOB dimension:	2D

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

The mask array must have an odd number of elements that are in the TRUE state.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
H(j, k)	J_HxK_H mask array
(j_k, k_k)	key pixel coordinate

Definition:

Enclosed mask array mode:

The 2D mask array is scanned over the j-k pixel plane of the source image. A destination pixel is computed whenever all elements of the array lie within the bounds of the source image; all other destination pixels are set to zero. The destination image size is the same as the source image size.

For all l, m, n, and for

$$j_c \le j \le J - 1 - j_c \qquad \text{if } J_H \text{ is odd}$$

$$j_c - 1 \le j \le J - 1 - j_c \qquad \text{if } J_H \text{ is even}$$

$$k_c \le k \le K - 1 - k_c \qquad \text{if } K_H \text{ is odd}$$

$$k_c - 1 \le k \le K - 1 - k_c \qquad \text{if } K_H \text{ is even}$$

$$D(j, k, l, m, n) = \text{SORT}\{S(j', k', l, m, n), H(j' - j - j_c, k' - k - k_c), j, k, l, m, n, j', k', r)\}$$

where $r = (R + 1)/2$ and R denotes the number of elements in the mask array that are in the TRUE state.

For all l, m, n and for

$$j < j_c \quad \text{or} \quad j > J - 1 - j_c \qquad \text{if } J_H \text{ is odd}$$

$$j < j_c - 1 \quad \text{or} \quad j > J - 1 - j_c \qquad \text{if } J_H \text{ is even}$$

$$k < k_c \quad \text{or} \quad k > K - 1 - k_c \qquad \text{if } K_H \text{ is odd}$$

$$k < k_c - 1 \quad \text{or} \quad k > K - 1 - k_c \qquad \text{if } K_H \text{ is even}$$

$$D(j, k, l, m, n) = 0$$

where

$$j_c = \frac{J_H - 1}{2} \qquad \text{if } J_H \text{ is odd}$$

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$$j_c = \frac{J_H}{2} \qquad \text{if } J_H \text{ is even}$$

$$k_c = \frac{K_H - 1}{2} \qquad \text{if } K_H \text{ is odd}$$

$$k_c = \frac{K_H}{2} \qquad \text{if } K_H \text{ is even}$$

The SORT function limits are

$$MAX\{0, j - j_c\} \le j' \le MIN\{J - 1, j + j_c\} \qquad \text{if } J_H \text{ is odd}$$

$$MAX\{0, j - j_c + 1\} \le j' \le MIN\{J-1, j + j_c\} \qquad \text{if } J_H \text{ is even}$$

$$MAX\{0, k - k_c\} \le k' \le MIN\{K-1, k + k_c\} \qquad \text{if } K_H \text{ is odd}$$

$$MAX\{0, k - k_c + 1\} \le k' \le MIN\{K-1, k + k_c\} \qquad \text{if } K_H \text{ is even}$$

Key pixel, zero exterior mode:

The 2D mask element array is scanned over the j-k pixel plane of the source image. A destination pixel is computed whenever the key pixel of the array is over a source pixel. The destination image size is the same as the source image size. Source pixels outside the j-k pixel plane are assumed to be zero valued.

For all l, m, n, and for

$$MAX\{0, -j_k\} \le j \le MIN\{J - 1, j + j_k\}$$

$$MAX\{0, -k_k\} \le k \le MIN\{K - 1, k + k_k\}$$

$$D(j, k, l, m, n) = SORT\{S(j', k', l, m, n), H(j' - j - j_k, k' - k - k_k), j, k, l, m, n, j', k', r)\}$$

where $r = (R + 1)/2$ and R denotes the number of elements in the mask array that are in the TRUE state

For all l, m, n, and for

$$j < MAX\{0, -j_k\} \text{ or } j > MIN\{J - 1, J - 1 + j_k\}$$

$$k < MAX\{0, -k_k\} \text{ or } k > MIN\{K - 1, K - 1 + j_k\}$$

$$D(j, k, l, m, n) = 0$$

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The SORT function limits are

$$\text{MAX}\{0,\ j - J_H + j_k + 1\} \leq j' \leq \text{MIN}\{J - 1,\ j + j_k\}$$

$$\text{MAX}\{0,\ k - K_H + k_k + 1\} \leq k' \leq \text{MIN}\{K - 1,\ k + k_k\}$$

Profile:

Technical

Error codes:

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FILTERING OPERATOR

FILTERING, PSEUDOMEDIAN

Description:

Computes pseudomedian of pixel planes of an image within a moving window plus-shaped mask.

Name:

filtering_pseudomedian

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
mask_width	mask width	NP	in
mask_height	mask height	NP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
J_H	mask width, positive odd integer
K_H	mask height, positive odd integer

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Definition:

The 2D plus-shaped mask is scanned over the j-k pixel plane of the source image. A destination pixel is computed whenever all elements of the array lie within the bounds of the source image; all other destination pixels are left unchanged. The destination image size is the same as the source image size.

For all l, m, n, and for

$$j_c \le j \le J - 1 - j_c$$

$$k_c \le k \le K - 1 - k_c$$

$$D(j, k, l, m, n) = (0.5)MAX\{MAXIMIN\{X_C\}, MAXIMIN\{Y_R\}\} + (0.5)MIN\{MINIMAX\{X_C\}, MINIMAX\{Y_R\}\}$$

where X_C is a sequence of J_H pixels along rows of S(j', k', l, m, n) over the index range

$$MAX\{0, j - j_c\} \le j' \le MIN\{J - 1, j + j_c\}$$

and Y_R is a sequence of K_H pixels along rows of S(j', k', l, m, n) over the index range

$$MAX\{0, k - k_c\} \le k' \le MIN\{K - 1, k + k_c\}$$

For all l, m, n and for

$$j < j_c \quad \text{or} \quad j > J - 1 - j_c$$

$$k < k_c \quad \text{or} \quad k > K - 1 - k_c$$

$$D(j, k, l, m, n) = 0$$

where

$$j_c = \frac{J_H - 1}{2}$$

$$k_c = \frac{K_H - 1}{2}$$

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Profile:

Scientific

Error codes:

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FILTERING OPERATOR

FILTERING, RANK ORDER

Description:

Computes rank order sort value of pixel planes of an image within a moving window mask. Computed pixel is the r-th largest amplitude pixel among pixels in the window mask.

Name:

filtering_rank_order

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	mask array object	ID	in
rank	rank value	NP	in
option	processing option enclosed array key pixel	SP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB structure:	NBHOOD_ARRAY
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type
SOB data type:	BD
SOB dimension:	2D

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
H(j, k)	J_HxK_H mask array
(j_k, k_k)	key pixel coordinate
r	rank order value, $r \geq 1$

Definition:

Enclosed mask array mode:

The 2D mask array is scanned over the j-k pixel plane of the source image. A destination pixel is computed whenever all elements of the array lie within the bounds of the source image; all other destination pixels are left unchanged. The destination image size is the same as the source image size.

For all l, m, n, and for

$$j_c \leq j \leq J - 1 - j_c \quad \text{if } J_H \text{ is odd}$$

$$j_c - 1 \leq j \leq J - 1 - j_c \quad \text{if } J_H \text{ is even}$$

$$k_c \leq k \leq K - 1 - k_c \quad \text{if } K_H \text{ is odd}$$

$$k_c - 1 \leq k \leq K - 1 - k_c \quad \text{if } K_H \text{ is even}$$

$$D(j, k, l, m, n) = SORT\{S(j', k', l, m, n), H(j' - j - j_c, k' - k - k_c), j, k, l, m, n, j', k', r\}$$

For all l, m, n and for

$$j < j_c \text{ or } j > J - 1 - j_c \quad \text{if } J_H \text{ is odd}$$

$$j < j_c - 1 \text{ or } j > J - 1 - j_c \quad \text{if } J_H \text{ is even}$$

$$k < k_c \text{ or } k > K - 1 - k_c \quad \text{if } K_H \text{ is odd}$$

$$k < k_c - 1 \text{ or } k > K - 1 - k_c \quad \text{if } K_H \text{ is even}$$

$$D(j, k, l, m, n) = 0$$

where

$$j_c = \frac{J_H - 1}{2} \quad \text{if } J_H \text{ is odd}$$

$$j_c = \frac{J_H}{2} \quad \text{if } J_H \text{ is even}$$

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$$k_c = \frac{K_H - 1}{2} \qquad \text{if } K_H \text{ is odd}$$

$$k_c = \frac{K_H}{2} \qquad \text{if } K_H \text{ is even}$$

The SORT function limits are

$$\text{MAX}\{0, j - j_c\} \le j' \le \text{MIN}\{J - 1, j + j_c\} \qquad \text{if } J_H \text{ is odd}$$

$$\text{MAX}\{0, j - j_c + 1\} \le j' \le \text{MIN}\{J - 1, j + j_c\} \qquad \text{if } J_H \text{ is even}$$

$$\text{MAX}\{0, k - k_c\} \le k' \le \text{MIN}\{K - 1, k + k_c\} \qquad \text{if } K_H \text{ is odd}$$

$$\text{MAX}\{0, k - k_c + 1\} \le k' \le \text{MIN}\{K - 1, k + k_c\} \qquad \text{if } K_H \text{ is even}$$

Key pixel, zero exterior mode:

The 2D mask element array is scanned over the j-k pixel plane of the source image. A destination pixel is computed whenever the key pixel of the array is over a source pixel. The destination image size is the same as the source image size. Source pixels outside the j-k pixel plane are assumed to be zero valued.

For all l, m, n, and for

$$\text{MAX}\{0, -j_k\} \le j \le \text{MIN}\{J - 1, J - 1 + j_k\}$$

$$\text{MAX}\{0, -k_k\} \le k \le \text{MIN}\{K - 1, K - 1 + k_k\}$$

$$D(j, k, l, m, n) = \text{SORT}\{S(j', k', l, m, n), H(j' - j - j_k, k' - k - k_k), j, k, l, m, n, j', k', r\}$$

For all l, m, n, and for

$$j < \text{MAX}\{0, -j_k\} \text{ or } j > \text{MIN}\{J - 1, J - 1 + j_k\}$$

$$k < \text{MAX}\{0, -k_k\} \text{ or } k > \text{MIN}\{K - 1, K - 1 + j_k\}$$

$$D(j, k, l, m, n) = 0$$

The SORT function limits are

$$\text{MAX}\{0,\ j - J_H + j_k + 1\} \le j' \le \text{MIN}\{J - 1,\ j + j_k\}$$

$$\text{MAX}\{0,\ k - K_H + k_k + 1\} \le k' \le \text{MIN}\{K - 1, k + k_k\}$$

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Profile:

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GEOMETRIC OPERATOR **FLIP, SPIN, TRANSPOSE**

Description:

Performs flip, spin, or transpose manipulations on pixel planes of an image.

Name:

flip_spin_transpose flip_spin_transpose_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
option	flip, spin, transpose option top-to-bottom flip left-to-right flip 90 degrees counterclockwise spin 180 degrees counterclockwise spin 270 degrees counterclockwise spin transpose, upper left to lower right transpose, lower left to upper right	EP	in

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SRC data type:	BD, ND, SD, RD, CD	BD
DST data type:	same as SRC data type	BD

Element functionality:

Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	yes	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	J_SxK_SxLxMxN operator input image
D(j, k, l, m, n)	J_DxK_DxLxMxN operator output image

Definition:

Definitions of the flip, spin, and transpose operations are given below. Examples are shown in the following figure.

For all j, k, l, m, n

Flip top-to-bottom:

$$D(j, k, l, m, n) = S(j, K_S-1-k, l, m, n) \qquad 0 \le j \le J_S - 1 \text{ and } 0 \le k \le K_S - 1$$

where

$$J_D = J_S$$

$$K_D = K_S$$

Flip left-to-right:

$$D(j, k, l, m, n) = S(J_S-1-j, k, l, m, n) \qquad 0 \le j \le J_S - 1 \text{ and } 0 \le k \le K_S - 1$$

where

$$J_D = J_S$$

$$K_D = K_S$$

Spin 90 degrees counterclockwise:

$$D(j, k, l, m, n) = S(J_S-1-k, j, l, m, n) \qquad 0 \le j \le K_S - 1 \text{ and } 0 \le k \le J_S - 1$$

where

$$J_D = K_S$$

$$K_D = J_S$$

Spin 180 degrees counterclockwise:

$$D(j, k, l, m, n) = S(J_S-1-j, K_S-1-k, l, m, n) \qquad 0 \le j \le J_S - 1 \text{ and } 0 \le k \le K_S - 1$$

where

$$J_D = J_S$$

$$K_D = K_S$$

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Spin 270 degrees counterclockwise:

$$D(j, k, l, m, n) = S(k, K_S - 1 - j, l, m, n) \qquad 0 \le j \le K_S - 1 \text{ and } 0 \le k \le J_S - 1$$

where

$$J_D = K_S$$

$$K_D = J_S$$

Transpose, upper left to lower right:

$$D(j, k, l, m, n) = S(k, j, l, m, n) \qquad 0 \le j \le K_S - 1 \text{ and } 0 \le k \le J_S - 1$$

where

$$J_D = K_S$$

$$K_D = J_S$$

Transpose, lower left to upper right:

$$D(j, k, l, m, n) = S(K_S - 1 - k, J_S - 1 - j, l, m, n) \qquad 0 \le j \le K_S - 1 \text{ and } 0 \le k \le J_S - 1$$

where

$$J_D = K_S$$

$$K_D = J_S$$

Profile:

Foundation	flip_spin_transpose
Foundation	flip_spin_transpose_roi

Error codes:

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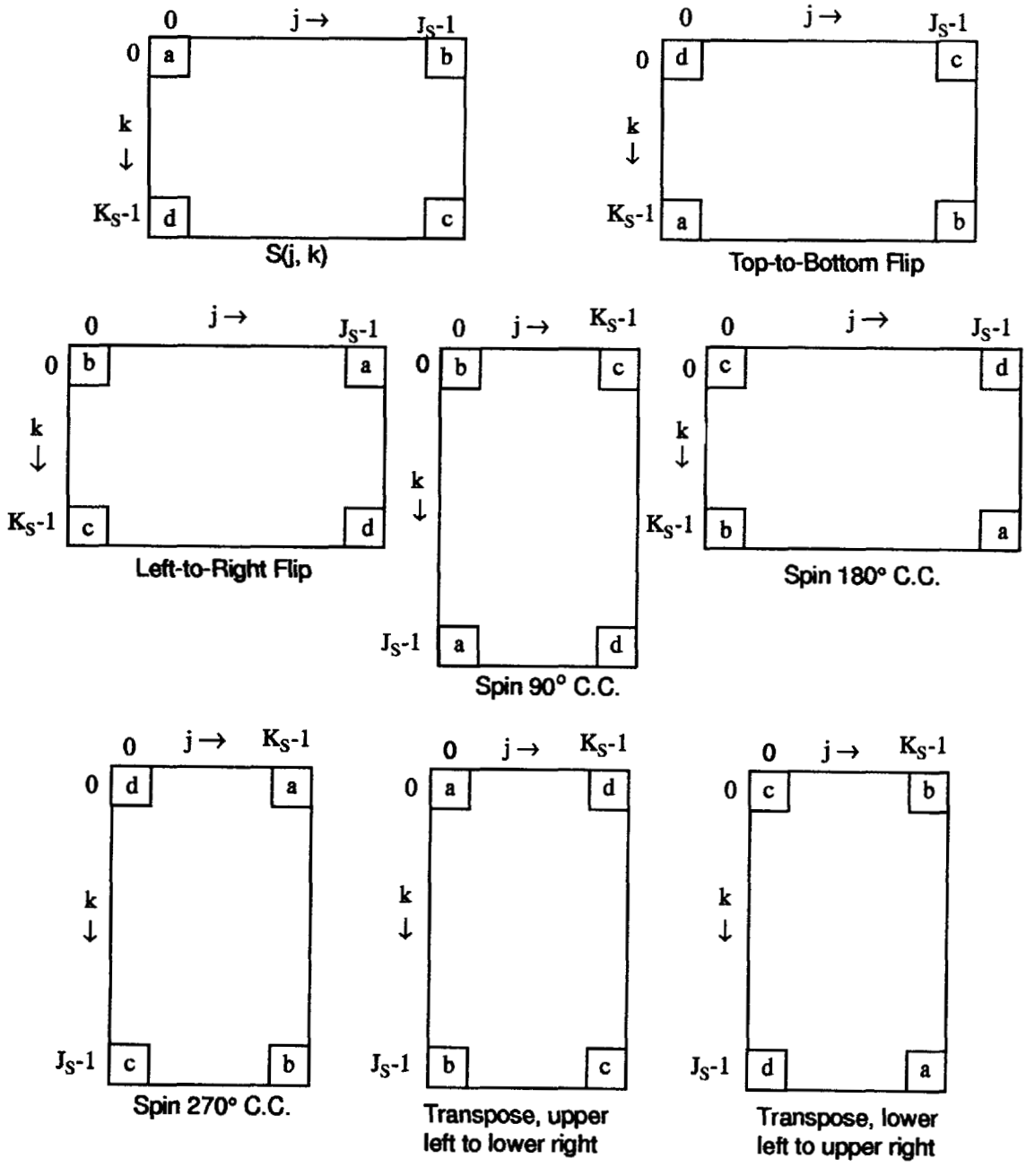

Examples of flip, spin, and transpose

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POINT OPERATOR

GAMMA CORRECTION

Description:

Applies gamma correction or inverse gamma correction to an image.

Name:

gamma_correction

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
c1	first constant	RP	in
c2	second constant	RP	in
c3	third constant	RP	in
c4	fourth constant	RP	in
bp	break point	RP	in
option	gamma correction option linear to gamma gamma to linear	EP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	RD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remark:

The following are commonly used constants and breakpoints for tristimulus values and the lightness value L*. For the general case, the gamma value is 2.2.

	general	SMPTE	CCIR 709	CIE L*
c1	1.0	1.1115	1.099	116.0
c2	0.45	0.45	0.45	0.3333
c3	0.0	–0.1115	–0.099	–16.0
c4	0.0	4.0	4.5	903.3
bp	0.0	0.0228	0.018	0.008856

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image, $S(x, y, z, t, b) \geq 0$
D(x, y, z, t, b)	XxYxZxTxB operator output image
c1	first constant
c2	second constant
c3	third constant
c4	fourth constant
bp	break point, $bp \geq 0$

Definition:

Linear space to gamma space option:

For all x, y, z, t, b

$$D(x, y, z, t, b) = (c1)[S(x, y, z, t, b)]^{C2} + c3 \qquad \text{for } S(x, y, z, t, b) \geq bp$$

$$D(x, y, z, t, b) = (c4)[S(x, y, z, t, b)] \qquad \text{for } 0 \leq S(x, y, z, t, b) < bp$$

Gamma space to linear space option:

$$D(x, y, z, t, b) = \left[\frac{S(x, y, z, t, b) - c3}{c1}\right]^{\frac{1}{c2}} \qquad \text{for } S(x, y, z, t, b) \geq (c4)(bp)$$

$$D(x, y, z, t, b) = \frac{S(x, y, z, t, b)}{c4} \qquad \text{for } 0 \leq S(x, y, z, t, b) < (c4)(bp)$$

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Profile:

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EXPORT UTILITY **GET COLOUR PIXEL**

Description:

Returns the value of a colour pixel to an application.

Name:

get_colour_pixel

Parameters:

SRC	source image	ID	in
pv0	band 0 pixel value	BP,NP SP,RP	out
pv1	band 1 pixel value	BP,NP,SP,RP	out
pv2	band 2 pixel value	BP,NP,SP,RP	out
pv3	band 3 pixel value	BP,NP,SP,RP,NULL	out
xv	horizontal index value	NP	in
yv	vertical index value	NP	in
zv	depth index value	NP	in
tv	temporal index value	NP	in

Object:

SRC structure:	COLR, VC, TC, VTC
SRC data type:	BD, ND, SD, RD

Element functionality:

Index assignment:	no
Match point:	no
ROI control:	no
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	vreg
Asynchronous:	no

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get_colour_pixel

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
pv0	band 0 pixel value
pv1	band 1 pixel value
pv2	band 2 pixel value
pv3	band 3 pixel value
xv	horizontal index value, xv ≥ 0
yv	vertical index value, yv ≥ 0
zv	depth index value, zv ≥ 0
tv	temporal index value, tv ≥ 0

Definition:

Additive colour image:

pv0 = SRC(xv, yv, zv, tv, 0)

pv1 = SRC(xv, yv, zv, tv, 1)

pv2 = SRC(xv, yv, zv, tv, 2)

Subtractive colour image:

pv0 = SRC(xv, yv, zv, tv, 0)

pv1 = SRC(xv, yv, zv, tv, 1)

pv2 = SRC(xv, yv, zv, tv, 2)

pv3 = SRC(xv, yv, zv, tv, 3)

Profile:

Foundation

Error codes:

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EXPORT UTILITY **GET PIXEL**

Description:

Returns the value of a single pixel to an application.

Name:

get_pixel get_pixel_roi

Parameters:

SRC	source image	ID	in
pv	pixel value	BP,NP,SP,RP,CP	out
xv	horizontal index value	NP	in
yv	vertical index value	NP	in
zv	depth index value	NP	in
tv	temporal index value	NP	in
bv	band index value	NP	in

Object:

SRC structure:	any image	any ROI
SRC data type:	BD, ND, SD, RD, CD	BD

Element functionality:

Index assignment:	no	no
Match point:	no	no
ROI control:	no	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	yes	no
Chainable element:	vreg	vreg
Asynchronous:	no	no

Remark:

The data type of the returned pixel value "pv" shall be of the same data type class as the pixel value extracted from the source image.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
pv	pixel value
xv	horizontal index value, $xv \geq 0$
yv	vertical index value, $yv \geq 0$
zv	depth index value, $zv \geq 0$
tv	temporal index value, $tv \geq 0$
bv	band index value, $bv \geq 0$

Definition:

$$pv = SRC(xv, yv, zv, tv, bv)$$

Profile:

Foundation	get_pixel
Foundation	get_pixel_roi

Error codes:

001
011
013
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101

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EXPORT UTILITY **GET PIXEL ARRAY**

Description:

Returns a rectangular array of pixels to an application.

Name:

get_pixel_array get_pixel_array_roi

Parameters:

SRC	source image	ID	in
DOB	pixel array object	IP	out
jo	first index offset	NP	in
ko	second index offset	NP	in
lv	third index value	NP	in
mv	fourth index value	NP	in
nv	fifth index value	NP	in
C	number of array columns	NP	in
R	number of array rows	NP	in

Objects:

SRC structure:	any image	any ROI
DOB structure:	EXT	EXT
SRC data type:	BD, ND, SD, RD, CD	BD
DOB data type:	BP, NP, SP, RP, CP	BP

Element functionality:

Index assignment:	yes	yes
Match point:	no	no
ROI control:	no	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	vreg	vreg
Asynchronous:	no	no

Remark:

The data type of each array data value shall be of the same class as the source image.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
S(j, k, l, m, n)	JxKxLxMxN operator input image
jo	first index offset
ko	second index offset
lv	third index value, $lv \geq 0$
mv	fourth index value, $mv \geq 0$
nv	fifth index value, $nv \geq 0$
A(c, r)	CxR array
C	number of array columns, positive integer, $R \geq 1$
R	number of array rows, positive integer, $C \geq 1$

Definition:

For

$$0 \leq c \leq C-1$$

$$0 \leq r \leq R-1$$

$$A(c, r) = S(c + jo, r + ko, lv, mv, nv)$$

Profile:

Foundation	get_pixel_array
Foundation	get_pixel_array_roi

Error codes:

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EXPORT UTILITY **GET PIXEL RECORD**

Description:

Returns an across-band pixel record to an application.

Name:

get_pixel_record get_pixel_record_roi

Parameters:

SRC	source image	ID	in
DOB	pixel record object	IP	out
data_type	data type B-tuple	ID	in
xv	horizontal index value	NP	in
yv	vertical index value	NP	in
zv	depth index value	NP	in
tv	temporal index value	NP	in

Objects:

SRC structure:	any image	any ROI
DOB structure:	EXT	EXT
SRC data type:	BD, ND, SD, RD, CD	BD
DOB data type:	BP, NP, SP, RP, CP	BP

Element functionality:

Index assignment:	no	no
Match point:	no	no
ROI control:	no	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneus bands:	yes	no
Chainable element:	vreg	vreg
Asynchronous:	no	no

Remarks:

1. The data type of each record data value shall be of the same corresponding class as the source image.
2. The *data_type* B-tuple contains parameters of the SD data type.
3. The *data_type* B-tuple is not required for the *get_pixel_record_roi* utility.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
r(b)	across-band record
B	band size
b	band index, $0 \leq b \leq B - 1$
xv	horizontal index value, $xv \geq 0$
yv	vertical index value, $yv \geq 0$
zv	depth index value, $zv \geq 0$
tv	temporal index value, $tv \geq 0$

Definition:

The *get_pixel_record* utility returns a sequence of pixel values to an application. The data types of the sequence, which can differ from band-to-band, are specified by the data type B-tuple.

For xv, yv, zv, tv and for all b

$$r(b) = SRC(xv, yv, zv, tv, b)$$

Profile:

Technical	get_pixel_record
Technical	get_pixel_record_roi

Error codes:

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ENHANCEMENT OPERATOR **HISTOGRAM MODIFICATION**

Description:

Performs image contrast stretching of each pixel in a pixel plane by a nonlinear point transformation using a lookup table transformation. The transformation is chosen such that the histogram of the resultant pixel plane has a desired mathematical form.

Name:

histogram_modification

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
gmax	output histogram upper value	NP,SP,RP,NULL	in
gmin	output histogram lower value	NP,SP,RP,NULL	in
a	exponential spread factor	RP, NULL	in
off	number of lookup table source offset entries	NP	in
histogram_option	histogram option cube root exponential logarithmic Rayleigh uniform	SP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	RD

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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histogram_modification

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
E	number of lookup table entries, $E \geq 2$
off	number of lookup table offset entries, $off \geq 0$
H(e)	source image histogram
g(f)	transformation function, $0 \leq e \leq E - 1$
a	exponential spread factor, $a > 0$
gmax	output histogram maximum value, gmax > gmin
gmin	output histogram minimum value, gmin > 0

Definition:

For all l, m, n, perform the following computational steps.

Step 1:

Compute the histogram, H(e), for $0 \leq e \leq E - 1$ of each j-k pixel plane, as described by the *histogram_1d* operator.

Step 2:

Compute the normalized cumulative histogram.

For $0 \leq f \leq E - 1$

$$P(f) = \frac{C(f)}{C(E-1)}$$

where

$$C(f) = \sum_{e=0}^{f} H(e)$$

Step 3:

Compute the transformation function, g(f), which is a function of the normalized cumulative histogram for the following histogram options.

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For $0 \leq f \leq E-1$

Cube root:

$$g(f) = [(gmax)^{1/3} - (gmin)^{1/3}]\,[P(f) + (gmin)^{1/3}]^3$$

Exponential:

$$g(f) = gmin - \frac{LOG\{1-P(f)\}}{a}$$

Logarithmic:

$$g(f) = (gmin)\,EXP\left\{[P(f)]\,LOG\left\{\frac{gmax}{gmin}\right\}\right\}$$

Rayleigh:

$$g(f) = gmin + \left[2(a)^2 LOG\left\{\frac{1}{1-P(f)}\right\}\right]^{1/2}$$

Uniform:

$$g(f) = (gmax - gmin)\,[P(f)] + gmin$$

Step 4:

For all j, k, store the transformation function, g(f), in a E entry lookup table, called table, and perform the lookup table transformation.

D(j, k, l, m, n) = LOOK{S(j, k, l, m, n), off, 0, table}

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Profile:

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POINT OPERATOR

HISTOGRAM SCALING

Description:

Performs window-level amplitude scaling of an image in which a specified fraction of high amplitude and low amplitude pixels are clipped to specified values and intermediate value pixels are linearly rescaled in amplitude.

Name:

histogram_scaling

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
lo	lower output value	NP, SP, RP	in
uo	upper output value	NP, SP, RP	in
lf	lower input clip fraction	RP	in
uf	upper input clip fraction	RP	in
P	number of histogram bins	NP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j,k, l, m, n)	JxKxLxMxN operator output image
lf	lower input clip fraction, $0 \leq lf \leq 1$
uf	upper input clip fraction, $0 \leq uf \leq 1$
li	lower input clip value
ui	upper input clip value, ui > li
lo	lower output value
uo	upper output value
H(p)	1D histogram array $0 \leq p \leq P-1$
P	number of histogram bins

Definition:

Step 1:

For all l, m, n, compute the 1D histogram, H(p), of each j-k pixel plane as defined in the *histogram_1d* operator.

Step 2:

For all l, m, n, determine the lower input clip value and the upper input clip value by summing the lower end and upper end of the histogram array as follows:

$$li = \frac{(pl)\,[MAX\{S(j,k,l,m,n)\} - MIN\{S(j,k,l,m,n)\}]}{P} + MIN\{S(j,k,l,m,n)\}$$

$$ui = \frac{(ph)\,[MAX\{S(j,k,l,m,n)\} - MIN\{S(j,k,l,m,n)\}]}{P} + MIN\{S(j,k,l,m,n)\}$$

where pl and ph are histogram indices that satisfy the inequalities

$$\sum_{p=0}^{pl} H(p) < (lf) \sum_{p=0}^{P-1} H(p) \leq \sum_{p=0}^{pl+1} H(p)$$

$$\sum_{p=ph-1}^{P-1} H(p) < (uf) \sum_{p=0}^{P-1} H(p) \leq \sum_{p=ph}^{P-1} H(p)$$

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Step 3:

For all l, m, n, perform window-level scaling over the input clip values and the output values as follows.

$$D(j, k, l, m, n) = lo \qquad S(j, k, l, m, n) < li$$

$$D(j, k, l, m, n) = \left[\frac{uo - lo}{ui - li}\right] S(j, k, l, m, n) + lo - (li)\left[\frac{uo - lo}{ui - li}\right] \qquad li \leq S(j, k, l, m, n) \leq ui$$

$$D(j, k, l, m, n) = uo \qquad S(j, k, l, m, n) > ui$$

Profile:

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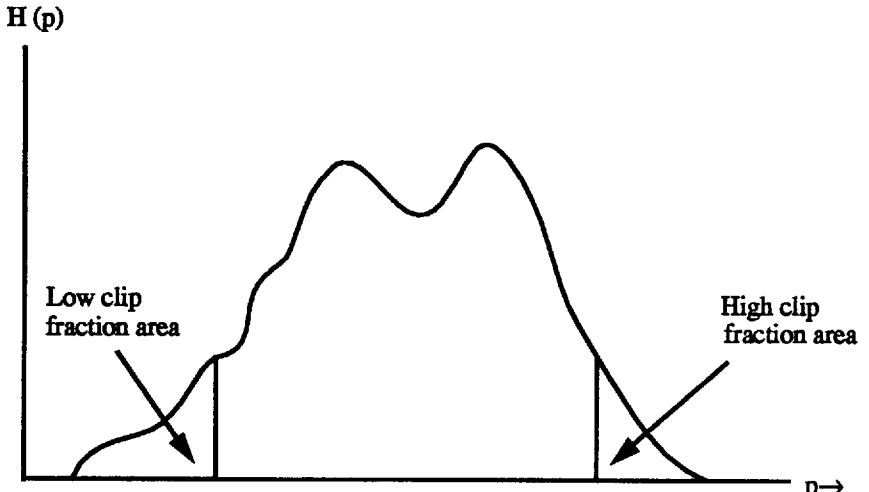
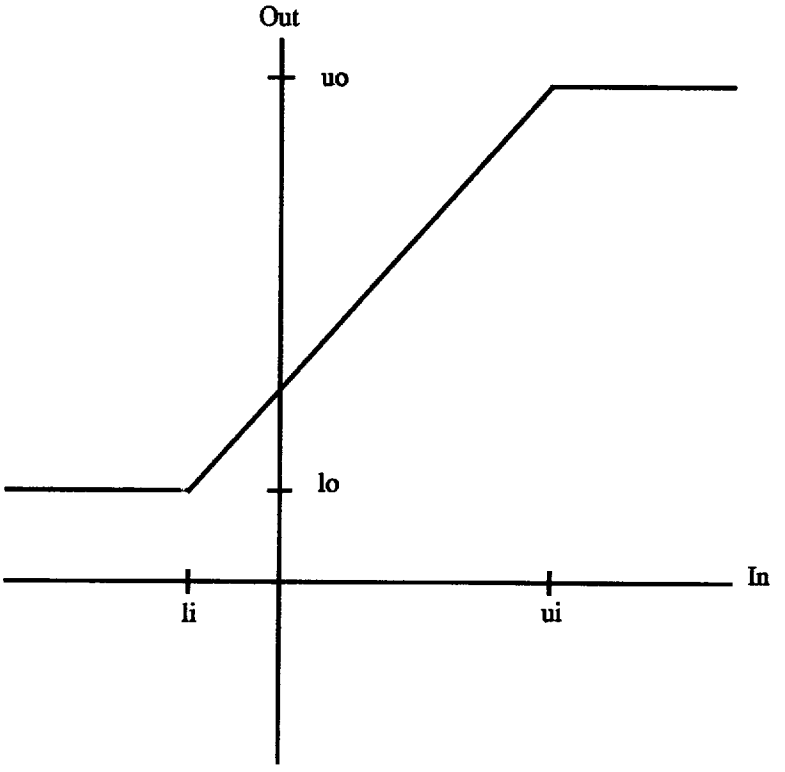


Image histogram



Scaling transformation

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HISTOGRAM SHAPE OPERATOR **HISTOGRAM SHAPE, 1D**

Description:

Computes shape descriptors of a one-dimensional histogram.

Name:

histogram_shape_1d

Parameters:

SOB	histogram object	ID	in
DOB	histogram shape array object	IP	out

Objects:

SOB structure:	HIST
DOB structure:	EXT
SOB data type:	ND
DOB data type:	RP
SOB dimension:	1D
DOB dimension:	1D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Nomenclature:

H(e)	histogram array, $0 \leq e \leq E-1$
N(e)	normalized histogram array, $0 \leq e \leq E-1$
E	number of histogram amplitude bins (table size), $E \geq 2$
sm	histogram mean
sd	histogram standard deviation
ss	histogram skewness
sk	histogram kurtosis
sn	histogram energy
se	histogram entropy
a(f)	external array, $1 \leq f \leq 6$

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Definition:

The external array is defined as follows:

a(1) = sm
a(2) = sd
a(3) = ss
a(4) = sk
a(5) = sn
a(6) = se

The entries are computed as follows.

For all e compute the normalized histogram

$$N(e) = \frac{H(e)}{\sum_{g=0}^{E-1} H(g)}$$

Mean:

$$sm = \sum_{e=0}^{E-1} (e)\,[N(e)]$$

Standard deviation:

$$sd = \left[\sum_{e=0}^{E-1} (e-sm)^2\,[N(e)]\right]^{1/2}$$

Skewness:

$$ss = \frac{1}{(sd)^3} \sum_{e=0}^{E-1} (e-sm)^3\,[N(e)]$$

Kurtosis:

$$sk = \frac{1}{(sd)^4} \sum_{e=0}^{E-1} (e-sm)^4\,[N(e)] - 3$$

Energy:

$$sn = \sum_{e=0}^{E-1} [N(e)]^2$$

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Entropy:

$$se = -\sum_{e=0}^{E-1} [N(e)] \frac{[LOG\{N(e)\}]}{LOG\{2\}}$$

Profile:

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Error codes:

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HISTOGRAM SHAPE OPERATOR **HISTOGRAM SHAPE, 2D**

Description:

Computes shape descriptors of a two-dimensional histogram (co-occurence matrix).

Name:

histogram_shape_2d

Parameters:

SOB	histogram array object	ID	in
DOB	histogram shape array object	IP	out

Object:

SOB structure:	STATIC_ARRAY
DOB structure:	EXT
SOB data type:	ND
DOB data type:	RP
SOB dimension:	2D
DOB dimension:	1D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

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Nomenclature:

H(e, f)	histogram array, $0 \leq e \leq E-1, 0 \leq f \leq F-1$
N(e, f)	normalized histogram array, $0 \leq e \leq E-1, 0 \leq f \leq F-1$
E	histogram table key size, $E \geq 2$
F	histogram table element size, $F \geq 2$
se	first index marginal mean
sf	second index marginal mean
sa	histogram autocorrelation
sc	histogram covariance
si	histogram inertia
sv	histogram absolute value
sr	histogram inverse difference
sg	histogram energy
sp	histogram entropy
a(g)	external array, $1 \leq g \leq 7$

Definition:

The external histogram shape array is defined as follows:

a(1) = se
a(2) = sf
a(3) = sa
a(4) = sc
a(5) = si
a(6) = sv
a(7) = sr
a(8) = sg
a(9) = sp

For all e and f, compute the normalized histogram

$$N(e,f) = \frac{H(e,f)}{\sum_{g=0}^{E-1} \sum_{h=0}^{F-1} H(g,h)}$$

First index marginal mean:

$$se = \sum_{e=0}^{E-1} \sum_{f=0}^{F-1} (e)\,[N(e,f)]$$

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Second index marginal mean:

$$sf = \sum_{e=0}^{E-1} \sum_{f=0}^{F-1} (f)\ [N(e,f)]$$

Autocorrelation:

$$sa = \sum_{e=0}^{E-1} \sum_{f=0}^{F-1} (e)\ (f)\ [N(e,f)]$$

Covariance:

$$sc = \sum_{e=0}^{E-1} \sum_{f=0}^{F-1} (e-se)\ (f-sf)\ [N(e,f)]$$

Inertia:

$$si = \sum_{e=0}^{E-1} \sum_{f=0}^{F-1} (e-f)^2 N(e,f)$$

Absolute value:

$$sv = \sum_{e=0}^{E-1} \sum_{f=0}^{F-1} |e-f|\ [N(e,f)]$$

Inverse difference:

$$sn = \sum_{e=0}^{E-1} \sum_{f=0}^{F-1} \frac{N(e,f)}{1-(e-f)^2}$$

Energy:

$$sg = \sum_{e=0}^{E-1} \sum_{f=0}^{F-1} [N(e,f)]^2$$

Entropy:

$$sp = -\sum_{e=0}^{E-1} \sum_{f=0}^{F-1} [N(e,f)]\ \frac{[LOG\{N(e,f)\}]}{LOG\{2\}}$$

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Profile:

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ANALYSIS OPERATOR

HISTOGRAM, 1D

Description:

Generates a one-dimensional histogram of an image.

Name:

histogram_1d

Parameters:

SRC	source image	ID	in
DOB	histogram object	ID	out
E	number of histogram bins	NP	in
A	lower amplitude bound	RP,NULL	in
B	upper amplitude bound	RP,NULL	in
option	histogram computation option	SP	in
	specified limits		
	image extrema limits		

Objects:

SRC structure:	any image
DOB structure:	HIST
SRC data type:	ND, SD, RD
DOB data type:	ND
DOB dimension:	1D

Element functionality:

Index assignment:	yes
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

A histogram of a particular pixel plane of a generic image can be generated by means of a ROI which is in the logical TRUE state only for that particular pixel plane.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
S(j, k, l, m, n)	JxKxLxMxN operator input image
H(e)	histogram array, $0 \leq e \leq E-1$
E	number of histogram amplitude bins (array size), $E \geq 1$
A	lower amplitude bound
B	upper amplitude bound, $B > A$

Definition:

The histogram array contains the counts of the number of pixels that have certain quantized amplitude values. The histogram algorithm is as follows:

Specified amplitude limits:

Step 1: Initialize histogram to zero.

For $0 \leq e \leq E-1$

$H(e) = 0$

Step 2: Compute histogram.

For all j, k, l, m, n, and for $0 \leq e \leq E-1$, if

$$q(e) \leq S(j, k, l, m, n) < q(e+1)$$

then

$$H(e) = H(e) + 1$$

where

$$q(e) = \frac{e(B-A)}{E} + A$$

Image extrema amplitude limits:

Step 1: Initialize histogram to zero.

For $0 \leq e \leq E-1$

$H(e) = 0$

Step 2: Compute histogram.

For all j, k, l, m, n, and for $0 \leq e \leq E-1$, if

$$q(e) \leq S(j, k, l, m, n) < q(e+1)$$

then

$$H(e) = H(e) + 1$$

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where

$$q(e) = \frac{e\,[MAX\{S(j,k,l,m,n)\} - MIN\{S(j,k,l,m,n)\}]}{E} + MIN\{S(j,k,l,m,n)\}$$

Profile:

Foundation

Error codes:

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ANALYSIS OPERATOR **HISTOGRAM, 2D**

Description:

Generates a two-dimensional histogram (co-occurrence matrix) of a monochrome image.

Name:

histogram_2d

Parameters:

SRC	source image	ID	in
DOB	histogram array object	ID	out
E	number of histogram bins in each dimension	NP	in
A	lower amplitude bound	RP	in
B	upper amplitude bound	RP	in
xo	horizontal offset	NP	in
yo	vertical offset	NP	in

Objects:

SRC structure:	MON
DOB structure:	STATIC_ARRAY
SRC data type:	ND, SD, RD
DOB data type:	ND
DOB dimension:	2D

Element functionality:

Index assignment:	no
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
S(x, y, z, t, b)	XxYxZxTxB operator input image
H(e, f)	histogram array, $0 \leq e \leq E-1$, $0 \leq f \leq E-1$
E	number of histogram bins in each dimension, $E \geq 1$
A	lower amplitude bound
B	upper amplitude bound, $B > A$
xo	horizontal offset, $xo \geq 0$
yo	vertical offset, $yo \geq 0$

Definition:

The histogram array contains the counts of the number of times a pixel at coordinate (x, y) and a pixel at coordinate (x + xo, y + yo) have the same quantized amplitude value.

Step 1: Initialize histogram table to zero.

For

$$0 \leq e \leq E-1$$

$$0 \leq f \leq E-1$$

set

$$H(e, f) = 0$$

Step 2: Compute the histogram

For

$$0 \leq x \leq X-xo$$

$$0 \leq y \leq Y-yo$$

$$0 \leq e \leq E-1$$

$$0 \leq f \leq E-1$$

if

$$q(e) \leq S(x, y, 0, 0, 0) < q(e+1)$$

and

$$q(f) \leq S(x + xo, y + yo, 0, 0, 0) < q(f+1)$$

then

$$H(e, f) = H(e, f) + 1$$

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where

$$q(e) = \frac{e[B - A]}{E} + A$$

$$q(f) = \frac{f[B - A]}{E} + A$$

Profile:

Scientific

Error codes:

001
011
012
013
014
021
024
041
044
061
101
102
171

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MORPHOLOGICAL OPERATOR

HIT OR MISS

Description:

Performs morphological operations on a Boolean image using a hit or miss transformation over a 3 x 3 pixel window.

Name:

hit_or_miss	hit_or_miss_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
iterations	number of iterations	SP	in
cycles	number of cycles	NP	out
option	transformation option	SP	in
	branch detect		
	bridge		
	convex hull fill		
	diagonal fill		
	dilate, eight-neighbour		
	end detect		
	end detect, east		
	end detect, north		
	end detect, northeast		
	end detect, northwest		
	end detect, south		
	end detect, southeast		
	end detect, southwest		
	end detect, west		
	erode, eight-neighbour		
	fatten		
	H-break		
	hole detect		
	interior pixel fill		
	interior pixel remove		
	isolated pixel detect		
	isolated pixel remove		
	majority black		
	spur remove		

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SRC data type:	BD	BD
DST data type:	BD	BD

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Element functionality:

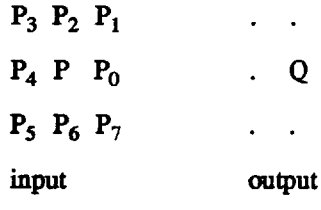
Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Remark:

If the "iterations" number is set to −1, the operation is performed until the destination image is unchanged after successive iterations. The parameter "cycles" is the number of iterations performed. The "iterations" parameter must be greater than −2.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
P	boolean state of centre pixel of 3x3 neighbourhood in j-k plane of S
P_0	boolean state of east neighbour of P
P_1	boolean state of northeast neighbour of P
P_2	boolean state of north neighbour of P
P_3	boolean state of northwest neighbour of P
P_4	boolean state of west neighbour of P
P_5	boolean state of southwest neighbour of P
P_6	boolean state of south neighbour of P
P_7	boolean state of southeast neighbour of P
Q	boolean state of output image pixel corresponding spatially to P



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Definition:

General operation:

For all j, k, the Boolean states (TRUE or FALSE) of the nine pixels in a 3x3 pixel neighbourhood of the source image, centred about coordinate (j, k), are logically combined to produce the state of an output pixel, Q, at coordinate (j, k). The output image is in the Boolean FALSE state in its first and last rows and columns. The general operation is repeated "iterations" number of times, or until the result becomes unchanged upon repeated iterations.

Branch detect: Detects Y and T branches.

$$Q = [P \cap (P_0 \cup P_1) \cap \overline{P}_2 \cap (P_3 \cup P_4) \cap \overline{P}_5 \cap P_6 \cap \overline{P}_7]$$
$$\cup [P \cap P_0 \cap \overline{P}_1 \cap (P_2 \cup P_3) \cap \overline{P}_4 \cap (P_5 \cup P_6) \cap \overline{P}_7]$$
$$\cup [P \cap (P_0 \cup P_7) \cap \overline{P}_1 \cap P_2 \cap \overline{P}_3 \cap (P_4 \cup P_5) \cap \overline{P}_6]$$
$$\cup [P \cap \overline{P}_0 \cap (P_1 \cup P_2) \cap \overline{P}_3 \cap P_4 \cap \overline{P}_5 \cap (P_6 \cup P_7)]$$
$$\cup [P \cap \overline{P}_0 \cap P_1 \cap \overline{P}_2 \cap P_3 \cap \overline{P}_4 \cap P_5 \cap \overline{P}_6 \cap \overline{P}_7]$$
$$\cup [P \cap \overline{P}_0 \cap P_1 \cap \overline{P}_2 \cap P_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap P_7]$$
$$\cup [P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap P_3 \cap \overline{P}_4 \cap P_5 \cap \overline{P}_6 \cap P_7]$$
$$\cup [P \cap \overline{P}_0 \cap P_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap P_5 \cap \overline{P}_6 \cap P_7]$$

Bridge: Creates a TRUE pixel if creation results in connectivity of previously unconnected neighbouring TRUE pixels.

$$Q = T \cup (T_1 \cup T_2 \cup T_3 \cup T_4 \cup T_5 \cup T_6)$$

where

$$T_1 = \overline{P}_2 \cap \overline{P}_6 \cap (P_3 \cup P_4 \cup P_5) \cap (P_0 \cup P_1 \cup P_7) \cap T_Q$$
$$T_2 = \overline{P}_0 \cap \overline{P}_4 \cap (P_1 \cup P_2 \cup P_3) \cap (P_5 \cup P_6 \cup P_7) \cap T_Q$$
$$T_3 = \overline{P}_0 \cap \overline{P}_6 \cap P_7 \cap (P_2 \cup P_3 \cup P_4)$$
$$T_4 = \overline{P}_0 \cap \overline{P}_2 \cap P_1 \cap (P_4 \cup P_5 \cup P_6)$$
$$T_5 = \overline{P}_2 \cap \overline{P}_4 \cap P_3 \cap (P_0 \cup P_6 \cup P_7)$$
$$T_6 = \overline{P}_4 \cap \overline{P}_6 \cap P_5 \cap (P_0 \cup P_1 \cup P_2)$$
$$T_Q = L_1 \cup L_2 \cup L_3 \cup L_4$$
$$L_1 = \overline{P} \cap \overline{P}_0 \cap P_1 \cap \overline{P}_2 \cap P_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7$$
$$L_2 = \overline{P} \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap P_3 \cap \overline{P}_4 \cap P_5 \cap \overline{P}_6 \cap \overline{P}_7$$
$$L_3 = \overline{P} \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap P_5 \cap \overline{P}_6 \cap P_7$$
$$L_4 = \overline{P} \cap \overline{P}_0 \cap P_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap P_7$$

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Convex hull fill: Fills convex hull of an object.

$$Q = P \cup [\overline{P} \cap \overline{P}_0 \cap P_2 \cap P_4 \cap P_6]$$
$$\cup [\overline{P} \cap P_0 \cap \overline{P}_2 \cap P_4 \cap P_6]$$
$$\cup [\overline{P} \cap P_0 \cap P_2 \cap \overline{P}_4 \cap P_6]$$
$$\cup [\overline{P} \cap P_0 \cap P_2 \cap P_4 \cap \overline{P}_6]$$
$$\cup [\overline{P} \cap P_0 \cap (P_1 \cup P_5) \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap P_6]$$
$$\cup [\overline{P} \cap \overline{P}_0 \cap (P_1 \cup P_5) \cap P_2 \cap P_4 \cap \overline{P}_6 \cap \overline{P}_7]$$
$$\cup [\overline{P} \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap (P_3 \cup P_7) \cap P_4 \cap P_6]$$
$$\cup [\overline{P} \cap P_0 \cap P_2 \cap (P_3 \cup P_7) \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6]$$

Diagonal fill: Creates a TRUE pixel if creation eliminates eight connectivity of the background.

$$Q = P \cup (T_1 \cup T_2 \cup T_3 \cup T_4)$$

where

$$T_1 = \overline{P} \cap P_0 \cap \overline{P}_1 \cap P_2$$
$$T_2 = \overline{P} \cap P_2 \cap \overline{P}_3 \cap P_4$$
$$T_3 = \overline{P} \cap P_4 \cap \overline{P}5 \cap P5$$
$$T_4 = \overline{P} \cap P_5 \cap \overline{P}_7 \cap P_0$$

Dilate, eight-neighbour: Creates a TRUE pixel if at least one eight-connected neighbour is TRUE.

$$Q = P \cup P_0 \cup P_1 \cup P_2 \cup P_3 \cup P_4 \cup P_5 \cup P_5 \cup P_7$$

End detect: Detects ends of a line.

$$Q = [P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_1 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap P_6 \cap \overline{P}_7]$$
$$\cup [P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap P_5 \cap \overline{P}_6 \cap \overline{P}_7]$$
$$\cup [P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap P_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7]$$
$$\cup [P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap P_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7]$$
$$\cup [P \cap \overline{P}_0 \cap \overline{P}_1 \cap P_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7]$$
$$\cup [P \cap \overline{P}_0 \cap P_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7]$$
$$\cup [P \cap P_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7]$$
$$\cup [P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap P_7]$$

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End detect, east: Detects east end of a line.

$$Q = P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap P_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7$$

End detect, north: Detects north end of a line.

$$Q = P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap P_6 \cap \overline{P}_7$$

End detect, northeast: Detects northeast end of a line.

$$Q = P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap P_5 \cap \overline{P}_6 \cap \overline{P}_7$$

End detect, northwest: Detects northwest end of a line.

$$Q = P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap P_7$$

End detect, south: Detects south end of a line.

$$Q = P \cap \overline{P}_0 \cap \overline{P}_1 \cap P_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7$$

End detect, southeast: Detects southeast end of a line.

$$Q = P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap P_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7$$

End detect, southwest: Detects southwest end of a line.

$$Q = P \cap \overline{P}_0 \cap P_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7$$

End detect, west: Detects west end of a line.

$$Q = P \cap P_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7$$

Erode, eight-neighbour: Complements a TRUE pixel if at least one eight-connected neighbour is FALSE.

$$Q = P \cap P_0 \cap P_1 \cap P_2 \cap P_3 \cap P_4 \cap P_5 \cap P_6 \cap P_7$$

Fatten: Creates a TRUE pixel if at least one eight-connected neighbour pixel is TRUE, provided that creation does not result in a bridge between previously neighbouring pixels in a 3 x 3 neighbourhood.

$$Q = P \cup [\overline{P} \ (P_0 \cup P_1 \cup P_2 \cup P_3 \cup P_4 \cup P_5 \cup P_6 \cup P_7) \cap T_B]$$

where

$$T_B = \overline{L}_1 \cap \overline{L}_2 \cap \overline{L}_3 \cap \overline{L}_4 \cap \overline{L}_5 \cap \overline{L}_6$$

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$L_1 = \overline{P}_2 \cap \overline{P}_6 \cap [(P_3 \cup P_4 \cup P_5) \cap (P_1 \cup P_0 \cup P_7)]$

$L_2 = \overline{P}_0 \cap \overline{P}_4 \cap [(P_1 \cup P_2 \cup P_3) \cap (P_5 \cup P_6 \cup P_7)]$

$L_3 = \overline{P}_0 \cap \overline{P}_6 \cap P_7 \cap (P_2 \cup P_3 \cup P_4)$

$L_4 = \overline{P}_0 \cap \overline{P}_2 \cap P_1 \cap (P_4 \cup P_5 \cup P_6)$

$L_5 = \overline{P}_2 \cap \overline{P}_4 \cap P_3 \cap (P_6 \cup P_7 \cup P_0)$

$L_6 = \overline{P}_4 \cap \overline{P}_6 \cap P_5 \cap (P_0 \cup P_1 \cup P_2)$

H-break: Complements a TRUE pixel which is H-connected.

$Q = P \cap \overline{L}_1 \cap \overline{L}_2$

where

$L_1 = \overline{P}_0 \cap P_1 \cap P_2 \cap P_3 \cap \overline{P}_4 \cap P_5 \cap P_6 \cap P_7$

$L_2 = P_0 \cap P_1 \cap \overline{P}_2 \cap P_3 \cap P_4 \cap P_5 \cap \overline{P}_6 \cap P_7$

Hole detect: Detects a FALSE pixel whose eight-connected neighbours are TRUE.

$Q = \overline{P} \cap P_0 \cap P_1 \cap P_2 \cap P_3 \cap P_4 \cap P_5 \cap P_6 \cap P_7$

Interior pixel fill: Creates a TRUE pixel if all four-connected neighbours are TRUE.

$Q = P \cup (\overline{P} \cap P_0 \cap P_2 \cap P_4 \cap P_6)$

Interior pixel remove: Complements a TRUE pixel if all four-connected neighbours are TRUE.

$Q = P \cap (\overline{P}_0 \cup \overline{P}_2 \cup \overline{P}_4 \cup \overline{P}_6)$

Isolated pixel detect: Detects a TRUE pixel with eight FALSE neighbours.

$Q = P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7$

Isloated pixel remove: Complements a TRUE pixel with eight FALSE neighbours.

$Q = P \cap (P_0 \cup P_1 \cup P_2 \cup P_3 \cup P_4 \cup P_5 \cup P_6 \cup P_7)$

Majority black: Creates a TRUE pixel if at least five pixels in neighbourhood, including the centre pixel, are TRUE; otherwise create a FALSE pixel.

if (P = TRUE), v = 1; else, v = 0

if (P_0 = TRUE), v_0 = 1; else, v_0 = 0

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if (P_1 = TRUE), $v_1 = 1$; else, $v_1 = 0$

if (P_2 = TRUE), $v_2 = 1$; else, $v_2 = 0$

if (P_3 = TRUE), $v_3 = 1$; else, $v_3 = 0$

if (P_4 = TRUE), $v_4 = 1$; else, $v_4 = 0$

if (P_5 = TRUE), $v_5 = 1$; else, $v_5 = 0$

if (P_6 = TRUE), $v_6 = 1$; else, $v_6 = 0$

if (P_7 = TRUE), $v_7 = 1$; else, $v_7 = 0$

$s = v + v_0 + v_1 + v_2 + v_3 + v_4 + v_5 + v_6 + v_7$

if ($s \geq 5$), Q = TRUE; else, Q = FALSE

Spur remove: Complements a TRUE pixel with a single eight-connected neighbour.

$$Q = P \cap \overline{L}_1 \cap \overline{L}_2 \cap \overline{L}_3 \cap \overline{L}_4$$

where

$$L_1 = \overline{P}_0 \cap P_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7$$

$$L_2 = \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap P_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7$$

$$L_3 = \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap P_5 \cap \overline{P}_6 \cap \overline{P}_7$$

$$L_4 = \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap P_7$$

Profile:

Technical	hit_or_miss
Technical	hit_or_miss_roi

Error codes:

001
003
011
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041
043
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ANALYSIS OPERATOR

HOUGH TRANSFORM

Description:

Computes the Duda and Hart version of the Hough transform of a Boolean image.

Name:

hough_transform

Parameters:

SRC	source image	ID	in
DOB	Hough array object	ID	out
C	number of array columns	NP	in
R	number of array rows	NP	in

Objects:

SRC structure:	MON
DOB structure:	STATIC_ARRAY
SRC data type:	BD
DOB data type:	ND

Element functionality:

Index assignment:	no
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Nomenclature:

SRC(x, y, z, t, b)	$X_S x Y_S x 1 x 1 x 1$ source image
S(x, y, z, t, b)	$X_S x Y_S x 1 x 1 x 1$ operator input image
H(c, r)	CxR Hough transform array
C	number of array columns, $C \geq 1$
R	number of array rows, $R \geq 1$

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Definition:

The Hough transform of a two-dimensional Boolean data type source image is a transformation that maps a straight line segment of TRUE state pixels in the image into a point in a polar coordinate array as shown in the following figure.

The Hough transform procedure is as follows.

Step 1: Initialize the Hough array to zero.

For

$$0 \leq c \leq C-1$$

$$0 \leq r \leq R-1$$

set

$$H(c, r) = 0$$

Step 2: Compute the quantized rho-theta values and increment the Hough array:

For all x, y, if and only if

$$S(x, y, 0, 0, 0) = \text{TRUE}$$

then increment the Hough array

$$H(c, r) = H(c, r) + 1$$

for all c over the range $0 \leq c \leq C-1$ such that

$$\phi - \frac{\pi}{2} \leq \theta\{c\} \leq \phi + \frac{\pi}{2}$$

where

$$\phi = \text{ATAN2}\{y, x\}$$

and

$$\theta\{c\} = \pi - \frac{(2\pi)\,(C-1-c)}{C-1}$$

and for each r index

$$r = \text{NIV}\left\{R-1-\frac{[\rho_{max}-\rho\{c\}]\,(R-1)}{2(\rho_{max})}\right\}$$

where

$$\rho\{c\} = (x)\text{COS}\{\theta\{c\}\} + (y)\text{SIN}\{\theta\{c\}\}$$

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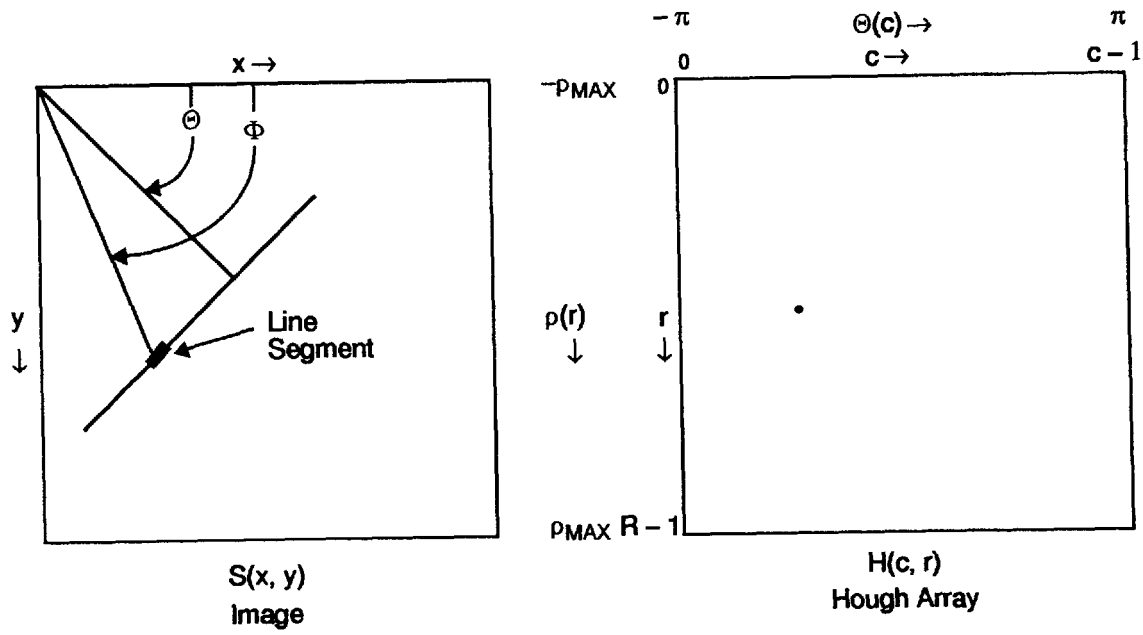
and

$$\rho_{max} = [(X_S)^2 + (Y_S)^2]^{1/2}$$



Relationship of an Image and its Hough array

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IMAGE GENERATION TOOL **IMAGE, BAR CHART**

Description:

Creates a bar chart monochrome image with eight vertical bars ranging in amplitude from zero to one or creates a colour image with eight vertical bars of different colours.

Name:

image_bar_chart

Parameters:

DST	destination image	ID	out
image_size	image size 5-tuple	ID	in
int_max	maximum integer size	NP	in
structure	image structure option	SP	in
	monochrome		
	colour		
data_type	destination data type option	SP	in
	ND		
	SD		
	RD		

Object:

DST structure:	MON, COLR
DST data type:	ND, SD, RD

Element functionality:

Index assignment:	no
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

The parameter tuple contains parameters of the ND data type.

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Nomenclature:

DST(x, y, z, t, b)	XxYx1x1xB destination image
IM	maximum integer size, IM $\geq$ 255

Definition:

The following are definitions for the bar values for a RD data type image, which is scaled over the range of 0.0 to 1.0. For a ND or SD data type image the bar value is the nearest integer value of the product of the RD data value and the maximum integer size IM. For example, if the bar value is 0.141 for a RD image and *int_max* is 255, the ND or SD bar value is NIV{(0.141)(255)} = 36.

For

$$0 \leq x \leq X - 1$$

$$0 \leq y \leq Y - 1$$

Monochrome image:

DST(x,y,0,0,0) = 0.000	0	$\leq$	x	$\leq$	NIV{X/8} – 1	and	0	$\leq$	y	$\leq$ Y – 1
DST(x,y,0,0,0) = 0.141	NIV{X/8}	$\leq$	x	$\leq$	NIV{2X/8} – 1	and	0	$\leq$	y	$\leq$ Y – 1
DST(x,y,0,0,0) = 0.282	NIV{2X/8}	$\leq$	x	$\leq$	NIV{3X/8} – 1	and	0	$\leq$	y	$\leq$ Y – 1
DST(x,y,0,0,0) = 0.424	NIV{3X/8}	$\leq$	x	$\leq$	NIV{4X/8} – 1	and	0	$\leq$	y	$\leq$ Y – 1
DST(x,y,0,0,0) = 0.565	NIV{4X/8}	$\leq$	x	$\leq$	NIV{5X/8} – 1	and	0	$\leq$	y	$\leq$ Y – 1
DST(x,y,0,0,0) = 0.706	NIV{5X/8}	$\leq$	x	$\leq$	NIV{6X/8} – 1	and	0	$\leq$	y	$\leq$ Y – 1
DST(x,y,0,0,0) = 0.847	NIV{6X/8}	$\leq$	x	$\leq$	NIV{7X/8} – 1	and	0	$\leq$	y	$\leq$ Y – 1
DST(x,y,0,0,0) = 1.000	NIV{7X/8}	$\leq$	x	$\leq$	X – 1	and	0	$\leq$	y	$\leq$ Y – 1

Colour image:

The colours of the eight bars, from left to right, are black, red, yellow, green, cyan, blue, magenta, and white.

red band:

DST(x,y,0,0,0) = 0.000	0	$\leq$	x	$\leq$	NIV{X/8} – 1	and	0	$\leq$	y	$\leq$ Y – 1
DST(x,y,0,0,0) = 1.000	NIV{X/8}	$\leq$	x	$\leq$	NIV{2X/8} – 1	and	0	$\leq$	y	$\leq$ Y – 1
DST(x,y,0,0,0) = 1.000	NIV{2X/8}	$\leq$	x	$\leq$	NIV{3X/8} – 1	and	0	$\leq$	y	$\leq$ Y – 1
DST(x,y,0,0,0) = 0.000	NIV{3X/8}	$\leq$	x	$\leq$	NIV{4X/8} – 1	and	0	$\leq$	y	$\leq$ Y – 1
DST(x,y,0,0,0) = 0.000	NIV{4X/8}	$\leq$	x	$\leq$	NIV{5X/8} – 1	and	0	$\leq$	y	$\leq$ Y – 1
DST(x,y,0,0,0) = 0.000	NIV{5X/8}	$\leq$	x	$\leq$	NIV{6X/8} – 1	and	0	$\leq$	y	$\leq$ Y – 1
DST(x,y,0,0,0) = 1.000	NIV{6X/8}	$\leq$	x	$\leq$	NIV{7X/8} – 1	and	0	$\leq$	y	$\leq$ Y – 1
DST(x,y,0,0,0) = 1.000	NIV{7X/8}	$\leq$	x	$\leq$	X – 1	and	0	$\leq$	y	$\leq$ Y – 1

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green band:

DST(x,y,0,0,1) = 0.000	0	≤	x	≤	NIV{X/8} – 1	and	0	≤	y	≤	Y – 1
DST(x,y,0,0,1) = 0.000	NIV{X/8}	≤	x	≤	NIV{2X/8} – 1	and	0	≤	y	≤	Y – 1
DST(x,y,0,0,1) = 1.000	NIV{2X/8}	≤	x	≤	NIV{3X/8} – 1	and	0	≤	y	≤	Y – 1
DST(x,y,0,0,1) = 1.000	NIV{3X/8}	≤	x	≤	NIV{4X/8} – 1	and	0	≤	y	≤	Y – 1
DST(x,y,0,0,1) = 1.000	NIV{4X/8}	≤	x	≤	NIV{5X/8} – 1	and	0	≤	y	≤	Y – 1
DST(x,y,0,0,1) = 0.000	NIV{5X/8}	≤	x	≤	NIV{6X/8} – 1	and	0	≤	y	≤	Y – 1
DST(x,y,0,0,1) = 0.000	NIV{6X/8}	≤	x	≤	NIV{7X/8} – 1	and	0	≤	y	≤	Y – 1
DST(x,y,0,0,1) = 1.000	NIV{7X/8}	≤	x	≤	X – 1	and	0	≤	y	≤	Y – 1

blue band:

DST(x,y,0,0,2) = 0.000	0	≤	x	≤	NIV{X/8} – 1	and	0	≤	y	≤	Y – 1
DST(x,y,0,0,2) = 0.000	NIV{X/8}	≤	x	≤	NIV{2X/8} – 1	and	0	≤	y	≤	Y – 1
DST(x,y,0,0,2) = 0.000	NIV{2X/8}	≤	x	≤	NIV{3X/8} – 1	and	0	≤	y	≤	Y – 1
DST(x,y,0,0,2) = 0.000	NIV{3X/8}	≤	x	≤	NIV{4X/8} – 1	and	0	≤	y	≤	Y – 1
DST(x,y,0,0,2) = 1.000	NIV{4X/8}	≤	x	≤	NIV{5X/8} – 1	and	0	≤	y	≤	Y – 1
DST(x,y,0,0,2) = 1.000	NIV{5X/8}	≤	x	≤	NIV{6X/8} – 1	and	0	≤	y	≤	Y – 1
DST(x,y,0,0,2) = 1.000	NIV{6X/8}	≤	x	≤	NIV{7X/8} – 1	and	0	≤	y	≤	Y – 1
DST(x,y,0,0,2) = 1.000	NIV{7X/8}	≤	x	≤	X – 1	and	0	≤	y	≤	Y – 1

Profile:

Technical

Error codes:

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IMAGE GENERATION TOOL **IMAGE, CONSTANT**

Description:

Creates an image whose pixels have the same constant value.

Name:

image_constant

Parameters:

DST	destination image	ID	out
image_size	image size 5-tuple	ID	in
c	value of constant	BP,NP,SP,RP,CP	in
data_type	destination data type option	SP	in
	BD		
	ND		
	SD		
	RD		
	CD		

Object:

DST structure:	any image
DST data type:	BD, ND, SD, RD, CD

Element functionality:

Index assignment:	no
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

The parameter tuple contains parameters of the ND data type.

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image_constant

Nomenclature:

DST(x, y, z, t, b)	XxYxZxTxB destination image
c	value of constant

Definition:

For all x, y, z, t, b

$$DST(x, y, z, t, b) = c$$

Profile:

Foundation

Error codes:

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IMAGE GENERATION TOOL IMAGE, GAUSSIAN

Description:

Creates a monochrome image with a Gaussian-shaped amplitude.

Name:

image_gaussian

Parameters:

DST	destination image	ID	out
image_size	image size 5-tuple	ID	in
xc	horizontal centre	RP	in
yc	vertical centre	RP	in
xs	horizontal standard deviation	RP	in
ys	vertical standard deviation	RP	in

Object:

DST structure:	MON
DST data type:	RD

Element functionality:

Index assignment:	no
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

The parameter tuple contains parameters of the ND data type.

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Nomenclature:

DST(x, y, z, t, b)	XxYx1x1x1 destination image
xc	horizontal center
yc	vertical center
xs	horizontal standard deviation, xs > 0
ys	vertical standard deviation, ys > 0

Definition:

For

$$0 \leq x \leq X-1$$

$$0 \leq y \leq Y-1$$

$$DST(x, y, 0, 0, 0) = EXP\left\{-\frac{1}{2}\left[\left(\frac{x-xc}{xs}\right)^2 + \left(\frac{y-yc}{ys}\right)^2\right]\right\}$$

Profile:

Scientific

Error codes:

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IMAGE GENERATION TOOL **IMAGE, GREY SCALE**

Description:

Creates a monochrome grey scale image whose amplitude increases linearly from left-to-right, right-to-left, top-to-bottom, or bottom-to-top.

Name:

image_grey_scale

Parameters:

DST	destination image	ID	out
image_size	image size 5-tuple	ID	in
IM	maximum positive integer size	NP	in
option	grey scale orientation	SP	in
	left-to-right		
	right-to-left		
	top-to-bottom		
	bottom-to-top		
data_type	destination data type	SP	in
	ND		
	SD		
	RD		

Object:

DST structure:	MON
DST data type:	ND, SD, RD

Element functionality:

Index assignment:	no
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

The parameter tuple contains parameters of the ND data type.

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Nomenclature:

DST(x, y, z, t, b)	XxYx1x1x1 destination image
IM	maximum positive integer size, IM ≥ 255

Definition:

ND or SD data type image:

For

$$0 \leq x \leq X - 1$$

$$0 \leq y \leq Y - 1$$

Left-to-right:

$$DST(x, y, 0, 0, 0) = NIV\left\{ \left[\frac{x}{X-1} \right] (IM) \right\}$$

Right-to-left:

$$DST(x, y, 0, 0, 0) = NIV\left\{ \left[\frac{X-1-x}{X-1} \right] (IM) \right\}$$

Top-to-bottom:

$$DST(x, y, 0, 0, 0) = NIV\left\{ \left[\frac{y}{Y-1} \right] (IM) \right\}$$

Bottom-to-top:

$$DST(x, y, 0, 0, 0) = NIV\left\{ \left[\frac{Y-1-y}{Y-1} \right] (IM) \right\}$$

RD data type image:

For

$$0 \leq x \leq X - 1$$

$$0 \leq y \leq Y - 1$$

Left-to-right

$$DST(x, y, 0, 0, 0) = \frac{x}{X-1}$$

Right-to-left:

$$DST(x, y, 0, 0, 0) = \frac{X-1-x}{X-1}$$

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Top-to-bottom:

$$DST(x, y, 0, 0, 0) = \frac{y}{Y-1}$$

Bottom-to-top:

$$DST(x, y, 0, 0, 0) = \frac{Y-1-y}{Y-1}$$

Profile:

Technical

Error codes:

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IMAGE GENERATION TOOL **IMAGE, RANDOM NUMBER**

Description:

Creates an image with pixels whose amplitudes are random numbers.

Name:

image_random_number

Parameters:

DST	destination image	ID	out
image_size	image size 5-tuple	ID	in
mv	probability density mean	RP	in
s	probability density standard deviation	RP	in
am	pixel amplitude maximum value	RP	in
an	pixel amplitude minimum value	RP	in
density	probability density option uniform Gaussian	SP	in

Object:

DST structure:	any image
DST data type:	RD

Element functionality:

Index assignment:	no
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The sequence of random numbers generated by a random number generator will be implementation dependent.
2. The parameter tuple contains parameters of the ND data type.

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Nomenclature:

DST(x, y, z, t, b)	XxYxZxTxB destination image
mv	probability density mean
s	probability density standard deviation
a	pixel amplitude
p(a)	probability density function
am	pixel amplitude maximum value
an	pixel amplitude minimum value, an < an

Definition:

For all x, y, z, t, b

$$D(x, y, z, t, b) = a$$

where a is the output of a random number generator whose probability density is uniform:

$$p(a) = \frac{1}{am - an} \qquad an \leq a \leq am$$

or Gaussian:

$$p(a) = \frac{1}{\sqrt{2\pi}s} EXP\left\{-\frac{1}{2}\left(\frac{a - mv}{s}\right)^2\right\} \qquad an \leq a \leq am$$

Profile:

Scientific

Error codes:

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IMPORT UTILITY **IMPORT HISTOGRAM**

Description:

Imports an external array of data values from an application and puts it into a histogram object.

Name:

import_histogram

Parameters:

SOB	external data value array object	IP	in
DOB	histogram object	ID	out
array_size	array size	NP, NULL	in
lower_bound	lower amplitude bound	RP, NULL	in
upper_bound	upper amplitude bound	RP, NULL	in

Objects:

SOB structure:	EXT
DOB structure:	HIST
SOB data type:	NP
DOB data type:	ND

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Nomenclature:

E	array size, $E \geq 1$
lb	lower amplitude bound
ub	upper amplitude bound, ub > lb

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Definition:

The external array is defined as follows:

value 1
value 2
.
.
value E

Profile:

Foundation

Error codes:

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IMPORT UTILITY **IMPORT IMAGE**

Description:

Imports an image from an application and converts it to the internal PIKS data type.

Name:

import_image

Parameters:

SRC	external source image	IP	in
DST	internal destination image	ID	out
bs	number of source bits per pixel	NP	in
src_data_type	source data type option BI NI SI TI RF CF	SP	in

Objects:

SRC structure:	EXT
DST structure:	any image
SRC data type:	BI, NI, SI, TI, RF, CF
DST data type:	BD, ND, SD, RD, CD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. Import is allowed only to an allocated image.
2. All bands of the external source image must be of the same data type.
3. The data type conversion is implementation dependent.
4. The following are allowable data type conversions upon import:

	Destination				
SRC	BD	ND	SD	RD	CD
BI	X				
NI		X	X	X	X
SI			X	X	X
TI			X	X	X
RF			X	X	X
CF					X

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
bs	number of source image bits per pixel, bs $\geq$ 1

Definition:

For all x, y, z, t, b

$$DST(x, y, z, t, b) = SRC(x, y, z, t, b)$$

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IMPORT UTILITY **IMPORT LOOKUP TABLE**

Description:

Imports an external array of data values from an application and puts it into a lookup table object.

Name:

import_lut

Parameters:

SOB	external data value array object	IP	in
DOB	lookup table object	ID	out
table_entries	number table entries	NP	in
table_bands	number table bands	NP	in
input_data_type	input table data type option	SP	in
	ND		
	SD		
output_data_type	output table data type option	SP	in
	BD		
	ND		
	SD		
	RD		
	CD		

Objects:

SOB structure:	EXT
DOB structure:	LUT
SOB data type:	BP, NP, SP, RP, CP
DOB data type:	BD, ND, SD, RD, CD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

The data type of each external data value shall be of the same class as the data type option.

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Nomenclature:

E	table entries, $E \geq 1$
B	table bands, $B \geq 1$

Definition:

The external array is defined as follows:

value 1, 1
value 2, 1
.
.
value E, 1
value 1, 2
.
.
.
value E, B

Profile:

Foundation

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IMPORT UTILITY **IMPORT MATRIX**

Description:

Imports an external array of data values from an application and puts it into a matrix object.

Name:

import_matrix

Parameters:

SOB	external data value array object	IP	in
DOB	matrix object	ID	out
col_size	matrix column size	NP	in
row_size	matrix row size	NP	in
data_type	matrix data type option ND SD RD CD	SP	in

Objects:

SOB structure:	EXT
DOB structure:	MATRIX
SOB data type:	NP, SP, RP, CP
DOB data type:	ND, SD, RD, CD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

The data type of each external data value shall be of the same class as the data type option.

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Nomenclature:

R	row size, $R \geq 1$
C	column size, $C \geq 1$

Definition:

The external array is defined as follows:

value 1, 1
value 2, 1
.
.
value C, 1
value 1, 2
.
.
value C, R

Profile:

Foundation

Error codes:

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IMPORT UTILITY **IMPORT NEIGHBOURHOOD ARRAY**

Description:

Imports an external array of data values from an application and puts it into a neighbourhood array object.

Name:

import_neighbourhood_array

Parameters:

SOB	external data value array	IP	in
DOB	neighbourhood array object	ID	out
array_size	array size 5-tuple	ID	in
key_pixel	key pixel 5-tuple	ID	in
scale_factor	scale factor	SP, NULL	in
label	semantic label code option	SP	in
	generic		
	dither		
	impulse response		
	mask		
	structuring element		
data_type	neighbourhood array data type option	SP	in
	BD		
	ND		
	SD		
	RD		
	CD		

Objects:

SOB structure:	EXT
DOB structure:	NBHOOD_ARRAY
SOB data type:	BP, NP, SP, RP, CP
DOB data type:	BD, ND, SD, RD, CD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. The data type of each external data value shall be of the same class as the data type option.
2. The *array-size* parameter tuple contains parameters of the ND data type.
3. The *key-pixel* parameter tuple contains parameters of the SD data type.
4. The scale factors for the BD, ND, RD, and CD data types shall be unity.

Nomenclature:

J	first index size, $J \geq 1$
K	second index size, $K \geq 1$
L	third index size, $L \geq 1$
M	fourth index size, $M \geq 1$
N	fifth index size, $N \geq 1$

Definition:

The external array is defined as follows:

value 1, 1, 1, 1, 1
value 2, 1, 1, 1, 1
.
.
value J, 1, 1, 1, 1
value 1, 2, 1, 1, 1
value 2, 2, 1, 1, 1
.
.
value J, K, L, M, N

Profile:

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IMPORT UTILITY **IMPORT ROI ARRAY**

Description:

Imports an external array of data values from an application and puts it into a ROI object.

Name:

import_roi_array

Parameters:

SOB	external data value array object	IP	in
DOB	ROI object	ID	out
roi_size	ROI size 5-tuple	ID	in

Objects:

SOB structure:	EXT
DOB structure:	ROI_ARRAY
SOB data type:	BP
DOB data type:	BD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

The parameter tuple contains parameters of the ND data type.

Nomenclature:

J	first index size, $J \geq 1$
K	second index size, $K \geq 1$
L	third index size, $L \geq 1$
M	fourth index size, $M \geq 1$
N	fifth index size, $N \geq 1$

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Definition:

The external array is defined as follows:

value 1, 1, 1, 1, 1
value 2, 1, 1, 1, 1
.
.
value J, 1, 1, 1, 1
value 1, 2, 1, 1, 1
value 2, 2, 1, 1, 1
.
.
value J, K, L, M, N

Profile:

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Error codes:

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IMPORT UTILITY **IMPORT STATIC ARRAY**

Description:

Imports an external array of data values from an application and puts it into a static array object.

Name:

import_static_array

Parameters:

SOB	external data value array object	IP	in
DOB	static array object	ID	out
array_size	array size 5-tuple	ID	in
label	semantic label code option	SP	in
	generic		
	power function		
	transfer function		
	windowing function		
data_type	static array data type option	SP	in
	BD		
	ND		
	SD		
	RD		
	CD		

Objects:

SOB structure:	EXT
DOB structure:	STATIC_ARRAY
SOB data type:	BP, NP, SP, RP, CP
DOB data type:	BD, ND, SD, RD, CD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. The data type of each external data value shall be of the same class as the data type option.
2. The parameter tuple contains parameters of the ND data type.

Nomenclature:

J	first index size, $J \geq 1$
K	second index size, $K \geq 1$
L	third index size, $L \geq 1$
M	fourth index size, $M \geq 1$
N	fifth index size, $N \geq 1$

Definition:

The external array is defined as follows:

value 1, 1, 1, 1, 1
value 2, 1, 1, 1, 1
.
.
value J, 1, 1, 1, 1
value 1, 2, 1, 1, 1
value 2, 2, 1, 1, 1
.
.
value J, K, L, M, N

Profile:

Technical

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IMPORT UTILITY **IMPORT TUPLE**

Description:

Imports an external array of data values from an application and puts it into a tuple object.

Name:

import_tuple

Parameters:

SOB	external data value array object	IP	in
DOB	tuple object	ID	out
tuple_size	tuple size	NP	in
data_type	tuple data type option BD ND SD RD CD CS	SP	in

Objects:

SOB structure:	EXT
DOB structure:	TUPLE
SOB data type:	BP, NP, SP, RP, CP, CS
DOB data type:	BD, ND, SD, RD, CD, CS

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The data type of each external data value shall be of the same class as the data type option.
2. The parameter tuple contains parameters of the ND data type.

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Nomenclature:

E tuple size, $E \geq 1$

Definition:

The external array is defined as follows:

value 1
value 2
.
.
value E

Profile:

Foundation

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IMPORT UTILITY **IMPORT VALUE BOUNDS**

Description:

Imports an external array of data values from an application and puts it into a value bounds collection object.

Name:

import_value_bounds

Parameters:

SOB	external data value array object	IP	in
DOB	value bounds collection object	ID	out
entry_size	number of entries	NP	in
lower_bound	lower amplitude bound	NP, SP, RP	in
upper_bound	upper amplitude bound	NP, SP, RP	in

Objects:

SOB structure:	EXT
DOB structure:	VALUE_BOUNDS
SOB data type:	NP, SP, RP
DOB data type:	ND, SD, RD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
ROI manipulation:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The data type of each external data value shall be of the same class as the data type option.
2. The image indices x(e), y(e), z(e), t(e), b(e) are of the ND data type; the pixel amplitude value S[x(e), y(e), z(e), t(e), b(e)] is of the ND, SD, or RD data type.

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Nomenclature:

E number of collection entries, $E \geq 1$

Definition:

The external array is defined as follows:

x(0)
y(0)
z(0)
t(0)
b(0)
S[x(0), y(0), z(0), t(0), b(0)]
.
.
.
x(E-1)
y(E-1)
z(E-1)
t(E-1)
b(E-1)
S[x(E-1), y(E-1), z(E-1), t(E-1), b(E-1)]

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IMPULSE RESPONSE ARRAY GENERATION TOOL

IMPULSE, BOXCAR

Description:

Generates a boxcar two-dimensional impulse response function neighbourhood array object.

Name:

impulse_boxcar

Parameters:

DOB	impulse response array object	ID	out
array_size	array size 5-tuple	ID	in
key_pixel	key pixel 5-tuple	ID	in
option	derivative option horizontal derivative vertical derivative	EP	in

Object:

DOB structure:	NBHOOD_ARRAY
DOB data type:	SD, RD
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The key pixel associated with the neighbourhood array is used by some operators as a reference point of the impulse response function array.
2. The *array-size* parameter tuple contains parameters of the ND data type.
3. The *key-pixel* parameter tuple contains parameters of the SD data type.

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Nomenclature:

A(c, r)	CxR impulse response array
C	number of array columns, positive odd integer
R	number of array rows, positive odd integer
ck	column key pixel coordinate
rk	row key pixel coordinate
S	scale factor

Definition:

For

$$0 \le c \le C-1$$

$$0 \le r \le R-1$$

Horizontal derivative:

$$A(c,r) = \frac{2}{S} \qquad 0 \le c \le (C-3)/2 \text{ and } 0 \le r \le R-1$$

$$A(c,r) = 0 \qquad c = (C-1)/2 \text{ and } 0 \le r \le R-1$$

$$A(c,r) = \frac{-2}{S} \qquad (C+1)/2 \le c \le C-1 \text{ and } 0 \le r \le R-1$$

where

$$S = R(C-1)$$

Vertical derivative:

$$A(c,r) = \frac{-2}{S} \qquad 0 \le c \le C-1 \text{ and } 0 \le r \le (R-3)/2$$

$$A(c,r) = 0 \qquad 0 \le c \le C-1 \text{ and } r = (R-1)/2$$

$$A(c,r) = \frac{2}{S} \qquad 0 \le c \le C-1 \text{ and } (R+1)/2 \le r \le R-1$$

where

$$S = C(R-1)$$

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IMPULSE RESPONSE ARRAY GENERATION TOOL IMPULSE, DERIVATIVE OF GAUSSIAN

Description:

Generates a derivative of Gaussian two-dimensional impulse response function neighbourhood array object.

Name:

impulse_derivative_of_gaussian

Parameters:

DOB	impulse response array object	ID	out
array_size	array size 5-tuple	ID	in
key_pixel	key pixel 5-tuple	ID	in
cs	column standard deviation	RP	in
rs	row index standard deviation	RP	in
option	derivative option horizontal derivative vertical derivative	EP	in

Object:

DOB structure:	NBHOOD_ARRAY
DOB data type:	RD
DOB structure:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The key pixel associated with the neighbourhood array is used by some operators as a reference point of the impulse response function array.
2. The *array-size* parameter tuple contains parameters of the ND data type.
3. The *key-pixel* parameter tuple contains parameters of the SD data type.

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Nomenclature:

A(c, r)	CxR impulse response array
C	number of array columns, positive odd integer
R	number of array rows, positive odd integer
ck	column key pixel coordinate
rk	row key pixel coordinate
cs	column index standard deviation
rs	row index standard deviation

Definition:

For

$$0 \leq c \leq C-1$$

$$0 \leq r \leq R-1$$

Horizontal derivative:

$$A(c, r) = k\, G_H(c, r)$$

where

$$G_H(c, r) = \frac{-h_c}{2\pi (cs)^3 (rs)} EXP\left\{-\frac{1}{2}\left[\left(\frac{h_c}{cs}\right)^2 + \left(\frac{v_r}{rs}\right)^2\right]\right\}$$

and

$$k = \frac{1}{2\sum_{r=0}^{R-1}\sum_{c=0}^{C-1} |G_H(c, r)|}$$

Vertical derivative:

$$A(c, r) = k\, G_V(c, r)$$

where

$$G_V(c, r) = \frac{-v_r}{2\pi (cs) (rs)^3} EXP\left\{-\frac{1}{2}\left[\left(\frac{h_c}{cs}\right)^2 + \left(\frac{v_r}{rs}\right)^2\right]\right\}$$

and

$$k = \frac{1}{2\sum_{r=1}^{R}\sum_{c=1}^{C} |G_V(c, r)|}$$

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where

$$h_c = c - \frac{C-1}{2}$$

$$v_r = \frac{R-1}{2} - r$$

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IMPULSE RESPONSE ARRAY GENERATION TOOL

IMPULSE, DIFFERENCE OF GAUSSIANS

Description:

Generates a difference of Gaussians two-dimensional impulse response function neighbourhood array object.

Name:

impulse_difference_of_gaussians

Parameters:

DOB	impulse response array object	ID	out
array_size	array size 5-tuple	ID	in
key_pixel	key pixel 5-tuple	ID	in
csw	column index wide standard deviation	RP	in
rsw	row index wide standard deviation	RP	in
csn	column index narrow standard deviation	RP	in
rsn	row index narrow standard deviation	RP	in

Object:

DOB structure:	NBHOOD_ARRAY
DOB data type:	RD
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The key pixel associated with the neighbourhood array is used by some operators as a reference point of the impulse response function array.
2. The *array-size* parameter tuple contains parameters of the ND data type.
3. The *key-pixel* parameter tuple contains parameters of the SD data type.

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Nomenclature:

A(c, r)	CxR impulse response array
C	number of array columns, positive odd integer
R	number of array rows, positive odd integer
ck	column key pixel coordinate
rk	row key pixel coordinate
csw	column index wide standard deviation, csw > 0
rsw	row index wide standard deviation, rsw > 0
csn	column index narrow standard deviation, csn < csw
rsn	row index narrow standard deviation, rsn < rsw

Definition:

For

$$0 \le c \le C-1$$

$$0 \le r \le R-1$$

$$A(c, r) = G_N(c, r) - G_W(c, r)$$

where

$$G_N(c, r) = \frac{1}{2\pi(csn)(rsn)} EXP\left\{-\frac{1}{2}\left[\left(\frac{h_c}{csn}\right)^2 + \left(\frac{v_r}{rsn}\right)^2\right]\right\}$$

$$G_W(c, r) = \frac{1}{2\pi(csw)(rsw)} EXP\left\{-\frac{1}{2}\left[\left(\frac{h_c}{csw}\right)^2 + \left(\frac{v_r}{rsw}\right)^2\right]\right\}$$

$$h_c = c - \frac{C+1}{2}$$

$$v_r = \frac{R+1}{2} - r$$

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IMPULSE RESPONSE ARRAY GENERATION TOOL — IMPULSE, ELLIPTICAL

Description:

Generates a uniform amplitude elliptical-shaped two-dimensional impulse response function neighbourhood array object.

Name:

impulse_elliptical

Parameters:

DOB	impulse response array object	ID	out
array_size	array size 5-tuple	ID	in
key_pixel	key pixel 5-tuple	ID	in

Object:

DOB structure:	NBHOOD_ARRAY
DOB data type:	SD, RD
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The key pixel associated with the neighbourhood array is used by some operators as a reference point of the impulse response function array.
2. The *array-size* parameter tuple contains parameters of the ND data type.
3. The *key-pixel* parameter tuple contains parameters of the SD data type.

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Nomenclature:

A(c, r)	CxR impulse response array
C	number of array columns, positive odd integer
R	number of array rows, positive odd integer
ck	column key pixel coordinate
rk	row key pixel coordinate
S	scale factor

Definition:

For

$$0 \le c \le C-1$$

$$0 \le r \le R-1$$

$$T(c,r) = 1 \qquad \text{if } \left[\frac{c-c_c}{c_c}\right]^2 + \left[\frac{r-r_c}{r_c}\right]^2 \le 1$$

$$T(c,r) = 0 \qquad \text{otherwise}$$

where

$$c_c = \frac{C-1}{2}$$

$$r_c = \frac{R-1}{2}$$

For

$$0 \le c \le C-1$$

$$0 \le r \le R-1$$

$$S = \sum_{c=0}^{C-1} \sum_{r=0}^{R-1} T(c,r)$$

For

$$0 \le c \le C-1$$

$$0 \le r \le R-1$$

$$A(c,r) = \frac{1}{S} T(c,r)$$

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IMPULSE RESPONSE ARRAY GENERATION TOOL **IMPULSE, GAUSSIAN**

Description:

Generates a Gaussian-shaped two-dimensional impulse response function neighbourhood array object.

Name:

impulse_gaussian

Parameters:

DOB	impulse response array object	ID	out
array_size	array size 5-tuple	ID	in
key_pixel	key pixel 5-tuple	ID	in
sh	horizontal standard deviation	RP	in
sv	vertical standard deviation	RP	in

Object:

DOB structure:	NBHOOD_ARRAY
DOB data type:	RD
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The key pixel associated with the neighbourhood array is used by some operators as a reference point of the impulse response function array.
2. The *array-size* parameter tuple contains parameters of the ND data type.
3. The *key-pixel* parameter tuple contains parameters of the SD data type.

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Nomenclature:

A(c, r)	CxR impulse response array
C	number of array columns, positive odd integer
R	number of array rows, positive odd integer
ck	column key pixel coordinate
rk	row key pixel coordinate
sh	horizontal standard deviation, sh > 0
sv	vertical standard deviation, sv > 0

Definition:

For

$$0 \leq c \leq C-1$$

$$0 \leq r \leq R-1$$

$$A(c,r) = \frac{1}{2\pi(sh)(sv)} EXP\left\{-\frac{1}{2}\left[\left(\frac{h_c}{sh}\right)^2 + \left(\frac{v_r}{sv}\right)^2\right]\right\}$$

where

$$h_c = c - \frac{C-1}{2}$$

$$v_r = \frac{R-1}{2} - r$$

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IMPULSE RESPONSE ARRAY GENERATION TOOL

IMPULSE, LAPLACIAN OF GAUSSIAN

Description:

Generates a Marr-Hildreth, Laplacian of Gaussian two-dimensional impulse response function neighbourhood array object.

Name:

impulse_laplacian_of_gaussian

Parameters:

DOB	impulse response array object	ID	out
array_size	array size 5-tuple	ID	in
key_pixel	key pixel 5-tuple	ID	in
s	standard deviation	RP	in

Object:

DOB structure:	NBHOOD_ARRAY
DOB data type:	RD
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The key pixel associated with the neighbourhood array is used by some operators as a reference point of the impulse response function array.
2. The *array-size* parameter tuple contains parameters of the ND data type.
3. The *key-pixel* parameter tuple contains parameters of the SD data type.

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Nomenclature:

A(c, r)	CxR impulse response array
C	number of array columns, positive odd integer
R	number of array rows, positive odd integer
ck	column key pixel coordinate
rk	row key pixel coordinate
s	standard deviation, s >0

Definition:

For

$$0 \leq c \leq C-1$$

$$0 \leq r \leq R-1$$

$$A(c,r) = \frac{1}{\pi s^4}\left[1 - \frac{(h_c)^2 + (v_r)^2}{2s^2}\right] EXP\left\{-\frac{(h_c)^2 + (v_r)^2}{2s^2}\right\}$$

where

$$h_c = c - \frac{C-1}{2}$$

$$v_r = \frac{R-1}{2} - r$$

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IMPULSE RESPONSE ARRAY GENERATION TOOL

IMPULSE, PYRAMID

Description:

Generates a pyramid-shaped two-dimensional impulse response function neighbourhood array object.

Name:

impulse_pyramid

Parameters:

DOB	impulse response array object	ID	out
array_size	array size 5-tuple	ID	in
key_pixel	key pixel 5-tuple	ID	in
option	pyramid shape option smoothing horizontal derivative vertical derivative	SP	in

Object:

DOB structure:	NBHOOD_ARRAY
DOB data type:	SD, RD
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The key pixel associated with the neighbourhood array is used by some operators as a reference point of the impulse response function array.
2. The *array-size* parameter tuple contains parameters of the ND data type.
3. The *key-pixel* parameter tuple contains parameters of the SD data type.

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Nomenclature:

A(c, r)	CxR impulse response array
C	number of array columns, positive odd integer
R	number of array rows, positive odd integer
rk	row key pixel coordinate
ck	column key pixel coordinate
S	scale factor

Definition:

For

$$0 \leq c \leq C-1$$

$$0 \leq r \leq R-1$$

Smoothing option:

$$A(c,r) = \frac{P(c,r)}{S}$$

where

$P(c, r) = MIN\{c + 1, r + 1\}$ $\quad 0 \leq c \leq C-1)/2$ and $0 \leq r \leq (R-1)/2$

$P(c, r) = MIN\{C - c, r + 1\}$ $\quad (C-1)/2 \leq c \leq C-1$ and $0 \leq r \leq (R-1)/2$

$P(c, r) = MIN\{c + 1, R - r\}$ $\quad 0 \leq c \leq (C-1)/2$ and $(R-1)/2 \leq r \leq R-1$

$P(c, r) = MIN\{C - c, R - r\}$ $\quad (C-1)/2 \leq c \leq C-1$ and $(R-1)/2 \leq r \leq R-1$

$$S = \sum_{c=0}^{C-1} \sum_{r=0}^{R-1} P(c,r)$$

Horizontal derivative option:

$$A(c,r) = \frac{P(c,r)}{S}$$

where

$P(c, r) = MIN\{c + 1, r + 1\}$ $\quad 0 \leq c \leq (C-1)/2$ and $0 \leq r \leq (R-1)/2$

$P(c, r) = -MIN\{C - c, r + 1\}$ $\quad (C-1)/2 \leq c \leq C-1$ and $0 \leq r \leq (R-1)/2$

$P(c, r) = MIN\{c + 1, R - r\}$ $\quad 0 \leq c \leq (C-1)/2$ and $(R-1)/2 \leq r \leq R-1$

$P(c, r) = -MIN\{C - c, R - r\}$ $\quad (C-1)/2 \leq c \leq C-1$ and $(R-1)/2 \leq r \leq R-1$

$P(c, r) = 0$ $\quad c = (C-1)/2$ and $0 \leq r \leq R-1$

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$$S = 2 \sum_{c=0}^{C-1} \sum_{r=0}^{R-1} |P(r,c)|$$

Vertical derivative option:

$$A(c,r) = \frac{P(c,r)}{S}$$

where

$P(c, r) = -MIN\{c + 1, r + 1\}$	$0 \le c \le (C - 1)/2$ and $0 \le r \le (R - 1)/2$
$P(c, r) = MIN\{C - c, r + 1\}$	$(C - 1)/2 \le c \le C - 1$ and $0 \le r \le (R - 1)/2$
$P(c, r) = -MIN\{c + 1, R - r\}$	$0 \le c \le (C - 1)/2$ and $(R - 1)/2 \le r \le R - 1$
$P(c, r) = MIN\{C - c, R - r\}$	$(C - 1)/2 \le c \le C - 1$ and $(R - 1)/2 \le r \le R - 1$
$P(c, r) = 0$	$0 \le c \le C - 1$ and $r = (R - 1)/2$

$$S = 2 \sum_{c=0}^{C-1} \sum_{r=0}^{R-1} |P(r,c)|$$

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IMPULSE RESPONSE ARRAY GENERATION TOOL **IMPULSE, RECTANGULAR**

Description:

Generates a uniform amplitude rectangular-shaped two-dimensional impulse response function neighbourhood array object.

Name:

impulse_rectangular

Parameters:

DOB	impulse response array object	ID	out
array_size	array size 5-tuple	ID	in
key_pixel	key pixel 5-tuple	ID	in

Object:

DOB structure:	NBHOOD_ARRAY
DOB data type:	SD, RD
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The key pixel associated with the neighbourhood array is used by some operators as a reference point of the impulse response function array.
2. The *array-size* parameter tuple contains parameters of the ND data type.
3. The *key-pixel* parameter tuple contains parameters of the SD data type.

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Nomenclature:

A(c, r)	CxR impulse response array
C	number of array columns, $C \geq 1$
R	number of array rows, $R \geq 1$
ck	column key pixel coordinate
rk	row key pixel coordinate
S	scale factor

Definition:

For

$$0 \leq c \leq C-1$$

$$0 \leq r \leq R-1$$

$$A(c, r) = \frac{1}{S}$$

where

$$S = RC$$

Profile:

Foundation

Error codes:

012
014
024
044
111
112

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IMPULSE RESPONSE ARRAY GENERATION TOOL — IMPULSE, SINC

Description:

Generates a sinc function two-dimensional impulse response function neighbourhood array object.

Name:

impulse_sinc

Parameters:

DOB	impulse response array object	ID	out
array_size	array size 5-tuple	ID	in
key_pixel	key pixel 5-tuple	ID	in
fh	horizontal scale factor	RP	in
fv	vertical scale factor	RP	in

Object:

DOB structure:	NBHOOD_ARRAY
DOB data type:	RD
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The key pixel associated with the neighbourhood array is used by some operators as a reference point of the impulse response function array.
2. The *array-size* parameter tuple contains parameters of the ND data type.
3. The *key-pixel* parameter tuple contains parameters of the SD data type.

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Nomenclature:

A(c, r)	CxR impulse response array
C	number of array columns, positive odd integer
R	number of array rows, positive integer
ck	column key pixel coordinate
rk	row key pixel coordinate
fh	horizontal scale factor, fh > 0
fv	vertical scale factor, fv > 0

Definition:

For

$$0 \leq c \leq C-1$$

$$0 \leq r \leq R-1$$

$$A(c,r) = \frac{\mathrm{SIN}\{\theta_h\}}{\theta_h}\frac{\mathrm{SIN}\{\theta_v\}}{\theta_v}$$

where:

$$\theta_h = (fh)\pi(h_c)$$

$$\theta_v = (fv)\pi(v_r)$$

and

$$h_c = c - \frac{C-1}{2}$$

$$v_r = \frac{R-1}{2} - r$$

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Profile:

Scientific

Error codes:

001
012
014
024
044
101
113
114

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IMPORT UTILITY **INPUT OBJECT**

Description:

Inputs a PIKS data object from the IIF or the application.

Name:

input_object

Parameters:

SOB	external object	IP	in
DOB	PIKS object	ID	out
source	data source option IIF application	SP	in
syntax	data source syntax option ASN.1 private	SP	in

Objects:

SOB structure:	HIST, LUT, MATRIX, NBHOOD_ARRAY, PIXEL_RECORD, ROI_ARRAY, ROI_COORD, ROI_ELLIP, ROI_POLY, ROI_RECT, STATIC_ARRAY, TUPLE, VALUE_BOUNDS plus PIKS image
DOB structure:	same as SOB structure
SOB data type:	all external data types accepted by PIKS
DOB data type:	same PIKS class as SOB data type

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. This utility only supports the input of PIKS data objects, as defined in Part 1 of this standard.
2. This utility shall be capable of supporting other (non-IIF) data sources through an extension mechanism.
3. This utility does not provide for the input of PIKS objects in a private syntax from the application.

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Such functionality is provided by PIKS import utilities.

Definition:

IIF to PIKS with ASN.1 syntax:

Invocation of this utility automatically opens a data stream port from the IIF and causes the ASN.1 stream that is received to be parsed to create the appropriate PIKS data object.

IIF to PIKS with private syntax:

Invocation of this utility automatically opens a data stream port from the IIF and causes the private syntax data stream that is received to be parsed to create the appropriate PIKS data object.

Application to PIKS with ASN.1 syntax:

Invocation of this utility automatically opens a data stream port from the application and causes the ASN.1 data stream that is received to be parsed to create the appropriate PIKS data object.

Profile:

Foundation - IIF capable

Error codes:

001
003
012
014
026
042
044
062

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INQUIRY UTILITY **INQUIRE CHAIN ENVIRONMENT**

Description:

Returns information on the implementation of the chaining environment within PIKS.

Name:

inquire_chain_environment

Parameters:

DOB	chaining attribute list	IP	out
data_validity	data validity indicator AVAILABLE NOT-AVAILABLE	EP	out

Object:

DOB structure: EXT

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remark:

The data validity indicator is NOT-AVAILABLE if and only if PIKS is not currently open.

Definition:

This inquiry mechanism provides implementation details of the PIKS chaining environment.

Profile:

Full

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Error code:

None

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INQUIRY UTILITY **INQUIRE CHAIN STATUS**

Description:

Inquires about the status of a chain.

Name:

inquire_chain_status

Parameters:

SOB	chain object	ID	in
chain_status	chain status	NP	out
data_validity	data validity indicator AVAILABLE NOT-AVAILABLE	EP	out

Object:

SOB structure: CHAIN

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remarks:

1. Chain execution is complete when all data input to the chain has been processed and all processing elements have completed execution, or when chain execution terminates due to a fatal error condition or application directed termination.
2. Because of the potential for different machine architectures, including parallel processors, no attempt is made in *inquire_chain_status* to return the status of individual chain elements.
3. The data validity indicator is NOT-AVAILABLE if and only if PIKS is not currently open.

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Definition:

This utility returns the current status of a chain.

The following are the chain status codes.

000
Status: Nonexistent
Meaning: No chain exists for the specified chain identifier.

001
Status: Unstarted
Meaning: Chain execution has not been requested.

002
Status: Scheduled
Meaning: Chain execution has been requested, but not begun.

003
Status: Running
Meaning: Chain execution has begun and at least one element is active.

004
Status: Idling
Meaning: Chain execution has begun, but no elements are active. (Elements are potentially awaiting data.)

005
Status: Complete - Aborted
Meaning: Chain execution is complete - the chain was explicitly aborted.

006
Status: Complete - Failure
Meaning: Chain execution is complete - the chain terminated with a failure of a chain element.

007
Status: Complete - Naturally
Meaning: The chain completed execution naturally.

The following are the data validity indicators:

AVAILABLE	inquiry data available
NOT-AVAILABLE	inquiry data not avialable (PIKS not currently open)

Profile:

Full

Error code:

None

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INQUIRY UTILITY **INQUIRE ELEMENTS**

Description:

Returns an array of information to an application regarding an implementation's support of elements.

Name:

inquire_elements

Parameters:

SOB	array of element registation numbers	IP	in
DOB	array of registration responses	IP	out
size	array size	NP	in
label	private label information	CS	out
data_validity	data validity indicator AVAILABLE NOT-AVAILABLE	EP	out

Objects:

SOB structure:	EXT
DOB structure:	EXT
SOB data type:	SP
DOB data type:	BP

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remarks:

1. The data validity indicator is NOT-AVAILABLE if and only if PIKS is not currently open.
2. The inquired element numbers in the registration number array may be positive or negative.

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Nomenclature:

E	array size, $E \geq 1$
e	array entry index, $1 \leq e \leq E$
s(e)	e-th entry of registration numbers array
d(e)	e-th entry of registration responses array

Definition:

The element registration numbers array is sequentially examined for all entries. If the PIKS implementation supports the inquired registation number, s(e), the corresponding entry, d(e), of the registration responses array is set to the Boolean state TRUE. Otherwise, d(e) is set to the Boolean state FALSE.

Profile:

Foundation

Error code:

None

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INQUIRY UTILITY **INQUIRE IMAGE**

Description:

Returns image attribute information to an application.

Name:

inquire_image

Parameters:

SRC	source image	ID	in
image_size	image size 5-tuple	ID	out
band_type	band data type B-tuple	ID	out
band_precision	band precision B-tuple	ID	out
match_point	match point 5-tuple	ID	out
roi	ROI identifier	ID	out
roi_offset	ROI offset 5-tuple	ID	out
X_o	X tristimulus value white point	RP	out
Y_o	Y tristimulus value white point	RP	out
Z_o	Z tristimulus value white point	RP	out
image_structure	image structure code MON VOL TEM COLR SPE VT VC VS TC TS VTC VTS GEN	SP	out
colour_space	colour space code unspecified uncalibrated RGB linear CCIR illuminant D65 RGB linear CIE illuminant E RGB linear EBU illuminant C RGB linear EBU illuminant D65 RGB linear NTSC illuminant C RGB linear NTSC illuminant D65 RGB linear SMPTE illuminant D65 RGB gamma CCIR illuminant D65 RGB gamma EBU illuminant C RGB gamma EBU illuminant D65 RGB gamma NTSC illuminant C RGB gamma NTSC illuminant D65 RGB	SP	out

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	gamma SMPTE illuminant D65 RGB luminance/chrominance EBU illuminant C YUV luminance/chrominance EBU illuminant D65 YUV luminance/chrominance NTSC illuminant C YIQ luminance/chrominance NTSC illuminant D65 YIQ luminance/chrominance SMPTE YCbCr CIE XYZ CIE UVW CIE Yxy CIE Yuv CIE L*a*b* CIE L*u*v* IHS CMY CMYK		
data_validity	data validity indicator AVAILABLE NOT-AVAILABLE	EP	out

Object:

SRC structure:	any image
SRC data type:	BD, ND, SD, RD, CD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remarks:

1. An implementation may return parameters in a public structure.
2. The *inquire_image* utility returns identifiers to the PIKS internal image attribute data structures, which can be used to export the image attribute information to an application or to the IIF.
3. The data validity indicator is NOT-AVAILABLE if and only if PIKS is not currently open.
4. The image size, band data type, and band precision tuples are defined in the *allocate_image* mechanism.
5. The match point tuple is defined in the *bind_match_point* mechanism.
6. The ROI offset tuple is defined in the *bind_roi* mechanism.
7. The *image-size* and *band-precision* parameter tuples contain parameters of the ND data type.
8. The *band_type*, *match_point*, and *roi_offset* parameter tuples contain parameters of the SD data type.

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Definition:

This utility returns image attribute and state information to an application. It does not provide access to the image data itself. Image data access can be accomplished using PIKS export utilities.

Profile:

Foundation

Error code:

None

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INQUIRY UTILITY **INQUIRE INDEX ASSIGNMENT**

Description:

Returns the index assignment state to an application.

Name:

inquire_index_assignment

Parameters:

j	j index assignment	CS	out
k	k index assignment	CS	out
l	l index assignment	CS	out
m	m index assignment	CS	out
n	n index assignment	CS	out
data_validity	data validity indicator AVAILABLE NOT-AVAILABLE	EP	out

Objects:

None

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remark:

The data value indicator is NOT-AVAILABLE if and only if PIKS is not currently open.

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Nomenclature:

j	operator input image first index assignment relationship
k	operator input image second index assignment relationship
l	operator input image third index assignment relationship
m	operator input image fourth index assignment relationship
n	operator input image fifth index assignment relationship

Definition:

The index assignment relationships are returned as character strings, which indicate the index assignment relationships between the image indices and the operator input indices. The returned values are:

j CHOICE{'x', 'y', 'z', 't', 'b'}

k CHOICE{'x', 'y', 'z', 't', 'b'}

l CHOICE{'x', 'y', 'z', 't', 'b'}

m CHOICE{'x', 'y', 'z', 't', 'b'}

n CHOICE{'x', 'y', 'z', 't', 'b'}

where '[ ]' denotes the character string corresponding to its argument.

Profile:

Technical

Error codes:

None

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INQUIRY UTILITY

INQUIRE NON-IMAGE OBJECT

Description:

Returns non-image data object attribute information to an application.

Name:

inquire_non_image_object

Parameters:

SOB	object	ID	in
information	information identifier	IP	out
object_type	object type option	SP	in
	histogram		
	identifier array		
	identifier list		
	identifier record		
	lookup table		
	matrix		
	neighbourhood array		
	pixel record		
	ROI array		
	ROI coordinate collection		
	ROI elliptical		
	ROI generic		
	ROI polygon		
	ROI rectangular		
	static array		
	tuple		
	value bounds collection		
	virtual register		
data_validity	data validity indicator	EP	out
	AVAILABLE		
	NOT-AVAILABLE		

Object:

SOB structure: any non-image object

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Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remarks:

1. An implementation may return information in a public structure.
2. The data value indicator is NOT-AVAILABLE if and only if PIKS is not currently open.
3. The chain and composite image identifier list data objects do not possess any attribute information.

Definition:

This utility returns attribute information about a non-image data object to the application. It does not provide access to the data object itself.

The following lists the returned information for each non-image data object.

Histogram:

array size	NP
lower amplitude bound	RP
upper amplitude bound	RP

Identifier array:

length	NP

Identifier record:

length	NP
first attribute name	CS
second attribute name	CS
.	.
.	.
last attribute name	CS

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Lookup table:

table entries	NP
table bands	NP
input table data type code	SP
ND	
SD	
output table data type code	SP
BD	
ND	
SD	
RD	
CD	

Matrix:

matrix column size	NP
matrix row size	NP
matrix data type code	SP
ND	
SD	
RD	
CD	

Neighbourhood array:

array size 5-tuple	ID
key pixel 5-tuple	ID
scale factor	SP
semantic label code	SP
generic	
dither	
impulse response	
mask	
structuring element	
array data type code	SP
BD	
ND	
SD	
RD	
CD	

Pixel record:

record length	NP
data type B-tuple	ID

ROI array:

virtual array size 5-tuple	ID

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ROI coordinate collection

virtual array size 5-tuple	ID
collection size	NP
polarity code	EP
TRUE	
FALSE	

ROI elliptical:

virtual array size 5-tuple	ID
ellipse centre 5-tuple	ID
ellipse axis length 5-tuple	ID
ellipse dimension	EP
polarity code	EP
TRUE	
FALSE	

ROI generic:

virtual array size 5-tuple	ID

ROI polygon:

virtual array size 5-tuple	ID
array entries	NP
polarity code	EP
TRUE	
FALSE	

ROI rectangular

virtual array size 5-tuple	ID
start position 5-tuple	ID
end position 5-tuple	ID
rectangle dimension code	EP
1D	
2D	
3D	
4D	
5D	
polarity code	EP
TRUE	
FALSE	

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Static array:

array size 5-tuple	ID
semantic label code	SP
generic	
power spectrum	
transfer function	
windowing function	
array data type code	SP
BD	
ND	
SD	
RD	
CD	

Tuple:

tuple size	NP
tuple data type code	SP
BD	
ND	
SD	
RD	
CD	
CS	

Value bounds collection:

collection size	NP
lower amplitude bound	RP
upper amplitude bound	RP
pixel data type code	SP
BD	
ND	
SD	
RD	

Virtual register:

register status	EP
register data type code	SP
BD	
ND	
SD	
RD	
CD	
CS	
ID	
IP	

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Profile:

Foundation

Error code:

None

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INQUIRY UTILITY

INQUIRE PIKS IMPLEMENTATION

Description:

Returns information about a PIKS implementation.

Name:

inquire_piks_implementation

Parameters:

profile	conformance profile	CS	out
image_size_limit	image size limit 5-tuple	ID	out
nd_precision	storage precision of ND data type	SP	out
sd_precision	storage precision of SD data type	SP	out
rd_precision	storage precision of RD data type	SP	out
rd_implementation	implementation method of RD data type	CS	out
implementation_notes	implementation-specific information	IP	out
asynch	asynchronous support code	EP	out
	yes		
	no		
data_validity	data validity indicator	EP	out
	AVAILABLE		
	NOT-AVAILABLE		

Objects:

None

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

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Remarks:

1. An implementation may return parameters in a public structure.
2. The data validity indicator is NOT-AVAILABLE if and only if PIKS is not currently open.
3. The parameter tuple contains parameters of the ND data type.

Definition:

This utility returns information about a PIKS implementation. A more detailed explanation of the information returned is provided below.

profile — Specifies the profile of PIKS conformance. The currently valid specified profiles are:

FOUNDATION	PIKS Foundation
TECHNICAL	PIKS Technical
SCIENTIFIC	PIKS Scientific
FULL	PIKS Full
FOUNDATION/IIF	PIKS Foundation, IIF capable
TECHNICAL/IIF	PIKS Technical, IIF capable
SCIENTIFIC/IIF	PIKS Scientific, IIF capable
FULL/IIF	PIKS Full, IIF capable

*_size_limit — Defines the maximum extent of an image object along a particular dimension supported by an implementation. The five dimensions are x, y, z, t, b. Note that, based upon the profile conformance level, the implementation may not support the full complement of five dimensional objects. If this is the case, the size limit will be zero for that dimension, as shown below.

–1	no limit established
0	objects have no extent along the dimension
> 0	limit value

Note also that the maximum extent of the dimensions supported should not be construed as a guarantee that an image object of maximum extent along all dimensions can be created at any point in time because of memory management limitations.

nd_precision — Number of bits of storage precision for ND data type

sd_precision — Number of bits of storage precision for SD data type.

rd_precision — Number of bits of storage precision for RD data type.

rd_implementation — Implementation technique for RD data type.

TI	fixed point integer
RF	real floating point number

implementation_notes — Pointer to implementation-specific text, which may be used to communicate implementation private information.

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data_validity	Data validity indicator	
	AVAILABLE	inquiry data available
	NOT-AVAILABLE	inquiry data not available (PIKS not currently open)

Profile:

Foundation

Error code:

None

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INQUIRY UTILITY **INQUIRE PIKS STATUS**

Description:

Returns information about PIKS state and global control mode status.

Name:

inquire_piks_status

Parameters:

piks_op_state	PIKS operational state code PIKS_CLOSED PIKS_OPEN	EP	out
piks_chain_state	PIKS chain state code BUILD_CHAIN EXECUTE_CHAIN NOT_CHAIN	EP	out
piks_error_state	PIKS error state code ERROR_SUBSTATE NO_ERROR	EP	out
roi_control_mode	ROI control mode code ROI_CONTROL_ON ROI_CONTROL_OFF	EP	out
roi_process_mode	ROI processing mode code ROI_PROCESS_ON ROI_PROCESS_OFF	EP	out
match_point_mode	match point control mode code MP_ON MP_OFF	EP	out
index_assign_mode	index assignment mode code INDEX_ASSIGN_ON INDEX_ASSIGN_OFF	EP	out
synchronicity mode	synchronicity mode code SYNCH_ON ASYNCH_ON	EP	out
error_reporting_mode	error reporting mode code ERROR_REPORT_ON ERROR_REPORT_OFF	EP	out
image_resampling_mode	image resampling selection mode code support 1 constant support 2 linear support 2 lookup table support 4 truncated sinc support 4 cubic B-spline support 4 cubic convolution support 4 Lagrangian support 4 lookup table support 8 truncated sinc support 8 lookup table	SP	out

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roi_resampling_mode	ROI resampling selection mode code support 1 constant support 2 linear support 2 lookup table support 4 truncated sinc support 4 cubic B-spline support 4 cubic convolution support 4 Lagrangian support 4 lookup table support 8 truncated sinc support 8 lookup table	SP	out
data_validity	data validity indicator AVAILABLE NOT-AVAILABLE	EP	out

Objects:

None

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remarks:

1. An implementation may return information in a public structure.
2. The data validity indicator is NOT-AVAILABLE if and only if PIKS is not currently open.

Definition:

This mechanism returns information about the status of PIKS state and global control. A more detailed explanation of the information returned is provided below.

piks_op_state	Specifies the PIKS operational state. PIKS_CLOSED PIKS_OPEN

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piks_chain_state	Specifies the PIKS chain state BUILD_CHAIN EXECUTE_CHAIN NOT_CHAIN
piks_error_state	Specifies the PIKS error state ERROR_SUBSTATE NO_ERROR
index_assign_mode	Specifies if the index assignment system management mechanism is activated in the PIKS operator processing model. INDEX_ASSIGN_ON — index assignment engaged INDEX_ASSIGN_OFF — index assignment disengaged
roi_control_mode	Specifies if the source and destination ROI control mechanisms are activated in the PIKS operator processing model. ROI_CONTROL_ON — ROI control engaged ROI_CONTROL_OFF — ROI control disengaged
roi_process_mode	Specifies if the source ROI control object is to be processed by an operator. ROI_PROCESS_ON — ROI processing engaged ROI_PROCESS_OFF — ROI processing disengaged
match_point_mode	Specifies if the match point control mechanism is activated in the PIKS operator processing model. MATCH_POINT_ON — match point control engaged MATCH_POINT_OFF — match point control disengaged
synchronicity_mode	Specifies if PIKS operators and chains operate synchronously or asynchronously. SYNCH_ON — synchronous operation only ASYNCH_ON — asynchronous operation
error_reporting_mode	Specifies if PIKS errors are reported. ERROR_REPORT_ON ERROR_REPORT_OFF
image_resampling_mode	Specifies which image resampling option has been selected. 1 - support 1 constant 2 - support 2 linear 3 - support 2 lookup table 4 - support 4 truncated sinc 5 - support 4 cubic B-spline 6 - support 4 cubic convolution 7 - support 4 Lagrangian 8 - support 4 lookup table 9 - support 8 truncated sinc 10 - support 8 lookup table

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roi_resampling_mode	Specifies which ROI resampling option has been selected. 1 - support 1 constant 2 - support 2 linear 3 - support 2 lookup table 4 - support 4 truncated sinc 5 - support 4 cubic B-spline 6 - support 4 cubic convolution 7 - support 4 Lagrangian 8 - support 4 lookup table 9 - support 8 truncated sinc 10 - support 8 lookup table
data_validity	Data validity indicator AVAILABLE — inquiry data available NOT-AVAILABLE — inquiry data not available (PIKS not currently open)

Profile:

Foundation

Error code:

None

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INQUIRY UTILITY **INQUIRE REPOSITORY**

Description:

Returns an array of information to an application regarding an implementation's support of data object repository entries.

Name:

inquire_repository

Parameters:

SOB	array of repository registration numbers	IP	in
DOB	array of element registration responses	IP	out
size	array size	NP	in
label	private label information	CS	out
class	repository class option impulse response array dither array colour conversion matrix	SP	in
data_validity	data validity indicator AVAILABLE NOT-AVAILABLE	EP	out

Objects:

SOB structure:	EXT
DOB structure:	EXT
SOB data type:	SP
DOB data type:	BP

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

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Remarks:

1. The data validity indicator is NOT-AVAILABLE if and only if PIKS is not currently open.
2. The inquired registration numbers in the registration number array may be positive or negative.

Nomenclature:

E	array size, $E \geq 1$
e	array entry index, $1 \leq e \leq E$
s(e)	e-th entry of element registration numbers array
d(e)	e-th entry of element registration responses array

Definition:

The repository registration numbers array is sequentially examined for all entries. If the PIKS implementation supports the inquired registration number, s(e), for a specified repository class, the corresponding entry, d(e), of the registration responses array is set to the Boolean state TRUE. Otherwise, d(e) is set to the Boolean state FALSE.

Profile:

Foundation

Error code:

None

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INQUIRY UTILITY

INQUIRE RESAMPLING

Description:

Returns an array of information to an application regarding an implementation's support of resampling options.

Name:

inquire_resampling

Parameters:

SOB	array of resampling registration numbers	IP	in
DOB	array of resampling registration responses	IP	out
size	array size	NP	in
label	private label information	CS	out
data_validity	data validity indicator AVAILABLE NOT-AVAILABLE	EP	out

Objects:

SOB structure:	EXT
DOB structure:	EXT
SOB data type:	SP
DOB data type:	BP

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Remarks:

1. The data validity indicator is NOT-AVAILABLE if and only if PIKS is not currently open.
2. The inquired registation numbers in the registration number array may be positive or negative.

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Nomenclature:

E	array size, $E \geq 1$
e	array entry index, $1 \leq e \leq E$
s(e)	e-th entry of resampling registration numbers array
d(e)	e-th entry of resampling registration responses array

Definition:

The resampling registration numbers array is sequentially examined for all entries. If the PIKS implementation supports the inquired registation number, s(e), the corresponding entry, d(e), of the registration responses array is set to the Boolean state TRUE. Otherwise, d(e) is set to the Boolean state FALSE.

Profile:

Foundation

Error code:

None

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INTERNAL UTILITY **INSERT PIXEL PLANE**

Description:

Inserts a monochrome image into a multi-plane image.

Name:

insert_pixel_plane	insert_pixel_plane_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
zv	depth index value	NP	in
tv	temporal index value	NP	in
bv	band index value	NP	in

Objects:

SRC structure:	MON	any ROI
DST structure:	any image	ROI_GEN
SRC data type:	BD, ND, SD, RD, CD	BD
DST data type:	BD, ND, SD, RD, CD	BD

Element functionality:

Index assignment:	no	no
Match point:	yes	no
ROI control:	yes	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	yes	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Nomenclature:

SRC(x, y, z, t, b)	XxYx1x1x1 source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
zv	depth index value, $zv \geq 0$
tv	temporal index value, $tv \geq 0$
bv	band index value, $bv \geq 0$

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Definition:

The *insert_pixel_plane* utility inserts a monochrome image into a specified pixel plane of a multi-plane image.

For zv, tv, bv and for all x, y

DST(x, y, zv, tv, bv) = SRC(x, y, 0, 0, 0)

Profile:

Foundation	insert_pixel_plane
Technical	insert_pixel_plane_roi

Error codes:

001
011
013
021
041
043
101

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Description:

Labels each pixel of each object in a pixel plane of a Boolean image with its object index.

Name:

label_objects

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
lv	third index value	NP	in
mv	fourth index value	NP	in
nv	fifth index value	NP	in
limit	object number limit	NP	in
number_objects	number of objects labeled	NP	out

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB structure:	LUT, internal to operator
SRC data type:	BD
DST data type:	ND
SOB data type:	ND
SOB dimension:	1D

Element functionality:

Index assignment:	yes
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. An object is defined to be a collection of eight-connected pixels of the Boolean TRUE state that are surrounded by pixels of the boolean FALSE state.
2. An object may have "holes" - Boolean FALSE state pixels within its interior.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
lv	third index value, $lv \geq 0$
mv	fourth index value, $mv \geq 0$
nv	fifth index value, $nv \geq 0$
Q	number of objects examined, $Q \geq 1$
q	object index, $1 \leq q \leq Q$
Q_{max}	object number limit, $0 < Q_{max} \leq E$
E	number of lookup table entries, $E \geq 1$
T(e)	e-th entry of lookup table, SOB, $0 \leq e \leq E - 1$

Definition:

Initialize object index.

$$q = 1$$

For all j, k, set

$$W(j, k, lv, mv, nv) = 0$$

Starting at the origin, the j-k plane of S(j, k, lv, mv, nv) is sequentially examined (raster scanned) in increasing index order (j index first). For each pixel of S(j, k, lv, mv, nv) that is TRUE, get the values of the four neighbours in the work image.

upper left: $Wul = W(j - 1, k - 1, lv, mv, nv)$

upper: $Wu = W(j, k - 1, lv, mv, nv)$

upper right: $Wur = W(j + 1, k - 1, lv, mv, nv)$

left: $Wl = W(j - 1, k, lv, mv, nv)$

If none of the neighbours are non-zero, set

$$W(j, k, lv, mv, nv) = q$$

$$T(q) = q$$

and increment the object index by one.

If exactly one neighbour is non-zero, set W(j, k, lv, mv, nv) to its value.

If more than one neighbour is non-zero, set

$$W(j, k, lv, mv, nv) = W_{min}$$

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where W_{min} is the minimum of the T(w), where w ranges over the non-zero members of {Wul, Wu, Wur, Wl}. Update the lookup table so that for each e and each w in {Wul, Wu, Wur, Wl} if w is not zero and T(e) = T(w), then T(e) is set equal to W_{min}.

Resume the scanning process if $q < Q_{max}$. If $q \geq Q_{max}$ or if the source image has been completely scanned, update the lookup table such that entries with the smallest value are assigned value 1, entries with the next smallest value are assigned value 2, etc.

Perform the lookup table transformation.

$$D(j, k, lv, mv, nv) = LOOK\{W(j, k, lv, mv, nv), 0, 0, SOB\}$$

The number of objects labeled is returned to the application.

Profile:

Scientific

Error codes:

001
011
013
025
041
043
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101

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FEATURE EXTRACTION OPERATOR **LAWS TEXTURE FEATURES**

Description:

Computes Laws texture features of an image.

Name:

laws_texture_features

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB1	low pass filter impulse response array object	ID	in
SOB2	texture mask impulse response array object	ID	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB1 structure:	NBHOOD_ARRAY
SOB2 structure:	NBHOOD_ARRAY
SRC data type:	ND, SD, RD
DST data type:	RD
SOB1 data type:	RD
SOB2 data type:	RD
SOB1 dimension:	2D
SOB2 dimension:	2D

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. The data object repository contains the following Laws texture impulse response arrays:

   LAWS_1

   LAWS_2

   LAWS_3

   LAWS_4

   LAWS_5

   LAWS_6

   LAWS_7

   LAWS_8

   LAWS_9

2. The data object repository contains the following low pass filter impulse response arrays:

   LOW_PASS_FILTER_3x3

   UNIFORM_3x3

   UNIFORM_5x5

   PYRAMID_3x3

   PYRAMID_5x5

3. PIKS tools can be used to generate the following low pass filter impulse response arrays:

   elliptical uniform

   Gaussian

   pyramid

   rectangular uniform

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
T(j, k, l, m, n)	JxKxLxMxN microtexture image
A(j, k, l, m, n)	neighbourhood mean image
V(j, k, l, m, n)	neighbourhood standard deviation image
$H_T(j, k)$	$J_T x K_T$ Laws texture mask impulse response array
$H_L(j, k)$	$J_L x K_L$ low pass filter impulse response array

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Definition:

Each j-k plane of the source image is convolved with a Laws texture mask to create a texture microstructure image. Then, the moving window standard deviation is estimated over each j-k pixel plane of the texture microstructure image by low pass filtering of the microstructure image and a squared pixel version of it.

For all j, k, l, m, n

$$D(j, k, l, m, n) = V(j, k, l, m, n)$$

where

$$T(j, k, l, m, n) = S(j, k, l, m, n) \circledast H_T(j, k)$$

$$A(j, k, l, m, n) = T(j, k, l, m, n) \circledast H_L(j, k)$$

$$V(j, k, l, m, n) = [[[T(j, k, l, m, n)]^2] \circledast H_L(j, k) - [A(j, k, l, m, n)]^2]^{1/2}$$

and $\circledast$ denotes two-dimensional, enclosed array mode convolution as defined by the *convolve_2d* operator.

Profile:

Scientific

Error codes:

011
012
013
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025
041
042
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061

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POINT OPERATOR **LEVEL SLICE**

Description:

Performs level slicing of an image in which destination pixels are set to a specified value if the corresponding source pixels lie within specified limits.

Name:

level_slice

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
us	upper slice amplitude	NP, SP, RP	in
ls	lower slice amplitude	NP, SP, RP	in
sv	slice output value	NP, SP, RP	in
background	background option zero background image background	EP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

The us, ls, and sv amplitude slice parameters shall be of the same data type as the source image.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
us	upper slice amplitude, us > ls
ls	lower slice amplitude
sv	slice output value

Definition:

As shown in the figure, for all x, y, z, t, b

Zero background mode:

$D(x, y, z, t, b) = sv$	$ls \leq S(x, y, z, t, b) \leq us$
$D(x, y, z, t, b) = 0$	$S(x, y, z, t, b) < ls$ or $S(x, y, z, t, b) > us$

Image background mode:

$D(x, y, z, t, b) = sv$	$ls \leq S(x, y, z, t, b) \leq us$
$D(x, y, z, t, b) = S(x, y, z, t, b)$	$S(x, y, z, t, b) < ls$ or $S(x, y, z, t, b) > us$

Profile:

Scientific

Error codes:

001
002
011
013
025
041
045
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102

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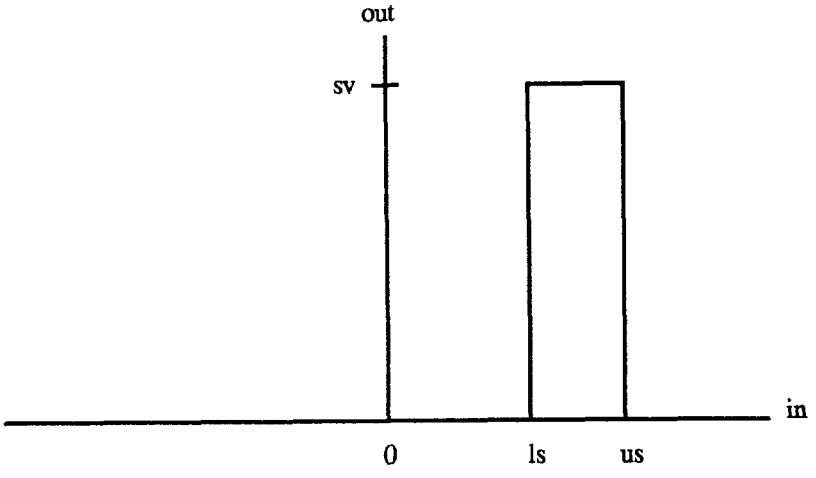

Zero background transformation

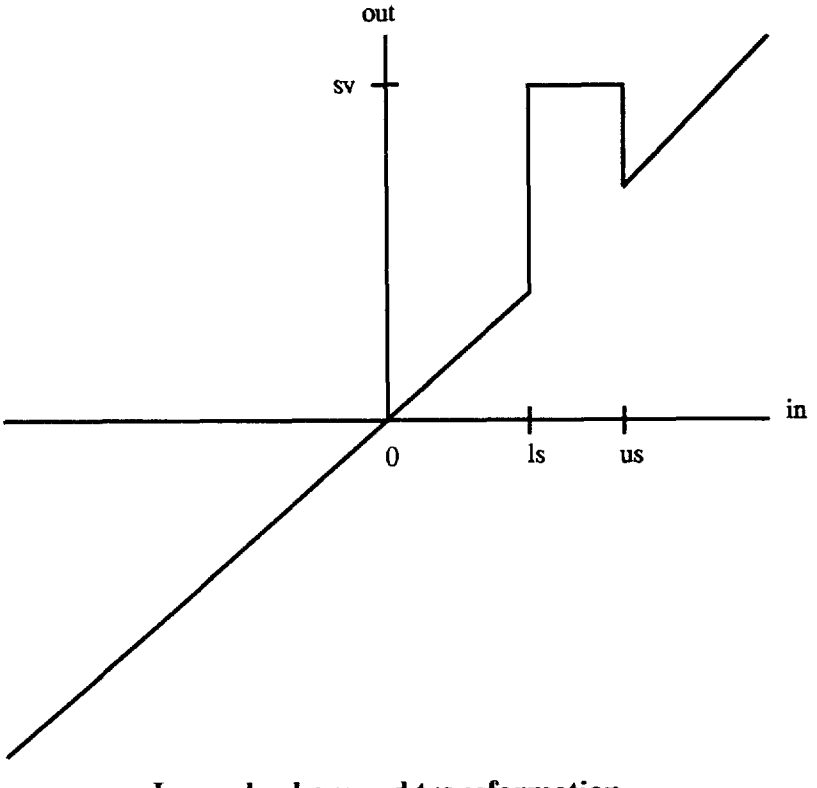

Image background transformation

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ANALYSIS OPERATOR **LINE PROFILE**

Description:

Computes amplitudes of pixels along a line passing through an image.

Name:

line_profile

Parameters:

SRC	source image	ID	in
DOB	array of pixels along line objects	IP	out
start	start point 5-tuple	ID	in
end	end point 5-tuple	ID	in
P	number of samples along line	NP	in

Objects:

SRC structure:	any image
DOB structure:	EXT
SRC data type:	ND, SD, RD
DOB data type:	RP
DOB dimension:	1D

Element functionality:

Index assignment:	yes
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	no
Asynchronous:	yes

Remark:

The parameter tuples contain parameters of the ND data type.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
S(j, k, l, m, n)	JxKxLxMxN operator input image
A(p)	line array, $0 \leq p \leq P-1$
P	number of samples along line, $P > 1$
(js, ks, ls, ms, ns)	start point coordinates, positive integers
(je, ke, le, me, ne)	end point coordinates, positive integer

Definition:

The P samples on the line between the start and end points lie at the following coordinate values for $0 \leq p \leq P-1$:

$$j(p) = js + \frac{p(je-js)}{P-1}$$

$$k(p) = ks + \frac{p(ke-ks)}{P-1}$$

$$l(p) = ls + \frac{p(le-ls)}{P-1}$$

$$m(p) = ms + \frac{p(me-ms)}{P-1}$$

$$n(p) = ns + \frac{p(ne-ns)}{P-1}$$

The array is composed of resampled image points as given by

$$A(p) = RES_5\{S, j(p), k(p), l(p), m(p), n(p)\}$$

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Profile:

Technical

Error codes:

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POINT OPERATOR **LOOKUP**

Description:

Performs lookup table manipulation of an image.

Name:

lookup

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	lookup table object	ID	in
off	source offset entry	NP	in
option	lookup table mode option	SP	in
	1D		
	2D		

Objects:

SRC structure:	any image
DST structure:	see Remarks
SOB structure:	LUT
SRC data type:	ND, SD
DST data type:	same as SOB data type
SOB data type:	BD, ND, SD, RD, CD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	yes
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. The destination data type shall be the same as the table data type, but need not be the same as the source data type.
2. In the 1D mode, the source may have any structure and the destination will have the same structure. In the 2D mode, the source shall be a single band image; the destination image will have multiple bands.
3. The contents of a lookup table can be filled by a lookup table tool.

Nomenclature:

SRC(x, y, z, t, b)	$XxYxZxTxB_S$ source image
DST(x, y, z, t, b)	$XxYxZxTxB_D$ destination image
S(x, y, z, t, b)	$XxYxZxTxB_S$ operator input image
D(x, y, z, t, b)	$XxYxZxTxB_D$ operator output image
E	number of lookup table entries, $E \geq 2$
off	source offset entry, $off \geq 0$

Definition:

For all x, y, z, t, b

1D table mode:

$$D(x, y, z, t, b) = LOOK\{W(x, y, z, t, b), off, 0, SOB\}$$

2D table mode:

$$D(x, y, z, t, b) = LOOK\{W(x, y, z, t, 0), off, b, SOB\}$$

If SRC is a ND data type:

$$W(x, y, z, t, b) = S(x, y, z, t, b)$$

If SRC is a SD data type:

$$W(x, y, z, t, b) = S(x, y, z, t, b) + |IN|$$

The term IN denotes the most negative integer value of the SD representation. For example, for a 16-bit SD integer representation, IN = –32768.

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Profile:

Foundation

Error codes:

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POINT OPERATOR **LOOKUP, INTERPOLATED**

Description:

Performs interpolated lookup table manipulation of an image.

Name:

lookup_interpolated

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	lookup table object	ID	in
eo	source offset bits	NP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB structure:	LUT
SRC data type:	ND, SD
DST data type:	same as SOB data type
SOB data type:	ND, SD, RD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	yes
Chainable element:	yes
Asynchronous:	yes

Remark:

The contents of a lookup table can be filled by a lookup table tool.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
SOB	lookup table identifier
eo	source offset bits, eo ≥ 0
E	number of lookup table entries

Definition:

For all x, y, z, t, b, let p denote an unsigned integer consisting of the eo least significant bits of S(x, y, z, t, b) where $0 \leq p \leq P - 1$ and P = POW{2, eo}. The destination pixel value is computed by linear interpolation of the value of the lookup table entry cell and the value of the next higher index cell.

$$D(x, y, z, t, b) = \frac{p(d - c)}{P} + c$$

where

$$c = LOOK\{s, 0, 0, SOB\}$$

and

$$s = \frac{S(x, y, z, t, b)}{P}$$

If $s < E - 1$,

$$d = LOOK\{s + 1, 0, 0, SOB\}$$

If $s = E - 1$,

$$d = c$$

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Profile:

Technical

Error codes:

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011
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041
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123

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COLOUR OPERATOR **LUMINANCE GENERATION**

Description:

Generates a luminance image from a tri-chromatic colour image.

Name:

luminance_generation

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
option	RGB colour option	SP	in
	linear CCIR illuminant D65 RGB		
	linear CIE illuminant E RGB		
	linear EBU illuminant C RGB		
	linear EBU illuminant D65 RGB		
	linear NTSC illuminant C RGB		
	linear NTSC illuminant D65 RGB		
	linear SMPTE illuminant D65 RGB		
	gamma EBU illuminant C RGB		
	gamma EBU illuminant D65 RGB		
	gamma NTSC illuminant C RGB		
	gamma NTSC illuminant D65 RGB		
	gamma SMPTE illuminant D65 RGB		

Objects:

SRC structure:	COLR, VC, TC, VTC
DST structure:	MON, VOL, TEM, VT
SRC data type:	ND, SD, RD
DST data type	same as SRC data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image

Definition:

For all x, y, z, t

linear CCIR illuminant D65 RGB:

$$D(x, y, z, t, 0) = (0.21261719)S(x, y, z, t, 0) + (0.71520276)S(x, y, z, t, 1) + (0.07218005)S(x, y, z, t, 2)$$

linear CIE illuminant E RGB:

$$D(x, y, z, t, 0) = (0.17701522)S(x, y, z, t, 0) + (0.81232418)S(x, y, z, t, 1) + (0.01066060)S(x, y, z, t, 2)$$

linear EBU illuminant C RGB:

$$D(x, y, z, t, 0) = (0.23272304)S(x, y, z, t, 0) + (0.68867804)S(x, y, z, t, 1) + (0.07859892)S(x, y, z, t, 2)$$

linear EBU illuminant D65 RGB:

$$D(x, y, z, t, 0) = (0.22198294)S(x, y, z, t, 0) + (0.70668844)S(x, y, z, t, 1) + (0.07132862)S(x, y, z, t, 2)$$

linear NTSC illuminant C RGB:

$$D(x, y, z, t, 0) = (0.29889531)S(x, y, z, t, 0) + (0.58662247)S(x, y, z, t, 1) + (0.11448223)S(x, y, z, t, 2)$$

linear NTSC illuminant D65 RGB:

$$D(x, y, z, t, 0) = (0.28964261)S(x, y, z, t, 0) + (0.60567484)S(x, y, z, t, 1) + (0.10468256)S(x, y, z, t, 2)$$

linear SMPTE illuminant D65 RGB:

$$D(x, y, z, t, 0) = (0.21235295)S(x, y, z, t, 0) + (0.70109788)S(x, y, z, t, 1) + (0.08654917)S(x, y, z, t, 2)$$

gamma EBU illuminant C RGB:

$$D(x, y, z, t, 0) = (0.29900000)S(x, y, z, t, 0) + (0.58700000)S(x, y, z, t, 1) + (0.11400000)S(x, y, z, t, 2)$$

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gamma EBU illuminant D65 RGB:

D(x, y, z, t, 0) = (0.29900000)S(x, y, z, t, 0) + (0.58700000)S(x, y, z, t, 1) + (0.11400000)S(x, y, z, t, 2)

gamma NTSC illuminant C RGB:

D(x, y, z, t, 0) = (0.29889531)S(x, y, z, t, 0) + (0.58662247)S(x, y, z, t, 1) + (0.11448223)S(x, y, z, t, 2)

gamma NTSC illuminant D65 RGB:

D(x, y, z, t, 0) = (0.29889531)S(x, y, z, t, 0) + (0.58662247)S(x, y, z, t, 1) + (0.11448223)S(x, y, z, t, 2)

gamma SMPTE illuminant D65 RGB:

D(x, y, z, t, 0) = (0.29900000)S(x, y, z, t, 0) + (0.58700000)S(x, y, z, t, 1) + (0.11400000)S(x, y, z, t, 2)

Profile:

Foundation

Error codes:

001
003
011
013
021
023
041
045
061

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STATIC ARRAY GENERATION TOOL

MARKOV SPECTRUM

Description:

Generates a Markov process two-dimensional power spectrum static array object.

Name:

markov_spectrum

Parameters:

DOB	power spectrum static array object	ID	out
array_size	array size 5-tuple	ID	in
cc	column index correlation factor	RP	in
rc	row index correlation factor	RP	in
option	symmetry option elliptical separable	SP	in

Object:

DOB structure:	STATIC_ARRAY
DOB data type:	CD
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The power spectrum origin is at (0,0) in correspondence to the standard definition of the discrete Fourier transform.
2. The parameter tuple contains parameters of the ND data type.

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Nomenclature:

A(c, r)	CxR power spectrum array
C	number of array columns, positive even integer
R	number of array rows, positive even integer
cc	column index correlation factor
rc	row index correlation factor

Definition:

For

$$0 \le c \le C - 1$$

$$0 \le r \le R - 1$$

$$A(c, r) = \mathcal{W}(c, r) \qquad 0 \le c \le C/2 \text{ and } 0 \le r \le R/2$$

$$A(c, r) = \mathcal{W}(C-c, r) \qquad 1 + C/2 \le c \le C - 1 \text{ and } 0 \le r \le R/2$$

$$A(c, r) = \mathcal{W}(c, R-r) \qquad 0 \le c \le C/2 \text{ and } 1 + R/2 \le r \le R - 1$$

$$A(c, r) = \mathcal{W}(C-c, R-r) \qquad 1 + C/2 \le c \le C - 1 \text{ and } 1 + R/2 \le r \le R - 1$$

where for elliptical symmetry

$$\mathcal{W}(c, r) = \frac{1}{\sqrt{(rc)(cc)}} \left[\frac{2}{1 + [r/rc]^2 + [c/cc]^2} \right] \qquad 1 \le r \le 1 + R/2 \text{ and } 1 \le c \le 1 + C/2$$

and for separable symmetry

$$\mathcal{W}(c, r) = \frac{4\,(rc)(cc)}{[\,(rc)^2 + r^2\,]\,[\,(cc)^2 + c^2\,]} \qquad 1 \le r \le 1 + R/2 \text{ and } 1 \le c \le 1 + C/2$$

Profile:

Scientific

Error codes:

001
003
012
014
024
044
115
116

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ANALYSIS OPERATOR

MOMENTS

Description:

Computes the mean and standard deviation moments of an image.

Name:

moments

Parameters:

SRC	source image	ID	in
mean	mean value	RP	out
deviation	standard deviation value	RP	out

Object:

SRC structure:	any image
SRC data type:	ND, SD, RD

Element functionality:

Index assignment:	no
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	vreg
Asynchronous:	yes

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
S(x, y, z, t, b)	XxYxZxTxB operator input image
m	mean value
s	standard deviation value, $s \geq 0$

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Definition:

For all x, y, z, t, b

$$m = \frac{1}{(X)\,(Y)\,(Z)\,(T)\,(B)} \sum_{x=0}^{X-1} \sum_{y=0}^{Y-1} \sum_{z=0}^{Z-1} \sum_{t=0}^{T-1} \sum_{b=0}^{B-1} S(x, y, z, t, b)$$

$$s = \left[\frac{1}{(X)\,(Y)\,(Z)\,(T)\,(B)} \sum_{x=0}^{X-1} \sum_{y=0}^{Y-1} \sum_{z=0}^{Z-1} \sum_{t=0}^{T-1} \sum_{b=0}^{B-1} [S(x, y, z, t, b) - m]^2 \right]^{1/2}$$

Profile:

Foundation

Error codes:

011
013
041
061

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POINT OPERATOR **MONADIC, ARITHMETIC**

Description:

Performs monadic arithmetic combination of an integer or real image and an integer or real constant.

Name:

monadic_arithmetic

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
c	value of constant	NP, SP, RP	in
option	combination option	SP	in
	addition by constant		
	addition by constant, scaled		
	division by constant		
	division of constant		
	maximum with constant		
	minimum with constant		
	multiplication by constant		
	subtraction by constant		
	subtraction by constant, scaled		
	subtraction of constant		
	subtraction of constant, scaled		

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Hetrogenous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. Result of division by zero is implementation dependent.
2. The constant must be of the same data type as the source image.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
c	constant

Definition:

Addition by constant:

For all x, y, z, t, b

$$D(x, y, z, t, b) = S(x, y, z, t, b) + c$$

Addition by constant, scaled:

$$D(x, y, z, t, b) = \frac{S(x, y, z, t, b) + c}{2}$$

Division by constant:

$$D(x, y, z, t, b) = \frac{S(x, y, z, t, b)}{c}$$

Division of constant:

$$D(x, y, z, t, b) = \frac{c}{S(x, y, z, t, b)}$$

Maximum with constant:

$D(x, y, z, t, b) = S(x, y, z, t, b)$ if $S(x, y, z, t, b) \geq c$

$D(x, y, z, t, b) = c$ if $S(x, y, z, t, b) < c$

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Minimum with constant:

$D(x, y, z, t, b) = c$ if $S(x, y, z, t, b) \geq c$

$D(x, y, z, t, b) = S(x, y, z, t, b)$ if $S(x, y, z, t, b) < c$

Multiplication by constant:

$$D(x, y, z, t, b) = S(x, y, z, t, b) \times c$$

Subtraction by constant:

$$D(x, y, z, t, b) = S(x, y, z, t, b) - c$$

Subtraction by constant, scaled:

$$D(x, y, z, t, b) = \frac{S(x, y, z, t, b) - c}{2}$$

Subtraction of constant:

$$D(x, y, z, t, b) = c - S(x, y, z, t, b)$$

Subtraction of constant, scaled:

$$D(x, y, z, t, b) = \frac{c - S(x, y, z, t, b)}{2}$$

Profile:

Foundation

Error codes:

001
003
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045
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172

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POINT OPERATOR **MONADIC, COMPLEX**

Description:

Performs monadic arithmetic combination of a complex image and a complex constant.

Name:

monadic_complex

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
c	value of constant	CP	in
option	combination option	SP	in
	addition by constant		
	division by constant		
	division of constant		
	multiplication by constant		
	subtraction by constant		
	subtraction of constant		

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	CD
DST data type:	CD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

Result of division by zero is implementation dependent.

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Nomenclature:

SRC (x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxS destination image
S(x, y, z, t, b)	XxYxZxTxS first operator input image
D(x, y, z, t, b)	XxYxZxTxS operator output image
c	constant

Definition:

For all x, y, z, t, b

Addition by constant:

$$REAL\{D(x, y, z, t, b)\} = REAL\{S(x, y, z, t, b)\} + REAL\{c\}$$

$$IMAG\{D(x, y, z, t, b)\} = IMAG\{S(x, y, z, t, b)\} + IMAG\{c\}$$

Division by constant:

$$REAL\{D(x, y, z, t, b)\} = \frac{[REAL\{S(x, y, z, t, b)\}][REAL\{c\}] + [IMAG\{S(x, y, z, t, b)\}][IMAG\{c\}]}{[REAL\{c\}]^2 + [IMAG\{c\}]^2}$$

$$IMAG\{D(x, y, z, t, b)\} = \frac{[IMAG\{S(x, y, z, t, b)\}][REAL\{c\}] - [REAL\{S(x, y, z, t, b)\}][IMAG\{c\}]}{[REAL\{c\}]^2 + [IMAG\{c\}]^2}$$

Division of constant:

$$REAL\{D(x, y, z, t, b)\} = \frac{[REAL\{c\}][REAL\{S(x, y, z, t, b)\}] + [IMAG\{c\}][IMAG\{S(x, y, z, t, b)\}]}{[REAL\{S(x, y, z, t, b)\}]^2 + [IMAG\{S(x, y, z, t, b)\}]^2}$$

$$IMAG\{D(x, y, z, t, b)\} = \frac{[IMAG\{c\}][REAL\{S(x, y, z, t, b)\}] - [REAL\{c\}][IMAG\{S(x, y, z, t, b)\}]}{[REAL\{S(x, y, z, t, b)\}]^2 + [IMAG\{S(x, y, z, t, b)\}]^2}$$

Multiplication by constant:

$$REAL\{D(x, y, z, t, b)\} = [REAL\{S(x, y, z, t, b)\}][REAL\{c\}] - [IMAG\{S(x, y, z, t, b)\}][IMAG\{c\}]$$

$$IMAG\{D(x, y, z, t, b)\} = [REAL\{S(x, y, z, t, b)\}][IMAG\{c\}] + [IMAG\{S(x, y, z, t, b)\}][REAL\{c\}]$$

Subtraction by constant:

$$REAL\{D(x, y, z, t, b)\} = REAL\{S(x, y, z, t, b)\} - REAL\{c\}$$

$$IMAG\{D(x, y, z, t, b)\} = IMAG\{S(x, y, z, t, b)\} - IMAG\{c\}$$

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Subtraction of constant:

REAL{D(x, y, z, t, b)} = REAL{c} – REAL{S(x, y, z, t, b)}

IMAG{D(x, y, z, t, b)} = IMAG{c} – IMAG{S(x, y, z, t, b)}

Profile:

Technical

Error codes:

001
003
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POINT OPERATOR **MONADIC, LOGICAL**

Description:

Performs monadic logical combination of a Boolean or integer image and a constant.

Name:

monadic_logical	monadic_logical_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
c	value of constant	BP, NP, SP	in
option	combination option	SP	in
	bitwise AND		
	bitwise NAND		
	bitwise NOR		
	bitwise OR		
	bitwise XOR		
	Boolean intersection		
	Boolean union		

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SRC data type:	BD, ND, SD	BD
DST data type:	same as SRC data type	BD

Element functionality:

Index assignment:	no	no
Match point:	yes	no
ROI control:	yes	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

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Remark:

The constant must be of the same data type as the source.

Nomenclature:

SRC (x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxS destination image
S(x, y, z, t, b)	XxYxZxTxS operator input image
D(x, y, z, t, b)	XxYxZxTxS operator output image
c	constant
s(p)	p-th bit of integer pixel of operator input image
c(p)	p-th bit of integer pixel of operator output image
d(p)	p-th bit of integer pixel of constant
bs	number of source bits per pixel, $bs \geq 1$
p	integer bit index, $0 \leq p \leq bs - 1$

Definition:

For all x, y, z, t, b

Bitwise AND:

For $0 \leq p \leq bs - 1$

$s(p) = BITEXT\{S(x, y, z, t, b), p\}$

$c(p) = BITEXT\{c, p\}$

$d(p) = [s(p)] \oplus [c(p)]$

$D(x, y, z, t, b) = BITINS\{D(x, y, z, t, b), d(p), p\}$

Bitwise NAND:

For $0 \leq p \leq bs - 1$

$s(p) = BITEXT\{S(x, y, z, t, b), p\}$

$c(p) = BITEXT\{c, p\}$

$d(p) = \overline{[s(p)] \oplus [c(p)]}$

$D(x, y, z, t, b) = BITINS\{D(x, y, z, t, b), d(p), p)\}$

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Bitwise NOR:

For $0 \leq p \leq bs - 1$

$s(p) = BITEXT\{S(x, y, z, t, b), p\}$

$c(p) = BITEXT\{c, p\}$

$d(p) = \overline{[s(p)] \ominus [c(p)]}$

$D(x, y, z, t, b) = BITINS\{D(x, y, z, t, b), d(p), p)\}$

Bitwise OR:

For $0 \leq p \leq bs - 1$

$s(p) = BITEXT\{S(x, y, z, t, b), p\}$

$c(p) = BITEXT\{c, p\}$

$d(p) = [s(p)] \ominus [c(p)]$

$D(x, y, z, t, b) = BITINS\{D(x, y, z, t, b), d(p), p\}$

Bitwise XOR:

For $0 \leq p \leq bs - 1$

$s(p) = BITEXT\{S(x, y, z, t, b), p\}$

$c(p) = BITEXT\{c\}$

$d(p) = [s(p)] \otimes [c(p)]$

$D(x, y, z, t, b) = BITINS\{D(x, y, z, t, b), d(p), p\}$

Boolean intersection:

$D(x, y, z, t, b) = [S(x, y, z, t, b)] \cap [c]$

Boolean union:

$D(x, y, z, t, b) = [S(x, y, z, t, b)] \cup [c]$

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Profile:

Foundation	monadic_logical
Technical	monadic_logical_roi

Error codes:

001
003
011
013
025
041
045
061
101

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MORPHOLOGICAL OPERATOR **MORPHIC PROCESSOR**

Description:

Performs morphological processing on a Boolean image using a 3 x 3 hit or miss transformation with a specified transformation table.

Name:

morphic_processor	morphic_processor_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	hit or miss transformation lookup table object	ID	in
iterations	number of iterations	SP	in
cycles	number of cycles	NP	out

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SOB structure:	LUT	LUT
SRC data type:	BD	BD
DST data type:	BD	BD
SOB input data type:	SD	SD
SOB output data type	BD	BD

Element functionality:

Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

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Remarks:

1. If the "iterations" number is set to −1, the operation is performed until the destination image is unchanged after successive iterations. The parameter "cycles" is the number of iterations performed.
2. If the parameter "iterations" is set to zero, the source image is copied to the destination image without modification. The "interations" parameters must be greater than −2.
3. The *import_lut* utility can be used to create a 512 entry hit or miss transportation table.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
P	Boolean state of centre pixel of 3x3 neighbourhood in j-k plane of S
P_0	Boolean state of east neighbour of P
P_1	Boolean state of northeast neighbour of P
P_2	Boolean state of north neighbour of P
P_3	Boolean state of northwest neighbour of P
P_4	Boolean state of west neighbour of P
P_5	Boolean state of southwest neighbour of P
P_6	Boolean state of south neighbour of P
P_7	Boolean state of southeast neighbour of P
Q	Boolean state of output image pixel corresponding spatially to P
it	number of iterations, $-1 \leq$ it

Definition:

The morphic processor conceptual model is shown below. For all l, m, n, at each pixel coordinate (j, k), the pixel stacker forms nine data bits in an intermediate pixel array I(j, k, l, m, n). The intermediate pixel is a mapping of the Boolean states of the source image pixel and its eight nearest neighbours, whereby a Boolean TRUE state is mapped to a 1 state bit and a Boolean FALSE state is mapped to a 0 state bit. The intermediate pixel is passed through a 512 entry lookup table that generates a destination pixel whose Boolean state is Q.

For all l, m, n

D(j, k, l, m, n) = LOOK{I(j, k, l, m, n), 0, 0, table}

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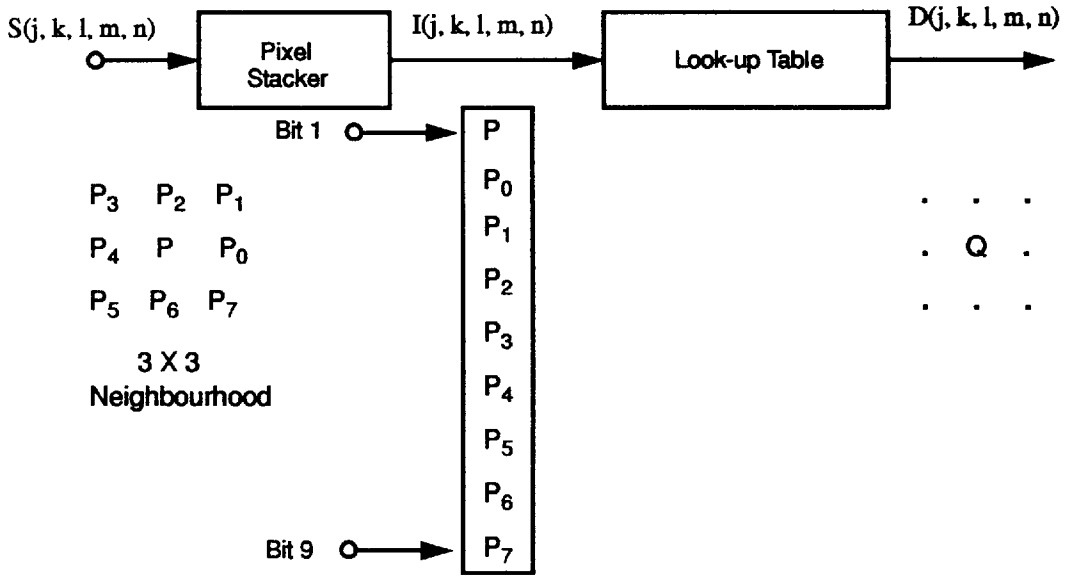

Morphic processor conceptual model

Profile:

Foundation	morphic_processor
Technical	morphic_processor_roi

Error codes:

001
011
012
013
014
022
025
041
042
043
061
101

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MORPHOLOGICAL OPERATOR

MORPHOLOGY

Description:

Performs connectivity-constrained morphological operations, such as shrinking and thinning, on a Boolean image using hit or miss transformations within a 3 x 3 window.

Name:

morphology morphology_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
iterations	number of iterations	SP	in
cycles	number of cycles	NP	out
option	morphological option	SP	in
	end grow		
	end grow, east		
	end grow, north		
	end grow, northeast		
	end grow, northwest		
	end grow, south		
	end grow, southeast		
	end grow, southwest		
	end grow, west		
	exoskeleton		
	exothin		
	shrink		
	skeleton		
	thicken		
	thin		

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SRC data type:	BD	BD
DST data type:	BD	BD

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Element functionality:

Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	yes	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Remark:

If the "iterations" number is set to –1, the operation is performed until the destination image is unchanged after successive iterations. The parameter "cycles" is the number of iterations performed. If the parameter "iterations" is set to zero, the source image is copied to the destination image without modification. The "iterations" parameter must be greater than –2.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
P	Boolean state of center pixel of 3x3 neighbourhood in j-k plane of S
P_0	Boolean state of east neighbour of P
P_1	Boolean state of northeast neighbour of P
P_2	Boolean state of north neighbour of P
P_3	Boolean state of northwest neighbour of P
P_4	Boolean state of west neighbour of P
P_5	Boolean state of southwest neighbour of P
P_6	Boolean state of south neighbour of P
P_7	Boolean state of southeast neighbour of P
M	Boolean state of center pixel of 3x3 neighbourhood in mark plane
M_0	Boolean state of east neighbour of M
M_1	Boolean state of northeast neighbour of M
M_2	Boolean state of north neighbour of M
M_3	Boolean state of northwest neighbour of M
M_4	Boolean state of west neighbour of M
M_5	Boolean state of southwest neighbour of M
M_6	Boolean state of south neighbour of M
M_7	Boolean state of southeast neighbour of M
Q	Boolean state of output image pixel corresponding spatially to P

P_3 P_2 P_1	M_3 M_2 M_1	. . .
P_4 P P_0	M_4 M M_0	. Q .
P_5 P_6 P_7	M_5 M_6 M_7	. . .
input	intermediate	output

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Definition:

General operation:

For all j, k, the Boolean states (TRUE or FALSE) of the nine pixels in a 3x3 pixel neighbourhood of the source image, centered about coordinate (j, k) are logically combined to produce the state of a pixel, M, at coordinate (j, k) in a conceptual intermediate plane, which is conditionally marked for erosion or dilation. For all j, k, the Boolean states of the nine marked pixels in a 3x3 pixel neighbourhood of the intermediate plane, centered at coordinate (j, k) and the source center pixel P are logically combined to produce the Boolean state of an output pixel. The output image is in the Boolean FALSE state in its first two and last two rows and columns. The general operation is repeated "iterations" number of times, or until the result becomes unchanged upon repeated iterations.

For all j, k, l, m, n, the following operations are performed:

End grow: Grow the ends of lines.

End grow is performed by sequentially growing the ends of all lines by a single pixel per iteration along each of eight compass directions in the following order:

north
northeast
east
southeast
south
southwest
west
northwest

The operation is repeated for each iteration. See definitions below of the eight compass end grow operations.

End grow, east: Grow the end of a line by a single pixel per iteration along its east end.

The conditional mark is formed by the logical combination

$$M = P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap P_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7$$

The uncondional output is formed by the logical combination

$$Q = P \cup (\overline{M} \cap M_4)$$

End grow, north: Grow the end of a line by a single pixel per iteration along its north end.

$$M = P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap P_6 \cap \overline{P}_7$$

$$Q = P \cup (\overline{M} \cap M_6)$$

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End grow, northeast: Grow the end of a line by a single pixel per iteration along its northeast end.

$$M = P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap P_5 \cap \overline{P}_6 \cap \overline{P}_7$$

$$Q = P \cup (\overline{M} \cap M_5)$$

End grow, northwest: Grow the end of a line by a single pixel per iteration along its northwest end.

$$M = P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap P_7$$

$$Q = P \cup (\overline{M} \cap M_7)$$

End grow, south: Grow the end of a line by a single pixel per iteration along its south end.

$$M = P \cap \overline{P}_0 \cap \overline{P}_1 \cap P_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7$$

$$Q = P \cup (\overline{M} \cap M_2)$$

End grow, southeast: Grow the end of a line by a single pixel per iteration along its southeast end.

$$M = P \cap \overline{P}_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap P_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7$$

$$Q = P \cup (\overline{M} \cap M_3)$$

End grow, southwest: Grow the end of a line by a single pixel per iteration along its southwest end.

$$M = P \cap \overline{P}_0 \cap P_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7$$

$$Q = P \cup (\overline{M} \cap M_1)$$

End grow, west: Grow the end of a line by a single pixel per iteration along its west end.

$$M = P \cap P_0 \cap \overline{P}_1 \cap \overline{P}_2 \cap \overline{P}_3 \cap \overline{P}_4 \cap \overline{P}_5 \cap \overline{P}_6 \cap \overline{P}_7$$

$$Q = P \cup (\overline{M} \cap M_0)$$

Exoskeleton: Skeletonize the background of an image.

Step 1: Complement the source image.

Step 2: Skeletonize the complemented source image using the skeleton operation defined below.

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Exothin: Thin the background of an image.

Step 1: Complement the source image.

Step 2: Thin the complemented source image "iterations" times using the thin operation defined below.

Step 3: Perform the hit-or-miss diagonal fill operation on the result of step 3.

The final diagonal fill operation is performed once after "iterations" thin iterations to eliminate eight-connectivity of background pixels.

Shrink: Complement TRUE pixels such that an object without holes erodes to a single pixel at or near its center of mass, and an object with holes erodes to a connected ring lying midway between each hole and its nearest outer boundary. Each iteration complements, at most, a single pixel thick outer boundary of an object.

The Conditional Mark Table lists all patterns, as indicated by the letter S in the table column, which are conditionally marked for complementation. The output pixel is formed by the logical combination

$$Q = P \cap [\overline{M} \cup C(M, M_0, M_1, M_2, M_3, M_4, M_5, M_6, M_7)]$$

where $C(M, M_0, M_1, M_2, M_3, M_4, M_5, M_6, M_7)$ is a complementation inhibiting logical variable, as defined in the shrink and thin Unconditional Mark Table.

Skeleton: Complement TRUE pixels such that the residual set of connected TRUE pixels is equi-distant from the nearest orthogonal points of the original object boundary. Each iteration erodes, at most, a single pixel thick outer boundary of an object.

The Conditional Mark Table lists all patterns, as indicated by the letter K in the table column, which are conditionally marked for complementation. The output pixel is formed by the logical combination

$$Q = P \cap [\overline{M} \cup C(M, M_0, M_1, M_2, M_3, M_4, M_5, M_6, M_7)]$$

where $C(M, M_0, M_1, M_2, M_3, M_4, M_5, M_6, M_7)$ is a complementation inhibiting logical variable, as defined in the skeltonize Unconditional Mark Table.

Thicken: Dilate objects with the restriction that previously unconnected objects do not fuse. This is accomplished by performing an exothin operation on the background followed by a logical complement operation. Each iteration dilates, at most, a single pixel thick outer boundary of an object.

Step 1: Perform exothin operation on source image.

Step 2: Complement the result of Step 1.

Thin: Complement TRUE black pixels such that an object without holes erodes to a minimally connected stroke located equi-distant from its nearest outer boundaries, and an object with holes erodes to a minimally connected ring midway between each hole and its nearest outer boundary. Each iteration complements, at most, a single pixel thick outer bounday of an object.

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The Conditional Mark Table lists all patterns, as indicated by the letter T in the table column, which are conditionally marked for complementation. The output pixel is formed by the logical combination

$$Q = P \cap [\overline{M} \cup C(M, M_0, M_1, M_2, M_3, M_4, M_5, M_6, M_7)]$$

where $C(M, M_0, M_1, M_2, M_3, M_4, M_5, M_6, M_7)$ is a complementation inhibiting logical variable, as defined in the shrink and thin Unconditional Mark Table.

Profile:

Technical	morphology
Technical	morphology_roi

Error codes:

001
003
011
013
025
041
043
061

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Shrink, thin, and Skeletonize conditional mark patterns – M = 1, if hit

Table	Pattern							
	001	100	000	000				
S	010	010	010	010				
	000	000	100	001				
S	000	010	000	000				
	011	010	110	010				
	000	000	000	010				
	001	011	110	100	000	000	000	000
S	011	010	010	110	110	010	010	011
	000	000	000	000	100	110	011	001
	010	010	000	000				
T K	011	110	110	011				
	000	000	010	010				
	001	111	100	000				
S T K	011	010	110	010				
	001	000	100	111				
	110	010	011	001				
S T	011	011	110	011				
	000	001	000	010				
	011	110	000	000				
S T	011	110	110	011				
	000	000	110	011				
	110	011						
S T	011	110						
	001	100						
	111	011	111	110	100	000	000	001
S T K	011	011	110	110	110	110	011	011
	000	001	000	100	110	111	111	011
	111	111	100	001				
S T K	011	110	110	011				
	001	100	111	111				
	011	111	110	000				
S T K	011	111	110	111				
	011	000	110	111				
	111	011	111	111	111	110	100	001
S T K	011	011	111	111	110	110	111	111
	011	111	100	001	110	111	111	011
	111	111	111	101				
S T K	011	111	110	111				
	111	101	111	111				
	111	111	110	011				
K	111	111	111	111				
	011	110	111	111				

NOTE – "1" indicates Boolean TRUE; "0" indicates Boolean FALSE

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Shrink and thin unconditional mark patterns

$C(M, M_0, M_1, M_2, M_3, M_4, M_5, M_6, M_7) = 1$, if hit

Pattern

Spur

```
0 0 M      M 0 0
0 M 0      0 M 0
0 0 0      0 0 0
```

Single 4-Connection

```
0 0 0      0 0 0
0 M 0      0 M M
0 M 0      0 0 0
```

L Cluster (thin only)

```
0 0 M   0 M M   M M 0   M 0 0   0 0 0   0 0 0   0 0 0   0 0 0
0 M M   0 M 0   0 M 0   M M 0   M M 0   0 M 0   0 M 0   0 M M
0 0 0   0 0 0   0 0 0   0 0 0   M 0 0   M M 0   0 M M   0 0 M
```

4-Connected Offset

```
0 M M   M M 0   0 M 0   0 0 M
M M 0   0 M M   0 M M   0 M M
0 0 0   0 0 0   0 0 M   0 M 0
```

Spur Corner Cluster

```
0 A M   M B 0   0 0 M   M 0 0
0 M B   A M 0   A M 0   0 M B
M 0 0   0 0 M   M B 0   0 A M
```

Corner Cluster

```
M M D
M M D
D D D
```

Tee Branch

```
D M 0   0 M D   0 0 D   D 0 0   D M D   0 M 0   0 M 0   D M D
M M M   M M M   M M M   M M M   M M 0   M M 0   0 M M   0 M M
D 0 0   0 0 D   0 M D   D M 0   0 M 0   D M D   D M D   0 M 0
```

Vee Branch

```
M D M   M D C   C B A   A D M
D M D   D M B   D M D   B M D
A B C   M D A   M D M   C D M
```

Diagonal Branch

```
D M 0   0 M D   D 0 M   M 0 D
0 M M   M M 0   M M 0   0 M M
M 0 D   D 0 M   0 M D   D M 0
```

NOTE 1 – "1" indicates Boolean TRUE; "0" indicates Boolean FALSE

NOTE 2 – $A \cup B = 1$ $A \cup B \cup C = 1$ $D = 0 \cup 1$ ("don't care" state)

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Skeletonize unconditional mark patterns

$C(M, M_0, M_1, M_2, M_3, M_4, M_5, M_6, M_7) = 1$, if hit

Pattern			
Spur			
0 0 0 0 M 0 0 0 M	0 0 0 0 M 0 M 0 0	0 0 M 0 M 0 0 0 0	M 0 0 0 M 0 0 0 0
Single 4-Connection			
0 0 0 0 M 0 0 M 0	0 0 0 0 M M 0 0 0	0 0 0 M M 0 0 0 0	0 M 0 0 M 0 0 0 0
L corner			
0 M 0 0 M M 0 0 0	0 M 0 M M 0 0 0 0	0 0 0 0 M M 0 M 0	0 0 0 M M 0 0 M 0
Corner Cluster			
D M M D M M D D D	D D D M M D M M D	M M D M M D D D D	D D D D M M D M M
Tee			
D M D M M M D 0 0	D M D M M D D M D	D D D M D M D M D	D M D D M M D M D
Vee Branch			
M D M D M D A B C	M D C D M B M D A	C B A D M D M D M	A D M B M D C D M
Diagonal Branch			
D M 0 0 M M M 0 D	0 M D M M 0 D 0 M	D 0 M M M 0 0 M D	M 0 D 0 M M D M 0

NOTE 1 – "1" indicates Boolean TRUE; "0" indicates Boolean FALSE

NOTE 2 – $A \cup B \cup C = 1$ $D = 0 \cup 1$ ("don't care" state)

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MORPHOLOGICAL OPERATOR — NEIGHBOUR COUNT

Description:

Counts the number of TRUE state neighbours of a TRUE state pixel within a structuring element in a Boolean image.

Name:

neighbour_count

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	structuring element array object	ID	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB structure:	NBHOOD_ARRAY
SRC data type:	BD
DST data type:	SD
SOB data type:	BD
SOB dimension:	2D

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

The *neighbour_count* operator counts the center pixel within the neighbourhood if it is TRUE.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
H(j, k)	J_HxK_H structuring element array
(j_k, k_k)	key pixel coordinate

Definition:

Enclosed structuring element array mode:

The 2D structuring element array is rotated 180 degrees and translated with respect to the j-k pixel plane of the source image. A destination pixel is computed whenever all elements of the array lie within the bounds of the source image; all other destination pixels are set to zero. The destination image size is the same as the source image size.

For all l, m, n, and for

$$j_c \le j \le J - 1 - j_c \quad \text{if } J_H \text{ is odd}$$

$$j_c - 1 \le j \le J - 1 - j_c \quad \text{if } J_H \text{ is even}$$

$$k_c \le k \le K - 1 - k_c \quad \text{if } K_H \text{ is odd}$$

$$k_c - 1 \le k \le K - 1 - k_c \quad \text{if } K_H \text{ is even}$$

if

$$S(j', k', l, m, n) = \text{TRUE}$$

then

$$D(j, k, l, m, n) = \sum_{j'} \sum_{k'} \tilde{S}(j', k', l, m, n)\, \tilde{H}(j - j' + j_c, k - k' + k_c)$$

where

$$\tilde{S}(j, k, l, m, n) = 1 \quad \text{if } S(j, k, l, m, n) = \text{TRUE}$$

$$\tilde{S}(j, k, l, m, n) = 0 \quad \text{if } S(j, k, l, m, n) = \text{FALSE}$$

$$\tilde{H}(j, k) = 1 \quad \text{if } H(j, k) = \text{TRUE}$$

$$\tilde{H}(j, k) = 0 \quad \text{if } H(j, k) = \text{FALSE}$$

For all l, m, n and for

$$j < j_c \text{ or } j > J - 1 - j_c \quad \text{if } J_H \text{ is odd}$$

$$j < j_c - 1 \text{ or } j > J - 1 - j_c \quad \text{if } J_H \text{ is even}$$

$$k < k_c \text{ or } k > K - 1 - k_c \quad \text{if } K_H \text{ is odd}$$

$$k < k_c - 1 \text{ or } k > K - 1 - k_c \quad \text{if } K_H \text{ is even}$$

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$$D(j, k, l, m, n) = 0$$

where

$$j_c = \frac{J_H - 1}{2} \quad \text{if } J_H \text{ is odd}$$

$$j_c = \frac{J_H}{2} \quad \text{if } J_H \text{ is even}$$

$$k_c = \frac{K_H - 1}{2} \quad \text{if } K_H \text{ is odd}$$

$$k_c = \frac{K_H}{2} \quad \text{if } K_H \text{ is even}$$

The summation limits are

$$MAX\{0, j - j_c\} \le j' \le MIN\{J - 1, j + j_c\} \quad \text{if } J_H \text{ is odd}$$

$$MAX\{0, j - j_c + 1\} \le j' \le MIN\{J-1, j + j_c\} \quad \text{if } J_H \text{ is even}$$

$$MAX\{0, k - k_c\} \le k' \le MIN\{K-1, k + k_c\} \quad \text{if } K_H \text{ is odd}$$

$$MAX\{0, k - k_c + 1\} \le k' \le MIN\{K-1, k + k_c\} \quad \text{if } K_H \text{ is even}$$

The following is an example of the neighbour count process for a particular placement of a 3x3 structuring element:

F T F	F T T	. . .
T T T	T T F	. 3 .
F T F	T F F	. . .
structuring element	pixel input	pixel output

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Key pixel, zero exterior mode:

The 2D structuring element array is rotated 180 degrees and translated with respect to the j-k pixel plane of the source image. A destination pixel is computed whenever the the key pixel of the array is over a source pixel. The destination image size is the same as the source image size. Source pixels outside the j-k pixel plane are assumed to be FALSE valued.

For all l, m, n, and for

$$\mathrm{MAX}\{0, -j_k\} \le j \le \mathrm{MIN}\{J-1, J-1+j_k\}$$

$$\mathrm{MAX}\{0, -k_k\} \le k \le \mathrm{MIN}\{K-1, K-1+k_k\}$$

if

$$S(j', k', l, m, n) = \mathrm{TRUE}$$

then

$$D(j, k, l, m, n) = \sum_{j'} \sum_{k'} \tilde{S}(j', k', l, m, n)\, \tilde{H}(j - j' + j_k, k - k' + k_k)$$

where

$$\tilde{S}(j, k, l, m, n) = 1 \quad \text{if } S(j, k, l, m, n) = \mathrm{TRUE}$$

$$\tilde{S}(j, k, l, m, n) = 0 \quad \text{if } S(j, k, l, m, n) = \mathrm{FALSE}$$

$$\tilde{H}(j, k) = 1 \quad \text{if } H(j, k) = \mathrm{TRUE}$$

$$\tilde{H}(j, k) = 0 \quad \text{if } H(j, k) = \mathrm{FALSE}$$

For all l, m, n, and for

$$j < \mathrm{MAX}\{0, -j_k\} \text{ or } j > \mathrm{MIN}\{J-1, j+j_k\}$$

$$k < \mathrm{MAX}\{0, -k_k\} \text{ or } k > \mathrm{MIN}\{K-1, k+k_k\}$$

$$D(j, k, l, m, n) = 0$$

The summation limits are

$$\mathrm{MAX}\{0,\ j - J_H + j_k + 1\} \le j' \le \mathrm{MIN}\{J-1,\ j+j_k\}$$

$$\mathrm{MAX}\{0,\ k - K_H + k_k + 1\} \le k' \le \mathrm{MIN}\{K-1, k+k_k\}$$

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Profile:

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Error codes:

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POINT OPERATOR **NOISE COMBINATION**

Description:

Adds uniform or Gaussian distributed white noise to an image such that the noisy image has a prescribed signal-to-noise ratio.

Name:

noise_combination

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
snr	signal-to-noise ratio	RP	in
option	probability density option	SP	in
	Gaussian		
	uniform		

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	RD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	yes
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	JxKxLxMxN operator input image
D(x, y, z, t, b)	JxKxLxMxN operator output image
U(x, y, z, t, b)	XxYxZxTxB noise image
snr	signal-to-noise ratio, snr > 0
S_P	image power, $S_p > 0$

Definition:

Step 1:

Measure the image signal power.

$$S_P = \sum_{x=0}^{X-1} \sum_{y=0}^{Y-1} \sum_{z=0}^{Z-1} \sum_{t=0}^{T-1} \sum_{b=0}^{B-1} [S(x, y, z, t, b) - M_S]^2$$

where

$$M_S = \frac{1}{(X)(Y)(Z)(T)(B)} \sum_{x=0}^{X-1} \sum_{y=0}^{Y-1} \sum_{z=0}^{Z-1} \sum_{t=0}^{T-1} \sum_{b=0}^{B-1} S(x, y, z, t, b)$$

Step 2:

Generate a noise image, U(x, y, z, t, b), according to the probability density option.

$$U(x, y, z, t, b) = a$$

where a is the output of a random number generator for the specified probability density, p(a).

Gaussian density:

$$p(a) = \frac{1}{\sqrt{2\pi}g} \mathrm{EXP}\left\{ -\frac{1}{2}\left[\frac{a}{g}\right]^2 \right\}$$

where

$$g = \left[\frac{S_P}{snr}\right]^{1/2}$$

Uniform density:

$$p(a) = \left[\frac{1}{2u}\right]^{1/2} \qquad -u \le a \le u$$

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where

$$u = \left[\frac{3S_P}{snr}\right]^{1/2}$$

Step 3:

Add the noise array to the source image.

$$D(x, y, z, t, b) = S(x, y, z, t, b) + U(x, y, z, t, b)$$

Profile:

Scientific

Error codes:

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MORPHOLOGICAL OPERATOR **OPEN CLOSE**

Description:

Performs opening or closing on a pixel plane of an image with a rectangular structuring element array.

Name:

open_close	open_close_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	structuring element array object	ID	in
operation	operation option	EP	in
	open		
	close		
erosion	erosion s.e. rotation option	EP	in
	non-rotated s.e.		
	rotated s.e.		
dilation	dilation s.e. rotation option	EP	in
	non-rotated s.e.		
	rotated s.e.		

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SOB structure:	NBHOOD_ARRAY	NBHOOD_ARRAY
SRC data type:	BD, ND, SD, RD	BD
DST data type:	same as SRC data type	BD
SOB data type:	BD, RD	BD
SOB dimension:	2D	2D

Element functionality:

Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
H(j, k)	J_HxK_H structuring element array

Definition:

The open operation consists of Boolean or grey scale dilation of a pixel plane with a structuring element followed by Boolean or grey scale erosion of the dilation result with the reflected structuring element. The close operation consists of Boolean or grey scale erosion with a reflected structuring element of a pixel plane followed by Boolean or grey scale dilation of the erosion result with the structuring element.

Open:

For all j, k, l, m, n

$$D(j,k,l,m,n) = [S(j,k,l,m,n) \boxminus \tilde{H}(j,k)] \boxplus H(j,k)$$

Close:

For all j, k, l, m, n

$$D(j,k,l,m,n) = [S(j,k,l,m,n) \boxplus H(j,k)] \boxminus \tilde{H}(j,k)$$

where $\tilde{H}(j, k)$ is the left-to-right and top-to-bottom reflection of H(j, k) about its centre, $\boxplus$ denotes key pixel, zero exterior dilation as defined by the *erosion_dilation_boolean* or *erosion_dilation_grey* operators, and $\boxminus$ denotes key pixel, zero exterior erosion as defined by the *erosion_dilation_boolean* or *erosion_dilation_grey* operators. Erosion and dilation are performed with or without 180 degree rotation of the structuring element according to the selected options.

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Profile:

Scientific	open_close
Scientific	open_close_roi

Error codes:

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CONTROL MECHANISM **OPEN PIKS**

Description:

Opens a PIKS session.

Name:

open_piks

Parameters:

error_file	error file identifier	IP	in

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Definition:

This control mechanism initiates a PIKS session. It initializes the PIKS state tables, establishes default global element control modes, and sets the PIKS state to PIKS_OPEN.

The following is a list of the PIKS default global control settings:

state	*default*
ROI control mode	ROI control disengaged
ROI process mode	ROI process disengaged
match point mode	match point control disengaged
synchronicity	synchronous operation engaged
error reporting mode	errors reported
index assignment mode	index assignment disengaged
image resampling selection	support 1 constant (nearest neighbour)
ROI resampling selection	support 1 constant (nearest neighbour)

The application shall be responsible for allocating the error file.

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Profile:

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Error codes:

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ENHANCEMENT OPERATOR

OUTLIER REMOVAL

Description:

Performs removal of outlier pixels in pixel planes that differ significantly from their neighbours. Removed pixels are replaced by the average of their neighbours.

Name:

outlier_removal

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	impulse response array object	ID	in
th	threshold value	RP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB structure:	NBHOOD_ARRAY
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type
SOB data type:	RD
SOB dimension:	2D

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remark:

The data object repository contains the following 3x3 neighbourhood average impulse response arrays:

EIGHT_NEIGHBOUR_AVERAGE

FOUR_NEIGHBOUR_AVERAGE

CORNER_NEIGHBOUR_AVERAGE

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
A(j, k, l, m, n)	neighbourhood average
H(j, k)	J_HxK_H neighbourhood average impulse response array
th	threshold value, th ≥ 0

Definition:

For all j, k, l, m, n

$$D(j, k, l, m, n) = S(j, k, l, m, n) \quad \text{if } |S(j, k, l, m, n) - A(j, k, l, m, n)| \leq th$$

$$D(j, k, l, m, n) = A(j, k, l, m, n) \quad \text{if } |S(j, k, l, m, n) - A(j, k, l, m, n)| > th$$

where

$$A(j, k, l, m, n) = S(j, k, l, m, n) \circledast H(j, k)$$

and $\circledast$ denotes two-dimensional, enclosed array mode convolution as defined by the *convolve_2d* operator.

Profile:

Technical

Error codes:

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EXPORT UTILITY **OUTPUT OBJECT**

Description:

Outputs a PIKS data object to the IIF or the application.

Name:

output_object

Parameters:

SOB	PIKS object	ID	in
DOB	external object	IP	out
destination	data destination option IIF application	SP	in
syntax	data destination syntax option ASN.1 private	SP	in

Objects:

SOB structure:	HIST, LUT, MATRIX, NBHOOD_ARRAY, PIXEL_RECORD, ROI_ARRAY, ROI_COORD, ROI_ELLIP, ROI_GEN, ROI_POLY, ROI_RECT, STATIC_ARRAY, TUPLE, VALUE_BOUNDS plus PIKS image
DOB structure:	same as SOB structure
SOB data type:	all PIKS data types
DOB data type:	same external data type class as SOB data type

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

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Remarks:

1. This utility only supports the output of PIKS data objects, as defined in Part 1 of this standard.
2. This utility converts the generic ROI data object, ROI_GEN, to one of the IPI_PIKS ROI data objects, ROI_ARRAY, ROI_COORD, ROI_ELLIP, ROI_POLY, or ROI_RECT. The conversion is implementaion dependent.
3. This utility shall be capable of supporting other (non-IIF) data destinations through an extension mechanism.
4. This utility does not provide for the output of PIKS objects in a private syntax to the application. Such functionality is provided by PIKS export utilities.

Definition:

PIKS to IIF with ASN.1 syntax:

The PIKS data object is converted to an ASN.1 data stream. Invocation of this utility automatically opens a data stream port to the IIF and causes the data stream to be transmitted to the IIF.

PIKS to IIF with private syntax:

The PIKS data object is converted to a private syntax data stream. Invocation of this utility automatically opens a data stream port to the IIF and causes the data stream to be transmitted to the IIF.

PIKS to application with ASN.1 syntax:

The PIKS data object is converted to an ASN.1 data stream. Invocation of this utility automatically opens a data stream port to the application and causes the data stream to be transmitted to the application.

Profile:

Foundation - IIF capable

Error codes:

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MODIFICATION OPERATOR

PAINT PIXELS

Description:

Paints pixels specified by an array of control points from a source image into a destination image.

Name:

paint_pixels

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB1	brush array object	ID	in
SOB2	control point array object	IP	in
lv	third index value	NP	in
mv	fourth index value	NP	in
nv	fifth index value	NP	in
points	number of control points	NP	in
paint	painting option point painting straight line painting	SP	in
brush	brush option hard brush soft brush	SP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB1 structure:	NBHOOD_ARRAY
SOB2 structure:	EXT
SRC data type:	ND, SD, RD
DST data type:	RD
SOB1 data type:	BD, RD
SOB2 data type:	NP
SOB1 dimension:	2D
SOB2 dimension:	2D

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Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. For a hard brush, the array data type is BD data type .
2. For a soft brush, the array data is RD data type .
3. The external array is defined as follows:

jc(0)	kc(0)
.	
.	
jc(q)	kc(q)
.	
.	
jc(Q–1)	kc(Q–1)

4. The key point of the brush array need not be in the array.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
B(c, r)	CxR brush array
lv	third index value, $lv \geq 0$
mv	fourth index value, $mv \geq 0$
nv	fifth index value, $nv \geq 0$
[jc(q), kc(q)]	q-th control point, $0 \leq q \leq Q - 1$
Q	number of control points, $Q \geq 1$
(ck, rk)	brush array key point

Definition:

Hard brush point painting:

The brush array assumes the logical values TRUE or FALSE at all points within the array. Conceptually, the brush array is aligned with each control point such that the brush key point and the control point are in spatial alignment. Then, all source pixels within the brush region are copied into the destination image if the corresponding brush point is TRUE. The operation is defined mathematically as follows.

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For

$$0 \le q \le Q-1$$
$$jc(q)-ck \le j \le C-1+jc(q)-ck$$
$$kc(q)-rk \le k \le R-1+kc(q)-rk$$

if B(c, r) = TRUE, then

D(j, k, lv, mv, nv) = S(j, k, lv, mv, nv)

where

$$c = j-jc(q)+ck$$
$$r = k-kc(q)+rk$$

If B(c, r) = FALSE, then

D(j, k, lv, mv, nv) = D(j, k, lv, mv, nv)

Soft brush point painting:

The brush array assumes values over the range [0, 1] at all points within the array. Conceptually, the brush array is aligned with each control point such that the brush key point and the control point are in spatial alignment. Then, all source pixels within the brush region are alpha blended with the destination pixels and copied into the destination image. The operation is defined mathematically as follows.

For

$$0 \le q \le Q-1$$
$$jc(q)-ck \le j \le C-1+jc(q)-ck$$
$$kc(q)-rk \le k \le R-1+kc(q)-rk$$

D(j, k, l, m, n) = [B(c, r)][S(j, k, lv, mv, nv)] + [1 − B(c, r)][D(j, k, lv, mv, nv)]

where

$$c = j-jc(q)+ck$$
$$r = k-kc(q)+rk$$

Hard brush line painting:

Painting is performed in the same manner as for hard brush point painting at all control points and at all pixels lying on straight lines sequentially connecting the control points. The P pixels on the discrete straight line between the q-th and the (q+1)-th control points lie at the following coordinate values.

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For $0 \leq p \leq P - 1$

$$j(p) = jc(q) + NIV\left\{\frac{p[jc(q+1) - kc(q)]}{d(q)}\right\}$$

$$k(p) = kc(q) + NIV\left\{\frac{p[kc(q+1) - kc(q)]}{d(q)}\right\}$$

where

$$d(q) = [[jc(q+1) - jc(q)]^2 + [kc(q+1) - kc(q)]^2]^{1/2}$$

and

$$P = 1 + NIV\{d(q)\}$$

Soft brush line painting:

Painting is performed in the same manner as for soft brush point painting at all control points and at all pixels lying on straight lines sequentially connecting the control points. The P pixels on the discrete straight line between the q-th and the (q+1)-th control points lie at the coordinate values defined above.

Profile:

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Error codes:

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SHAPE OPERATOR **PERIMETER CODE GENERATOR**

Description:

Generates the crack code of the outer perimeter of each object in a pixel plane of a Boolean image.

Name:

perimeter_code_generator

Parameters:

SRC	source image	ID	in
DOB	crack code array object	IP	out
lv	third index value	NP	in
mv	fourth index value	NP	in
nv	fifth index value	NP	in
limit	object number limit	NP	in

Objects:

SRC structure:	any image
DOB structure:	EXT
SRC data type:	BD
DOB data type:	NP

Element functionality:

Index assignment:	yes
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	no
Asynchronous:	no

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Remarks:

1. This operator generates crack codes of the outer perimeter of objects in a pixel plane.
2. An object is defined to be a collection of eight-connected pixels of the Boolean TRUE state that are surrounded by pixels of the Boolean FALSE state.
3. An outer perimeter pixel is a TRUE state pixel that has at least one eight-connected FALSE state neighbour, which is a member of a connected set of pixels as determined by a perimeter traversal test, as described in the Definition.
4. An object may have "holes" - Boolean FALSE state pixels within its interior.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
S(j, k, l, m, n)	JxKxLxMxN operator input image
lv	third index value, $lv \geq 0$
mv	fourth index value, $mv \geq 0$
nv	fifth index value, $nv \geq 0$
P	number of entries in crack code array (outer perimeter)
s(p)	p-th crack code array entry, $0 \leq p \leq P - 1$
Q	number of objects examined, $Q \geq 1$
q	object index, $1 \leq q \leq Q$
Q_{max}	object number limit, $Q_{max} \geq 1$

Definition:

Starting at the origin, the j-k plane of S(j, k, lv, mv, nv) is sequentially examined (raster scanned) in increasing index order (j index first) until a TRUE state pixel is encountered. This first encountered TRUE pixel is called the reference pixel. Starting at the upper left-hand corner of the reference pixel, the outer perimeter of the object is then traversed, in a clockwise manner, along the edges (cracks) of perimeter pixels until the reference pixel is again encountered.

The crack code of the outer perimeter of an object is an integer, C(p), of value 0, 1, 2, or 3, where p is the perimeter traversal index over the range $0 \leq p \leq P - 1$, and P is the outer perimeter length. The crack code for traversal movement is

C(p) = 0	left-to-right
C(p) = 1	top-to-bottom
C(p) = 2	right-to-left
C(p) = 3	bottom-to-top

The following is an example of an object consisting of four eight-connected TRUE state pixels, shown shaded, and its associated crack code.

p:	0 1 2 3 4 5 6 7 8 9 10 11
C(p):	0 1 0 3 0 1 2 1 2 2 3 3

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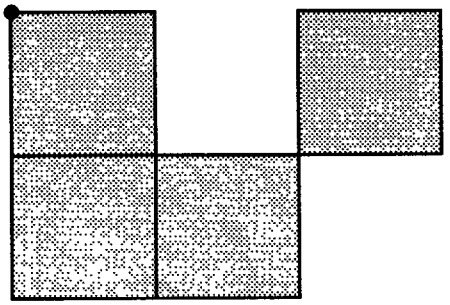

After the crack code of an object has been generated, all TRUE state pixels within the interior of the object are removed from further consideration (virtually, but not physically set to the FALSE state). The scanning process resumes until all objects are detected or until the object number limit has been reached.

The external array is defined as follows:

1
P_1
C(0)
.
.
C(p)
.
.
$C(P_1 - 1)$
.
.
.
.
q
P_q
C(0)
.
.
C(p)
.
.
$C(P_q - 1)$
.
.
.
.
Q
P_Q
C(0)
.
.
C(p)

.
.
$C(P_Q - 1)$

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Profile:

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GEOMETRIC OPERATOR

POLAR TO CARTESIAN

Description:

Performs conversion of a pixel plane in polar coordinates to a pixel plane in cartesian coordinates.

Name:

polar_to_cartesian

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
rho_min	minimum value of rho	RP	in
rho_max	maximum value of rho	RP	in
theta_min	minimum value of theta	RP	in
theta_max	maximum value of theta	RP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	RD
DST data type:	RD

Element functionality:

Index assignment:	yes
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ source image
DST(x, y, z, t, b)	$X_D x Y_D x Z_D x T_D x B_D$ destination image
S(j, k, l, m, n)	$J_S x K_S x L_S x M_S x N_S$ operator input image
D(j, k, l, m, n)	$J_D x K_D x L_D x M_D x N_D$ operator output image
ρ_{min}	minimum value of rho, $0 < \rho_{min} < \rho_{max}$
ρ_{max}	maximum value of rho, $\rho_{min} < \rho_{max} \leq [(J_S)^2 + (K_S)^2]^{1/2}$
Θ_{min}	minimum value of theta, $0 < \Theta_{min} < \Theta_{max}$
Θ_{max}	maximum value of theta, $\Theta_{min} < \Theta_{max} \leq \pi/2$

Definition:

The polar to cartesian conversion involves two processing stages. In the first stage, for all l, m, n, an inverse address calculation is made whereby (j', k') source image coordinates are computed according to cartesian to polar conversion equations based upon the destination image coordinates (j, k). In general, the (j', k') coordinates are not integer valued. The second stage of the algorithm entails two-dimensional resampling of the source image to evaluate the destination image at integer coordinates.

As shown in the figure, for all j, k, l, m, n and for j and k coordinate pairs jointly satisfying the following inqualities, i.e., in the pie-shaped area of the figure,

$$\rho_{min} \leq \rho(j) \leq \rho_{max}$$

$$\Theta_{min} \leq \Theta(k) \leq \Theta_{max}$$

then

$$D(j, k, l, m, n) = RES2\{S, j', k', l, m, n\}$$

otherwise

$$D(j, k, l, m, n) = 0$$

where

$$\rho(j) = \frac{j[\rho_{max} - \rho_{min}]}{J_D - 1} + \rho_{min}$$

$$\Theta(k) = \frac{k[\Theta_{max} - \Theta_{min}]}{K_D - 1} + \Theta_{min}$$

$$j' = [j^2 + k^2]^{1/2}$$

$$k' = ATAN2\{k, j\}$$

$$L_D = L_S$$

$$M_D = M_S$$

$$N_D = N_S$$

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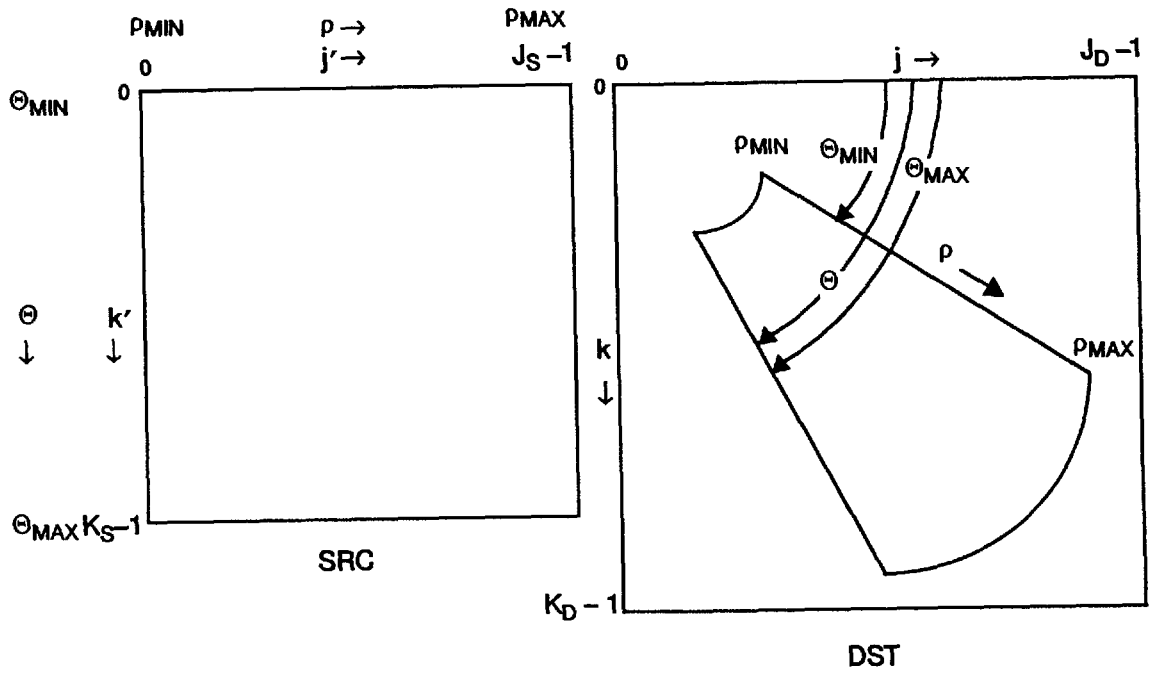

Relationship between source and destination images

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Profile:

Scientific

Error codes:

001
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102

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POINT OPERATOR **POWER LAW SCALING**

Description:

Performs power law amplitude scaling of an image in which each source pixel is raised to a power law exponent.

Name:

power_law_scaling

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
p	power law exponent	RP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	yes
Chainable element:	yes
Asynchronous:	yes

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
p	power law exponent

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power_law_scaling

Definition:

$$D(x, y, z, t, b) = POW\{S(x, y, z, t, b), p\} \quad \text{for } S(x, y, z, t, b) > 0$$

$$D(x, y, z, t, b) = 0 \quad \text{for } S(x, y, z, t, b) \leq 0$$

Profile:

Technical

Error codes:

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ENHANCEMENT OPERATOR **PSEUDOCOLOUR**

Description:

Performs pseudocolouring of a grey scale image in which each grey scale value is mapped into a red, green, blue tristimulus value through a lookup table transformation.

Name:

pseudocolour

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	lookup table object	ID	in
off	number of lookup table source offset entries	NP	in

Objects:

SRC structure:	MON, VOL, TEM, VT
DST structure:	COLR, VC, TC, VTC
SOB structure:	LUT
SRC data type:	ND, SD
DST data type:	same as SRC data type
SOB data type:	same as SRC data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remark:

The following are allowable image structure transformations:

MON to COLR

VOL to VC

TEM to TC

VT to VTC

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
off	number of lookup table source offset entries, off ≥ 0

Definition:

For all x, y, z, t

D(x, y, z, t, 0) = LOOK{S(x, y, z, t, 0), off, 0, table}

D(x, y, z, t, 1) = LOOK{S(x, y, z, t, 0), off, 1, table}

D(x, y, z, t, 2) = LOOK{S(x, y, z, t, 0), off, 2, table}

Profile:

Technical

Error codes:

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IMPORT UTILITY **PUT COLOUR PIXEL**

Description:

Inserts a colour pixel in a colour image.

Name:

put_colour_pixel

Parameters:

DST	destination image	ID	in, out
pv0	band 0 pixel value	BP,NP,SP,RP	in
pv1	band 1 pixel value	BP,NP,SP,RP	in
pv2	band 2 pixel value	BP,NP,SP,RP	in
pv3	band 3 pixel value	BP,NP,SP,RP, NULL	in
xv	horizontal index value	NP	in
yv	vertical index value	NP	in
zv	depth index value	NP	in
tv	temporal index value	NP	in

Object:

DST structure:	COLR, VC, TC, VTC
DST data type:	BD, ND, SD, RD

Element functionality:

Index assignment:	no
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

The data parameters shall be of the same data type class as the destination image.

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put_colour_pixel

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
pv0	band 0 pixel value
pv1	band 1 pixel value
pv2	band 2 pixel value
pv3	band 3 pixel value
xv	horizontal index value, $xv \geq 0$
yv	vertical index value, $yv \geq 0$
zv	depth index value, $zv \geq 0$
tv	temporal index value, $tv \geq 0$

Definition:

Three-band colour image:

DST(xv, yv, zv, tv, 0) = pv0

DST(xv, yv, zv, tv, 1) = pv1

DST(xv, yv, zv, tv, 2) = pv2

Four-band colour image:

DST(xv, yv, zv, tv, 0) = pv0

DST(xv, yv, zv, tv, 1) = pv1

DST(xv, yv, zv, tv, 2) = pv2

DST(xv, yv, zv, tv, 3) = pv3

Profile:

Foundation

Error codes:

001
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IMPORT UTILITY **PUT PIXEL**

Description:

Inserts a pixel into an image.

Name:

put_pixel put_pixel_roi

Parameters:

DST	destination image	ID	in, out
pv	pixel value	BP,NP,SP,RP,CP	in
xv	horizontal index value	NP	in
yv	vertical index value	NP	in
zv	depth index value	NP	in
tv	temporal index value	NP	in
bv	band index value	NP	in

Object:

DST structure:	any image	ROI_GEN
DST data type:	BD, ND, SD, RD, CD	BD

Element functionality:

Index assignment:	no	no
Match point:	no	no
ROI control:	yes	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Remark:

The data parameter shall be of the same data type class as the destination image.

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Nomenclature:

DST(x, y, z, t, b)	XxYxZxTxB destination image
pv	pixel value
xv	horizontal index value, $xv \geq 0$
yv	vertical index value, $yv \geq 0$
zv	depth index value, $zv \geq 0$
tv	temporal index value, $tv \geq 0$
bv	band index value, $bv \geq 0$

Definition:

DST(xv, yv, zv, tv, bv) = pv

Profile:

Foundation	put_pixel
Technical	put_pixel_roi

Error codes:

001
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IMPORT UTILITY

PUT PIXEL ARRAY

Description:

Inserts an array of pixels into an image.

Name:

put_pixel_array put_pixel_array_roi

Parameters:

DST	destination image	ID	in, out
SOB	pixel array object	IP	in
jo	first index offset	NP	in
ko	second index offset	NP	in
lv	third index value	NP	in
mv	fourth index value	NP	in
nv	fifth index value	NP	in
C	number of array columns	NP	in
R	number of array rows	NP	in

Objects:

DST structure:	any image	ROI_GEN
SOB structure:	EXT	EXT
DST data type:	BD, ND, SD, RD, CD	BD
SOB data type:	BP, NP, SP, RP, CP	BP
SOB dimension:	2D	2D

Element functionality:

Index assignment:	no	no
Match point:	no	no
ROI control:	yes	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

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Nomenclature:

DST(x, y, z, t, b)	XxYxZxTxB destination image
D(j, k, l, m, n)	JxKxLxMxN utility output image
jo	first index offset
ko	second index offset
lv	third index value, $lv \geq 0$
mv	fourth index value, $mv \geq 0$
nv	fifth index value, $nv \geq 0$
A(c, r)	CxR array
C	number of array columns, $C \geq 1$
R	number of array rows, $R \geq 1$

Definition:

For

$$jo \leq j \leq J-1$$

$$ko \leq k \leq K-1$$

$$0 \leq c \leq C-1$$

$$0 \leq r \leq R-1$$

$$D(c + jo, r + ko, lv, mv, nv) = A(c, r)$$

and D(j, k, l, m, n) is unchanged otherwise.

Profile:

Foundation	put_pixel_array
Technical	put_pixel_array_roi

Error codes:

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IMPORT UTILITY **PUT PIXEL RECORD**

Description:

Inserts an across-band pixel record into an image.

Name:

put_pixel_record	put_pixel_record

Parameters:

DST	destination image	ID	in, out
SOB	pixel record object	IP	in
data_type	data type B-tuple	ID	in
xv	horizontal index value	NP	in
yv	vertical index value	NP	in
zv	depth index value	NP	in
tv	temporal index value	NP	in

Objects:

DST structure:	any image	ROI_GEN
SOB structure:	EXT	EXT
DST data type:	BD, ND, SD, RD, CD	BD
SOB data type:	BP, NP, SP, RP, CP	BP

Element functionality:

Index assignment:	no	no
Match point:	no	no
ROI control:	no	no
ROI processing:	no	no
Source promotion:	no	no
Heterogeneous bands:	yes	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Remarks:

1. The record data type shall be of the same data type class as the destination image.
2. The parameter tuple contains parameters of the SP data type.

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Nomenclature:

DST(x, y, z, t, b)	XxYxZxTxB destination image
r(b)	across-band record
B	band size
b	band index, $0 \leq b \leq B-1$
xv	horizontal index value, $xv \geq 0$
yv	vertical index value, $yv \geq 0$
zv	depth index value, $zv \geq 0$
tv	temporal index value, $tv \geq 0$

Definition:

The *put_pixel_record* utility inserts a sequence of pixel values into an image. The data types of the sequence, which can differ from band to band, are specified by the data type B-tuple.

For all b

SRC(xv, yv, zv, tv, b) = r(b)

Profile:

Technical	put_pixel_record
Technical	put_pixel_record_roi

Error codes:

001
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GEOMETRIC OPERATOR **RESCALE**

Description:

Performs size rescaling of a five-dimensional window of an image.

Name:

rescale	rescale_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
scale_factor	scale factor 5-tuple	ID	in
upper	upper value 5-tuple	ID	in
lower	lower value 5-tuple	ID	in

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SRC data type:	BD, ND, SD, RD, CD	BD
DST data type:	same as SRC data type	BD

Element functionality:

Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	yes	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Remarks:

1. For geometric operators, all pixels are assumed to be of unit dimension. The geometric origin along a coordinate direction is at the center of the pixel with index value zero. The geometric bounds of an origin pixel are – 0.5 to 0.5.
2. Geometric resampling is performed according to the global resampling option selected by the *set_globals* utility.
3. The parameter tuples contain parameters of the RD data type.
4. Rescaling is not performed along the band index of a colour image.

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Nomenclature:

SRC(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ source image
DST(x, y, z, t, b)	$X_D x Y_D x Z_D x T_D x B_D$ destination image
S(j, k, l, m, n)	$J_S x K_S x L_S x M_S x N_S$ operator input image
D(j, k, l, m, n)	$J_D x K_D x L_D x M_D x N_D$ operator output image
Sj	first index scale factor, Sj > 0
Sk	second index scale factor, Sk > 0
Sl	third index factor, Sl > 0
Sm	fourth index scale factor, Sm > 0
Sn	fifth index scale factor, Sn > 0
ju	first index upper value, $0 \le ju \le J_S - 1$
ku	second index upper value, $0 \le ku \le K_S - 1$
lu	third index upper value, $0 \le lu \le L_S - 1$
mu	fourth index upper value, $0 \le mu \le M_S - 1$
nu	fifth index upper value, $0 \le nu \le N_S - 1$
jl	first index lower value, $0 \le jl \le J_S - 1$, $jl \le ju$
kl	second index lower value, $0 \le kl \le K_S - 1$, $kl \le ku$
ll	third index lower value, $0 \le ll \le L_S - 1$, $ll \le lu$
ml	fourth index lower value, $0 \le ml \le Ms - 1$, $ml \le mu$
nl	fifth index lower value, $0 \le nl \le N_S - 1$, $nl \le nu$

Definition:

The *rescale* operator is based upon a two-stage algorithm. In the first stage a reverse address calculation is made whereby (j', k', l', m', n') source image coordinates are calculated for integer values of the destination image coordinates (j, k, l, m, n). In general, the (j', k', l', m', n') coordinates are not integer valued. The second stage of the algorithm entails resampling of the source image to evaluate the destination image at integer coordinates.

The following figure illustrates the rescaling operation in two dimensions:

In general, for all j, k, l, m, n

$$D(j, k, l, m, n) = RES_S\{S, j', k', l', m', n'\}$$

where

$$j' = \frac{j + 0.5}{Sj} + jl - 0.5$$

$$k' = \frac{k + 0.5}{Sk} + kl - 0.5$$

$$l' = \frac{l + 0.5}{Sl} + ll - 0.5$$

$$m' = \frac{m + 0.5}{Sm} + ml - 0.5$$

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$$n' = \frac{n+0.5}{Sn} + nl - 0.5$$

and

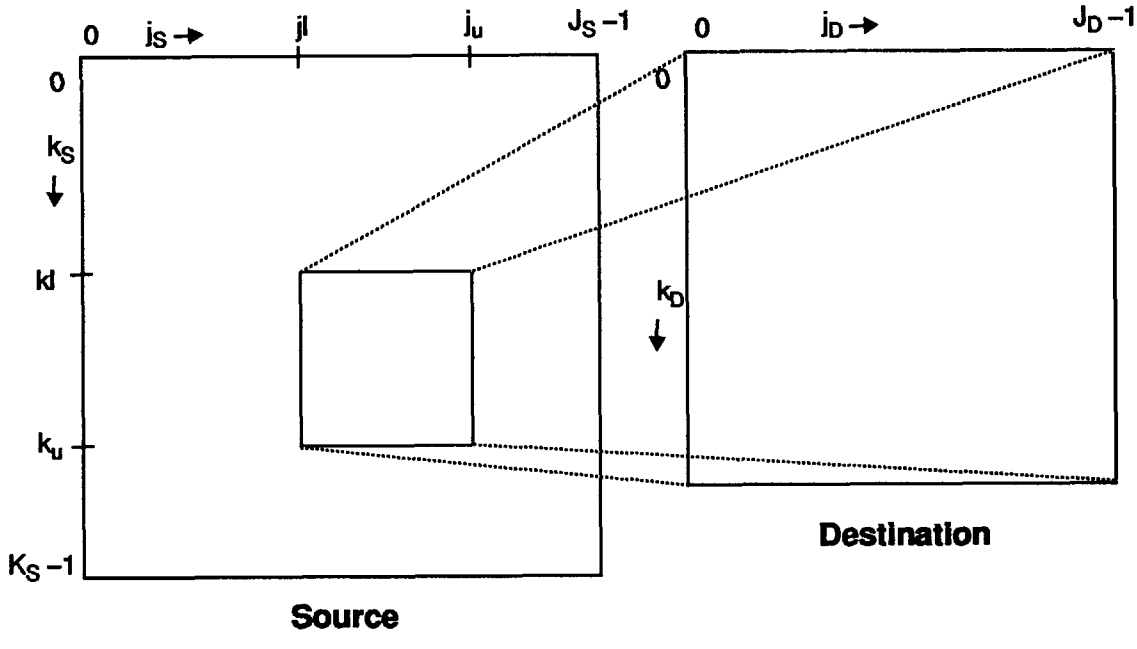
$$J_D = NIV\{(Sj)(ju - jl)\}$$

$$K_D = NIV\{(Sk)(ku - kl)\}$$

$$L_D = NIV\{(Sl)(lu - ll)\}$$

$$M_D = NIV\{Sm)(mu - ml)\}$$

$$N_D = NIV\{(Sn)(nu - nl)\}$$



Two-dimensional rescaling

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Profile:

Foundation	rescale
Foundation	rescale_roi

Error codes:

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GEOMETRIC OPERATOR **RESIZE**

Description:

Performs resizing of an image by reducing or enlarging its coordinate sizes.

Name:

resize	resize_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
dst_size	destination size 5-tuple	ID	in

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SRC data type:	BD, ND, SD, RD, CD	BD
DST data type:	same as SRC data type	BD

Element functionality:

Index assignment:	no	no
Match point:	no	no
ROI control:	yes	no
ROI processing:	yes	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Remarks:

1. For geometric operators, all pixels are assumed to be of unit dimension. The geometric origin along a coordinate direction is at the center of the pixel with index value zero. The geometric bounds of an origin pixel are – 0.5 to 0.5.
2. If the source and destination images have the same size for any coordinate, resampling is not required along that coordinate.
3. Geometric resampling is performed according to the global resampling option selected by the *set_globals* utility.
4. The parameter tuple contains parameters of the ND data type.
5. Resizing is not performed along the band index of a colour image.

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Nomenclature:

SRC(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ source image
DST(x, y, z, t, b)	$X_D x Y_D x Z_D x T_D x B_D$ destination image
S(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ operator input image
D(x, y, z, t, b)	$X_D x Y_D x Z_D x T_D x B_D$ operator output image
xd	destination x index size, xd > 0
yd	destination y index size, yd > 0
zd	destination z index size, zd > 0
td	destination t index size, td > 0
bd	destination b index size, bd > 0

Definition:

The *resize* operator is based upon a two-stage algorithm. In the first stage, a reverse address calculation is made whereby (x', y', z', t', b') source image coordinates are calculated for integer values of the destination image coordinates (x, y, z, t, b). In general, the (x', y', z', t', b') coordinates are not integer valued. The second stage of the algorithm entails resampling of the source image to evaluate the destination image at integer coordinates. The *resize* operator is defined as follows:

Let

$$X_D = xd$$

$$Y_D = yd$$

$$Z_D = zd$$

$$T_D = td$$

$$B_D = bd$$

then for all x, y, z, t, b

$$D(x, y, z, t, b) = RES_5\{S, x', y', z', t', b'\}$$

where

$$x' = \frac{X_S}{X_D}(x + 0.5) - 0.5$$

$$y' = \frac{Y_S}{Y_D}(y + 0.5) - 0.5$$

$$z' = \frac{Z_S}{Z_D}(z + 0.5) - 0.5$$

$$t' = \frac{T_S}{T_D}(t + 0.5) - 0.5$$

$$b' = \frac{B_S}{B_D}(b + 0.5) - 0.5$$

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Profile:

Foundation	resize
Foundation	resize_roi

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SYSTEM MANAGEMENT MECHANISM

RETURN REPOSITORY IDENTIFIER

Description:

Returns the identifier of a data object repository entry to an application.

Name:

return_repository_id

Parameters:

index	repository index	SP	in
id	repository identifier	ID	out
class	repository class option	SP	in
	impulse response array		
	dither array		
	colour conversion matrix		

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

Annex G contains a listing of data objects in the data object repository numerically indexed for each of the three classes of data objects: impulse response array, dither array, and colour conversion matrix.

Definition:

An identifier associated with a data object repository entry index is returned to the application.

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Profile:

Foundation

Error code:

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Description:

Generates a 5D coordinate collection ROI object for which the ROI is logically TRUE or FALSE at specified coordinates in an external coordinate array, and is logically FALSE or TRUE at all other coordinates.

Name:

roi_coordinate

Parameters:

SOB	5D coordinate array object	IP	in
DOB	region-of-interest object	ID	out
roi_size	roi size 5-tuple	ID	in
E	number of array entries	NP	in
polarity	ROI polarity option set TRUE set FALSE	EP	in

Objects:

SOB structure:	EXT
DOB structure:	ROI_COORD
SOB data type:	NP
DOB data type:	BD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The coordinate collection ROI object need not be implemented as a ROI array.
2. The parameter tuple contains parameters of the ND data type.

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Nomenclature:

ROI(x, y, z, t, b)	XxYxZxTxB ROI generator tool output array
x(e)	e-th entry of first index, $0 \leq e \leq E-1$
y(e)	e-th entry of second index, $0 \leq e \leq E-1$
z(e)	e-th entry of third index, $0 \leq e \leq E-1$
t(e)	e-th entry of fourth index, $0 \leq e \leq E-1$
b(e)	e-th entry of fifth index, $0 \leq e \leq E-1$
E	number of entries in array, $E \geq 1$

Definition

The external array is defined as follows:

x(0)	y(0)	z(0)	t(0)	b(0)
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
x(e)	y(e)	z(e)	t(e)	b(e)
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
x(E–1)	y(E–1)	z(E–1)	t(E–1)	b(E–1)

For $0 \leq e \leq E-1$ and for all x, y, z, t, b, if

x = x(e)

y = y(e)

z = z(e)

t = t(e)

b = b(e)

then

ROI(x, y, z, t, b) = TRUE if polarity is set TRUE

ROI(x, y, z, t, b) = FALSE if polarity is set FALSE

otherwise

ROI(x, y, z, t, b) = FALSE if polarity is set TRUE

ROI(x, y, z, t, b) = TRUE if polarity is set FALSE

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Profile:

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Error codes:

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REGION-OF-INTEREST GENERATION TOOL **ROI, ELLIPTICAL**

Description:

Generates a 2D, 3D, 4D, or 5D elliptically-shaped ROI object.

Name:

roi_elliptical

Parameters:

DOB	region-of-interest object	ID	out
roi_size	roi size 5-tuple	ID	in
ellipse_centre	ellipse centre 5-tuple	ID	in
ellipse_axis	ellipse axis length 5-tuple	ID	in
index_manipulate	index manipulation 5-tuple	ID	in
option	ellipse dimension option	EP	in
	2D		
	3D		
	4D		
	5D		
polarity	ROI polarity option	EP	in
	set TRUE		
	set FALSE		

Object:

DOB structure:	ROI_ELLIP
DOB data type:	BD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. The elliptical ROI object need not be implemented as a ROI array.
2. The r-th order region-of-interest is replicated over all other pixel planes in the ROI data object for $r < 5$.
3. The *row_size* parameter tuple contains parameters of the ND data type.
4. The *ellipse_centre* and *ellipse_axis* parameter tuples contain parameters of the RD data type.
5. The ROI elliptical object is constructed according to an index manipulation procedure, identical to the operator index assignment procedure, whereby the ROI tool input and output indices are related by an index manipulation specified by the index manipulation tuple.

Nomenclature:

ROI(x, y, z, t, b)	XxYxZxTxB ROI data object
R(j, k, l, m, n)	JxKxLxMxN ROI generator tool output array
jc	first index ellipse centre
kc	second index ellipse centre
lc	third index ellipse centre
mc	fourth index ellipse centre
nc	fifth index ellipse centre
jl	first index axis length, jl > 0
kl	second index axis length, kl > 0
ll	third index axis length, ll > 0
ml	fourth index axis length, ml > 0
nl	fifth index axis length, nl > 0

Definition:

For all j, k, l, m, n

2D mode:

If

$$\left[\frac{j - jc}{ja}\right]^2 + \left[\frac{k - kc}{ka}\right]^2 \leq 1$$

then

R(j, k, l, m, n) = TRUE if polarity is set TRUE

R(j, k, l, m, n) = FALSE if polarity is set FALSE

otherwise

R(j, k, l, m, n) = FALSE if polarity is set TRUE

R(j, k, l, m, n) = TRUE if polarity is set FALSE

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where

$$ja = \frac{jl}{2}$$

$$ka = \frac{kl}{2}$$

3D mode:

If

$$\left[\frac{j-jc}{ja}\right]^2 + \left[\frac{k-kc}{ka}\right]^2 + \left[\frac{l-lc}{la}\right]^2 \leq 1$$

then

R(j, k, l, m, n) = TRUE if polarity is set TRUE

R(j, k, l, m, n) = FALSE if polarity is set FALSE

otherwise

R(j, k, l, m, n) = FALSE if polarity is set TRUE

R(j, k, l, m, n) = TRUE if polarity is set FALSE

where

$$la = \frac{ll}{2}$$

4D mode:

If

$$\left[\frac{j-jc}{ja}\right]^2 + \left[\frac{k-kc}{ka}\right]^2 + \left[\frac{l-lc}{la}\right]^2 + \left[\frac{m-mc}{ma}\right]^2 \leq 1$$

then

R(j, k, l, m, n) = TRUE if polarity is set TRUE

R(j, k, l, m, n) = FALSE if polarity is set FALSE

otherwise

R(j, k, l, m, n) = FALSE if polarity is set TRUE

R(j, k, l, m, n) = TRUE if polarity is set FALSE

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5D mode:

If

$$\left[\frac{j-jc}{ja}\right]^2+\left[\frac{k-kc}{ka}\right]^2+\left[\frac{l-lc}{la}\right]^2+\left[\frac{m-mc}{ma}\right]^2+\left[\frac{n-nc}{na}\right]^2\le 1$$

then

R(j, k, l, m, n) = TRUE if polarity is set TRUE

R(j, k, l, m, n) = FALSE if polarity is set FALSE

otherwise

R(j, k, l, m, n) = FALSE if polarity is set TRUE

R(j, k, l, m, n) = TRUE if polarity is set FALSE

The index manipulation tuple contains the following information:

5
CS
j
k
l
m
n

where

j = CHOICE{x, y, z, t, b}

k = CHOICE{x, y, z, t, b} but not j choice

l = CHOICE{x, y, z, t, b} but not j or k choices

m = CHOICE{x, y, z, t, b} but not j, k, or l choices

n = CHOICE{x, y, z, t, b} but not j, k, l, or m choices

Profile:

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Error codes:

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REGION-OF-INTEREST GENERATION TOOL ROI, POLYGON

Description:

Generates a 2D polygon-shaped ROI object from an external array of polygon coordinates.

Name:

roi_polygon

Parameters:

SOB	2D coordinate array	IP	in
DOB	region-of-interest object	ID	out
roi_size	*roi size 5-tuple*	ID	in
E	number of array entries	NP	in
index_manipulate	index manipulation 5-tuple	ID	in
polarity	ROI polarity option set TRUE set FALSE	EP	in

Objects:

SOB structure:	EXT
DOB structure:	ROI_POLY
SOB data type:	NP
DOB data type:	BD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The polygon ROI object need not be implemented as a ROI array.
2. The 2D region-of-interest is replicated over all other pixel planes in the ROI data object.
3. If the polygon crosses itself, the ROI structure may be ill-defined.
4. The parameter tuple contains parameters of the ND data type.
5. The ROI polygon object is constructed according to an index manipulation procedure, identical to the operator index assignment procedure, whereby the ROI tool input and output indices are related

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by an index manipulation specified by the index manipulation tuple (see *roi_elliptical*).

Nomenclature:

ROI(x, y, z, t, b)	XxYxZxTxB ROI data object
R(j, k, l, m, n)	JxKxLxMxN ROI generator tool output array
j(e)	e-th entry of first index, $0 \leq e \leq E - 1$
k(e)	e-th entry of second index, $0 \leq e \leq E - 1$
E	number of array entries, $E \geq 1$

Definition:

The external array is defined as follows:

j(0)	k(0)
.	.
.	.
.	.
j(e)	k(e)
.	.
.	.
.	.
j(E–1)	k(E – 1)

A closed contour is created by sequentially connecting points in the coordinate list, i.e., connect [j(0), k(0)] to [j(1), k(1)] to ... to [j(E–1), k(E–1)] to [j(0), k(0)]. Next, for all j, k, l, m, n, set

R(j, k, l, m, n) = TRUE if polarity is set TRUE

R(j, k, l, m, n) = FALSE if polarity is set FALSE

if j, k is within or on the contour, set

R(j, k, l, m, n) = FALSE if polarity is set TRUE

R(j, k, l, m, n) = TRUE if polarity is set FALSE

elsewhere.

Contour filling is performed according to the *fill_region* operator definition.

Profile:

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REGION-OF-INTEREST GENERATION TOOL **ROI, RECTANGULAR**

Description:

Generates a 1D, 2D, 3D, 4D, or 5D rectangular-shaped ROI object.

Name:

roi_rectangular

Parameters:

DOB	region-of-interest object	ID	out
roi_size	ROI size 5-tuple	ID	in
start_position	start position 5-tuple	ID	in
end_position	end position 5-tuple	ID	in
index_manipulate	index manipulation 5-tuple	ID	in
dimension	rectangle dimension option	EP	in
	1D		
	2D		
	3D		
	4D		
	5D		
polarity	ROI polarity option	EP	in
	set TRUE		
	set FALSE		

Object:

DOB structure:	ROI_RECT
DOB data type:	BD

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. The rectangular ROI object need not be implemented as a ROI array.
2. The r-th order region-of-interest is replicated over all other pixel planes in the ROI data object for $r < 5$.
3. The parameter tuples contain parameters of the ND data type.
4. The ROI rectangular object is constructed according to an index manipulation procedure, identical to the operator index assignment procedure, whereby the ROI tool input and output indices are related by an index manipulation specified by the index manipulation tuple (see *roi_elliptical*).

Nomenclature:

ROI(x, y, z, t, b)	XxYxZxTxB ROI data object
R(j, k, l, m, n)	JxKxLxMxN ROI generator tool output array
js	first index start position, $0 \leq js \leq J - 1$
ks	second index start position, $0 \leq ks \leq K - 1$
ls	third index start position, $0 \leq ls \leq L - 1$
ms	fourth index start position, $0 \leq ms \leq M - 1$
ns	fifth index start position, $0 \leq ns \leq N - 1$
je	first index end position, $je > js$
ke	second index end position, $ke > ks$
le	third index end position, $le > ls$
me	fourth index end position, $me > ms$
ne	fifth index end position, $ne > ns$

Definition:

For all j, k, l, m, n

1D mode:

If $js \leq j \leq je$, then

R(j, k, l, m, n) = TRUE if polarity is set TRUE

R(j, k, l, m, n) = FALSE if polarity is set FALSE

otherwise

R(j, k, l, m, n) = FALSE if polarity is set TRUE

R(j, k, l, m, n) = TRUE if polarity is set FALSE

2D mode:

If $js \leq j \leq je$ and $ks \leq k \leq ke$, then

R(j, k, l, m, n) = TRUE if polarity is set TRUE

R(j, k, l, m, n) = FALSE if polarity is set FALSE

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otherwise

R(j, k, l, m, n) = FALSE if polarity is set TRUE

R(j, k, l, m, n) = TRUE if polarity is set FALSE

3D mode:

If $js \leq j \leq je$ and $ks \leq k \leq ke$ and $ls \leq l \leq le$, then

R(j, k, l, m, n) = TRUE if polarity is set TRUE

R(j, k, l, m, n) = FALSE if polarity is set FALSE

otherwise

R(j, k, l, m, n) = FALSE if polarity is set TRUE

R(j, k, l, m, n) = TRUE if polarity is set FALSE

4D mode:

If $js \leq j \leq je$ and $ks \leq k \leq ke$ and $ls \leq l \leq le$ and $ms \leq m \leq me$, then

R(j, k, l, m, n) = TRUE if polarity is set TRUE

R(j, k, l, m, n) = FALSE if polarity is set FALSE

otherwise

R(j, k, l, m, n) = FALSE if polarity is set TRUE

R(j, k, l, m, n) = TRUE if polarity is set FALS

5D mode:

If $js \leq j \leq je$ and $ks \leq k \leq ke$ and $ls \leq l \leq le$ and $ms \leq m \leq me$ and $ns \leq n \leq ne$, then

R(j, k, l, m, n) = TRUE if polarity is set TRUE

R(j, k, l, m, n) = FALSE if polarity is set FALSE

otherwise

R(j, k, l, m, n) = FALSE if polarity is set TRUE

R(j, k, l, m, n) = TRUE if polarity is set FALSE

Profile:

Foundation

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GEOMETRIC OPERATOR **ROTATE**

Description:

Performs two-dimensional or three-dimensional rotation of an image about a point.

Name:

rotate	rotate_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
js	first index source rotation centre	RP	in
ks	second index source rotation centre	RP	in
ls	third index source rotation centre	RP, NULL	in
rjk	j-k plane rotation angle	RP	in
rjl	j-l plane rotation angle	RP	in
rkl	k-l plane rotation angle	RP, NULL	in
option	rotation option 2D rotation 3D rotation	SP	in

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SRC data type:	BD, ND, SD, RD, CD	BD
DST data type:	same as SRC data type	BD

Element functionality:

Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	yes	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

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Remarks:

1. For geometric operators, all pixels are assumed to be of unit dimension. The geometric origin along a coordinate direction is at the centre of the pixel with index value zero. The geometric bounds of an origin pixel are – 0.5 to 0.5.
2. Rotation angles are positive for counterclockwise rotation about a vector emanating toward a viewer from the rotation centre of a rotation plane.
3. Rotation angles are measured in radians.
4. The order of rotation is rjk, followed by rjl, followed by rkl.
5. The rotation centre coordinates need not be integer valued.
6. Geometric resampling is performed according to the global resampling option selected by the *set_globals* utility.
7. Source image pixels outside its index range are assumed to be of zero value for ND, SD, RD, or CD data type images and are assumed to be of FALSE value for BD data type images.
8. Rotation is not performed along the band index of a colour image.

Nomenclature:

SRC(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ source image
DST(x, y, z, t, b)	$X_D x Y_D x Z_D x T_D x B_D$ destination image
S(j, k, l, m, n)	$J_S x K_S x L_S x M_S x N_S$ operator input image
D(j, k, l, m, n)	$J_D x K_D x L_D x M_D x N_D$ operator output image
js	first index source rotation centre
ks	second index source rotation centre
ls	third index source rotation centre
rjk	j-k plane rotation angle, $-\pi \leq rjk \leq \pi$
rjl	j-l plane rotation angle, $-\pi \leq rjl \leq \pi$
rkl	k-l plane rotation angle, $-\pi \leq rkl \leq \pi$

Definition:

2D mode:

The 2D *rotate* operator is based upon a two-stage algorithm. In the first stage, a reverse address calculation is made whereby (j', k') source coordinates of the rotation transformation are calculated for integer values of the destination coordinates (j, k) for all l, m, n. In general, the (j', k') coordinates are not integer valued. The second stage of the algorithm entails resampling of the source image to evaluate the destination image at integer coordinates. The following figure defines the relationship between the source and destination images. The 2D *rotate* operator is defined as follows.

For all l, m, n

$$D(j, k, l, m, n) = RES_2\{S, j', k', l, m, n\}$$

where j' and k' are components of the vector space transformation

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$$\begin{bmatrix} j' \\ k' \\ l \end{bmatrix} = \begin{bmatrix} 1 & 0 & js \\ 0 & 1 & ks \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \text{COS}\{rjk\} & \text{SIN}\{rjk\} & 0 \\ -\text{SIN}\{rjk\} & \text{COS}\{rjk\} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -js \\ 0 & 1 & -ks \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} j \\ k \\ l \end{bmatrix}$$

3D mode:

The 3D *rotate* operator is based upon separable application of the 2D *rotate* operator to the j-k, j-l, and k-l planes. The *rotate* 3D operator is defined as follows.

For all m, n

$$D(j, k, l, m, n) = RES_3\{S, j', k', l', m, n\}$$

where j', k', and l' are components of the vector space transformation

$$\begin{bmatrix} j' \\ k' \\ l' \\ l \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & js \\ 0 & 1 & 0 & ks \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \text{COS}\{rjk\} & \text{SIN}\{rjk\} & 0 & 0 \\ -\text{SIN}\{rjk\} & \text{COS}\{rjk\} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & -js \\ 0 & 1 & 0 & -ks \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\times \begin{bmatrix} 1 & 0 & 0 & js \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & ls \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \text{COS}\{rjl\} & 0 & -\text{SIN}\{rjl\} & 0 \\ 0 & 1 & 0 & 0 \\ \text{SIN}\{rjl\} & 0 & \text{COS}\{rjl\} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & -js \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & -ls \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\times \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & ks \\ 0 & 0 & 1 & ls \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \text{COS}\{rkl\} & \text{SIN}\{rkl\} & 0 \\ 0 & -\text{SIN}\{rkl\} & \text{COS}\{rkl\} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & -ks \\ 0 & 0 & 1 & -ls \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} j \\ k \\ l \\ l \end{bmatrix}$$

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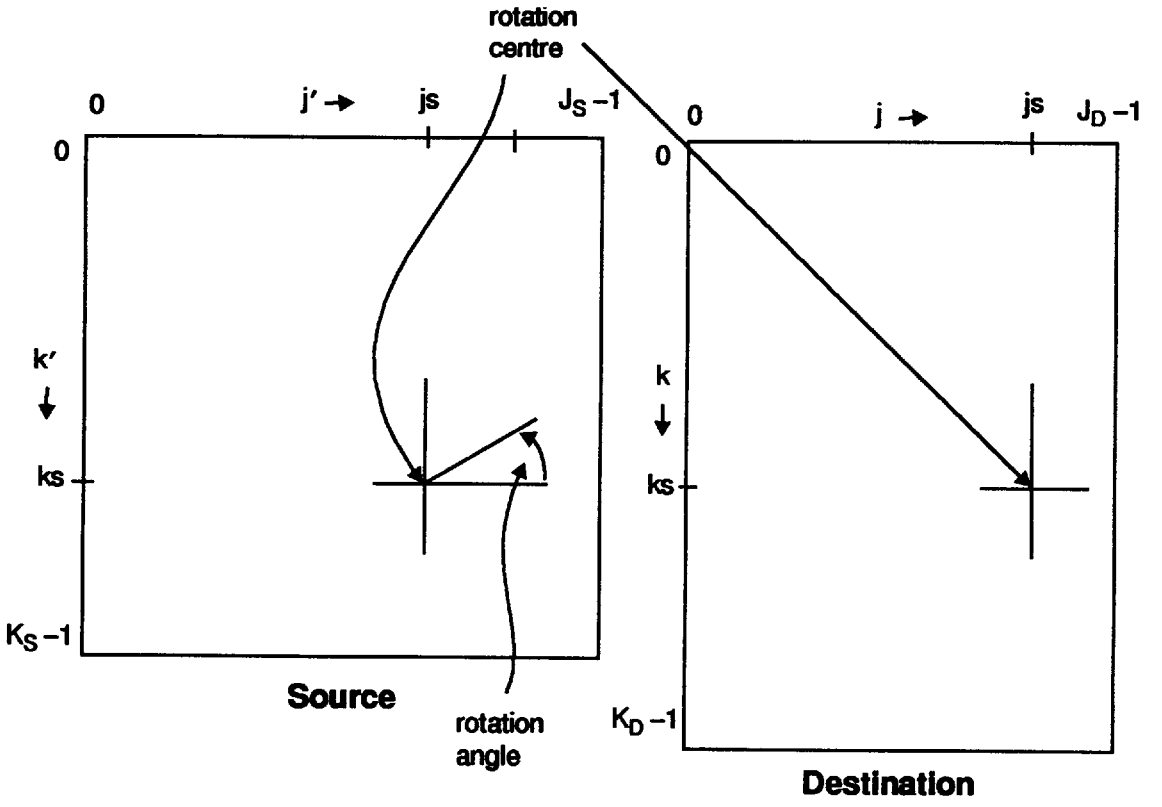

2D rotation

Profile:

Foundation	rotate
Foundation	rotate_roi

Error codes:

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POINT OPERATOR **RUBBER BAND SCALING**

Description:

Performs rubber band amplitude scaling of an image in which the image undergoes a piecewise linear transformation over two linear segments.

Name:

rubber_band_scaling

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
li	low input clip value	NP, SP, RP	in
lo	low output value	NP, SP, RP	in
ui	high input clip value	NP, SP, RP	in
uo	high output value	NP, SP, RP	in
ii	inflection input value	NP, SP, RP	in
io	inflection output value	NP, SP, RP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
li	lower input clip value
ii	inflection point input value, ii > li
ui	upper input clip value, ui > ii
lo	lower output value
io	inflection point output value
uo	upper output value

Definition:

For all x, y, z, t, b,

$$D(x, y, z, t, b) = lo \qquad S(x, y, z, t, b) \leq li$$

$$D(x, y, z, t, b) = \left[\frac{io - lo}{ii - li}\right] S(x, y, z, t, b) + lo - (ii)\left[\frac{io - lo}{ii - li}\right] \qquad li < S(x, y, z, t, b) \leq ii$$

$$D(x, y, z, t, b) = \left[\frac{uo - io}{ui - ii}\right] S(x, y, z, t, b) + io - (ui)\left[\frac{uo - io}{ui - ii}\right] \qquad ii < S(x, y, z, t, b) \leq ui$$

$$D(x, y, z, t, b) = uo \qquad S(x, y, z, t, b) > ui$$

Profile:

Scientific

Error codes:

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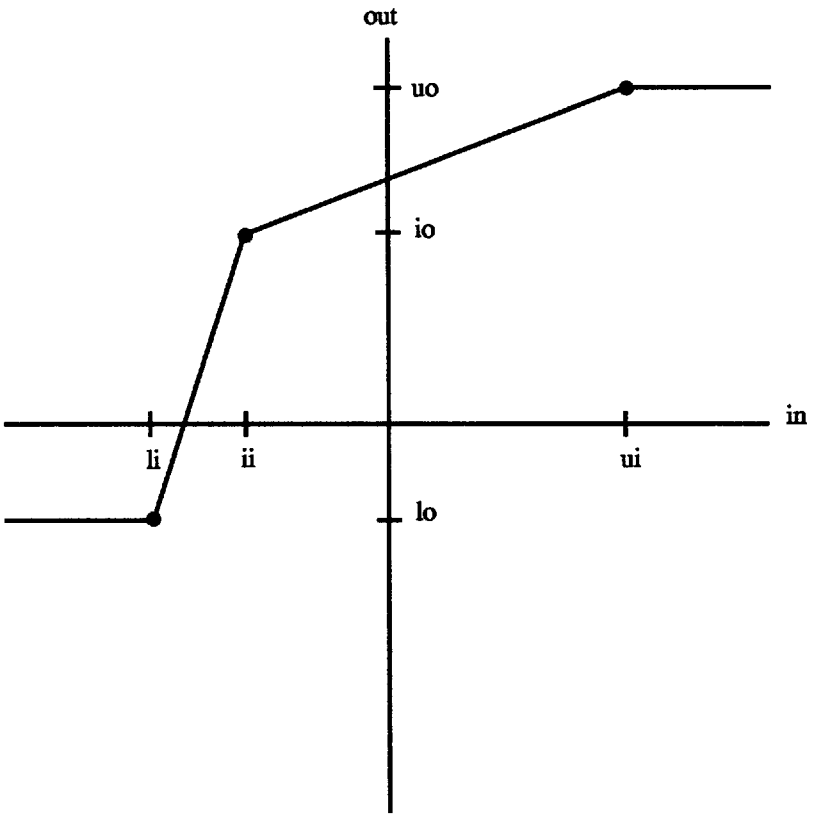

Rubber band scaling transformation

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3D SPECIFIC OPERATOR

SEQUENCE AVERAGE

Description:

Computes the pixel plane average of an image sequence.

Name:

sequence_average

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
option	dimension option	SP	in
	volume		
	temporal		
	spectral		

Objects:

SRC structure:	any image
DST structure:	see Remark
SRC data type:	ND, SD, RD
DST data type:	RD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

The destination image size in the depth, temporal, or spectral index is reduced to unity in the index being averaged.

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sequence_average

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image, Z = 1, T = 1, or B = 1
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image

Definition:

The average pixel amplitude is computed at each coordinate (x,y) across the volume, temporal, or spectral index.

Volume image option:

For all x, y, z, t, b

$$D(x, y, 0, t, b) = \frac{1}{Z} \sum_{z=0}^{Z-1} S(x, y, z, t, b)$$

Temporal image option:

For all x, y, z, t, b

$$D(x, y, z, 0, b) = \frac{1}{T} \sum_{t=0}^{T-1} S(x, y, z, t, b)$$

Spectral image option:

For all x, y, z, t, b

$$D(x, y, z, t, 0) = \frac{1}{B} \sum_{b=0}^{B-1} S(x, y, z, t, b)$$

Profile:

Scientific

Error codes:

011
013
021
023
041
043
061

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3D SPECIFIC OPERATOR

SEQUENCE KARHUNEN-LOEVE

Description:

Performs a Karhunen-Loeve transform of an image sequence based upon an application-supplied covariance matrix.

Name:

sequence_karhunen_loeve

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	sequence covariance matrix object	ID	in
mv	fourth index value	NP	in
nv	fifth index value	NP	in
direction	transform direction option forward transform inverse transform	EP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB structure:	MATRIX
SRC data type:	ND, SD, RD
DST data type:	RD
SOB data type:	RD

Element functionality:

Index assignment:	yes
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
f	vector of source pixels
g	vector of destination pixels
f(p)	p-th element of **f**, $0 \leq p \leq P-1$
g(q)	q-th element of **g**, $0 \leq q \leq Q-1$
A	Karhunen-Loeve transformation matrix
K	covariance matrix of **f**

Definition:

A singular value decomposition procedure is performed on the covariance matrix to determine its eigenvectors, which become the columns of the transformation matrix **A**. Next, for each (j, k) coordinate, a vector **f** is formed along the third dimension of the source image. The matrix product of **f** and the transformation matrix $\mathbf{A}^T$ is formed, and the resulting vector is inserted in the destination image at the (j, k) coordinate.

The transformation matrix **A** is that matrix which satisfies the equation

$$\mathbf{A}^T\mathbf{K}\mathbf{A} = \mathbf{D}$$

where **A** is a matrix whose columns are eigenvectors of **K** and **D** is a diagonal matrix whose elements are the corresponding eigenvalues of **K**. Computationally, **A** can be derived by a singular value decomposition of **K**.

For all j, k, l, let

$$f(l) = S(j, k, l, mv, nv)$$

Then, the forward Karhunen-Loeve transformation of the sequence is

$$\mathbf{g} = \mathbf{A}^T\mathbf{f}$$

and the inverse Karhunen-Loeve transformation of the sequence is

$$\mathbf{g} = \mathbf{A}\mathbf{f}$$

and

$$D(j, k, l, mv, nv) = g(l)$$

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Profile:

Scientific

Error codes:

001
002
011
012
013
014
022
041
042
043
061
101
111
112
134

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3D SPECIFIC OPERATOR

SEQUENCE RUNNING MEASURES

Description:

Computes running difference, ratio, and log ratio measures of depth, time, and spectral sequences of pixel planes.

Name:

sequence_running_measures

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
structure_option	structure option volume temporal spectral	SP	in
measure_option	measure option difference ratio log ratio	SP	in

Objects:

SRC structure:	any image
DST structure:	see Remark
SRC data type:	ND, SD, RD
DST data type:	RD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

The destination image sequence size in the depth, temporal, or spectral index is one less than the corresponding source dimension.

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Nomenclature:

SRC(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ source image, SRC(x, y, z, t, b) > 0
DST(x, y, z, t, b)	$X_D x Y_D x Z_D x T_D x B_D$ destination image
S(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ operator input image
D(x, y, z, t, b)	$X_D x Y_D x Z_D x T_D x B_D$ operator output image

Definition:

Volume image option:

Running difference:

For all x, y, t, b, and for $0 \leq z \leq Z_S - 2$

$$D(x, y, z, t, b) = S(x, y, z + 1, t, b) - S(x, y, z, t, b)$$

Running ratio:

For all x, y, t, b, and for $0 \leq z \leq Z_S - 2$

$$D(x, y, z, t, b) = \frac{S(x, y, z+1, t, b)}{S(x, y, z, t, b)}$$

Running log ratio:

For all x, y, t, b, and for $0 \leq z \leq Z_S - 2$

$$D(x, y, z, t, b) = LOG\left\{\frac{S(x, y, z+1, t, b)}{S(x, y, z, t, b)}\right\}$$

Temporal image option:

Running difference:

For all x, y, z, b, and for $0 \leq t \leq T_S - 2$

$$D(x, y, z, t, b) = S(x, y, z, t + 1, b) - S(x, y, z, t, b)$$

Running ratio:

For all x, y, z, b, and for $0 \leq t \leq T_S - 2$

$$D(x, y, z, t, b) = \frac{S(x, y, z, t+1, b)}{S(x, y, z, t, b)}$$

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Running log ratio:

For all x, y, z, b, and for $0 \leq t \leq T_S - 2$

$$D(x, y, z, t, b) = LOG\left\{ \frac{S(x, y, z, t+1, b)}{S(x, y, z, t, b)} \right\}$$

Spectral image option:

Running difference:

For all x, y, z, t, and for $0 \leq b \leq B_S - 2$

$$D(x, y, z, t, b) = S(x, y, z, t, b + 1) - S(x, y, z, t, b)$$

Running ratio:

For all x, y, z, t, and for $0 \leq b \leq B_S - 2$

$$D(x, y, z, t, b) = \frac{S(x, y, z, t, b+1)}{S(x, y, z, t, b)}$$

Running log ratio:

For all x, y, z, t, and for $0 \leq b \leq B_S - 2$

$$D(x, y, z, t, b) = LOG\left\{ \frac{S(x, y, z, t, b+1)}{S(x, y, z, t, b)} \right\}$$

Profile:

Scientific

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Error codes:

001
003
011
013
014
021
025
041
043
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103
172
173

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Description:

Sets the PIKS global modes.

Name:

set_globals

Parameters:

roi_control_mode	ROI control mode option ROI control engaged ROI control disengaged	EP	in
roi_process_mode	ROI processing mode option ROI source processing engaged ROI source processing disengaged	EP	in
match_point_mode	match point mode option match point engaged match point disengaged	EP	in
index_assign_mode	index assignment mode option index assign engaged index assign disengaged	EP	in
synchronicity_mode	synchronicity mode option synchronous asynchronous	EP	in
error_reporting_mode	error reporting mode option errors reported errors not reported	EP	in
image_resampling_select	image resampling selection support 1 constant support 2 linear support 2 lookup table support 4 truncated sinc support 4 cubic B-spline support 4 cubic convolution support 4 Lagrangian support 4 lookup table support 8 truncated sinc support 8 lookup table	SP	in
roi_resampling_select	ROI resampling selection support 1 constant support 2 linear support 2 lookup table support 4 truncated sinc support 4 cubic B-spline support 4 cubic convolution support 4 Lagrangian support 4 lookup table support 8 truncated sinc	SP	in

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support 8 lookup table

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

Invocation of this mechanism with synchronous mode specified as "synchronous" shall cause an implicit synchronization when operating in the asynchronous mode.

Definition:

This control mechanism sets the following PIKS global attributes

ROI control engagement
ROI processing engagement
match point engagement
index assignment engagement
synchronous versus asynchronous operation engagement
error reporting
image resampling method selection
ROI resampling method selection

The following are definitions of the parameters:

roi_control_mode	Determines if the source and destination ROI control mechanisms are activated in the PIKS operator processing model.
roi_process_mode	Determines if the source ROI processing mechnism is activated in the PIKS operator processing model.
match_point_mode	Determines if the match point control mechanism is activated in the PIKS operator processing model.
index_assign_mode	Determines if the index assignment control mechanism is activated in the PIKS operator processing model.
synchroncity_mode	Determines if PIKS operators and chains operate synchronously (do not return to the application until complete), or asynchronously (return control to the application before execution completes).
error_reporting_mode	Determines if PIKS errors are reported.
image_resampling_select	Selects image resampling option for operators.
roi_resampling_select	Selects ROI resampling option for operators.

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Profile:

Foundation

Error codes:

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003

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Description:

Sets image attributes of a previously allocated image.

Name:

set_image_attributes

Parameters:

DST	destination image	ID	in/out
image_size	image size 5-tuple	ID, NULL	in
band_type	band data B-type tuple	ID, NULL	in
band_precision	band precision B-tuple	ID, NULL	in
X_o	X tristimulus value white point	RP, NULL	in
Y_o	Y tristimulus value white point	RP, NULL	in
Z_o	Z tristimulus value white point	RP, NULL	in
structure	image structure option	SP, NULL	in
	MON		
	VOL		
	TEM		
	COLR		
	SPE		
	VT		
	VC		
	VS		
	TC		
	TS		
	VTC		
	VTS		
	GEN		
colour	colour space option	SP, NULL	in
	unspecified		
	non-standard RGB		
	linear CCIR illuminant D65 RGB		
	linear CIE illuminant E RGB		
	linear EBU illuminant C RGB		
	linear EBU illuminant D65 RGB		
	linear NTSC illuminant C RGB		
	linear NTSC illuminant D65 RGB		
	linear SMPTE illuminant D65 RGB		
	gamma CCIR illuminant D65 RGB		
	gamma EBU illuminant C RGB		
	gamma EBU illuminant D65 RGB		
	gamma NTSC illuminant C RGB		
	gamma NTSC illuminant D65 RGB		
	gamma SMPTE illuminant D65 RGB		
	luminance/chrominance EBU illuminant C YUV		
	luminance/chrominance EBU illuminant D65 YUV		

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luminance/chrominance NTSC illuminant C YIQ
luminance/chrominance NTSC illuminant D65 YIQ
luminance/chrominance SMPTE illuminant D65 YCbCr
CIE XYZ
CIE UVW
CIE Yxy
CIE Yuv
CIE L*a*b*
CIE L*u*v*
IHS
CMY
CMYK

Object:

DST structure:	as specified
DST data type:	as specified

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The tuples can be created by the *create_tuple* utility.
2. Each image attribute may be specified as NULL. In each instance, the attribute will be set when the image data is created by a PIKS element.
3. The band_precision_tuple may be set as a request for a certain precision for arithmetic data types. PIKS implementations are not required to grant such requests.
4. The *image_size* and *band_precision* tuples contain parameters of the ND data type.
5. The *band_type* tuple contains parameters of the SD data type.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB destination image

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Definition:

This mechanism performs the following functions:

replaces image size, band data type, and band precision tuples in the image attributes.

replaces image structure and colour space information in the image attributes.

Profile:

Foundation

Error codes:

001
003
011
013

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SYSTEM MANAGEMENT MECHANISM **SET INDEX ASSIGNMENT**

Description:

Sets the global index assignment state.

Name:

set_index_assignment

Parameters:

j_assign	j index assignment option x y z t b	EP	in
k_assign	k index assignment option x y z t b	EP	in
l_assign	l index assignment option x y z t b	EP	in
m_assign	m index assignment option x y z t b	EP	in
n_assign	n index assignment option x y z t b	EP	in

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Objects:

None

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

A source image index can be assigned only once, e.g., if x is assigned to k, it cannot be assigned to any other operator index.

Nomenclature:

x	source image horizontal index
y	source image vertical index
z	source image depth index
t	source image temporal index
b	source image band index
j	operator input image first index
k	operator input image second index
l	operator input image third index
m	operator input image fourth index
n	operator input image fifth index

Definition:

The *index_assignment* mechanism sets the relationships between the image indices and the operator input image indices as follows:

Operator index	Image index
j	CHOICE{x, y, z, t, b}
k	CHOICE{x, y, z, t, b} but not j choice
l	CHOICE{x, y, z, t, b} but not j or k choices
m	CHOICE{x, y, z, t, b} but not j, k, or l choices
n	CHOICE{x, y, z, t, b} but not j, k, l, or m choices

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The following is an example of an index assignment to perform a 3D operation on the x, y and t indices of an image.

Operator index	Image index
j	x
k	y
l	t
m	z
n	b

In this example, the assignment of z to m and b to n is arbitrary; the same result would be achieved by the assignment of b to m and z to n.

Profile:

Technical

Error codes:

001
002
012
014
024
044

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SHAPE OPERATOR **SHAPE METRICS**

Description:

Generates an array of shape metrics of objects in a pixel plane of a Boolean image.

Name:

shape_metrics

Parameters:

SRC	source image	ID	in
DOB	shape metric array object	IP	out
lv	third index value	NP	in
mv	fourth index value	NP	in
nv	fifth index value	NP	in
limit	object number limit	NP	in

Objects:

SRC structure:	any image
DOB structure:	EXT
SRC data type:	BD
DOB data type:	RP

Element functionality:

Index assignment:	yes
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	no
Asynchronous:	no

Remarks:

1. An object is defined to be a collection of eight-connected pixels of the Boolean TRUE state that are surrounded by pixels of the Boolean FALSE state.
2. An object may have "holes" - Boolean FALSE state pixels within its interior, which are four-connected.
3. The *perimeter_code_generator* operator defines the object identification process.

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Nomenclature:

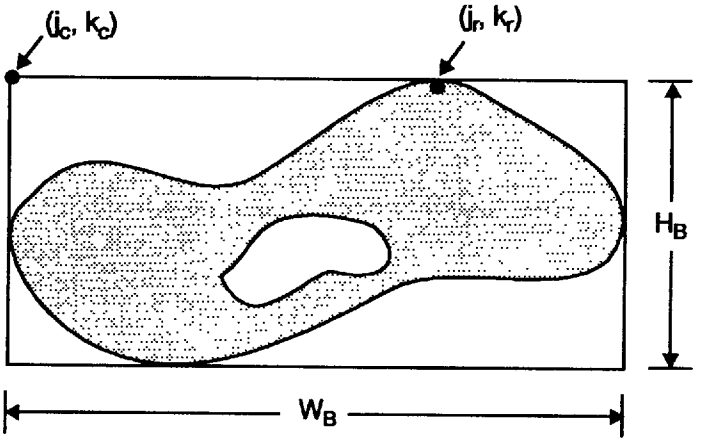
SRC(x, y, z, t, b)	XxYxZxTxB source image
S(j, k, l, m, n)	JxKxLxMxN operator input image
lv	third index value, $lv \geq 0$
mv	fourth index value, $mv \geq 0$
nv	fifth index value, $nv \geq 0$
P	number of shape metrics per object, $P \geq 0$
s(p)	p-th shape metrics sub list entry, $0 \leq p \leq P - 1$
Q	number of objects examined, $Q \leq Q_M$
q	object index, $1 \leq q \leq Q$
Q_M	object number limit

Definition:

Starting at the origin, the j-k plane of S(j, k, lv, mv, nv) is sequentially examined (raster scanned) in increasing index order (j index first) until a TRUE state pixel is encountered. This first encountered TRUE pixel is called the reference pixel. Starting at the upper left-hand corner of the reference pixel, the outer perimeter of the object is then traversed, in a clockwise manner, along the edges (cracks) of perimeter pixels until the reference pixel is again encountered.

After the shape metrics of an object have been generated, all TRUE state pixels within the interior of the object are removed from further consideration (virtually, but not physically set to the FALSE state). The scanning process resumes until all objects are detected or until the object number limit has been reached.

With reference to the figure, the following are definitions of the shape metrics for each object. The shape metrics are defined in the text "Digital Image Processing" by W. K. Pratt. See Annex K.



Object in bounding box

Reference pixel column index:

$$s(1) = j_r$$

where j_r is the column index of the first TRUE state pixel in the object that was encountered during a raster scan of the image.

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Reference pixel row index:

$$s(2) = k_r$$

where k_r is the row index of the first TRUE state pixel in the object that was encountered during a raster scan of the image.

Object city block outer perimeter:

$$s(3) = P_E$$

where P_E is the count of the number of pixel cracks traversed while following the object's outer contour starting and stopping at the upper left corner of the reference pixel.

Area enclosed by city block outer perimeter:

$$s(4) = A_E$$

where A_E is the count of the number of pixels (TRUE or FALSE state) enclosed by the outer perimeter of the object.

Object area:

$$s(5) = A_O$$

where A_O is the count of the number of TRUE state pixels enclosed by the city block outer perimeter of the object.

Hole area:

$$s(6) = A_E - A_O$$

Object Euclidean perimeter:

$$s(7) = P_O$$

where P_O is an approximation of the perimeter of a continuous object that has been discretized. It is computed as:

$$P_O = n\{Q_2\} + \frac{1}{\sqrt{2}}[n\{Q_1\} + n\{Q_3\} + 2n\{Q_D\}]$$

where n{.} is the count of the number of "bit quad" patterns detected while traversing the pixel cracks of the city block outer perimeter. The following figure defines the bit quad patterns.

Object Euclidean area:

$$s(8) = A_O$$

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where A_O is an approximation of the area of a continuous object that has been discretized. It is computed as:

$$A_O = \frac{1}{4}n\{Q_1\} + \frac{1}{2}n\{Q_2\} + \frac{7}{8}n\{Q_3\} + n\{Q_4\} + \frac{3}{4}n\{Q_D\}$$

Eight-connectivity Euler number:

$$s(9) = E$$

where

$$E = \frac{1}{4}[n\{Q_1\} - n\{Q_3\} - 2n\{Q_D\}]$$

Circularity:

$$s(10) = \frac{4\pi A_O}{(P_O)^2}$$

Number of holes:

Count of the number of holes in the object.

Bounding box upper left corner column index:

$$s(11) = j_c$$

where j_c is the column index of a bounding box that encloses the object. Let j_n denote the smallest column index of a pixel in the object, then

$$j_c = j_n - 1$$

Bounding box upper left corner row index:

$$s(12) = k_c$$

where k_c is the row index of a bounding box that encloses the object. Let k_n denote the smallest row index of a pixel in the object, then

$$k_c = k_n - 1$$

Bounding box width:

$$s(13) = W_B$$

where W_B is the bounding box width. Let j_m denote the largest column index of a pixel in the object, then

$$W_B = j_m - j_n + 2$$

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Bounding box height:

$$s(14) = H_B$$

where H_B is the bounding box height. Let k_m denote the largest row index of a pixel in the object. Then

$$H_B = k_m - k_n + 2$$

Bounding box area:

$$s(15) = A_B$$

where

$$A_B = W_B \times H_B$$

Bounding box area ratio:

Ratio of bounding box area to enclosed area of object.

$$s(16) = \frac{A_B}{A_E}$$

The external array is defined as follows:

1
s(1)
.
.
s(16)
.
.
.
.
q
s(1)
.
.
s(16)
.
.
.
.
Q
s(1)
.
.
s(16)

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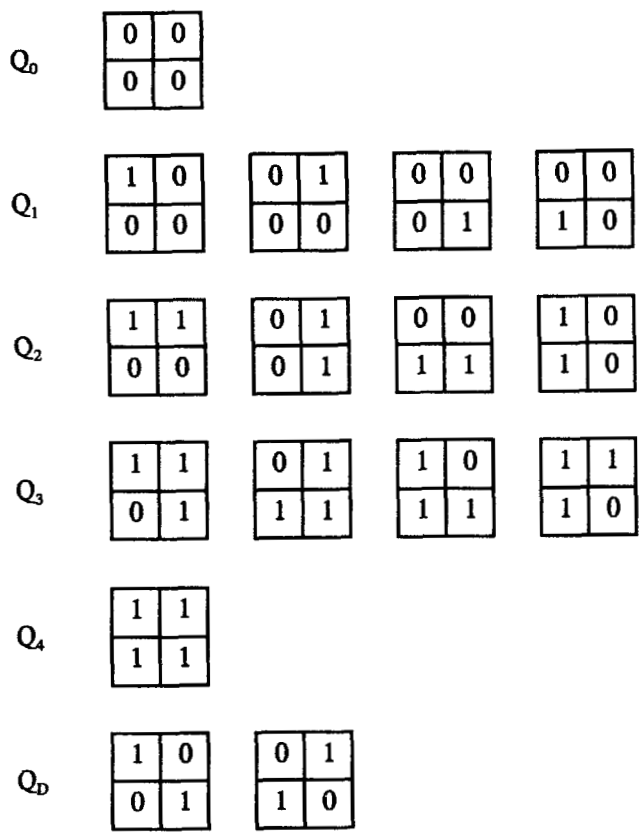

Bit Quad Patterns

Profile:

Scientific

Error codes:

001
011
012
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014
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041
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SHAPE OPERATOR **SPATIAL MOMENTS, INVARIANT**

Description:

Generates an array of Hu's invariant spatial moments of a pixel plane of an image.

Name:

spatial_moments_invariant

Parameters:

SRC	source image	ID	in
DOB	spatial moments array object	IP	out
lv	third index value	NP	in
mv	fourth index value	NP	in
nv	fifth index value	NP	in

Objects:

SRC structure:	any image
DOB structure:	EXT
SRC data type:	BD, ND, SD, RD
DOB data type:	RP

Element functionality:

Index assignment:	yes
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	no
Asynchronous:	no

Remark:

Prior to computation, a Boolean data type image is converted to real data type form such that TRUE state pixels are represented in value as 1.0 and FALSE state pixels are represented in value as 0.0.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
S(j, k, l, m, n)	JxKxLxMxN operator input image
lv	third index value, $lv \leq 0$
mv	fourth index value, $mv \leq 0$
nv	fifth index value, $nv \leq 0$
h(r)	r-th invariant spatial moment, $1 \leq r \leq 7$
r	spatial moment variable

Definition:

This operator generates an array of the seven invariant spatial moments. These spatial moments are reasonably invariant to translation, minification, magnification, and rotation of an object within an image.

The invariant spatial moments array contains the following entries:

h(1)
h(2)
h(3)
h(4)
h(5)
h(6)
h(7)

The invariant spatial moments are defined as follows.

$$h(1) = V(2, 0) + V(0, 2)$$

$$h(2) = [V(2, 0) - V(0, 2)]^2 + 4[V(1, 1)]^2$$

$$h(3) = [V(3, 0) - 3V(1, 2)]^2 + [V(0, 3) - 3V(2, 1)]^2$$

$$h(4) = [V(3, 0) + V(1, 2)]^2 + [V(0, 3) + V(2, 1)]^2$$

$$h(5) = [V(3, 0) - 3V(1, 2)][V(3, 0) + V(1, 2)][[V(3, 0) + V(1, 2)]^2 - 3[V(0, 3) + V(2, 1)]^2]$$
$$+ [3V(2, 1) - V(0, 3)][V(0, 3) + V(2, 1)][3[V(3, 0) + V(1, 2)]^2 - [V(0, 3) + V(2, 1)]^2]$$

$$h(6) = [V(2, 0) - V(0, 2)][[V(3, 0) + V(1, 2)]^2 - [V(0, 3) + V(2, 1)]^2]$$
$$+ 4V(1, 1)[V(3, 0) + V(1, 2)][V(0, 3) + V(2, 1)]$$

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$$h(7) = [3V(2, 1) - V(0, 3)][V(3, 0) + V(1, 2)][[V(3, 0) + V(1, 2)]^2 - 3[V(0, 3) + V(2, 1)]^2]$$
$$+ [3V(1, 2) - V(3, 0)][V(0, 3) + V(2, 1)][3[V(3, 0) + V(1, 2)]^2 - [V(0, 3) + V(2, 1)]^2]$$

where the normalized central moment is

$$V(p, q) = \frac{U(p, q)}{[M(0, 0)]^a}$$

with

$$a = \frac{p+q}{2} + 1$$

The non-normalized, non-central spatial moment is

$$M(p, q) = \sum_{j=0}^{J-1} \sum_{k=0}^{K-1} (j)^p (k)^q S(j, k, lv, mv, nv)$$

The non-normalized, central spatial moment is

$$U(p, q) = \sum_{j=0}^{J-1} \sum_{k=0}^{K-1} (j - \bar{j})^p (k - \bar{k})^q S(j, k, lv, mv, nv)$$

and the first and second index centres of gravity are

$$\bar{j} = \frac{M(1, 0)}{M(0, 0)}$$

$$\bar{k} = \frac{M(0, 1)}{M(0, 0)}$$

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Profile:

Scientific

Error codes:

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SHAPE OPERATOR **SPATIAL MOMENTS, SCALED**

Description:

Generates a list of scaled spatial moments of a pixel plane of an image.

Name:

spatial_moments_scaled

Parameters:

SRC	source image	ID	in
DOB	spatial moments array object	IP	out
lv	third index value	NP	in
mv	fourth index value	NP	in
nv	fifth index value	NP	in

Objects:

SRC structure:	any image
DOB structure:	EXT
SRC data type:	BD, ND, SD, RD
DOB data type:	RP

Element functionality:

Index assignment:	yes
Match point:	no
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	no
Asynchronous:	no

Remark:

Prior to computation, a Boolean data type image is converted to real data type form such that TRUE state pixels are represented in value as 1.0 and FALSE state pixels are represented in value as 0.0.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
S(j, k, l, m, n)	JxKxLxMxN operator input image
lv	third index value, $lv \geq 0$
mv	fourth index value, $mv \geq 0$
nv	fifth index value, $nv \geq 0$
p	first index spatial moment variable
q	second index spatial moment variable
h(r)	n-th array element, $1 \leq r \leq 22$

Definition:

This operator generates a list of the scaled non-central spatial moments of order up to three, the first index and second index centres of gravity, the scaled central spatial moments of order up to three, the maximum and minimum eigenvalues of the central moments covariance matrix, and the orientation angle associated with the covariance matrix.

The scaled spatial moments array contains the following entries

h(1) = M(0, 0)
h(2) = M(1, 0)
h(3) = M(0, 1)
h(4) = M(2, 0)
h(5) = M(1, 1)
h(6) = M(0, 2)
h(7) = M(3, 0)
h(8) = M(2, 1)
h(9) = M(1, 2)
h(10) = M(0, 3)
h(11) = J_COG
h(12) = K_COG
h(13) = U(2, 0)
h(14) = U(1, 1)
h(15) = U(0, 2)
h(16) = U(3, 0)
h(17) = U(2, 1)
h(18) = U(1, 2)
h(19) = U(0, 3)
h(20) = EIGEN_MAX
h(21) = EIGEN_MIN
h(22) = ANGLE

The entries are defined as follows.

Scaled non-central spatial moments:

$$M(p,q) = \frac{1}{(J)^p (K)^q} \sum_{j=0}^{J-1} \sum_{k=0}^{K-1} (j)^p (k)^q S(j, k, lv, mv, nv)$$

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First index centre of gravity:

$$J_COG = \bar{j}$$

where

$$\bar{j} = \frac{M(1, 0)}{M(0, 0)}$$

Second index centre of gravity:

$$K_COG = \bar{k}$$

where

$$\bar{k} = \frac{M(0, 1)}{M(0, 0)}$$

Scaled central spatial moments:

$$U(p, q) = \frac{1}{(J)^p (K)^q} \sum_{j=0}^{J-1} \sum_{k=0}^{K-1} (j - \bar{j})^p (k - \bar{k})^q S(j, k, lv, mv, nv)$$

Eigenvalues:

$$EIGEN_MAX = \lambda_M$$

$$EIGEN_MIN = \lambda_N$$

where

$$\lambda_M = MAX\ \{\lambda_1, \lambda_2\}$$

$$\lambda_N = MIN\{\lambda_1, \lambda_2\}$$

and

$$\lambda_1 = (0.5)[U(2, 0) + U(0, 2)] + (0.5)[U(2, 0)^2 + U(0, 2)^2 - 2U(2, 0)U(0, 2) + 4U(1, 1)^2]^{1/2}$$

$$\lambda_2 = (0.5)[U(2, 0) + U(0, 2)] - (0.5)[U(2, 0)^2 + U(0, 2)^2 - 2U(2, 0)U(0, 2) + 4U(1, 1)^2]^{1/2}$$

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Orientation angle:

$$ANGLE = ATAN2\{[\lambda_M - U(0, 2)], U(1, 1)\}$$

Profile:

Scientific

Error codes:

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DYADIC OPERATOR

SPLIT IMAGE

Description:

Generates split image views of a pair of monochrome or colour images.

Name:

split_image

Parameters:

SRC1	first source image	ID	in
SRC2	second source image	ID	in
DST	destination image	ID	out
s	split position	NP	in
option	split image option left 1-left 2 right 1-right 2 top 1-top 2 bottom 1-bottom 2 left 1-right 2 top 1-bottom 2	SP	in

Objects:

SRC1 structure:	MON, COLR
SRC2 structure:	same as SRC1 structure
DST structure:	same as SRC1 structure
SRC1 data type:	BD, ND, SD, RD
SRC2 data type:	same as SRC1 data type
DST data type:	same as SRC1 data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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split_image

Nomenclature:

SRC1(x, y, z, t, b)	XxYxZxTxB first source image
SRC2(x, y, z, t, b)	XxYxZxTxB second source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S1(x, y, z, t, b)	XxYxZxTxB first operator input image
S2(x, y, z, t, b)	XxYxZxTxB second operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
s	split position, $0 < s < X$ for vertical split or $0 < s < Y$ for horizontal split

Definition:

For all x, y, b

Left 1–left 2:

$$D(x, y, 0, 0, b) = S1(x, y, 0, 0, b) \qquad 0 \le x \le s - 1$$

$$D(x, y, 0, 0, b) = S2(x-s, y, 0, 0, b) \qquad s \le x \le X - 1$$

Right 1–right 2:

$$D(x, y, 0, 0, b) = S1(x+s, y, 0, 0, b) \qquad 0 \le x \le s - 1$$

$$D(x, y, 0, 0, b) = S2(x, y, 0, 0, b) \qquad s \le x \le X - 1$$

Top 1–top 2:

$$D(x, y, 0, 0, b) = S1(x, y, 0, 0, b) \qquad 0 \le y \le s - 1$$

$$D(x, y, 0, 0, b) = S2(x, y-s, 0, 0, b) \qquad s \le y \le Y - 1$$

Bottom 1–bottom 2:

$$D(x, y, 0, 0, b) = S1(x, y+s, 0, 0, b) \qquad 0 \le y \le s - 1$$

$$D(x, y, 0, 0, b) = S2(x, y, 0, 0, b) \qquad s \le y \le Y - 1$$

Left 1–right 2:

$$D(x, y, 0, 0, b) = S1(x, y, 0, 0, b) \qquad 0 \le x \le s - 1$$

$$D(x, y, 0, 0, b) = S2(x, y, 0, 0, b) \qquad s \le x \le X - 1$$

Top 1–bottom 2:

$$D(x, y, 0, 0, b) = S1(x, y, 0, 0, b) \qquad 0 \le y \le s - 1$$

$$D(x, y, 0, 0, b) = S2(x, y, 0, 0, b) \qquad s \le y \le Y - 1$$

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Profile:

Foundation

Error codes:

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GEOMETRIC OPERATOR **SUBSAMPLE**

Description:

Performs spatial subsampling of an image. Pixels are extracted from a source window offset with respect to the source origin and placed in a destination image window offset with respect to the destination origin.

Name:

subsample subsample_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
jf	source first index subsampling factor	NP	in
kf	source second index subsampling factor	NP	in
js	source first index offset	NP	in
ks	source second index offset	NP	in
jd	destination first index offset	NP	in
kd	destination second index offset	NP	in
jw	source first index window width	NP	in
kw	source second index window height	NP	in

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SRC data type:	BD, ND, SD, RD, CD	BD
DST data type:	same as SRC data type	BD

Element functionality:

Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	yes	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Remark:

Subsampling is not performed along the band index of a colour image.

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Nomenclature:

SRC(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ source image
DST(x, y, z, t, b)	$X_D x Y_D x Z_D x T_D x B_D$ destination image
S(j, k, l, m, n)	$J_S x K_S x L_S x M_S x N_S$ operator input image
D(j, k, l, m, n)	$J_D x K_D x L_D x M_D x N_D$ operator output image
jf	source first index subsampling factor, $1 \leq jf \leq J_S$
kf	source second index subsampling factor, $1 \leq kf \leq K_S$
js	source first index offset, $0 \leq js \leq J_S - 1$
ks	source second index offset, $0 \leq ks \leq K_S - 1$
jd	destination first index offset, $0 \leq jd \leq J_D - 1$
kd	destination second index offset, $0 \leq kd \leq K_D - 1$
jw	source first index window width
kw	source second index window height

Definition:

For all l, m, n and for

$$jd \leq j \leq MIN\{J_S - 1, J_M\}$$

$$kd \leq k \leq MIN\{K_S - 1, K_M\}$$

$$D(j, k, l, m, n) = S[(jf)(j - jd) + js, (kf)(k - kd) + ks, l, m, n]$$

D(j, k, l, m, n) is unchanged otherwise

where

$$J_M = LIV\{jw/jf\}$$

$$K_M = LIV\{kw/kf\}$$

Profile:

Foundation	subsample
Technical	subsample_roi

Error codes:

001
011
013
025
041
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101

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Description:

Provides an application wait until all asynchronous operations have been completed.

Name:

synchronize

Parameters:

None

Objects:

None

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

Definition:

This control mechanism tests for ongoing or queued asynchronous operations including chained operations. It causes an operational wait until all activity has been completed and the queue has been emptied before returning.

Profile:

Scientific

Error codes:

062
302

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CORRELATION OPERATOR **TEMPLATE MATCH**

Description:

Computes the cross-correlation function array of a pixel plane of an image and a template extracted from another image.

Name:

template_match

Parameters:

SRC1	first source image	ID	in
SRC2	second source image	ID	in
DOB	cross-correlation array object	ID	out
lv	third index value	NP	in
mv	fourth index value	NP	in
nv	fifth index value	NP	in
js	first image first index offset	NP	in
ks	first image second index offset	NP	in
jt	second image first index offset	NP	in
kt	second image second index offset	NP	in
U	number of columns of search window	NP	in
V	number of rows of search window	NP	in
P	number of columns of template	NP	in
Q	number of rows of template	NP	in

Objects:

SRC1 structure:	any image
SRC2 structure:	same as SRC1 structure
DOB structure:	STATIC_ARRAY
SRC1 data type:	ND, SD, RD
SRC2 data type:	same as SRC1 data type
DOB data type:	RD

Element functionality:

Index assignment:	yes
Match point:	no
ROI control:	no
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC1(x, y, z, t, b)	XxYxZxTxB first source image
SRC2(x, y, z, t, b)	XxYxZxTxB second source image
S1(j, k, l, m, n)	JxKxLxMxN first operator input image
S2(j, k, l, m, n)	JxKxLxMxN second operator input image
A(c, r)	CxR cross-correlation array
C	number of array columns, $C \geq 1$
R	number of array rows, $R \geq 1$
lv	third index value, $lv \geq 0$
mv	fourth index value, $mv \geq 0$
nv	fifth index value, $nv \geq 0$
js	first image first index offset, $0 \leq js \leq J - 1$
ks	first image second index offset, $0 \leq ks \leq K - 1$
jt	second image first index offset, $0 \leq jt \leq J - 1$
kt	second image second index offset, $0 \leq kt \leq K - 1$
U	number of columns of search window, $0 < U < J - 1$
V	number of rows of search window, $0 < V < K - 1$
P	number of columns of template, $P < U$
Q	number of rows of template, $Q < V$
F(u, v)	UxV search window, $U \geq 1, V \geq 1$
T(p, q)	PxQ template, $P \geq 1, Q \geq 1$

Definition:

A PxQ template sub-image, T(p, q), is extracted from source image S2(j, k, l, m, n) and the cross-correlation function array is formed over a UxV search area, F(u, v), in S1(j, k, l, m, n).

For

$$0 \leq u \leq U - 1$$

$$0 \leq v \leq V - 1$$

$$F(u, v) = S1(u + js, v + ks, lv, mv, nv)$$

For

$$0 \leq p \leq P - 1$$

$$0 \leq q \leq Q - 1$$

$$T(p, q) = S2(p + jt, q + kt, lv, mv, nv)$$

For

$$0 \leq r \leq R - 1$$

$$0 \leq c \leq C - 1$$

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and

$$C = U - P + 1$$

$$R = V - Q + 1$$

$$A(c,r) = \frac{\sum_u \sum_v F(u,v)\, T(u - c + c_c, v - r + r_c)}{\left[\sum_u \sum_v [F(u,v)]^2\right]^{1/2} \left[\sum_u \sum_v [T(u - c + c_c, v - r + r_c)]^2\right]^{1/2}}$$

where

$$c_c = \mathrm{LIV}\{\frac{C-1}{2}\}$$

$$r_c = \mathrm{LIV}\{\frac{R-1}{2}\}$$

and the summation limits are

$$c - c_c \leq u \leq c - c_c + P - 1$$

$$r - r_c \leq v \leq r - r_c + Q - 1$$

Profile:

Scientific

Error codes:

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POINT OPERATOR **THRESHOLD**

Description:

Performs pixel amplitude thresholding of an image such that a destination pixel is set at a specified value if the source pixel is equal to or above a threshold, and the destination pixel is set at another specified value if the source pixel is below the threshold.

Name:

threshold

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
ac	above threshold clip value	BP,NP,SP,RP,CP	in
bc	below threshold clip value	BP,NP,SP,RP,CP	in
th	threshold value	NP,SP,RP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	BD, ND, SD, RD, CD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. Destination data type need not be the same as the source data type.
2. The parameter "th" must be of the same data type as the source image.
3. The parameters "ac" and "bc" must be of the same data type as the destination image.

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Nomenclature:

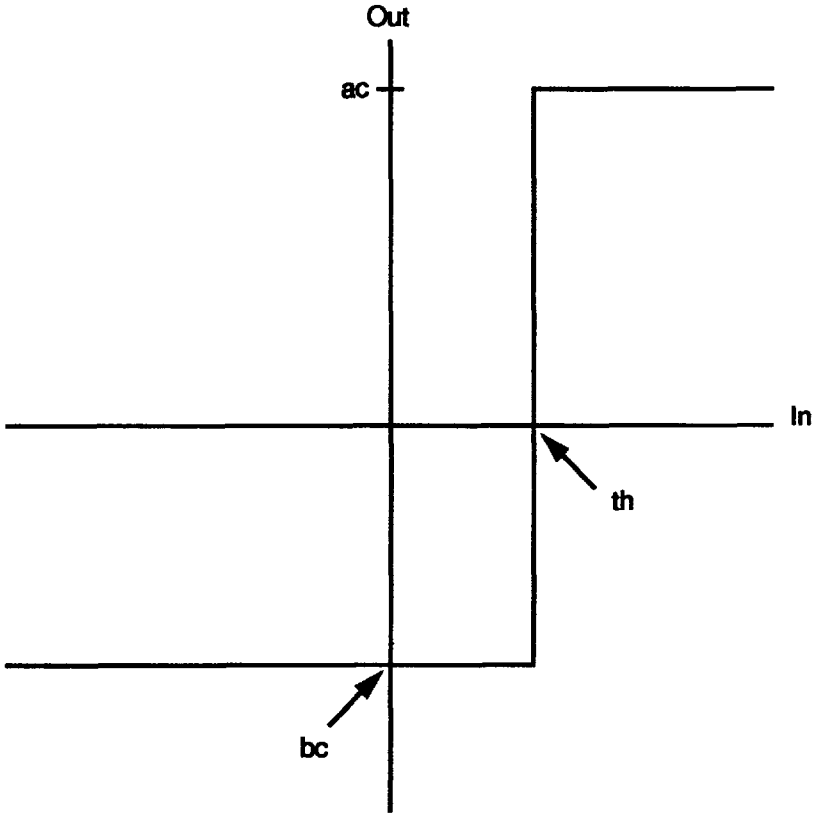
SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
ac	above threshold output value
bc	below threshold output value
th	threshold value

Definition:

As shown in the following figure, for all x, y, z, t, b

$D(x, y, z, t, b) = ac$ if $S(x, y, z, t, b) \geq th$

$D(x, y, z, t, b) = bc$ if $S(x, y, z, t, b) < th$



Threshold transformation

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UNITARY TRANSFORM OPERATOR **TRANSFORM, COSINE**

Description:

Performs a two-dimensional cosine transform in rectangular blocks on pixel planes of an image.

Name:

transform_cosine

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
horizontal_block	horizontal block size	NP	in
vertical_block	vertical block size	NP	in
direction	direction option forward transform inverse transform	EP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	RD

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	no
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The block size dimensions shall be a power of two.
2. The j-k pixel plane dimensions must be integer multiples of the block size.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
$S(j_s, k_s, l, m, n)$	JxKxLxMxN operator input image
$D(j_d, k_d, l, m, n)$	JxKxLxMxN operator output image
J_B	horizontal block size, $J_B > 0$
K_B	vertical block size, $K_B > 0$

Definition:

Forward transform:

For all l, m, n and for

$$0 \le j_s \le J-1$$

$$0 \le k_s \le K-1$$

$$0 \le j_d \le J-1$$

$$0 \le k_d \le K-1$$

$$D(j_d, k_d, l, m, n) = \frac{2}{\sqrt{J_B K_B}} C(j_d)\, C(k_d) \sum_{j'_s}^{J_B-1} \sum_{k'_s}^{K_B-1} S(j_s, k_s, l, m, n)$$

$$\times \cos\left\{\frac{\pi}{J} j'_d (j'_s + 0.5)\right\} \cos\left\{\frac{\pi}{K} k'_d (k'_s + 0.5)\right\}$$

Inverse transform:

For all l, m, n and for

$$0 \le j_s \le J-1$$

$$0 \le k_s \le K-1$$

$$0 \le j_d \le J-1$$

$$0 \le k_d \le K-1$$

$$D(j_d, k_d, l, m, n) = \frac{2}{\sqrt{J_B K_B}} \sum_{j'_s}^{J_B-1} \sum_{k'_s}^{K_B-1} C(j_s)\, C(k_s)\, S(j_s, k_s, l, m, n)$$

$$\times \cos\left\{\frac{\pi}{J} j'_d (j'_s + 0.5)\right\} \cos\left\{\frac{\pi}{K} k'_d (k'_s + 0.5)\right\}$$

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where

$$C(0) = (2)^{-1/2}$$

$$C(u) = 1 \text{ for } 0 \leq u \leq U - 1$$

$$j_s' = MOD\{j_s, J_B\}$$

$$k_s' = MOD\{k_s, K_B\}$$

$$j_d' = MOD\{j_d, J_B\}$$

$$k_d' = MOD\{k_d, K_B\}$$

Profile:

Technical

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UNITARY TRANSFORM OPERATOR

TRANSFORM, FOURIER

Description:

Performs 1D, 2D, 3D, 4D, or 5D Fourier transform of an image.

Name:

transform_fourier

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
order	order option	EP	in
	1D		
	2D		
	3D		
	4D		
	5D		
direction	direction option	EP	in
	forward transform		
	inverse transform		
shift	frequency shift option	EP	in
	d.c. term at origin		
	d.c. term at centre		

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD, CD
DST data type:	RD, CD

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	no
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remarks:

1. Images need not have sizes that are a power of two.
2. For a forward transform, the source image data type may be real or complex; the destination data type must be complex.
3. For an inverse transform, the source image data type shall be complex; the destination data type may be real or complex. If the destination data type is real, the imaginary part result of the inverse Fourier transform is discarded under the assumption that it should be zero valued.

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image

Definition:

For all j, k, l, m, n

1D mode, forward transform:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{J}} \sum_{j'=0}^{J-1} C(j')\, S(j',k,l,m,n)\, EXP\{-2\pi i\,[jj'/J]\}$$

where

$C(j') = 1$ for d.c. term at origin

$C(j') = (-1)^{j'}$ for d.c. term at centre

1D mode, inverse transform:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{J}} \sum_{j'=0}^{J-1} S(j',k,l,m,n)\, EXP\{2\pi i\,[jj'/J]\}$$

2D mode, forward transform:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{JK}} \sum_{j'=0}^{J-1} \sum_{k'=0}^{K-1} C(j',k')\, S(j',k',l,m,n)\, EXP\{-2\pi i\,(jj'/J + kk'/K)\}$$

where

$C(j',k') = 1$ for d.c. term at origin

$C(j',k') = (-1)^{(j'+k')}$ for d.c. term at centre

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2D mode, inverse transform:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{JK}} \sum_{j'=0}^{J-1} \sum_{k'=0}^{K-1} S(j',k',l,m,n)\, EXP\{2\pi i (jj'/J + kk'/K)\}$$

3D mode, forward transform:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{JKL}} \sum_{j'=0}^{J-1} \sum_{k'=0}^{K-1} \sum_{l'=0}^{L-1} C(j',k',l')\, S(j',k',l',m,n)$$

$$\times \; (EXP\{-2\pi i [jj'/J + kk'/K + ll'/L]\})$$

where

$C(j', k', l') = 1$ for d.c. term at origin

$C(j', k', l') = (-1)^{(j'+k'+l')}$ for d.c. term at centre

3D mode, inverse transform:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{JKL}} \sum_{j'=0}^{J-1} \sum_{k'=0}^{K-1} \sum_{l'=0}^{L-1} S(j',k',l',m,n)\, EXP\{2\pi i [jj'/J + kk'/K + ll'/L]\}$$

4D mode, forward transform:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{JKLM}} \sum_{j'=0}^{J-1} \sum_{k'=0}^{K-1} \sum_{l'=0}^{L-1} \sum_{m'=0}^{M-1} C(j',k',l',m')\, S(j',k',l',m',n)$$

$$\times \; EXP\{-2\pi i [jj'/J + kk'/K + ll'/L + mm'/M]\}$$

where

$C(j', k', l', m') = 1$ for d.c. term at origin

$C(j', k', l', m') = (-1)^{(j'+k'+l'+m')}$ for d.c. term at centre

4D mode, inverse transform:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{JKLM}} \sum_{j'=0}^{J-1} \sum_{k'=0}^{K-1} \sum_{l'=0}^{L-1} \sum_{m'=0}^{M-1} S(j',k',l',m',n)$$

$$\times \; EXP\{2\pi i [jj'/J + kk'/K + ll'/L + mm'/M]\}$$

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5D mode, forward transform:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{JKLMN}} \sum_{j'=0}^{J-1} \sum_{k'=0}^{K-1} \sum_{l'=0}^{L-1} \sum_{m'=0}^{M-1} \sum_{n'=0}^{N-1} C(j',k',l',m',n')\, S(j',k',l',m',n')$$

$$\times \text{EXP}\{-2\pi i [jj'/J + kk'/K + ll'/L + mm'/M + nn'/N]\}$$

where

$C(j', k', l', m', n') = 1$ for d.c. term at origin

$C(j', k', l', m', n') = (-1)^{(j'+k'+l'+m'+n')}$ for d.c. term at centre

5D mode, inverse transform:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{JKLMN}} \sum_{j'=0}^{J-1} \sum_{k'=0}^{K-1} \sum_{l'=0}^{L-1} \sum_{m'=0}^{M-1} \sum_{n'=0}^{N-1} S(j',k',l',m',n')$$

$$\times \text{EXP}\{2\pi i [jj'/J + kk'/K + ll'/L + mm'/M + nn'/N]\}$$

Profile:

Technical

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UNITARY TRANSFORM OPERATOR

TRANSFORM, HADAMARD

Description:

Performs a two-dimensional Hadamard transform on pixel planes of an image in rectangular blocks.

Name:

transform_hadamard

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
block_size	block size	NP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	RD

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	no
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The block size dimension shall be a power of two.
2. The j-k pixel plane dimensions shall be integer multiples of the block sizes.
3. An ordered Hadamard matrix is a Hadamard matrix whose rows have an increasing number of zero crossings, i.e., row p has p zero crossings for $0 \leq p \leq P - 1$.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
W	block size, W > 0
U	WxW matrix of pixels in a source image block
V	WxW matrix of pixels in a destination image block
H	WxW ordered Hadamard matrix

Definition:

As shown on the following figure, for all l, m, n

Step 1:

Form a matrix U, with general term U(j', k'), from a block of source pixels in each j-k plane.

For all j, k

$$U(j', k') = S(j, k, l, m, n)$$

where

$$j' = MOD\{j, W\}$$

$$k' = MOD\{k, W\}$$

Step 2:

Compute the matrix product.

$$V = HUH$$

Step 3:

Insert the elements of V, with general term V(j', k'), into the destination image block.

For all j, k

$$D(j, k, l, m, n) = V(j', k')$$

where

$$j' = MOD\{j, W\}$$

$$k' = MOD\{k, W\}$$

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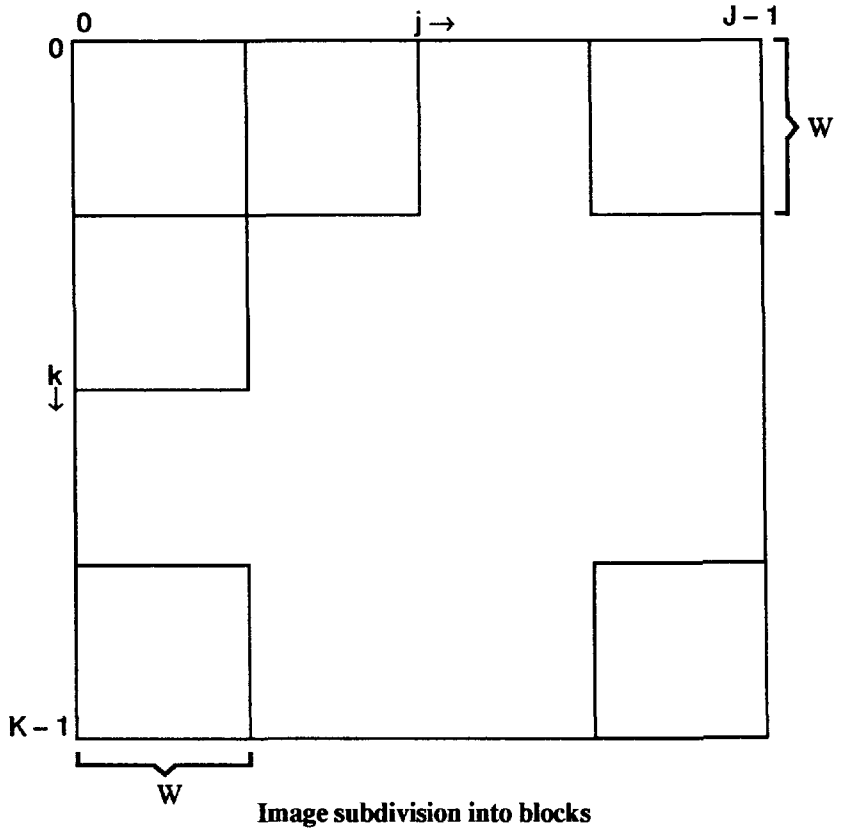

Image subdivision into blocks

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UNITARY TRANSFORM OPERATOR

TRANSFORM, HARTLEY

Description:

Performs 1D, 2D, 3D, 4D, or 5D Hartley transform of an image.

Name:

transform_hartley

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
order	order option	EP	in
	1D		
	2D		
	3D		
	4D		
	5D		

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	RD

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	no
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

Images need not have sizes that are a power of two.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image

Definition:

For all j, k, l, m, n

1D mode:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{J}} \sum_{j'=0}^{J-1} S(j',k,l,m,n)\,CAS\{2\pi[jj'/J]\}$$

2D mode:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{JK}} \sum_{j'=0}^{J-1}\sum_{k'=0}^{K-1} S(j',k',l,m,n)\,CAS\{2\pi(jj'/J + kk'/K)\}$$

3D mode:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{JKL}} \sum_{j'=0}^{J-1}\sum_{k'=0}^{K-1}\sum_{l'=0}^{L-1} S(j',k',l',m,n)\,CAS\{2\pi[jj'/J + kk'/K + ll'/L]\}$$

4D mode:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{JKLM}} \sum_{j'=0}^{J-1}\sum_{k'=0}^{K-1}\sum_{l'=0}^{L-1}\sum_{m'=0}^{M-1} S(j',k',l',m',n)$$

$$\times\, CAS\{2\pi[jj'/J + kk'/K + ll'/L + mm'/M]\}$$

5D mode:

$$D(j,k,l,m,n) = \frac{1}{\sqrt{JKLMN}} \sum_{j'=0}^{J-1}\sum_{k'=0}^{K-1}\sum_{l'=0}^{L-1}\sum_{m'=0}^{M-1}\sum_{n'=0}^{N-1} S(j',k',l',m',n')$$

$$\times\, CAS\{2\pi[jj'/J + kk'/K + ll'/L + mm'/M + nn'/N]\}$$

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Profile:

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GEOMETRIC OPERATOR **TRANSLATE**

Description:

Performs five-dimensional translation of an image with respect to its origin.

Name:

translate	translate_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
offset	index offset 5-tuple	ID	in

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SRC data type:	BD, ND, SD, RD, CD	BD
DST data type:	same as SRC data type	BD

Element functionality:

Index assignment:	no	no
Match point:	yes	no
ROI control:	yes	no
ROI processing:	yes	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Remarks:

1. The offset coordinates need not be integer valued.
2. Positive offset values shift a volume source image right, down, and away from the origin of the source image.
3. Geometric resampling is performed according to the global resampling option selected by the *set_globals* utility.
4. The parameter tuple contains parameters of the RD data type.
5. Translation is not performed along the band index of a colour image.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
jo	first index offset, $-J+1 < jo < J-1$
ko	second index offset, $-K+1 < ko < K-1$
ko	third index offset, $-L+1 < lo < L-1$
mo	fourth index offset, $-M+1 < mo < N-1$
no	fifth index offset, $-N+1 < no < N-1$

Definition:

The *translate* operator is based upon a two-stage algorithm. In the first stage, a reverse address calculation is made whereby (j', k', l', m', n') source image coordinates are calculated for integer values of the destination image coordinates (j, k, l, m, n). In general, the (j', k', l', m', n') coordinates are not integer valued. The second stage of the algorithm entails resampling of the source image to evaluate the destination image at integer coordinates. The *translate* operator is defined as follows:

For all j, k, l, m, n

$$MAX\{0, jo\} \leq j \leq MIN\{J-1, J-1+jo\}$$

$$MAX\{0, ko\} \leq k \leq MIN\{K-1, K-1+ko\}$$

$$MAX\{0, lo\} \leq l \leq MIN\{L-1, L-1+lo\}$$

$$MAX\{0, mo\} \leq m \leq MIN\{M-1, M-1+mo\}$$

$$MAX\{0, no\} \leq n \leq MIN\{N-1, N-1+no\}$$

$$D(j, k, l, m, n) = RES_5\{S, j', k', l', m', n'\}$$

where

$$j' = j - jo$$
$$k' = k - ko$$
$$l' = l - lo$$
$$m' = m - mo$$
$$n' = n - no$$

otherwise

$$D(j, k, l, m, n) = 0$$

Profile:

Foundation	translate
Foundation	translate_roi

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POINT OPERATOR **UNARY INTEGER**

Description:

Performs unary point conversion of pixels of an integer data type image.

Name:

unary_integer

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
option	conversion option	SP	in
	absolute value		
	cube		
	negative		
	square		

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD
DST data type:	same as SRC data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	yes
Chainable element:	yes
Asynchronous:	yes

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image

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Definition:

Absolute value:

$$D(x, y, z, t, b) = S(x, y, z, t, b) \quad \text{if } S(x, y, z, t, b) \geq 0$$

$$D(x, y, z, t, b) = -S(x, y, z, t, b) \quad \text{if } S(x, y, z, t, b) < 0$$

Cube:

$$D(x, y, z, t, b) = [S(x, y, z, t, b)]^3$$

Negative:

$$D(x, y, z, t, b) = -S(x, y, z, t, b)$$

Square:

$$D(x, y, z, t, b) = [S(x, y, z, t, b)]^2$$

Profile:

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POINT OPERATOR **UNARY REAL**

Description:

Performs unary point conversion of pixels of a real data type image.

Name:

unary_real

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
option	conversion option	SP	in
	absolute value		
	arc cosine		
	arc sine		
	arc tangent		
	cosecant		
	cosine		
	cotangent		
	cube		
	cube root		
	exponential		
	logarithm, base e		
	logarithm, base 10		
	logarithm, base 2		
	negative		
	reciprocal		
	secant		
	sine		
	square		
	square root		
	tangent		

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	RD
DST data type:	RD

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unary_real

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	yes
Chainable element:	yes
Asynchronous:	yes

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image

Definition:

Absolute value:

$$D(x, y, z, t, b) = S(x, y, z, t, b) \quad \text{if } S(x, y, z, t, b) \geq 0$$

$$D(x, y, z, t, b) = -S(x, y, z, t, b) \quad \text{if } S(x, y, z, t, b) < 0$$

Arc cosine:

$$D(x, y, z, t, b) = \mathrm{ACOS}\{S(x, y, z, t, b)\} \quad \text{for } -1 \leq S(x, y, z, t, b) \leq 1$$

Arc sine:

$$D(x, y, z, t, b) = \mathrm{ASIN}\{S(x, y, z, t, b)\} \quad \text{for } -1 \leq S(x, y, z, t, b) \leq 1$$

Arc tangent:

$$D(x, y, z, t, b) = \mathrm{ATAN}\{S(x, y, z, t, b)\}$$

Cosecant:

$$D(x, y, z, t, b) = \frac{1}{\mathrm{SIN}\{S(x, y, z, t, b)\}}$$

Cosine:

$$D(x, y, z, t, b) = \mathrm{COS}\{S(x, y, z, t, b)\}$$

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Cotangent:

$$D(x, y, z, t, b) = \frac{1}{TAN\{S(x, y, z, t, b)\}}$$

Cube:

$$D(x, y, z, t, b) = [S(x, y, z, t, b)]^3$$

Cube root:

$$D(x, y, z, t, b) = [S(x, y, z, t, b)]^{1/3} \quad \text{for } S(x, y, z, t, b) \geq 0$$

Exponential:

$$D(x, y, z, t, b) = EXP\{S(x, y, z, t, b)\}$$

Logarithm, base e:

$$D(x, y, z, t, b) = LOG\{S(x, y, z, t, b)\} \quad \text{for } S(x, y, z, t, b) > 0$$

Logarithm, base 10:

$$D(x, y, z, t, b) = \frac{LOG\{S(x, y, z, t, b)\}}{LOG\{10\}} \quad \text{for } S(x, y, z, t, b) > 0$$

Logarithm, base 2:

$$D(x, y, z, t, b) = \frac{LOG\{S(x, y, z, t, b)\}}{LOG\{2\}} \quad \text{for } S(x, y, z, t, b) > 0$$

Negative:

$$D(x, y, z, t, b) = -S(x, y, z, t, b)$$

Reciprocal:

$$D(x, y, z, t, b) = \frac{1}{S(x, y, z, t, b)} \quad \text{for } S(x, y, z, t, b) \neq 0$$

Secant:

$$D(x, y, z, t, b) = \frac{1}{COS\{S(x, y, z, t, b)\}}$$

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Sine:

$$D(x, y, z, t, b) = SIN\{S(x, y, z, t, b)\}$$

Square:

$$D(x, y, z, t, b) = [S(x, y, z, t, b)]^2$$

Square root:

$$D(x, y, z, t, b) = [S(x, y, z, t, b)]^{1/2} \qquad \text{for } S(x, y, z, t, b) \geq 0$$

Tangent:

$$D(x, y, z, t, b) = TAN\{S(x, y, z, t, b)\}$$

Profile:

Technical

Error codes:

001
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ENHANCEMENT OPERATOR **UNSHARP MASK**

Description:

Performs image detail sharpening by two-dimensional high pass filtering of pixel planes by forming the weighted difference between an image and a blurred version of the image.

Name:

unsharp_mask

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	low pass filter impulse response array object	ID	in
w1	first weight factor	RP, NULL	in
w2	second weight factor	RP, NULL	in
bf	bias factor	RP, NULL	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB structure:	NBHOOD_ARRAY
SRC data type:	ND, SD, RD
DST data type:	RD
SOB data type:	RD
SOB dimension:	2D

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remark:

The data object repository contains the following low pass filter impulse response arrays:

LOW_PASS_3x3

UNIFORM_3x3

UNIFORM_5x5

PYRAMID_3x3

PYRAMID_5x5

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
A(j, k, l, m, n)	low pass filtered image
H(j, k)	J_HxK_H low pass filter impulse response array
w1	first weight factor
w2	second weight factor
bf	bias factor

Definition:

For all j, k, l, m, n

$$D(j,k,l,m,n) = (w1)\,S(j,k,l,m,n) + (w2)\,A(j,k,l,m,n) + bf$$

where

$$A(j,k,l,m,n) = S(j,k,l,m,n) \circledast H(j,k)$$

and $\circledast$ denotes two-dimensional, enclosed array mode convolution as defined by the *convolve_2d* operator.

Hint:

Commonly-used values for the weight and bias factors are

$$w1 = \frac{p}{2p-1}$$

$$w2 = \frac{-(1-p)}{2p-1}$$

$$bf = 0$$

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where

$$0 \leq p \leq 1$$

Profile:

Technical

Error codes:

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041
042
043
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101

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ANALYSIS OPERATOR **VALUE BOUNDS**

Description:

Compiles a collection of all pixels in an image that lie within prescribed amplitude bounds.

Name:

value_bounds

Parameters:

SRC	source image	ID	in
DOB	value bounds collection object	ID	out
lb	lower amplitude bound	NP, SP, RP	in
ub	upper amplitude bound	NP, SP, RP	in

Objects:

SRC structure:	any image
DOB structure:	VALUE_BOUNDS
SRC data type:	ND, SD, RD
DOB data type:	See remarks

Element functionality:

Index assignment:	no
Match point:	no
ROI control:	yes
ROI processing:	no
ROI manipulation:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remarks:

1. The x, y, z, t, b indices are recorded in the list as ND data types.
2. The source image pixel value S(x, y, z, t, b) is recorded in the collection as the same data type as the source image.
3. The input parameters "lb" and "ub" must be of the same data type as the source image.

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
S(x, y, z, t, b)	XxYxZxTxB operator input image
lb	lower amplitude bound
ub	upper amplitude bound, ub > lb
f	collection index
F	total number of pixels within collection

Definition:

The image is searched for pixels whose amplitudes lie between the lower and upper amplitude bounds, and an ordered collection is formed.

For all x, y, z, t, b and for all $0 \leq f \leq F - 1$, if

$$lb \leq S(x, y, z, t, b) \leq ub$$

then

$$x(f) = x$$

$$y(f) = y$$

$$z(f) = z$$

$$t(f) = t$$

$$b(f) = b$$

and the following ordered collection is then formed.

x(0)	y(0)	z(0)	t(0)	b(0)	S[x(0), y(0), z(0), t(0), b(0)]
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
x(F-1)	y(F-1)	z(F-1)	t(F-1)	b(F-1)	S[x(F-1), y(F-1), z(F-1), t(F-1), b(F-1)]

Profile:

Scientific

Error codes:

001
011
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VIRTUAL REGISTER MECHANISM **VREG ALTER**

Description:

Alters the contents of a virtual register.

Name:

vreg_alter

Parameters:

SOB	virtual register object	ID	in
delta	value to add to virtual register	BP,NP,SP,RP,CP	in
mode	immediate mode flag	BP	in

Object:

SOB structure:	VREG

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

This mechanism alters the virtual register contents by the specified delta value. This mechanism in conjunction with the *vreg_conditional* mechanism can be used to support "test and branch" and iteration.

If the virtual register is in the state VREG_CLEARED, an error will result.

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Profile:

Full

Error codes:

001
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252

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Description:

Clears the virtual register and initializes its PIKS state to VREG_CLEARED.

Name:

vreg_clear

Parameters:

SOB	virtual register object	ID	in
mode	immediate mode flag	BP	in

Object:

SOB structure:	VREG

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

This mechanism clears the virtual register and initializes its state to VREG_CLEARED. The contents associated with the VREG will be considered meaningless, but will not be deallocated unless a *vreg_delete* is issued. The register can only be reset by a *vreg_set* or *vreg_copy*.

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Profile:

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Error codes:

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VIRTUAL REGISTER MECHANISM VREG CONDITIONAL

Description:

Tests the virtual register value against a value range, and conditionally branches to a chain.

Name:

vreg_conditional

Parameters:

SOB	virtual register object	ID	in
floor	lower value to test register value against	BP,NP,SP,RP,CP,CS	in
ceiling	upper value to test register value against	BP,NP,SP,RP,CP,CS	in
conditional	logical flag variable for conditional control	BP	in
chain	chain to branch for execution	ID	in
mode	immediate mode flag	BP	in

Object:

SOB structure: VREG

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

This mechanism tests the virtual register contents against the specified range. This mechanism in conjunction with the *vreg_alter* mechanism can be used to support "test and branch" and iteration for chains.

The test is TRUE if the value of vreg ≥ floor and value of vreg ≤ ceiling. Floor and ceiling can be set to plus or minus infinity according to the implementation specification of infinity for the PIKS data type, when appropriate.

The conditional flag controls the reaction to the conditional test. The following conditionals are recognized to control the conditional action:

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Branch Conditional (one only)

BRANCH_IF_TRUE-	If the test is TRUE, execution of the specified chain is performed.
BRANCH_IF_FALSE	If the test is FALSE, execution of the specified chain is performed.

Completion Conditional (one only):

RETURN_ON_COMPLETION	When the invoked chain is executed, return control to the chain operator immediately following *vreg_conditional.*
NO_RETURN_ON_COMPLETION	When the invoked chain is executed, the chain invoking *vreg_conditional* is terminated.

Note that a chain can be aborted if the condition for branch is met by a branch to another chain without returning. The *chain_abort* mechanism is automatically issued within PIKS. If the intent is to delete a chain, this can be accomplished by a branch to a chain that deletes the calling chain.

Profile:

Full

Error codes:

001
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VIRTUAL REGISTER MECHANISM **VREG COPY**

Description:

Copies the contents of a virtual register to another virtual register.

Name:

vreg_copy

Parameters:

SOB	source virtual register object	ID	in
DOB	destination virtual register object	ID	out
mode	immediate mode flag	BP	in

Objects:

SOB structure:	VREG
DOB structure:	VREG

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

The virtual register contents are copied from the source virtual register to the destination virtual register. The data type for the two registers must be the same PIKS data type. The destination virtual register is put in a VREG_SET state.

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Profile:

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Description:

Deletes a virtual register and its contents.

Name:

vreg_delete

Parameters:

SOB	virtual register object	ID	in
mode	immediate mode flag	BP	in

Object:

SOB structure: VREG

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

The virtual register, referenced by the identifier assigned when it was allocated, is deleted. If the content of the virtual register was an object identifier, that object is not affected by the deletion of the virtual register.

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Profile:

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001
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VIRTUAL REGISTER **VREG GET**

Description:

Gets the contents of virtual register.

Name:

vreg_get

Parameters:

SOB	virtual register object	ID	in
mode	immediate mode flag	BP	in
value	value of register	ID, IP, BP, NP, SP, RP, CP, CS, NULL	out
state	register state VREG_SET VREG_CLEARED	EP	out
type	virtual register data type ID IP BP NP SP RP CP CS	SP	out

Object:

SOB structure:	VREG

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	no
Asynchronous:	no

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Definition:

The virtual register is specified according to the identifier returned by the *allocate_vreg* mechanism. The value will correspond to the virtual register's data type. The register variable value is valid only if the register is in the VREG_SET state.

The value is returned as NULL if the virtual register is in the VREG_CLEARED state.

Profile:

Full

Error codes:

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VIRTUAL REGISTER MECHANISM **VREG SET**

Description:

Sets the virtual register to a value appropriate for the PIKS data type.

Name:

vreg_set

Parameters:

SOB	virtual register object	ID	in
value	value to be loaded	ID, IP, BP, NP, SP, RP, CP, CS	in
mode	immediate mode flag	BP	in
type	virtual register data type ID IP BP NP SP RP CP CS	SP	in

Object:

SOB structure: VREG

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

The virtual register is specified according to the identifier returned by the *allocate_vreg* mechanism. The value will correspond to the virtual register's data type. The virtual register is put in the VREG_SET state.

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Profile:

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VIRTUAL REGISTER MECHANISM **VREG WAIT**

Description:

Waits for the contents of a virtual register to be set.

Name:

vreg_wait

Parameters:

SOB	virtual register object	ID	in
value	value to wait for	ID, IP, BP, NP, SP, RP, CP,CS	in
mode	immediate mode flag	BP	in

Object:

SOB structure:	VREG

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Definition:

This mechanism blocks execution of the program or a chain until the virtual register is set.

This mechanism blocks execution of an application or a chain until the virtual register changes to VREG_SET and the value of the virtual register matches the value parameter. If the value parameter is NULL, a value match is ignored, and the wait is on any VREG_SET condition.

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vreg_wait

Profile:

Full

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ENHANCEMENT OPERATOR **WALLIS STATISTICAL DIFFERENCING**

Description:

Performs amplification of pixels by a gain factor that is dependent upon the moving window standard deviation of pixels within a pixel plane.

Name:

wallis_statistical_differencing

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB	low pass filter impulse response array object	ID	in
g	gain factor	RP	in
a	average factor	RP	in
v	deviation factor	RP	in
p	proportionality factor	RP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SOB structure:	NBHOOD_ARRAY
SRC data type:	ND, SD, RD
DST data type:	RD
SOB data type:	RD
SOB dimension:	2D

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Remark:

The data object repository contains the following low pass filter impulse response arrays:

LOW_PASS_3x3

UNIFORM_3x3

UNIFORM_5x5

PYRAMID_3x3

PYRAMID_5x5

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
A(j, k, l, m, n)	neighbourhood average
V(j, k, l, m, n)	neighbourhood standard deviation
H(j, k)	J_HxK_H neighbourhood average impulse response array
g	gain factor, g > 0
a	average factor, a > 0
v	deviation factor, v > 0
p	proportionality factor, p > 0

Definition:

Moving window estimates of the mean and standard deviation of j-k pixel planes are formed by low pass filtering the source image and a squared pixel version of it. Next, the difference between a pixel and its mean is amplified by a factor inversely dependent upon the moving window standard deviation. The amplified difference is then added to a proportionally combined moving window mean and constant mean.

For all j, k, l, m, n

$$D(j,k,l,m,n) = [S(j,k,l,m,n) - A(j,k,l,m,n)]\left[\frac{(g)(v)}{(g)([V(j,k,l,m,n)]+v)}\right] + [(p)(a) + (1-p)[A(j,k,l,m,n)]]$$

where

$$A(j,k,l,m,n) = S(j,k,l,m,n) \circledast H(j,k)$$

$$V(j,k,l,m,n) = [[[S(j,k,l,m,n)]^2] \circledast H(j,k) - [A(j,k,l,m,n)]^2]^{1/2}$$

and $\circledast$ denotes two-dimensional, enclosed array mode convolution as defined by the *convolve_2d* operator.

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Profile:

Technical

Error codes:

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GEOMETRIC OPERATOR **WARP, CONTROL POINT**

Description:

Performs two-dimensional geometric warping of an image using polynomial inverse address calculation for which the polynomial coefficients are computed from control points.

Name:

warp_control_point warp_control_point_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB1	source image control point array object	IP	in
SOB2	destination image control point array object	IP	in
points	number of control points	NP	in

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SOB1 structure:	EXT	EXT
SOB2 structure:	EXT	EXT
SRC data type:	BD, ND, SD, RD, CD	BD
DST data type:	same as SRC data type	BD
SOB1 data type:	NP	NP
SOB2 data type:	NP	NP

Element functionality:

Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	yes	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Remark:

For geometric operators, all pixels are assumed to be of unit dimension. The geometric origin along a coordinate direction is at the center of the pixel with index value zero. The geometric bounds of an origin pixel are – 0.5 to 0.5.

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Nomenclature:

SRC(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ source image
DST(x, y, z, t, b)	$X_D x Y_D x Z_D x T_D x B_D$ destination image
S(j, k, l, m, n)	$J_S x K_S x L_S x M_S x N_S$ operator input image
D(j, k, l, m, n)	$J_D x K_D x L_D x M_D x N_D$ operator output image
a_i	i-th polynomial warp coefficient for horizontal computation, $0 \leq i \leq 15$
b_i	i-th polynomial warp coefficient for vertical computation, $0 \leq i \leq 15$
a	16x1 vector of horizontal polynomial coefficients
b	16x1 vector of vertical polynomial coefficients
u	Px1 vector of source image horizontal contol points
v	Px1 vector of source image vertical control points
A	Px16 matrix of destination image polynomial control points
P	number of control points

The source control point array is defined as follows:

$$\begin{matrix} u_1 & v_1 \\ \cdot & \cdot \\ \cdot & \cdot \\ u_p & v_p \\ \cdot & \cdot \\ \cdot & \cdot \\ u_P & v_P \end{matrix}$$

The destination control point array is defined as follows:

$$\begin{matrix} j_1 & k_1 \\ \cdot & \cdot \\ \cdot & \cdot \\ j_p & k_p \\ \cdot & \cdot \\ \cdot & \cdot \\ j_P & k_P \end{matrix}$$

Definition:

Warping involves two processing stages. In the first stage, for all l, m, n, an inverse address calculation is made whereby (j', k') source image coordinates are computed from a third order polynomial expansion of the destination image coordinates (j, k) using polynomial coefficients derived from control points. In general, the (j', k') coordinates are not integer valued. The second stage of the algorithm entails two-dimensional resampling of the source image to evaluate the destination image at integer coordinates.

Control points are a set of P indices in the j-k planes of the source and destination images corresponding to known points in the source image that map into known points in the destination image.

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The *warp_control_point* operator is defined as follows.

Step 1: Compute the polynomial coefficients from the control points.

The vectors of horizontal and vertical polynomial coefficients are given by

$$\mathbf{a} = \mathbf{A}^{-}\mathbf{u}$$

$$\mathbf{b} = \mathbf{A}^{-}\mathbf{v}$$

where $\mathbf{A}^{-}$ is the generalized inverse of the matrix of destination image polynomial control points

$$\mathbf{A} = \begin{bmatrix} 1 & j_1 & k_1 & (j_1)^2 & (j_1)(k_1) & (k_1)^2 & (j_1)^3 & (j_1)^2(k_1) & \cdots & (j_1)^2(k_1)^3 & (j_1)^3(k_1)^3 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ 1 & j_p & k_p & (j_p)^2 & (j_p)(k_p) & (k_p)^2 & (j_p)^3 & (j_p)^2(k_p) & \cdots & (j_p)^2(k_p)^3 & (j_p)^3(kp)^3 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ 1 & j_P & k_P & (j_P)^2 & (j_P)(k_P) & (k_P)^2 & (j_p)^3 & (j_p)^2(k_P) & \cdots & (j_P)^2(k_P)^3 & (j_P)^3(k_P)^3 \end{bmatrix}$$

The rows of A follow the same structure as the polynomial defined below.

Step 2: Perform the polynomial warp.

For all l, m, n

$$D(j, k, l, m, n) = RES2\{S, j', k', l, m, n\}$$

where

$$j' = a_0 + a_1 j + a_2 k + a_3 j^2 + a_4 jk + a_5 k^2 + a_6 j^3 + a_7 j^2 k + a_8 jk^2 + a_9 k^3 + a_{10} j^3 k + a_{11} j^2 k^2 + a_{12} jk^3 + a_{13} j^3 k^2 + a_{14} j^2 k^3 + a_{15} j^3 k^3$$

$$k' = b_0 + b_1 j + b_2 k + b_3 j^2 + b_4 jk + b_5 k^2 + b_6 j^3 + b_7 j^2 k + b_8 jk^2 + b_9 k^3 + b_{10} j^3 k + b_{11} j^2 k^2 + b_{12} jk^3 + b_{13} j^3 k^2 + b_{14} j^2 k^3 + b_{15} j^3 k^3$$

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Profile:

Technical	warp_control_point
Technical	warp_control_point_roi

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001
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GEOMETRIC OPERATOR **WARP, LOOKUP TABLE**

Description:

Performs two-dimensional geometric warping of an image using lookup table inverse address calculation.

Name:

warp_lut warp_lut_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB1	row address lookup table object	ID	in
SOB2	column address lookup table object	ID	in
off	number of lookup table source offset entries	NP	in

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SOB1 structure:	LUT	LUT
SOB2 structure:	LUT	LUT
SRC data type:	BD, ND, SD, RD, CD	BD
DST data type:	same as SRC data type	BD
SOB1 data type:	RD	RD
SOB2 data type:	RD	RD

Element functionality:

Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	yes	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Remark:

For geometric operators, all pixels are assumed to be of unit dimension. The geometric origin along a coordinate direction is at the center of the pixel with index value zero. The geometric bounds of an origin pixel are – 0.5 to 0.5.

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Nomenclature:

SRC(x,y,z,t,b)	$X_S x Y_S x Z_S x T_S x B_S$ source image
DST(x,y,z,t,b)	$X_D x Y_D x Z_D x T_D x B_D$ destination image
S(j,k,l,m,n)	$J_S x K_S x L_S x M_S x N_S$ operator input image
D(j,k,l,m,n)	$J_D x K_D x L_D x M_D x N_D$ operator output image
row_lut	LUT for along row address computation
col_lut	LUT for along column address computation
off	number of lookup table source offset entries, off ≥ 0

Definition:

Warping involves two processing stages. In the first stage, for all l, m, n, an inverse address determination is made whereby (j', k') source image coordinates are extracted from a pre-computed lookup table using the integer values of the destination image coordinates (j, k) as lookup table indices. In general, the (j', k') coordinates are not integer valued. The second stage of the algorithm entails two-dimensional resampling of the source image to evaluate the destination image at integer coordinates. The *warp_lut* operator is defined as follows.

For all l, m, n

$$D(j, k, l, m, n) = RES_2\{S, j', k', l, m, n\}$$

where

$$j' = LOOK\{u, off, 0, row_lut\}$$

$$k' = LOOK\{u, off, 0, col_lut\}$$

and

$$u = j + (k)\,(J_D) \qquad 0 \leq u \leq (J_D) \times (K_D)$$

Profile:

Technical	warp_lut
Technical	warp_lut_roi

Error codes:

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GEOMETRIC OPERATOR **WARP, POLYNOMIAL**

Description:

Performs two-dimensional geometric warping of an image using polynomial inverse address calculation.

Name:

warp_polynomial warp_polynomial_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
SOB1	row polynomial coefficient array object	IP	in
SOB1	column polynomial coefficient array object	IP	in

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SOB1 structure:	EXT	EXT
SOB2 structure:	EXT	EXT
SRC data type:	BD, ND, SD, RD, CD	BD
DST data type:	same as SRC data type	BD
SOB1 data type:	RP	RP
SOB2 data type:	RP	RP

Element functionality:

Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	yes	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

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Remarks:

1. For geometric operators, all pixels are assumed to be of unit dimension. The geometric origin along a coordinate direction is at the center of the pixel with index value zero. The geometric bounds of an origin pixel are – 0.5 to 0.5.
2. An affine geometrical warping is a special case of this operator in which all coefficients of second or higher order are set to zero.

Nomenclature:

SRC(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ source image
DST(x, y, z, t, b)	$X_D x Y_D x Z_D x T_D x B_D$ destination image
S(j, k, l, m, n)	$J_S x K_S x L_S x M_S x N_S$ operator input image
D(j, k, l, m, n)	$J_D x K_D x L_D x M_D x N_D$ operator output image
a_i	i-th polynomial warp coefficient for along row computation, $0 \leq i \leq 15$
b_i	i-th polynomial warp coefficient for along column computation, $0 \leq i \leq 15$

The external row polynomial coefficient array is defined as follows:

a_0
a_1
.
.
a_i
.
.
a_{15}

The external column polynomial array is defined as follows:

b_0
b_1
.
.
b_i
.
.
b_{15}

Definition:

Warping involves two processing stages. In the first stage, for all l, m, n, an inverse address calculation is made whereby (j', k') source image coordinates are computed from a third order polynomial expansion of the destination image coordinates (j, k) using pre-computed polynomial coefficients. In general, the (j', k') coordinates are not integer valued. The second stage of the algorithm entails two-dimensional resampling of the source image to evaluate the destination image at integer coordinates. The *warp_polynomial* operator is defined as follows.

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For all l, m, n

$$D(j, k, l, m, n) = RES2\{S, j', k', l, m, n\}$$

where

$$j' = a_0 + a_1j + a_2k + a_3j^2 + a_4jk + a_5k^2 + a_6j^3 + a_7j^2k + a_8jk^2 + a_9k^3 + a_{10}j^3k + a_{11}j^2k^2 + a_{12}jk^3 + a_{13}j^3k^2 + a_{14}j^2k^3 + a_{15}j^3k^3$$

$$k' = b_0 + b_1j + b_2k + b_3j^2 + b_4jk + b_5k^2 + b_6j^3 + b_7j^2k + b_8jk^2 + b_9k^3 + b_{10}j^3k + b_{11}j^2k^2 + b_{12}jk^3 + b_{13}j^3k^2 + b_{14}j^2k^3 + b_{15}j^3k^3$$

Profile:

Technical	warp_polynomial
Technical	warp_polynomial_roi

Error codes:

011
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STATIC ARRAY GENERATION TOOL

WINDOWING FUNCTION

Description:

Generates a windowing function two-dimensional array.

Name:

windowing_function

Parameters:

DOB	windowing function array object	ID	out
array_size	array size 5-tuple	ID	in
cg	column guard band	NP	in
rg	row guard band	NP	in
option	windowing option	SP	in
	Bartlett		
	Blackman		
	Hamming		
	Hanning		
	rectangular		

Object:

DOB structure:	STATIC_ARRAY
DOB data type:	RD
DOB dimension:	2D

Element functionality:

Index assignment:	NA
Match point:	NA
ROI control:	NA
ROI processing:	NA
Source promotion:	NA
Heterogeneous bands:	NA
Chainable element:	yes
Asynchronous:	yes

Remark:

The parameter tuple contains parameters of the ND data type.

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Nomenclature:

A(c, r)	CxR windowing function array
C	number of array columns, positive even integer
R	number of array rows, positive even integer
w(n)	window element sequence, $0 \leq n \leq N-1$
cg	column guard band, $cg \geq 0$
rg	column guard band, $rg \geq 0$

Definition:

For

$$0 \leq c \leq C-1$$

$$0 \leq r \leq R-1$$

$$A(c, r) = u(c)v(r)$$

where in general

$$u(c) = 0 \qquad 0 \leq c < cg$$

$$u(c) = w(n) \qquad cg \leq c \leq C-cg$$

$$u(c) = 0 \qquad C-cg < c \leq C$$

$$v(r) = 0 \qquad 0 \leq r < rg$$

$$v(r) = w(n) \qquad rg \leq r \leq R-rg$$

$$v(r) = 0 \qquad R-rg < r \leq R$$

The windowing functions are defined as follows for

$$n = c - cg \quad \text{or} \quad n = r - rg$$

where

$$N = C - 2(cg) \quad \text{or} \quad N = R - 2(rg)$$

Bartlett:

$$w(n) = \frac{2n}{N-1} \qquad 0 \leq n \leq (N-1)/2$$

$$w(n) = 2 - \frac{2n}{N-1} \qquad (N-1)/2 \leq n \leq N-1$$

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Blackman:

$$w(n) = 0.42 - (0.5)\,COS\left\{\frac{2\pi n}{N-1}\right\} + (0.08)\,COS\left\{\frac{4\pi n}{N-1}\right\} \qquad 0 \le n \le N-1$$

Hamming:

$$w(n) = 0.54 - (0.46)\,COS\left\{\frac{2\pi n}{N-1}\right\} \qquad 0 \le n \le N-1$$

Hanning:

$$w(n) = (0.5)\left[1 - COS\left\{\frac{2\pi n}{N-1}\right\}\right] \qquad 0 \le n \le N-1$$

Rectangular:

$$w(n) = 1 \qquad 0 \le n \le N-1$$

Profile:

Scientific

Error codes:

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POINT OPERATOR **WINDOW-LEVEL**

Description:

Performs window-level scaling of an image in which high amplitude source pixels above the window value are clipped to a specified value, low amplitude source pixels below the window value are clipped to a specified value, and intermediate source pixels are linearly rescaled in amplitude.

Name:

window_level

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
ac	above window clip value	NP, SP, RP	in
bc	below window clip value	NP, SP, RP	in
W	window width	NP, SP, RP	in
V	window level	NP, SP, RP	in

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	same as SRC data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

Remark:

The data parameters must be of the same data type as the source image.

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window_level

Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(x, y, z, t, b)	XxYxZxTxB operator input image
D(x, y, z, t, b)	XxYxZxTxB operator output image
ac	above window clip value
bc	below window clip value
W	window width, W > 0
V	window level

Definition:

As shown in the figure, for all x, y, z, t, b,

if $S(x, y, z, t, b) < V - W/2$

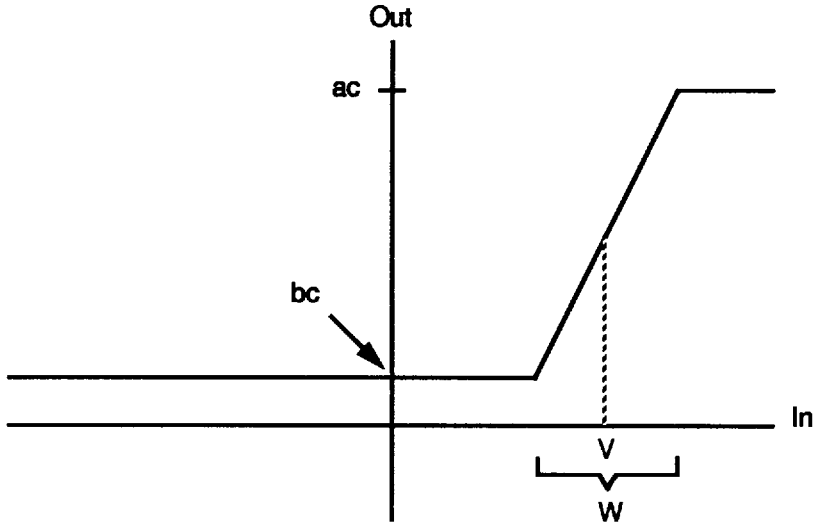
$$D(x, y, z, t, b) = bc$$

if $V - W/2 \leq S(x, y, z, t, b) \leq V + W/2$

$$D(x, y, z, t, b) = \left[\frac{ac - bc}{W}\right] S(x, y, z, t, b) + \left[\frac{(ac)(W - 2V) + (bc)(W + 2V)}{2W}\right]$$

if $V + W/2 < S(x, y, z, t, b)$

$$D(x, y, z, t, b) = ac$$



Window-level scaling transformation

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Profile:

Foundation

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FEATURE EXTRACTION OPERATOR **WINDOW STATISTICS**

Description:

Computes two-dimensional moving window statistics of an image.

Name:

window_statistics

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
lv	third index value	NP	in
mv	fourth index value	NP	in
nv	fifth index value	NP	in
W	window size	NP	in
option	statistic option	SP	in
	mean		
	standard deviation		
	median		
	mode		

Objects:

SRC structure:	any image
DST structure:	same as SRC structure
SRC data type:	ND, SD, RD
DST data type:	RD

Element functionality:

Index assignment:	yes
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC(x, y, z, t, b)	XxYxZxTxB source image
DST(x, y, z, t, b)	XxYxZxTxB destination image
S(j, k, l, m, n)	JxKxLxMxN operator input image
D(j, k, l, m, n)	JxKxLxMxN operator output image
W	window size, odd integer, W > Q
Q	(W – 1) /2

Definition:

For all j, k

Moving window mean:

$$D(j, k, lv, mv, nv) = M(j, k, lv, mv, nv)$$

where

$$M(j,k,lv,mv,nv) = \frac{1}{W^2} \sum_{j'=-Q}^{Q} \sum_{k'=-Q}^{Q} S(j+j', k+p', lv, mv, nv)$$

Moving window standard deviation:

$$D(j,k,lv,mv,nv) = \frac{1}{W^2} \left[\sum_{j'=-Q}^{Q} \sum_{k'=-Q}^{Q} [S(j+j', k+k', lv, mv, nv) - M(j+j', k+k', lv, mv, nv)]^2 \right]^{1/2}$$

Moving window median:

$$D(j, k, lv, mv, nv) = S(j_m, k_m, lv, mv, nv)$$

where (j_m, k_m) are the coordinates of the median-valued pixel, which is defined as the pixel for which $(W^2 - 1)/2$ pixels within the WxW window are equal or larger in size, and $(W^2 - 1)/2$ pixels within the window are equal or smaller in size.

Moving window mode:

$$D(j, k, lv, mv, nv) = S(j_d, k_d, lv, mv, nv)$$

where (j_d, k_d) are the coordinates of the mode-valued pixel, which is defined as the most frequently occurring value of pixels within the WxW window. If the mode is not unique, the destination value corresponds to the lowest amplitude mode.

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Profile:

Scientific

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ENSEMBLE OPERATOR **Z MERGE**

Description:

Copies source image pixels into a destination image based upon the relative values of two Z-merge control images.

Name:

z_merge

Parameters:

SRC1	first source image (data)	ID	in
SRC2	second source image (control)	ID	in
SRC3	third source image (control)	ID	in
DST	destination image (data)	ID	out

Objects:

SRC1 structure:	any image
SRC2 structure:	same as SRC1 structure
SRC3 structure:	same as SRC1 structure
DST structure:	same as SRC1 structure
SRC1 data type:	ND, SD, RD
SRC2 data type:	same as SRC1 data type
SRC3 data type:	same as SRC1 data type
DST data type:	same as SRC1 data type

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	no
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC1(x, y, z, t, b)	XxYxZxTxB first source image (data)
SRC2(x, y, z, t, b)	XxYxZxTxB second source image (control)
SRC3(x, y, z, t, b)	XxYxZxTxB third source image (control)
DST(x, y, z, t, b)	XxYxZxTxB destination image (data)
S1(x, y, z, t, b)	XxYxZxTxB first operator input image (data)
S2(x, y, z, t, b)	XxYxZxTxB second operator input image (control)
S3(x, y, z, t, b)	XxYxZxTxB third operator input image (control)
D(x, y, z, t, b)	XxYxZxTxB operator output image (data)

Definition:

For all x, y, z, t, b if

$$S2(x, y, z, t, b) > S3(x, y, z, t, b)$$

then

$$D(x, y, z, t, b) = S1(x, y, z, t, b)$$

otherwise D(x, y, z, t, b) is unchanged.

Profile:

Technical

Error codes:

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GEOMETRIC OPERATOR **ZOOM**

Description:

Performs zooming of an image by magnifying its pixel planes by integer scale factors using pixel replication interpolation.

Name:

zoom	zoom_roi

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
zoom	zoom scale factor 5-tuple	ID	in

Objects:

SRC structure:	any image	any ROI
DST structure:	same as SRC structure	ROI_GEN
SRC data type:	BD, ND, SD, RD, CD	BD
DST data type:	same as SRC data type	BD

Element functionality:

Index assignment:	yes	yes
Match point:	yes	no
ROI control:	yes	no
ROI processing:	yes	no
Source promotion:	no	no
Heterogeneous bands:	no	no
Chainable element:	yes	yes
Asynchronous:	yes	yes

Remarks:

1. The parameter tuple contains parameters of the ND data type.
2. Zooming is not performed along the band index of a colour image.

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Nomenclature:

$SRC(x_S, y_S, z_S, t_S, b_S)$	$X_S x Y_S x Z_S x T_S x B_S$ source image
$DST(x_D, y_D, z_D, t_D, b_D)$	$X_D x Y_D x Z_D x T_D x B_D$ destination image
$S(j_S, k_S, l_S, m_S, n_S)$	$J_S x K_S x L_S x M_S x N_S$ operator input image
$D(j_D, k_D, l_D, m_D, n_D)$	$J_D x K_D x L_D x M_D x N_D$ operator output image
Sj	first index zoom scale factor, positive integer
Sk	second index zoom scale factor, positive integer
Sl	third index zoom scale factor, positive integer
Sm	fourth index zoom scale factor, positive integer
Sn	fifth index zoom scale factor, positive integer

Definition:

For

$$0 \le j_D \le J_D - 1$$

$$0 \le k_D \le K_D - 1$$

$$0 \le l_D \le L_S - 1$$

$$0 \le m_D \le M_S - 1$$

$$0 \le n_D \le N_S - 1$$

$$D(j_D, k_D, l_D, m_D, n_D) = S(j_S, k_S, l_S, m_S, n_S)$$

where

$$j_s = \left[j_D - MOD\{j_D, Sj\} \right] \div Sj$$

$$k_s = [k_D - MOD\{k_D, Sk\}] \div Sk$$

$$l_s = [l_D - MOD\{l_D, Sl\}] \div Sl$$

$$m_S = [m_D - MOD\{m_D, Sm\}] \div Sm$$

$$n_S = [n_D - MOD\{n_D, Sn\}] \div Sn$$

$$J_D = (Sj)(J_S)$$

$$K_D = (Sk)(K_S)$$

$$L_D = (Sl)(L_S)$$

$$M_D = (Sm)(M_S)$$

$$N_D = (Sn)(N_S)$$

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Profile:

Foundation	zoom
Foundation	zoom_roi

Error codes:

001
011
012
013
014
025
041
045
061
101

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3D SPECIFIC OPERATOR **3D SLICE**

Description:

Creates a monochrome image from a three-dimensional slice of a volume, temporal, or spectral image.

Name:

3d_slice

Parameters:

SRC	source image	ID	in
DST	destination image	ID	out
xs	source x coordinate offset	RP	in
ys	source y coordinate offset	RP	in
us	source third coordinate offset	RP	in
xd	destination x coordinate offset	RP	in
yd	destination y coordinate offset	RP	in
rxy	x-y plane rotation angle	RP	in
rxu	x-u plane rotation angle	RP	in
ryu	y-u plane rotation angle	RP	in

Objects:

SRC structure:	VOL, TEM, SPE
DST structure:	MON
SRC data type:	ND, SD, RD
DST data type:	RD

Element functionality:

Index assignment:	no
Match point:	yes
ROI control:	yes
ROI processing:	no
Source promotion:	yes
Heterogeneous bands:	no
Chainable element:	yes
Asynchronous:	yes

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Nomenclature:

SRC(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ source image
DST(x, y, z, t, b)	$X_D x Y_D x 1 x 1 x 1$ destination image
S(x, y, z, t, b)	$X_S x Y_S x Z_S x T_S x B_S$ operator input image
D(x, y, z, t, b)	$X_D x Y_D x 1 x 1 x 1$ operator output image
xs	source x index offset, $0 \leq xs \leq X_S - 1$
ys	source y index, $0 \leq ys \leq Y_S - 1$
us	source z, t, or b index offset, $0 \leq us \leq U_S - 1$
xd	destination x index offset, $0 \leq xd \leq X_D - 1$
yd	destination y index offset, $0 \leq yd \leq Y_D - 1$
rxy	x-y plane rotation angle, $-\pi \leq rxy \leq \pi$
rxu	x-u plane rotation angle, $-\pi \leq rxu \leq \pi$
ryu	y-u plane rotation angle, $-\pi \leq ryu \leq \pi$

Definition:

A plane in the three-dimensional volume, temporal, or spectral image is generated at the offset coordinate. The plane is oriented with respect to the three coordinate axes by the three rotation angles.

For a volume image, xs, ys, and us denote the plane offset with respect to the x, y, and z axes, respectively. The parameters rxy, rxu, and ryu denote the rotation angles about x-y, x-z, and y-z planes, respectively.

For a temporal image, xs, ys, and us denote the plane offset with respect to the x, y, and t axes, respectively. The parameters rxy, rxu, and ryu denote the rotation angles about x-y, x-t, and y-t planes, respectively.

For a spectral image, xs, ys, and us denote the plane offset with respect to the x, y, and b axes, respectively. The parameters rxy, rxu, and ryu denote the rotation angles about x-y, x-b, and y-b planes, respectively.

The *3d_slice* operator is defined as follows.

For

$$0 \leq x \leq X_D - 1$$

$$0 \leq y \leq Y_D - 1$$

Volume image:

$$D(x, y, 0, 0, 0) = RES_3\{S(x', y', u', 0, 0)\}$$

where

$$u = z$$

$$U_S = Z_S$$

Temporal image:

$$D(x, y, 0, 0, 0) = RES_3\{S(x', y', 0, u', 0)\}$$

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where

$u = t$

$U_S = T_S$

Spectral image:

$D(x, y, 0, 0, 0) = RES_3\{S(x', y', 0, 0, u')\}$

where

$u = b$

$U_S = B_S$

The terms x', y', and u' are components of the vector space transformation

$$\begin{bmatrix} x' \\ y' \\ u' \end{bmatrix} = \begin{bmatrix} t(1,1) & t(1,2) & t(1,3) \\ t(2,1) & t(2,2) & t(2,3) \\ t(3,1) & t(3,2) & t(3,3) \end{bmatrix} \begin{bmatrix} x - xd \\ y - yd \\ 1 \end{bmatrix}$$

where

$t(1, 1) = COS\{rxu\}COS\{rxy\}$

$t(1, 2) = -COS\{rxu\}SIN\{rxy\}$

$t(1, 3) = xs$

$t(2, 1) = SIN\{ryu\}SIN\{rxu\}COS\{rxy\} + COS\{ryu\}SIN\{rxy\}$

$t(2, 2) = COS\{ryu\}COS\{rxy\} - SIN\{ryu\}SIN\{rxu\}SIN\{rxy\}$

$t(2, 3) = ys$

$t(3, 1) = SIN\{ryu\}SIN\{rxy\} - COS\{ryu\}SIN\{rxu\}COS\{rxy\}$

$t(3, 2) = SIN\{ryu\}COS\{rxy\} + COS\{ryu\}SIN\{rxu\}SIN\{rxy\}$

$t(3, 3) = us$

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Profile:

Scientific

Error codes:

001
011
013
021
025
041
043
061
101

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Annex A (normative)

Definitions of mathematical functions

This annex provides a notational guide and references to commonly used mathematical symbols and functions used within this part 2 of the standard. Annex A also provides notation and definitions for special mathematical functions used in this standard.

A.1 Conventional mathematical symbols

+	plus or positive symbol
−	minus or negative symbol
×	multiply symbol
/	arithmetic divide symbol
÷	integer divide symbol
<	less than symbol
≤	less than or equal to symbol
>	greater than symbol
≥	greater than or equal to symbol
|[.]|	magnitude of argument symbol
∪	boolean union symbol
∩	boolean intersection symbol
$\overline{[.]}$	complement overbar symbol
⊕	logical AND symbol
⊗	logical XOR symbol
⊖	logical OR symbol
⊞	morphological dilation symbol
⊟	morphological erosion symbol

A.2 Operational symbols

Sequence summation symbol:

$$\sum_{j=p}^{q} a(j) = a(p) + a(p+1) + \ldots + a(j) + \ldots + a(q)$$

where j, p, and q are integer numbers and a(j) is an integer or real number

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Sequence product symbol:

$$\prod_{j=p}^{q} a(j) = a(p) \times a(p+1) \times \ldots \times a(j) \times \ldots \times a(q)$$

where j, p, and q are integer numbers and a(j) is an integer or real number

Sequence maxima symbol:

$$\mathop{M}_{j=p}^{q} a(j) = MAX\{a(p), a(p+1), \ldots., a(j), \ldots., a(q)\}$$

where j, p, and q are integer numbers and a(j) is an integer or real number

Sequence minima symbol:

$$\mathop{N}_{j=p}^{q} a(j) = MIN\{a(p), a(p+1), \ldots., a(j), \ldots., a(q)\}$$

where j, p, and q are integer numbers and a(j) is an integer or real number

Sequence union symbol:

$$\bigcup_{j=p}^{q} a(j) = a(p) \cup a(p+1) \cup \ldots \cup a(j) \cup \ldots \cup a(q)$$

where j, p, and q are integer numbers and a(j) is a boolean variable

Sequence intersection symbol:

$$\bigcap_{j=p}^{q} a(j) = a(p) \cap a(p+1) \cap \ldots \cap a(j) \cap \ldots \cap a(q)$$

where j, p, and q are integer numbers and a(j) is a boolean variable

Convolution symbol:

$$D(j, k, l, m, n) = S(j, k, l, m, n) \circledast H(j, k)$$

The symbol $\circledast$ denotes two-dimensional, enclosed impulse response array convolution as defined by the *convolve_2d* operator.

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A.3 Mathematical functions

ACOS arc cosine function

$ACOS\{a\} = \arccos(a) \qquad -1.0 \le a \le 1.0$

ASIN arc sine function

$ASIN\{a\} = \arcsin(a) \qquad -1.0 \le a \le 1.0$

ASSIGN index assignment function

$S(j,k,l,m,n) = SRC(ASSIGN\{x,y,z,t,b\})$

where SRC(x,y,z,t,b) denotes a source image and S(j,k,l,m,n) denotes an operator input image. The ASSIGN function assigns unique relationships between the source image indices (x,y,z,t,b) and the operator input image indices (j,k,l,m,n) according to the following table.

Operator Index	Image index
j	CHOICE{x,y,z,t,b}
k	CHOICE{x,y,z,t,b}but not j choice
l	CHOICE{x,y,z,t,b}but not j or k choices
m	CHOICE{x,y,z,t,b}but not j, k or l choices
n	CHOICE{x,y,z,t,b}but not j, k, l, or m choices

ATAN arc tangent function

$ATAN\{a\} = \arctan(a)$

ATAN2 arc tangent ratio function

$$ATAN2\{a, b\} = \arctan\left[\frac{a}{b}\right] \qquad 0 \le ATAN2\{a, b\} < 2\pi$$

CAS Hartley cas function

$CAS\{a\} = \cos(a) + \sin(a)$

CHOICE choice function

$j = CHOICE\{x, y, z, t, b\}$

The variable j is equated to x or y or z or t or b.

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CONJ complex conjugate function

CONJ{c} = d

where

d = a − ib if c = a + ib

d = a + ib if c = a − ib

where c = a + ib is a complex number and a and b are real numbers

COS cosine function

COS{a} = cos(a)

ERF Gaussian error function

$$ERF\{a\} = \frac{2}{\sqrt{\pi}} \int_0^a (e)^{-b^2} db$$

where e is the natural logarithm base value

EXP exponential function

EXP{a} = $(e)^a$

where e is the natural logarithm base value

IMAG imaginary part function

IMAG{c} = b

where c = a + ib is a complex number and a and b are real numbers

LIV lowest integer value function

LIV{a} = p if $p \leq a < p + 1$

where a is a real number and p is an integer number

LOG base e natural logarithm function

LOG{a} = ln(a)

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LOOK lookup table function

$d(b) = LOOK\{s, f, b, id\}$

The lookup table referenced by the table identifier, id, has E entries and B cells per entry. The unsigned integer input to the lookup table, s, is biased negatively by the table offset, f, where $f \geq 0$, to form the lookup table entry cell index

$e = s - f$

The content of the lookup table cell, T(e, b), for $0 \leq e \leq E - 1$ and $0 \leq b \leq B - 1$ is assigned to the table output, d(b).

MAX maximum of sequence function

$MAX\{s(1), s(2), \ldots s(q), \ldots s(Q)\} = s(p)$

where s(p) is an element of the sequence for which $s(p) \geq s(q)$ for all q.

MAXIMIN one-dimensional maximin function

$s = MAXIMIN\{S\}$

Let S denote a sequence of elements s(1), s(2),...,s(L) and let M = (L + 1)/2 where L is an odd integer. The MAXIMIN of the sequence S is the MAX of the MIN of all running subsequences of length M as defined below.

$MAXIMIN\{S\} = MAX\{[MIN\{s(1), \ldots, s(M)\}], [MIN\{ s(2), \ldots, s(M+1)\}],$

$\ldots, MIN\{s(L-M+1), \ldots, s(L)\}\}$

MIN minimum of sequence function

$MIN\{s(1), s(2), \ldots s(q), \ldots s(Q)\} = s(p)$

where s(p) is an element of the sequence for which $s(p) \leq s(q)$ for all q.

MINIMAX one-dimensional minimax function

$s = MINIMAX\{S\}$

Let S denote a sequence of elements s(1), s(2),..., s(L) and let M = (L + 1)/2 where L is an odd integer. The MINIMAX of the sequence S is the MIN of the MAX of all running subsequences of length M as defined below.

$MINIMAX\{S\} = MIN\{[MAX\{s(1),\ldots, s(M)\}], [MAX\{s(2),\ldots, s(M+1)\}],$

$\ldots, MAX\{s(L-M+1),\ldots, s(L)\}\}$

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MOD modulus function

$$MOD\{p, q\} = p - [q \times (p \div q)]$$

NIV nearest integer value function

$$NIV\{a\} = p \quad \text{if } p \leq a < p + 1/2$$

$$NIV\{a\} = p + 1 \quad \text{if } p + 1/2 \leq a < p + 1$$

where a is a real number and p is an integer number

POW power law function

$$POW\{a, b\} = (a)^b$$

where a and b are integer or real numbers.

REAL real part function

$$REAL\{c\} = a$$

where c = a + ib is a complex number and a and b are real numbers

REASSIGN index reassignment function

$$DST(x, y, z, t, b) = D(REASSIGN\{j, k, l, m, n\})$$

where DST(x, y, z, t, b) denotes a destination image and D(j, k, l, m, n) denotes an operator output image. The REASSIGN function assigns unique relationships between the operator output image indicies (j,k,l,m,n) and the destination image indices (x,y,z,t,b) according to the inverse of the ASSIGN function table.

RES_1 one-dimensional resampling function

$$D(j, k, l, m, n) = RES_1\{S, j', k, l, m, n\}$$

The function RES_1 is defined in Annex H.

RES_2 two-dimensional resampling function

$$D(j, k, l, m, n) = RES_2\{S, j', k', l, m, n\}$$

The function RES_2 is defined in Annex H.

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RES3 three-dimensional resampling function

$D(j, k, l, m, n) = RES3\{S, j', k', l', m, n\}$

The function RES3 is defined in Annex H.

RES4 four-dimensional resampling function

$D(j, k, l, m, n) = RES4\{S, j', k', l', m', n\}$

The function RES4 is defined in Annex H.

RES5 five-dimensional resampling function

$D(j, k, l, m, n) = RES5\{S, j', k', l', m', n'\}$

The function RES5 is defined in Annex H.

SIN sine function

$SIN\{a\} = \sin(a)$

SORT two-dimensional sort function

$D(j, k, l, m, n) = SORT\{S(j', k', l, m, n), H(j - j' + j_k, k - k' + k_k), j, k, l, m, n, j', k', r\}$

For all l, m, n, the pixels S(j', k', l, m, n) for which the translated mask array $H(j - j' + j_k, k - k' + k_k)$ = TRUE are sorted by amplitude from smallest to largest into an array of R entries where R equals the number of TRUE elements of H and (j_k, k_k) is the key pixel of the mask array. The r-th entry of the sort array is assigned to D(j, k, l, m, n).

TAN tangent function

$TAN\{a\} = \tan(a)$

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Annex B (informative)

PIKS element support - source image structure

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
abort_asynchronous_execution														X
accumulator	X	X	X	X	X	X	X	X	X	X	X	X	X	
adaptive_histogram_equalization	X	X	X	X	X	X	X	X	X	X	X	X	X	
allocate_chain														X
allocate_composite_identifier_array														X
allocate_composite_identifier_list														X
allocate_composite_identifier_record														X
allocate_histogram														X
allocate_image														X
allocate_lookup_table														X
allocate_matrix														X
allocate_neighbourhood_array														X
allocate_pixel_record														X
allocate_roi														X
allocate_static_array														X
allocate_tuple														X
allocate_value_bounds														X
allocate_vreg														X
alpha_blend_constant	X	X	X	X	X	X	X	X	X	X	X	X	X	
alpha_blend_variable	X	X	X	X	X	X	X	X	X	X	X	X	X	
array_to_lut														X
bind_match_point	X	X	X	X	X	X	X	X	X	X	X	X	X	
bind_roi	X	X	X	X	X	X	X	X	X	X	X	X	X	
bit_shift	X	X	X	X	X	X	X	X	X	X	X	X	X	
cartesian_to_polar	X	X	X	X	X	X	X	X	X	X	X	X	X	
chain_abort														X
chain_begin														X

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Annex B (informative)

PIKS element support - source image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
chain_delete														X
chain_end														X
chain_execute														X
chain_reload														X
classifier_bayes					X									
classifier_nearest_neighbour					X									
close_piks														X
close_piks_emergency														X
colour_conversion_linear				X			X		X		X			
colour_conversion_matrix														X
colour_conversion_nonlinear				X			X		X		X			
colour_conversion_subtractive				X			X		X		X			
colour_lookup_interpolated				X			X		X		X			
complement	X	X	X	X	X	X	X	X	X	X	X	X	X	
complement_roi														X
complex_composition	X	X	X	X	X	X	X	X	X	X	X	X	X	
complex_conjugate	X	X	X	X	X	X	X	X	X	X	X	X	X	
complex_decomposition	X	X	X	X	X	X	X	X	X	X	X	X	X	
complex_magnitude	X	X	X	X	X	X	X	X	X	X	X	X	X	
composite_identifier_array_equal														X
composite_identifier_array_get														X
composite_identifier_array_put	X	X	X	X	X	X	X	X	X	X	X	X	X	
composite_identifier_list_empty														X
composite_identifier_list_equal														X
composite_identifier_list_get														X
composite_identifier_list_insert	X	X	X	X	X	X	X	X	X	X	X	X	X	
composite_identifier_list_remove														X

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Annex B (informative)

PIKS element support - source image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
composite_identifier_record_equal														X
composite_identifier_record_get														X
composite_identifier_record_put	X	X	X	X	X	X	X	X	X	X	X	X	X	
constant_predicate	X	X	X	X	X	X	X	X	X	X	X	X	X	
convert_array_to_image														X
convert_image_datatype	X	X	X	X	X	X	X	X	X	X	X	X	X	
convert_image_to_array	X													
convert_image_to_roi	X	X	X	X	X	X	X	X	X	X	X	X	X	
convert_roi_to_image														X
convolve_2d	X	X	X	X	X	X	X	X	X	X	X	X	X	
convolve_5d	X	X	X	X	X	X	X	X	X	X	X	X	X	
copy_window	X	X	X	X	X	X	X	X	X	X	X	X	X	
copy_window_roi														X
create_tuple														X
cross_correlation	X	X	X	X	X	X	X	X	X	X	X	X	X	
deallocate_data_object														X
define_sub_image	X	X	X	X	X	X	X	X	X	X	X	X	X	
difference_measures	X	X	X	X	X	X	X	X	X	X	X	X	X	
diffuse	X	X	X	X	X	X	X	X	X	X	X	X	X	
dither	X	X	X	X	X	X	X	X	X	X	X	X	X	
draw_pixels														X
draw_pixels_roi														X
dyadic_arithmetic	X	X	X	X	X	X	X	X	X	X	X	X	X	
dyadic_complex	X	X	X	X	X	X	X	X	X	X	X	X	X	
dyadic_logical	X	X	X	X	X	X	X	X	X	X	X	X	X	
dyadic_logical_roi														X

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Annex B (informative)

PIKS element support - source image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
dyadic_predicate	X	X	X	X	X	X	X	X	X	X	X	X	X	
edge_detection_orthogonal_gradient	X	X	X	X	X	X	X	X	X	X	X	X	X	
edge_detection_second_derivative	X	X	X	X	X	X	X	X	X	X	X	X	X	
edge_detection_template_gradient	X	X	X	X	X	X	X	X	X	X	X	X	X	
equal_predicate	X	X	X	X	X	X	X	X	X	X	X	X	X	
erosion_dilation_boolean	X	X	X	X	X	X	X	X	X	X	X	X	X	
erosion_dilation_boolean_roi														X
erosion_dilation_grey	X	X	X	X	X	X	X	X	X	X	X	X	X	
error_function_scaling	X	X	X	X	X	X	X	X	X	X	X	X	X	
error_handler														X
error_logger														X
error_test														X
export_histogram														X
export_image	X	X	X	X	X	X	X	X	X	X	X	X	X	
export_lut														X
export_matrix														X
export_neighbourhood_array														X
export_roi_array														X
export_static_array														X
export_tuple														X
export_value_bounds														X
extract_pixel_plane	X	X	X	X	X	X	X	X	X	X	X	X	X	
extract_pixel_plane_roi														X
extrema	X	X	X	X	X	X	X	X	X	X	X	X	X	
false_colour					X			X		X		X		
fill_region	X	X	X	X	X	X	X	X	X	X	X	X	X	
fill_region_roi														X

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Annex B (informative)

PIKS element support - source image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
filter_butterworth														X
filter_gaussian														X
filter_inverse														X
filter_matched														X
filter_wiener														X
filter_zonal														X
filtering_homomorphic	X	X	X	X	X	X	X	X	X	X	X	X	X	
filtering_linear	X	X	X	X	X	X	X	X	X	X	X	X	X	
filtering_median	X	X	X	X	X	X	X	X	X	X	X	X	X	
filtering_pseudomedian	X	X	X	X	X	X	X	X	X	X	X	X	X	
filtering_rank_order	X	X	X	X	X	X	X	X	X	X	X	X	X	
flip_spin_transpose	X	X	X	X	X	X	X	X	X	X	X	X	X	
flip_spin_transpose_roi														X
gamma_correction	X	X	X	X	X	X	X	X	X	X	X	X	X	
get_colour_pixel				X			X		X		X			
get_pixel	X	X	X	X	X	X	X	X	X	X	X	X	X	
get_pixel_roi														X
get_pixel_array	X	X	X	X	X	X	X	X	X	X	X	X	X	
get_pixel_array_roi														X
get_pixel_record	X	X	X	X	X	X	X	X	X	X	X	X	X	
get_pixel_record_roi														X
histogram_modification	X	X	X	X	X	X	X	X	X	X	X	X	X	
histogram_scaling	X	X	X	X	X	X	X	X	X	X	X	X	X	
histogram_shape_1d														X
histogram_shape_2d														X
histogram_1d	X	X	X	X	X	X	X	X	X	X	X	X	X	
histogram_2d	X													

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Annex B (informative)

PIKS element support - source image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
hit_or_miss	X	X	X	X	X	X	X	X	X	X	X	X	X	
hit_or_miss_roi														X
hough_transform	X													
image_bar_chart														X
image_constant														X
image_gaussian														X
image_grey_scale														X
image_random_number														X
import_histogram														X
import_image														X
import_lut														X
import_matrix														X
import_neighbourhood_array														X
import_roi_array														X
import_static_array														X
import_tuple														X
import_value_bounds														X
impulse_boxcar														X
impulse_derivative_of_gaussian														X
impulse_difference_of_gaussians														X
impulse_elliptical														X
impulse_gaussian														X
impulse_laplacian_of_gaussian														X
impulse_pyramid														X
impulse_rectangular														X
impulse_sinc														X
input_object														X

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Annex B (informative)

PIKS element support - source image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
inquire_chain_environment														X
inquire_chain_status														X
inquire_elements														X
inquire_image	X	X	X	X	X	X	X	X	X	X	X	X	X	
inquire_index_assignment														X
inquire_non_image_object														X
inquire_piks_implementation														X
inquire_piks_status														X
inquire_repository														X
inquire_resampling														X
insert_pixel_plane	X													
insert_pixel_plane_roi														X
label_objects	X	X	X	X	X	X	X	X	X	X	X	X	X	
laws_texture_features	X	X	X	X	X	X	X	X	X	X	X	X	X	
level_slice	X	X	X	X	X	X	X	X	X	X	X	X	X	
line_profile	X	X	X	X	X	X	X	X	X	X	X	X	X	
lookup	X	X	X	X	X	X	X	X	X	X	X	X	X	
lookup_interpolated	X	X	X	X	X	X	X	X	X	X	X	X	X	
luminance_generation				X			X		X		X			
markov_spectrum														X
moments	X	X	X	X	X	X	X	X	X	X	X	X	X	
monadic_arithmetic	X	X	X	X	X	X	X	X	X	X	X	X	X	
monadic_complex	X	X	X	X	X	X	X	X	X	X	X	X	X	
monadic_logical	X	X	X	X	X	X	X	X	X	X	X	X	X	
monadic_logical_roi														X
morphic_processor	X	X	X	X	X	X	X	X	X	X	X	X	X	
morphic_processor_roi														X

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Annex B (informative)

PIKS element support - source image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
morphology	X	X	X	X	X	X	X	X	X	X	X	X	X	
morphology_roi														X
neighbour_count	X	X	X	X	X	X	X	X	X	X	X	X	X	
noise_combination	X	X	X	X	X	X	X	X	X	X	X	X	X	
open_close	X	X	X	X	X	X	X	X	X	X	X	X	X	
open_piks														X
outlier_removal	X	X	X	X	X	X	X	X	X	X	X	X	X	
output_object														X
paint_pixels	X	X	X	X	X	X	X	X	X	X	X	X	X	
perimeter_code_generator	X	X	X	X	X	X	X	X	X	X	X	X	X	
polar_to_cartesian	X	X	X	X	X	X	X	X	X	X	X	X	X	
power_law_scaling	X	X	X	X	X	X	X	X	X	X	X	X	X	
pseudocolour	X	X	X			X								
put_colour_pixel														X
put_pixel														X
put_pixel_roi														X
put_pixel_array														X
put_pixel_array_roi														X
put_pixel_record														X
put_pixel_record_roi														X
rescale	X	X	X	X	X	X	X	X	X	X	X	X	X	
rescale_roi														X
resize	X	X	X	X	X	X	X	X	X	X	X	X	X	
resize_roi														X
return_repository_id														X
roi_coordinate														X
roi_elliptical														X

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Annex B (informative)

PIKS element support - source image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
roi_polygon														X
roi_rectangular														X
rotate	X	X	X	X	X	X	X	X	X	X	X	X	X	
rotate_roi														X
rubber_band_scaling	X	X	X	X	X	X	X	X	X	X	X	X	X	
sequence_average		X	X		X									
sequence_karhunen_loeve	X	X	X	X	X	X	X	X	X	X	X	X	X	
sequence_running_measures		X	X		X									
set_globals														X
set_image_attributes														X
set_index_assignment														X
shape_metrics	X	X	X	X	X	X	X	X	X	X	X	X	X	
spatial_moments_invariant	X	X	X	X	X	X	X	X	X	X	X	X	X	
spatial_moments_scaled	X	X	X	X	X	X	X	X	X	X	X	X	X	
split_image	X			X										
subsample	X	X	X	X	X	X	X	X	X	X	X	X	X	
subsample_roi														X
synchronize														X
template_match	X	X	X	X	X	X	X	X	X	X	X	X	X	
threshold	X	X	X	X	X	X	X	X	X	X	X	X	X	
transform_cosine	X	X	X	X	X	X	X	X	X	X	X	X	X	
transform_fourier	X	X	X	X	X	X	X	X	X	X	X	X	X	
transform_hadamard	X	X	X	X	X	X	X	X	X	X	X	X	X	
transform_hartley	X	X	X	X	X	X	X	X	X	X	X	X	X	
translate	X	X	X	X	X	X	X	X	X	X	X	X	X	
translate_roi														X
unary_integer	X	X	X	X	X	X	X	X	X	X	X	X	X	

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Annex B (informative)

PIKS element support - source image structure *(concluded)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
unary_real	X	X	X	X	X	X	X	X	X	X	X	X	X	
unsharp_mask	X	X	X	X	X	X	X	X	X	X	X	X	X	
value_bounds	X	X	X	X	X	X	X	X	X	X	X	X	X	
vreg_alter														X
vreg_clear														X
vreg_conditional														X
vreg_copy														X
vreg_delete														X
vreg_get														X
vreg_set														X
vreg_wait														X
wallis_statistical_differencing	X	X	X	X	X	X	X	X	X	X	X	X	X	
warp_control_point	X	X	X	X	X	X	X	X	X	X	X	X	X	
warp_control_point_roi														X
warp_lut	X	X	X	X	X	X	X	X	X	X	X	X	X	
warp_lut_roi														X
warp_polynomial	X	X	X	X	X	X	X	X	X	X	X	X	X	
warp_polynomial_roi														X
windowing_function														X
window_level	X	X	X	X	X	X	X	X	X	X	X	X	X	
window_statistics	X	X	X	X	X	X	X	X	X	X	X	X	X	
z_merge	X	X	X	X	X	X	X	X	X	X	X	X	X	
zoom	X	X	X	X	X	X	X	X	X	X	X	X	X	
zoom_roi														X
3d_slice		X	X		X									

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Annex C (informative)

PIKS element support - destination image structure

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
abort_asynchronous_execution														X
accumulator														X
adaptive_histogram_equalization	X	X	X	X	X	X	X	X	X	X	X	X	X	
allocate_chain														X
allocate_composite_identifier_array														X
allocate_composite_identifier_list														X
allocate_composite_identifier_record														X
allocate_histogram														X
allocate_image	X	X	X	X	X	X	X	X	X	X	X	X	X	
allocate_lookup_table														X
allocate_matrix														X
allocate_neighbourhood_array														X
allocate_pixel_record														X
allocate_roi														X
allocate_static_array														X
allocate_tuple														X
allocate_value_bounds														X
allocate_vreg														X
alpha_blend_constant	X	X	X	X	X	X	X	X	X	X	X	X	X	
alpha_blend_variable	X	X	X	X	X	X	X	X	X	X	X	X	X	
array_to_lut														X
bind_match_point														X
bind_roi														X
bit_shift	X	X	X	X	X	X	X	X	X	X	X	X	X	
cartesian_to_polar	X	X	X	X	X	X	X	X	X	X	X	X	X	
chain_abort														X
chain_begin														X

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Annex C (informative)

PIKS element support - destination image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
chain_delete														X
chain_end														X
chain_execute														X
chain_reload														X
classifier_bayes	X													
classifier_nearest_neighbour	X													
close_piks														X
close_piks_emergency														X
colour_conversion_linear				X			X		X		X			
colour_conversion_matrix														X
colour_conversion_nonlinear				X			X		X		X			
colour_conversion_subtractive				X			X		X		X			
colour_lookup_interpolated				X			X		X		X			
complement	X	X	X	X	X	X	X	X	X	X	X	X	X	
complement_roi														X
complex_composition	X	X	X	X	X	X	X	X	X	X	X	X	X	
complex_conjugate	X	X	X	X	X	X	X	X	X	X	X	X	X	
complex_decomposition	X	X	X	X	X	X	X	X	X	X	X	X	X	
complex_magnitude	X	X	X	X	X	X	X	X	X	X	X	X	X	
composite_identifier_array_equal														X
composite_identifier_array_get	X	X	X	X	X	X	X	X	X	X	X	X	X	
composite_identifier_array_put														X
composite_identifier_list_empty														X
composite_identifier_list_equal														X
composite_identifier_list_get	X	X	X	X	X	X	X	X	X	X	X	X	X	
composite_identifier_list_insert														X
composite_identifier_list_remove														X

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Annex C (informative)

PIKS element support - destination image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
composite_identifier_record_equal														X
composite_identifier_record_get	X	X	X	X	X	X	X	X	X	X	X	X	X	
composite_identifier_record_put														X
constant_predicate														X
convert_array_to_image	X													
convert_image_datatype	X	X	X	X	X	X	X	X	X	X	X	X	X	
convert_image_to_array														X
convert_image_to_roi														X
convert_roi_to_image	X	X	X	X	X	X	X	X	X	X	X	X	X	
convolve_2d	X	X	X	X	X	X	X	X	X	X	X	X	X	
convolve_5d	X	X	X	X	X	X	X	X	X	X	X	X	X	
copy_window	X	X	X	X	X	X	X	X	X	X	X	X	X	
copy_window_roi														X
create_tuple														X
cross_correlation														X
deallocate_data_object														X
define_sub_image													X	
difference_measures														X
diffuse	X	X	X	X	X	X	X	X	X	X	X	X	X	
dither	X	X	X	X	X	X	X	X	X	X	X	X	X	
draw_pixels	X	X	X	X	X	X	X	X	X	X	X	X	X	
draw_pixels_roi														X
dyadic_arithmetic	X	X	X	X	X	X	X	X	X	X	X	X	X	
dyadic_complex	X	X	X	X	X	X	X	X	X	X	X	X	X	
dyadic_logical	X	X	X	X	X	X	X	X	X	X	X	X	X	
dyadic_logical_roi														X
dyadic_predicate	X	X	X	X	X	X	X	X	X	X	X	X	X	

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Annex C (informative)

PIKS element support - destination image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
edge_detection_orthogonal_gradient	X	X	X	X	X	X	X	X	X	X	X	X	X	
edge_detection_second_derivative	X	X	X	X	X	X	X	X	X	X	X	X	X	
edge_detection_template_gradient	X	X	X	X	X	X	X	X	X	X	X	X	X	
equal_predicate														X
erosion_dilation_boolean	X	X	X	X	X	X	X	X	X	X	X	X	X	
erosion_dilation_boolean_roi														X
erosion_dilation_grey	X	X	X	X	X	X	X	X	X	X	X	X	X	
error_function_scaling	X	X	X	X	X	X	X	X	X	X	X	X	X	
error_handler														X
error_logger														X
error_test														X
export_histogram														X
export_image														X
export_lut														X
export_matrix														X
export_neighbourhood_array														X
export_roi_array														X
export_static_array														X
export_tuple														X
export_value_bounds														X
extract_pixel_plane	X													
extract_pixel_plane_roi														X
extrema														X
false_colour				X			X		X		X			
fill_region	X	X	X	X	X	X	X	X	X	X	X	X	X	
fill_region_roi														X

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Annex C (informative)

PIKS element support - destination image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
filter_butterworth														X
filter_gaussian														X
filter_inverse														X
filter_matched														X
filter_wiener														X
filter_zonal														X
filtering_homomorphic	X	X	X	X	X	X	X	X	X	X	X	X	X	
filtering_linear	X	X	X	X	X	X	X	X	X	X	X	X	X	
filtering_median	X	X	X	X	X	X	X	X	X	X	X	X	X	
filtering_pseudomedian	X	X	X	X	X	X	X	X	X	X	X	X	X	
filtering_rank_order	X	X	X	X	X	X	X	X	X	X	X	X	X	
flip_spin_transpose	X	X	X	X	X	X	X	X	X	X	X	X	X	
flip_spin_transpose_roi														X
gamma_correction	X	X	X	X	X	X	X	X	X	X	X	X	X	
get_colour_pixel														X
get_pixel														X
get_pixel_roi														X
get_pixel_array														X
get_pixel_array_roi														X
get_pixel_record														X
get_pixel_record_roi														X
histogram_modification	X	X	X	X	X	X	X	X	X	X	X	X	X	
histogram_scaling	X	X	X	X	X	X	X	X	X	X	X	X	X	
histogram_shape_1d														X
histogram_shape_2d														X
histogram_1d														X
histogram_2d														X

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Annex C (informative)

PIKS element support - destination image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
hit_or_miss	X	X	X	X	X	X	X	X	X	X	X	X	X	
hit_or_miss_roi														X
hough_transform														X
image_bar_chart	X			X										
image_constant	X	X	X	X	X	X	X	X	X	X	X	X	X	
image_gaussian	X													X
image_grey_scale	X													X
image_random_number	X	X	X	X	X	X	X	X	X	X	X	X	X	
import_histogram														X
import_image	X	X	X	X	X	X	X	X	X	X	X	X	X	
import_lut														X
import_matrix														X
import_neighbourhood_array														X
import_roi_array														X
import_static_array														X
import_tuple														X
import_value_bounds														X
impulse_boxcar														X
impulse_derivative_of_gaussian														X
impulse_difference_of_gaussians														X
impulse_elliptical														X
impulse_gaussian														X
impulse_laplacian_of_gaussian														X
impulse_pyramid														X
impulse_rectangular														X
impulse_sinc														X
input_object														X

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Annex C (informative)

PIKS element support - destination image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
inquire_chain_environment														X
inquire_chain_status														X
inquire_elements														X
inquire_image														X
inquire_index_assignment														X
inquire_non_image_object														X
inquire_piks_implementation														X
inquire_piks_status														X
inquire_repository														X
inquire_resampling														X
insert_pixel_plane	X	X	X	X	X	X	X	X	X	X	X	X	X	
label_objects	X	X	X	X	X	X	X	X	X	X	X	X	X	
laws_texture_features	X	X	X	X	X	X	X	X	X	X	X	X	X	
level_slice	X	X	X	X	X	X	X	X	X	X	X	X	X	
line_profile														X
lookup	X	X	X	X	X	X	X	X	X	X	X	X	X	
lookup_interpolated	X	X	X	X	X	X	X	X	X	X	X	X	X	
luminance_generation	X	X	X			X								
markov_spectrum														X
moments														X
monadic_arithmetic	X	X	X	X	X	X	X	X	X	X	X	X	X	
monadic_complex	X	X	X	X	X	X	X	X	X	X	X	X	X	
monadic_logical	X	X	X	X	X	X	X	X	X	X	X	X	X	
monadic_logical_roi														X
morphic_processor	X	X	X	X	X	X	X	X	X	X	X	X	X	
morphic_processor_roi														X
morphology	X	X	X	X	X	X	X	X	X	X	X	X	X	

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Annex C (informative)

PIKS element support - destination image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
morphology_roi														X
neighbour_count	X	X	X	X	X	X	X	X	X	X	X	X	X	
noise_combination	X	X	X	X	X	X	X	X	X	X	X	X	X	
open_close	X	X	X	X	X	X	X	X	X	X	X	X	X	
open_piks														X
outlier_removal	X	X	X	X	X	X	X	X	X	X	X	X	X	
output_object														X
paint_pixels	X	X	X	X	X	X	X	X	X	X	X	X	X	
perimeter_code_generator														X
polar_to_cartesian	X	X	X	X	X	X	X	X	X	X	X	X	X	
power_law_scaling	X	X	X	X	X	X	X	X	X	X	X	X	X	
pseudocolour				X			X		X		X			
put_colour_pixel				X			X		X		X			
put_pixel	X	X	X	X	X	X	X	X	X	X	X	X	X	
put_pixel_roi														X
put_pixel_array	X	X	X	X	X	X	X	X	X	X	X	X	X	
put_pixel_array_roi														X
put_pixel_record	X	X	X	X	X	X	X	X	X	X	X	X	X	
put_pixel_record_roi														X
rescale	X	X	X	X	X	X	X	X	X	X	X	X	X	
rescale_roi														X
resize	X	X	X	X	X	X	X	X	X	X	X	X	X	
resize_roi														X
return_repository_id														X
roi_coordinate														X
roi_elliptical														X
roi_polygon														X

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Annex C (informative)

PIKS element support - destination image structure *(continued)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
roi_rectangular														X
rotate	X	X	X	X	X	X	X	X	X	X	X	X	X	
rotate_roi														X
rubber_band_scaling	X	X	X	X	X	X	X	X	X	X	X	X	X	
sequence_average	X													
sequence_karhunen_loeve	X	X	X	X	X	X	X	X	X	X	X	X	X	
sequence_running_measures		X	X		X									
set_globals														X
set_image_attributes	X	X	X	X	X	X	X	X	X	X	X	X	X	
set_index_assignment														X
shape_metrics														X
spatial_moments_invariant														X
spatial_moments_scaled														X
split_image	X			X										
subsample	X	X	X	X	X	X	X	X	X	X	X	X	X	
subsample_roi														X
synchronize														X
template_match														X
threshold	X	X	X	X	X	X	X	X	X	X	X	X	X	
transform_cosine	X	X	X	X	X	X	X	X	X	X	X	X	X	
transform_fourier	X	X	X	X	X	X	X	X	X	X	X	X	X	
transform_hadamard	X	X	X	X	X	X	X	X	X	X	X	X	X	
transform_hartley	X	X	X	X	X	X	X	X	X	X	X	X	X	
translate	X	X	X	X	X	X	X	X	X	X	X	X	X	
translate_roi														X
unary_integer	X	X	X	X	X	X	X	X	X	X	X	X	X	
unary_real	X	X	X	X	X	X	X	X	X	X	X	X	X	

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Annex C (informative)

PIKS element support - destination image structure *(concluded)*

Element	MON	VOL	TEM	COLR	SPE	VT	VC	VS	TC	TS	VTC	VTS	GEN	NA
unsharp_mask	X	X	X	X	X	X	X	X	X	X	X	X	X	
value_bounds														X
vreg_alter														X
vreg_clear														X
vreg_conditional														X
vreg_copy														X
vreg_delete														X
vreg_get														X
vreg_set														X
vreg_wait														X
wallis_statistical_differencing	X	X	X	X	X	X	X	X	X	X	X	X	X	
warp_control_point	X	X	X	X	X	X	X	X	X	X	X	X	X	
warp_control_point_roi														X
warp_lut	X	X	X	X	X	X	X	X	X	X	X	X	X	
warp_lut_roi														X
warp_polynomial	X	X	X	X	X	X	X	X	X	X	X	X	X	
warp_polynomial_roi														X
windowing_function														X
window_level	X	X	X	X	X	X	X	X	X	X	X	X	X	
window_statistics	X	X	X	X	X	X	X	X	X	X	X	X	X	
z_merge	X	X	X	X	X	X	X	X	X	X	X	X	X	
zoom	X	X	X	X	X	X	X	X	X	X	X	X	X	
zoom_roi														X
3d_slice	X													

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Annex D (informative)

PIKS element support - source and destination image data type

	Source						Destination					
Element	BD	ND	SD	RD	CD	NA	BD	ND	SD	RD	CD	NA
abort_asynchronous_execution						X						X
accumulator		X	X	X								X
adaptive_histogram_equalization		X	X					X	X			
allocate_chain						X						X
allocate_composite_identifier_array						X						X
allocate_composite_identifier_list						X						X
allocate_composite_identifier_record						X						X
allocate_histogram						X						X
allocate_image						X						X
allocate_lookup_table						X						X
allocate_matrix						X						X
allocate_neighbourhood_array						X						X
allocate_pixel_record						X						X
allocate_roi						X						X
allocate_static_array						X						X
allocate_tuple						X						X
allocate_value_bounds						X						X
allocate_vreg						X						X
alpha_blend_constant		X	X	X				X	X	X		
alpha_blend_variable		X	X	X				X	X	X		
array_to_lut						X						X
bind_match_point						X						X
bind_roi						X						X
bit_shift		X	X					X	X			X
cartesian_to_polar		X	X	X						X		
chain_abort						X						X
chain_begin						X						X
chain_delete						X						X

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Annex D (informative)

PIKS element support - source and destination image data type *(continued)*

Element	Source						Destination					
	BD	ND	SD	RD	CD	NA	BD	ND	SD	RD	CD	NA
chain_end						X						X
chain_execute						X						X
chain_reload						X						X
classifier_bayes		X	X	X					X			
classifier_nearest_neighbour		X	X	X					X			
close_piks						X						X
close_piks_emergency						X						X
colour_conversion_linear			X	X					X	X		
colour_conversion_matrix						X						X
colour_conversion_nonlinear				X						X		
colour_conversion_subtractive		X	X	X				X	X	X		
colour_lookup_interpolated		X	X	X				X	X	X		
complement	X	X	X				X	X	X			
complement_roi						X						X
complex_composition				X							X	
complex_conjugate					X						X	
complex_decomposition					X					X		
complex_magnitude					X					X		
composite_identifier_array_equal						X						X
composite_identifier_array_get						X						X
composite_identifier_array_put						X						X
composite_identifier_list_empty						X						X
composite_identifier_list_equal						X						X
composite_identifier_list_get						X						X
composite_identifier_list_insert						X						X
composite_identifier_list_remove						X						X
composite_identifier_record_equal						X						X

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Annex D (informative)

PIKS element support - source and destination image data type *(continued)*

	Source						Destination					
Element	BD	ND	SD	RD	CD	NA	BD	ND	SD	RD	CD	NA
composite_identifier_record_get						X						X
composite_identifier_record_put						X						X
constant_predicate		X	X	X								X
convert_array_to_image						X	X	X	X	X	X	
convert_image_datatype		X	X	X	X			X	X	X	X	
convert_image_to_array	X	X	X	X	X							X
convert_image_to_roi	X											X
convert_roi_to_image						X	X					
convolve_2d		X	X	X				X	X	X		
convolve_5d		X	X	X				X	X	X		
copy_window	X	X	X	X	X		X	X	X	X	X	
copy_window_roi						X						X
create_tuple						X						X
cross_correlation		X	X	X								X
deallocate_data_object						X						X
define_sub_image	X	X	X	X	X		X	X	X	X	X	
difference_measures			X	X								X
diffuse		X						X				
dither		X						X				
draw_pixels						X	X	X	X	X	X	
draw_pixels_roi						X						X
dyadic_arithmetic		X	X					X	X			
dyadic_complex					X						X	
dyadic_logical	X	X	X				X	X	X			
dyadic_logical_roi						X						X
dyadic_predicate		X	X	X			X					
edge_detection_orthogonal_gradient		X	X	X			X			X		
edge_detection_second_derivative		X	X	X			X			X		

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Annex D (informative)

PIKS element support - source and destination image data type *(continued)*

Element	Source						Destination					
	BD	ND	SD	RD	CD	NA	BD	ND	SD	RD	CD	NA
edge_detection_template_gradient		X	X	X			X			X		
equal_predicate		X	X	X				X	X	X		
erosion_dilation_boolean	X						X					
erosion_dilation_boolean_roi						X						X
erosion_dilation_grey		X	X	X				X	X	X		
error_function_scaling				X						X		
error_handler						X						X
error_logger						X						X
error_test						X						X
export_histogram						X						X
export_image	X	X	X	X	X							X
export_lut						X						X
export_matrix						X						X
export_neighbourhood_array						X						X
export_roi_array						X						X
export_static_array						X						X
export_tuple						X						X
export_value_bounds						X						X
extract_pixel_plane	X	X	X	X	X		X	X	X	X	X	
extract_pixel_plane_roi						X						X
extrema		X	X	X								X
false_colour		X	X	X				X	X	X		
fill_region	X						X					
fill_region_roi						X						X
filter_butterworth						X						X
filter_gaussian						X						X
filter_inverse						X						X
filter_matched						X						X

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Annex D (informative)

PIKS element support - source and destination image data type *(continued)*

	Source						Destination					
Element	BD	ND	SD	RD	CD	NA	BD	ND	SD	RD	CD	NA
filter_wiener						X						X
filter_zonal						X						X
filtering_homomorphic		X	X	X						X		
filtering_linear		X	X	X						X		
filtering_median		X	X	X				X	X	X		
filtering_pseudomedian		X	X	X				X	X	X		
filtering_rank_order		X	X	X				X	X	X		
flip_spin_transpose	X	X	X	X	X		X	X	X	X	X	
flip_spin_transpose_roi						X						X
gamma_correction				X						X		
get_colour_pixel		X	X	X								X
get_pixel	X	X	X	X	X							X
get_pixel_roi						X						X
get_pixel_array	X	X	X	X	X							X
get_pixel_array_roi						X						X
get_pixel_record	X	X	X	X	X							X
get_pixel_record_roi						X						X
histogram_modification		X	X	X						X		
histogram_scaling		X	X	X				X	X	X		
histogram_shape_1d						X						X
histogram_shape_2d						X						X
histogram_1d		X	X	X								X
histogram_2d		X	X	X								X
hit_or_miss	X						X					
hit_or_miss_roi						X						X
hough_transform	X											X
image_bar_chart						X		X	X	X		
image_constant						X	X	X	X	X	X	

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Annex D (informative)

PIKS element support - source and destination image data type *(continued)*

Element	Source						Destination					
	BD	ND	SD	RD	CD	NA	BD	ND	SD	RD	CD	NA
image_gaussian						X				X		
image_grey_scale						X		X	X	X		
image_random_number						X				X		
import_histogram						X						X
import_image						X	X	X	X	X	X	
import_lut						X						X
import_matrix						X						X
import_neighbourhood_array						X						X
import_roi_array						X						X
import_static_array						X						X
import_tuple						X						X
import_value_bounds						X						X
impulse_boxcar						X						X
impulse_derivative_of_gaussian						X						X
impulse_difference_of_gaussians						X						X
impulse_elliptical						X						X
impulse_gaussian						X						X
impulse_laplacian_of_gaussian						X						X
impulse_pyramid						X						X
impulse_rectangular						X						X
impulse_sinc						X						X
input_object						X						X
inquire_chain_environment						X						X
inquire_chain_status						X						X
inquire_elements						X						X
inquire_image						X						
inquire_index_assignment						X						X
inquire_non_image_object						X						X

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Annex D (informative)

PIKS element support - source and destination image data type *(continued)*

	Source						Destination					
Element	BD	ND	SD	RD	CD	NA	BD	ND	SD	RD	CD	NA
inquire_piks_implementation						X						X
inquire_piks_status						X						X
inquire_repository						X						X
inquire_resampling						X						
insert_pixel_plane	X	X	X	X	X		X	X	X	X	X	
insert_pixel_plane_roi						X						X
label_objects	X								X			
laws_texture_features		X	X	X						X		
level_slice		X	X	X				X	X	X		
line_profile		X	X	X								X
lookup		X	X				X	X	X	X	X	
lookup_interpolated		X	X				X	X	X	X	X	
luminance_generation		X	X	X				X	X	X		
markov_spectrum					X							X
moments		X	X	X								X
monadic_arithmetic		X	X	X				X	X	X		
monadic_complex					X						X	
monadic_logical	X	X	X				X	X	X			
monadic_logical_roi						X						X
morphic_processor	X						X					
morphic_processor_roi						X						X
morphology	X						X					
morphology_roi						X						X
neighbour_count	X								X			
noise_combination		X	X	X						X		
open_close	X	X	X	X			X	X	X	X		
open_piks						X						X
outlier_removal		X	X	X				X	X	X		

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Annex D (informative)

PIKS element support - source and destination image data type *(continued)*

	Source						Destination					
Element	BD	ND	SD	RD	CD	NA	BD	ND	SD	RD	CD	NA
output_object						X						X
paint_pixels										X		
perimeter_code_generator	X											X
polar_to_cartesian				X						X		
power_law_scaling		X	X	X				X	X	X		
pseudocolour		X	X					X	X			
put_colour_pixel						X		X	X	X		
put_pixel						X	X	X	X	X	X	
put_pixel_roi						X						X
put_pixel_array						X	X	X	X	X	X	
put_pixel_array_roi						X						X
put_pixel_record						X	X	X	X	X	X	
put_pixel_record _roi						X						X
rescale	X	X	X	X	X		X	X	X	X	X	
rescale_roi						X						X
resize	X	X	X	X	X		X	X	X	X	X	
resize_roi						X						X
return_repository_id						X						X
roi_coordinate						X						X
roi_elliptical						X						X
roi_polygon						X						X
roi_rectangular						X						X
rotate	X	X	X	X	X		X	X	X	X	X	
rotate_roi						X						X
rubber_band_scaling		X	X	X				X	X	X		
sequence_average		X	X	X						X		
sequence_karhunen_loeve		X	X	X						X		

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Annex D (informative)

PIKS element support - source and destination image data type *(continued)*

	Source						Destination					
Element	BD	ND	SD	RD	CD	NA	BD	ND	SD	RD	CD	NA
sequence_running_measures		X	X	X						X		
set_globals						X						X
set_image_attributes						X						X
set_index_assignment						X						X
shape_metrics	X											X
spatial_moments_invariant	X	X	X	X								X
spatial_moments_scaled	X	X	X	X								X
split_image	X	X	X	X			X	X	X	X		
subsample	X	X	X	X	X		X	X	X	X	X	
subsample_roi						X						X
synchronize						X						X
template_match		X	X	X								X
threshold		X	X	X			X	X	X	X	X	
transform_cosine		X	X	X						X		
transform_fourier		X	X	X	X					X	X	
transform_hadamard		X	X	X						X		
transform_hartley		X	X	X						X		
translate	X	X	X	X	X		X	X	X	X	X	
translate_roi						X						X
unary_integer		X	X					X	X			
unary_real				X						X		
unsharp_mask		X	X	X						X		
value_bounds		X	X	X								X
vreg_alter						X						X
vreg_clear						X						X
vreg_conditional						X						X
vreg_copy						X						X
vreg_delete						X						X

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Annex D (informative)

PIKS element support - source and destination image data type *(concluded)*

	Source						Destination					
Element	BD	ND	SD	RD	CD	NA	BD	ND	SD	RD	CD	NA
vreg_get						X						X
vreg_set						X						X
vreg_wait						X						X
wallis_statistical_differencing		X	X	X						X		
warp_control_point	X	X	X	X	X		X	X	X	X	X	
warp_control_point_roi						X						X
warp_lut	X	X	X	X	X		X	X	X	X	X	
warp_lut_roi						X						X
warp_polynomial	X	X	X	X	X		X	X	X	X	X	
warp_polynomial_roi						X						X
windowing_function						X						X
window_level		X	X	X				X	X	X		
window_statistics		X	X	X						X		
z_merge		X	X	X				X	X	X		
zoom	X	X	X	X	X		X	X	X	X	X	
zoom_roi						X						X
3d_slice		X	X	X						X		

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Annex E (informative)

PIKS operator support - operator order

	Operator order						
Operator	0 D	1 D	2 D	3 D	4 D	5 D	N A
accumulator		X	X	X	X	X	
adaptive_histogram_equalization			X				
alpha_blend_constant	X						
alpha_blend_variable	X						
bit_shift	X						
cartesian_to_polar			X				
classifier_bayes		X					
classifier_nearest_neighbour		X					
colour_conversion_linear	X						
colour_conversion_nonlinear	X						
colour_conversion_subtractive	X						
colour_lookup_interpolated	X						
complement	X						
complement_roi	X						
complex_composition	X						
complex_conjugate	X						
complex_decomposition	X						
complex_magnitude	X						
convolve_2d			X				
convolve_5d		X	X	X	X	X	
cross_correlation			X				
difference_measures						X	
diffuse			X				
dither			X				
draw_pixels	X						
draw_pixels_roi	X						
dyadic_arithmetic	X						
dyadic_complex	X						

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Annex E (informative)

PIKS operator support - operator order *(continued)*

Operator	Operator order						
	0 D	1 D	2 D	3 D	4 D	5 D	N A
dyadic_logical	X						
dyadic_logical_roi	X						
dyadic_predicate	X						
edge_detection_orthogonal_gradient			X				
edge_detection,_second_derivative			X				
edge_detection_template_gradiant			X				
erosion_dilation_boolean			X				
erosion_dilation_boolean_roi			X				
erosion_dilation_grey			X				
error_function_scaling	X						
extrema		X	X	X	X	X	
false_colour	X						
fill_region			X				
fill_region_roi			X				
filtering_homomorphic			X				
filtering_linear			X				
filtering_median			X				
filtering_pseudomedian			X				
filtering_rank_order			X				
flip_spin_transpose			X				
flip_spin_transpose_roi			X				
gamma_correction	X						
histogram_modification	X						
histogram_scaling	X						
histogram_shape_1d							X
histogram_shape_2d							X
histogram_1d	X						
histogram_2d			X				

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Annex E (informative)

PIKS operator support - operator order *(continued)*

Operator	Operator order						
	0 D	1 D	2 D	3 D	4 D	5 D	N A
hit _or_miss			X				
hit_roi			X				
hough_transform			X				
label_objects			X				
laws_texture_features			X				
level_slice	X						
line_profile				X			
lookup	X						
lookup_interpolated	X						
luminance_generation	X						
moments						X	
monadic_arithmetic	X						
monadic_complex	X						
monadic_logical	X						
monadic_logical_roi	X						
morphic_processor			X				
morphic_processor_roi			X				
morphology			X				
morphology_roi			X				
neighbour_count			X				
noise_combination	X						
open_close			X				
outlier_removal			X				
paint_pixels			X				
perimeter_code_generator			X				
polar_to_cartesian			X				
power_law_scaling	X						
pseudocolour	X						

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Annex E (informative)

PIKS operator support - operator order *(continued)*

Operator	Operator order						
	0 D	1 D	2 D	3 D	4 D	5 D	N A
rescale						X	
rescale_roi						X	
resize						X	
resize_roi						X	
rotate			X	X			
rotate_roi			X	X			
rubber_band_scaling	X						
sequence_average		X					
sequence_karhunen_loeve		X					
sequence_running_measures		X					
shape_metrics			X				
spatial_moments_invariant			X				
spatial_moments_scaled			X				
split_image			X				
subsample			X				
subsample_roi			X				
template_match			X				
threshold	X						
transform_cosine			X				
transform_fourier		X	X	X	X	X	
translate_hadamard			X				
translate_hartley		X	X	X	X	X	
translate						X	
translate_roi						X	
unary_integer	X						
unary_real	X						
unsharp_mask			X				
value_bounds	X						

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Annex E (informative)

PIKS operator support - operator order *(concluded)*

Operator	Operator order						
	0 D	1 D	2 D	3 D	4 D	5 D	N A
wallis_statistical_differencing			X				
warp_control_point			X				
warp_control_point_roi			X				
warp_lut			X				
warp_lut_roi			X				
warp_polynomial			X				
warp_polynomial_roi			X				
window_level	X						
window_statistics			X				
z_merge	X						
zoom						X	
zoom_roi						X	
3d_slice				X			

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Annex F (informative)

PIKS element functionality

Element	Ind Assi	Mat Pt	ROI Ctl	ROI Pro	Src Pro	Het Band	Chai Elem	Asyn
abort_asynchronous_execution	NA	NA	NA	NA	NA	NA	n	n
accumulator	y	n	y	n	n	n	n	n
adaptive_histogram_equalization	y	y	y	n	n	n	y	y
allocate_chain	NA	NA	NA	NA	NA	NA	v	y
allocate_composite_identifier_array	NA	NA	NA	NA	NA	NA	v	y
allocate_composite_identifier_list	NA	NA	NA	NA	NA	NA	v	y
allocate_composite_identifier_record	NA	NA	NA	NA	NA	NA	v	y
allocate_histogram	NA	NA	NA	NA	NA	NA	v	y
allocate_image	NA	NA	NA	NA	NA	NA	v	y
allocate_lookup_table	NA	NA	NA	NA	NA	NA	v	y
allocate_matrix	NA	NA	NA	NA	NA	NA	v	y
allocate_neighbourhood_array	NA	NA	NA	NA	NA	NA	v	y
allocate_pixel_record	NA	NA	NA	NA	NA	NA	v	y
allocate_roi	NA	NA	NA	NA	NA	NA	v	y
allocate_static_array	NA	NA	NA	NA	NA	NA	v	y
allocate_tuple	NA	NA	NA	NA	NA	NA	v	y
allocate_value_bounds	NA	NA	NA	NA	NA	NA	v	y
allocate_vreg	NA	NA	NA	NA	NA	NA	v	y
alpha_blend_constant	n	y	y	n	n	n	y	y
alpha_blend_variable	n	y	y	n	n	n	y	y
array_to_lut	NA	NA	NA	NA	NA	NA	y	y
bind_match_point	NA	NA	NA	NA	NA	NA	y	y
bind_roi	NA	NA	NA	NA	NA	NA	y	y
bit_shift	n	y	y	n	n	n	y	y
cartesian_to_polar	y	n	y	n	y	n	y	y
chain_abort	NA	NA	NA	NA	NA	NA	y	y
chain_begin	NA	NA	NA	NA	NA	NA	n	n
chain_delete	NA	NA	NA	NA	NA	NA	y	y

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Annex F (informative)

PIKS element functionality *(continued)*

Element	Ind Assi	Mat Pt	ROI Ctl	ROI Pro	Src Pro	Het Band	Chai Elem	Asyn
chain_end	NA	NA	NA	NA	NA	NA	n	n
chain_execute	NA	NA	NA	NA	NA	NA	y	y
chain_reload	NA	NA	NA	NA	NA	NA	y	y
classifier_bayes	n	n	y	n	y	n	y	y
classifier_nearest_neighbour	n	n	y	n	y	n	y	y
close_piks	NA	NA	NA	NA	NA	NA	n	n
close_piks_emergency	NA	NA	NA	NA	NA	NA	n	n
colour_conversion_linear	n	y	y	n	n	n	y	y
colour_conversion_matrix	NA	NA	NA	NA	NA	NA	y	y
colour_conversion_nonlinear	n	y	y	n	n	n	y	y
colour_conversion_subtractive	n	y	y	n	n	n	y	y
colour_lookup_interpolated	n	y	y	n	n	n	y	y
complement	n	y	y	y	n	n	y	y
complement_roi	n	n	n	n	n	n	y	y
complex_composition	n	y	y	n	n	n	y	y
complex_conjugate	n	y	y	n	n	n	y	y
complex_decomposition	n	y	y	n	n	n	y	y
complex_magnitude	n	y	y	n	n	n	y	y
composite_identifier_array_equal	NA	NA	NA	NA	NA	NA	v	n
composite_identifier_array_get	NA	NA	NA	NA	NA	NA	y	y
composite_identifier_array_put	NA	NA	NA	NA	NA	NA	y	y
composite_identifier_list_empty	NA	NA	NA	NA	NA	NA	v	n
composite_identifier_list_equal	NA	NA	NA	NA	NA	NA	v	n
composite_identifier_list_get	NA	NA	NA	NA	NA	NA	y	y
composite_identifier_list_insert	NA	NA	NA	NA	NA	NA	y	y
composite_identifier_list_remove	NA	NA	NA	NA	NA	NA	y	y
composite_identifier_record_equal	NA	NA	NA	NA	NA	NA	v	n

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Annex F (informative)

PIKS element functionality *(continued)*

Element	Ind Assi	Mat Pt	ROI Ctl	ROI Pro	Src Pro	Het Band	Chai Elem	Asyn
composite_identifier_record_get	NA	NA	NA	NA	NA	NA	y	y
composite_identifier_record_put	NA	NA	NA	NA	NA	NA	y	y
constant_predicate	n	n	y	n	n	n	v	n
convert_array_to_image	NA	NA	NA	NA	NA	NA	y	y
convert_image_datatype	n	y	y	n	n	y	y	y
convert_image_to_array	NA	NA	NA	NA	NA	NA	y	y
convert_image_to_roi	NA	NA	NA	NA	NA	NA	y	y
convert_roi_to_image	NA	NA	NA	NA	NA	NA	y	y
convolve_2d	y	y	y	n	n	n	y	y
convolve_5d	y	y	y	n	n	n	y	y
copy_window	y	y	y	n	n	n	y	y
copy_window_roi	y	n	n	n	n	n	y	y
create_tuple	NA	NA	NA	NA	NA	NA	y	y
cross_correlation	y	n	y	n	n	n	y	y
deallocate_data_object	NA	NA	NA	NA	NA	NA	y	y
define_sub_image	NA	NA	NA	NA	NA	NA	y	y
difference_measures	y	y	y	n	n	n	v	n
diffuse	y	y	y	n	n	n	y	y
dither	y	y	y	n	n	n	y	y
draw_pixels	n	n	y	n	n	n	y	y
draw_pixels_roi	n	n	n	n	n	n	y	y
dyadic_arithmetic	n	y	y	n	n	n	y	y
dyadic_complex	n	y	y	n	n	n	y	y
dyadic_logical	n	y	y	n	n	n	y	y
dyadic_logical_roi	n	n	n	n	n	n	y	y
dyadic_predicate	n	y	y	n	n	n	y	y
edge_detection_orthogonal_gradient	y	y	y	n	y	n	y	y
edge_detection_second_derivative	y	y	y	n	y	n	y	y

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Annex F (informative)

PIKS element functionality *(continued)*

Element	Ind Asi	Mat Pt	ROI Ctl	ROI Pro	Src Pro	Het Band	Chai Elem	Asyn
edge_detection_template_gradient	y	y	y	n	y	n	y	y
equal_predicate	n	y	y	n	n	n	v	n
erosion_dilation_boolean	y	y	y	y	n	n	y	y
erosion_dilation_boolean_roi	y	n	n	n	n	n	y	y
erosion_dilation_grey	y	y	y	n	n	n	y	y
error_function_scaling	n	y	y	n	y	n	y	y
error_handler	NA	NA	NA	NA	NA	NA	n	n
error_logger	NA	NA	NA	NA	NA	NA	n	n
error_test	NA	NA	NA	NA	NA	NA	v	n
export_histogram	NA	NA	NA	NA	NA	NA	n	n
export_image	NA	NA	NA	NA	NA	NA	n	n
export_lut	NA	NA	NA	NA	NA	NA	n	n
export_matrix	NA	NA	NA	NA	NA	NA	n	n
export_neighbourhood_array	NA	NA	NA	NA	NA	NA	n	n
export_roi_array	NA	NA	NA	NA	NA	NA	n	n
export_static_array	NA	NA	NA	NA	NA	NA	n	n
export_tuple	NA	NA	NA	NA	NA	NA	n	n
export_value_bounds	NA	NA	NA	NA	NA	NA	n	n
extract_pixel_plane	n	y	y	n	n	y	y	y
extract_pixel_plane_roi	n	n	n	n	n	n	y	y
extrema	y	n	y	n	n	n	n	n
false_colour	n	y	y	n	n	n	y	y
fill_region	y	y	y	n	n	n	y	y
fill_region_roi	y	n	n	n	n	n	y	y
filter_butterworth	NA	NA	NA	NA	NA	NA	y	y
filter_gaussian	NA	NA	NA	NA	NA	NA	y	y
filter_inverse	NA	NA	NA	NA	NA	NA	y	y
filter_matched	NA	NA	NA	NA	NA	NA	y	y

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Annex F (informative)

PIKS element functionality *(continued)*

Element	Ind Assi	Mat Pt	ROI Ctl	ROI Pro	Src Pro	Het Band	Chai Elem	Asyn
filter_wiener	NA	NA	NA	NA	NA	NA	y	y
filter_zonal	NA	NA	NA	NA	NA	NA	y	y
filtering_homomorphic	y	y	y	n	y	n	y	y
filtering_linear	y	y	y	n	y	n	y	y
filtering_median	y	y	y	n	n	n	y	y
filtering_pseudomedian	y	y	y	n	n	n	y	y
filtering_rank_order	y	y	y	n	n	n	y	y
flip_spin_transpose	y	y	y	y	n	n	y	y
flip_spin_transpose_roi	y	n	n	n	n	n	y	y
gamma_correction	n	y	y	n	y	n	y	y
get_colour_pixel	n	n	n	n	n	n	v	n
get_pixel	n	n	n	n	n	y	v	n
get_pixel_roi	n	n	n	n	n	n	v	n
get_pixel_array	y	n	n	n	n	n	v	n
get_pixel_array_roi	y	n	n	n	n	n	v	n
get_pixel_record	n	n	n	n	n	y	v	n
get_pixel_record_roi	n	n	n	n	n	n	v	n
histogram_modification	y	y	y	n	y	n	y	y
histogram_scaling	y	y	y	n	n	n	y	y
histogram_shape_1d	NA	NA	NA	NA	NA	NA	n	n
histogram_shape_2d	NA	NA	NA	NA	NA	NA	n	n
histogram_1d	y	n	y	n	n	n	y	y
histogram_2d	n	n	y	n	n	n	y	y
hit_or_miss	y	y	y	n	n	n	y	y
hit_or_miss_roi	y	n	n	n	n	n	y	y
hough_transform	n	n	y	n	n	n	y	y
image_bar_chart	n	n	y	n	n	n	y	y
image_constant	n	n	y	n	n	n	y	y

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Annex F (informative)

PIKS element functionality *(continued)*

Element	Ind Asni	Mat Pt	ROI Ctl	ROI Pro	Src Pro	Het Band	Chai Elem	Asyn
image_gaussian	n	n	y	n	n	n	y	y
image_grey_scale	n	n	y	n	n	n	y	y
image_random_number	n	n	y	n	n	n	y	y
import_histogram	NA	NA	NA	NA	NA	NA	y	y
import_image	NA	NA	NA	NA	NA	NA	y	y
import_lut	NA	NA	NA	NA	NA	NA	y	y
import_matrix	NA	NA	NA	NA	NA	NA	y	y
import_neighbourhood_array	NA	NA	NA	NA	NA	NA	y	y
import_roi_array	NA	NA	NA	NA	NA	NA	y	y
import_static_array	NA	NA	NA	NA	NA	NA	y	y
import_tuple	NA	NA	NA	NA	NA	NA	y	y
import_value_bounds	NA	NA	NA	NA	NA	NA	y	y
impulse_boxcar	NA	NA	NA	NA	NA	NA	y	y
impulse_derivative_of_gaussian	NA	NA	NA	NA	NA	NA	y	y
impulse_difference_of_gaussians	NA	NA	NA	NA	NA	NA	y	y
impulse_elliptical	NA	NA	NA	NA	NA	NA	y	y
impulse_gaussian	NA	NA	NA	NA	NA	NA	y	y
impulse_laplacian_of_gaussian	NA	NA	NA	NA	NA	NA	y	y
impulse_pyramid	NA	NA	NA	NA	NA	NA	y	y
impulse_rectangular	NA	NA	NA	NA	NA	NA	y	y
impulse_sinc	NA	NA	NA	NA	NA	NA	y	y
input_object	NA	NA	NA	NA	NA	NA	n	n
inquire_chain_environment	NA	NA	NA	NA	NA	NA	n	n
inquire_chain_status	NA	NA	NA	NA	NA	NA	n	n
inquire_elements	NA	NA	NA	NA	NA	NA	n	n
inquire_image	NA	NA	NA	NA	NA	NA	n	n
inquire_index_assignment	NA	NA	NA	NA	NA	NA	n	n
inquire_non_image_object	NA	NA	NA	NA	NA	NA	n	n

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Annex F (informative)

PIKS element functionality *(continued)*

Element	Ind Assi	Mat Pt	ROI Ctl	ROI Pro	Src Pro	Het Band	Chai Elem	Asyn
inquire_piks_implementation	NA	NA	NA	NA	NA	NA	n	n
inquire_piks_status	NA	NA	NA	NA	NA	NA	n	n
inquire_repository	NA	NA	NA	NA	NA	NA	n	n
inquire_resampling	NA	NA	NA	NA	NA	NA	n	n
insert_pixel_plane	n	y	y	n	n	y	y	y
insert_pixel_plane_roi	n	n	n	n	n	n	y	y
label_objects	y	n	y	n	n	n	y	y
laws_texture_features	y	y	y	n	y	n	y	y
level_slice	n	y	y	n	n	n	y	y
line_profile	y	n	y	n	n	n	n	y
lookup	n	y	y	n	n	y	y	y
lookup_interpolated	n	y	y	n	n	y	y	y
luminance_generation	n	y	y	n	n	n	y	y
markov_spectrum	NA	NA	NA	NA	NA	NA	y	y
moments	n	n	y	n	n	n	v	y
monadic_arithmetic	n	y	y	n	n	n	y	y
monadic_complex	n	y	y	n	n	n	y	y
monadic_logical	n	y	y	n	n	n	y	y
monadic_logical_roi	n	n	n	n	n	n	y	y
morphic_processor	y	y	y	n	n	n	y	y
morphic_processor_roi	y	n	n	n	n	n	y	y
morphology	y	y	y	y	n	n	y	y
morphology_roi	y	n	n	n	n	n	y	y
neighbour_count	y	y	y	n	n	n	y	y
noise_combination	n	y	y	n	y	y	y	y
open_close	y	y	y	n	n	n	y	y
open_piks	NA	NA	NA	NA	NA	NA	n	n
outlier_removal	y	y	y	n	n	n	y	y

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Annex F (informative)

PIKS element functionality *(continued)*

Element	Ind Assi	Mat Pt	ROI Ctl	ROI Pro	Src Pro	Het Band	Chai Elem	Asyn
output_object	NA	NA	NA	NA	NA	NA	n	n
paint_pixels	y	y	y	n	y	n	y	y
perimeter_code_generator	y	n	y	n	n	n	n	n
polar_to_cartesian	y	n	y	n	n	n	y	y
power_law_scaling	n	y	y	n	n	y	y	y
pseudocolour	n	y	y	n	n	n	y	y
put_colour_pixel	n	n	y	n	n	n	y	y
put_pixel	n	n	y	n	n	y	y	y
put_pixel_roi	n	n	n	n	n	n	y	y
put_pixel_array	n	n	y	n	n	n	y	y
put_pixel_array_roi	n	n	n	n	n	n	y	y
put_pixel_record	n	n	n	n	n	y	y	y
put_pixel_record_roi	n	n	n	n	n	n	y	y
rescale	y	y	y	y	n	n	y	y
rescale_roi	y	n	n	n	n	n	y	y
resize	n	n	y	y	n	n	y	y
resize_roi	n	n	n	n	n	n	y	y
return_repository_id	NA	NA	NA	NA	NA	NA	y	y
roi_coordinate	n	NA	NA	NA	NA	NA	NA	y
roi_elliptical	y	NA	NA	NA	NA	NA	NA	y
roi_polygon	y	NA	NA	NA	NA	NA	NA	y
roi_rectangular	y	NA	NA	NA	NA	NA	NA	y
rotate	y	y	y	y	n	n	y	y
rotate_roi	y	n	n	n	n	n	y	y
rubber_band_scaling	n	y	y	n	n	n	y	y
sequence_average	n	y	y	n	y	n	y	y
sequence_karhunen_loeve	y	n	y	n	y	n	y	y
sequence_running_measures	n	y	y	n	y	n	y	y

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Annex F (informative)

PIKS element functionality *(continued)*

Element	Ind Assi	Mat Pt	ROI Ctl	ROI Pro	Src Pro	Het Band	Chai Elem	Asyn
set_globals	NA	NA	NA	NA	NA	NA	y	y
set_image_attributes	NA	NA	NA	NA	NA	NA	y	y
set_index_assignment	NA	NA	NA	NA	NA	NA	y	y
shape_metrics	y	n	y	n	n	n	n	n
spatial_moments_invariant	y	n	y	n	n	n	n	n
spatial_moments_scaled	y	n	y	n	n	n	n	n
split_image	n	y	y	n	n	n	y	y
subsample	y	y	y	y	n	n	y	y
subsample_roi	y	n	n	n	n	n	y	y
synchronize	NA	NA	NA	NA	NA	NA	n	n
template_match	y	n	n	n	n	n	y	y
threshold	n	y	y	n	n	n	y	y
transform_cosine	y	y	n	n	y	n	y	y
transform_fourier	y	y	n	n	y	n	y	y
transform_hadamard	y	y	n	n	y	n	y	y
transform_hartley	y	y	n	n	y	n	y	y
translate	n	y	y	y	n	n	y	y
translate_roi	n	n	n	n	n	n	y	y
unary_integer	n	y	y	n	n	y	y	y
unary_real	n	y	y	n	n	y	y	y
unsharp_mask	y	y	y	n	y	n	y	y
value_bounds	n	n	y	n	n	n	y	y
vreg_alter	NA	NA	NA	NA	NA	NA	y	y
vreg_clear	NA	NA	NA	NA	NA	NA	y	y
vreg_conditional	NA	NA	NA	NA	NA	NA	y	y
vreg_copy	NA	NA	NA	NA	NA	NA	y	y
vreg_delete	NA	NA	NA	NA	NA	NA	y	y
vreg_get	NA	NA	NA	NA	NA	NA	n	y

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Annex F (informative)

PIKS element functionality *(concluded)*

vreg_set	NA	NA	NA	NA	NA	NA	y	y
vreg_wait	NA	NA	NA	NA	NA	NA	y	y
wallis_statistical_differencing	y	y	y	n	y	n	y	y
warp_control_point	y	y	y	y	n	n	y	y
warp_control_point_roi	y	n	n	n	n	n	y	y
warp_lut	y	y	y	y	n	n	y	y
warp_lut_roi	y	n	n	n	n	n	y	y
warp_polynomial	y	y	y	y	n	n	y	y
warp_polynomial_roi	y	n	n	n	n	n	y	y
windowing_function	NA	NA	NA	NA	NA	NA	y	y
window_level	n	y	y	n	n	n	y	y
window_statistics	y	y	y	n	y	n	y	y
z_merge	n	y	y	n	n	n	y	y
zoom	y	y	y	y	n	n	y	y
zoom_roi	y	n	n	n	n	n	y	y
3d_slice	n	y	y	n	y	n	y	y

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Annex G (normative)

PIKS data object repository

The following clauses contain listings of the impulse response function arrays, dither arrays, and colour conversion matrices in the data object repository.

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G.1 Impulse response function arrays

The following impulse response function arrays are in the PIKS data object repository.

1. DELTA_3x3

$$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

2. UNIFORM_3x3

$$\frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

3. PYRAMID_3x3

$$\frac{1}{10}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

4. LOW_PASS_3x3

$$\frac{1}{16}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

5. EIGHT_NEIGHBOUR_AVERAGE

$$\frac{1}{8}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

6. FOUR_NEIGHBOUR_AVERAGE

$$\frac{1}{4}\begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

7. CORNER_NEIGHBOUR_AVERAGE

$$\frac{1}{4}\begin{bmatrix} 1 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 1 \end{bmatrix}$$

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8. HIGH_PASS_1_3x3

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

9. HIGH_PASS_2_3x3

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

10. HIGH_PASS_3_3x3

$$\begin{bmatrix} 1 & -2 & 1 \\ -2 & 5 & -2 \\ 1 & -2 & 1 \end{bmatrix}$$

11. PIXEL_DIFFERENCE_HORIZONTAL

$$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & -1 \\ 0 & 0 & 0 \end{bmatrix}$$

12. PIXEL_DIFFERENCE_VERTICAL

$$\begin{bmatrix} 0 & -1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

13. SEPARATED_PIXEL_DIFFERENCE_HORIZONTAL

$$\begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & -1 \\ 0 & 0 & 0 \end{bmatrix}$$

14. SEPARATED_PIXEL_DIFFERENCE_VERTICAL

$$\begin{bmatrix} 0 & -1 & 0 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

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15. ROBERTS_HORIZONTAL

$$\begin{bmatrix} 0 & 0 & -1 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

16. ROBERTS_VERTICAL

$$\begin{bmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

17. PREWITT_HORIZONTAL

$$\frac{1}{3}\begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}$$

18. PREWITT_VERTICAL

$$\frac{1}{3}\begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

19. SOBEL_HORIZONTAL

$$\frac{1}{4}\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$$

20. SOBEL_VERTICAL

$$\frac{1}{4}\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

21. FREI_HORIZONTAL

$$\frac{1}{3414}\begin{bmatrix} 1000 & 0 & -1000 \\ 1414 & 0 & -1414 \\ 1000 & 0 & -1000 \end{bmatrix} \approx \frac{1}{2+\sqrt{2}}\begin{bmatrix} 1 & 0 & -1 \\ \sqrt{2} & 0 & -\sqrt{2} \\ 1 & 0 & -1 \end{bmatrix}$$

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22. FREI_VERTICAL

$$\frac{1}{3414}\begin{bmatrix} -1000 & -1414 & -1000 \\ 0 & 0 & 0 \\ 1000 & 1414 & 1000 \end{bmatrix} \approx \frac{1}{2+\sqrt{2}}\begin{bmatrix} -1 & -\sqrt{2} & -1 \\ 0 & 0 & 0 \\ 1 & \sqrt{2} & 1 \end{bmatrix}$$

23. PREWITT_COMPASS_E

$$\frac{1}{5}\begin{bmatrix} 1 & 1 & -1 \\ 1 & -2 & -1 \\ 1 & 1 & -1 \end{bmatrix}$$

24. PREWITT_COMPASS_NE

$$\frac{1}{5}\begin{bmatrix} 1 & -1 & -1 \\ 1 & -2 & -1 \\ 1 & 1 & 1 \end{bmatrix}$$

25. PREWITT_COMPASS_N

$$\frac{1}{5}\begin{bmatrix} -1 & -1 & -1 \\ 1 & -2 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

26. PREWITT_COMPASS_NW

$$\frac{1}{5}\begin{bmatrix} -1 & -1 & 1 \\ -1 & -2 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

27. PREWITT_COMPASS_W

$$\frac{1}{5}\begin{bmatrix} -1 & 1 & 1 \\ -1 & -2 & 1 \\ -1 & 1 & 1 \end{bmatrix}$$

28. PREWITT_COMPASS_SW

$$\frac{1}{5}\begin{bmatrix} 1 & 1 & 1 \\ -1 & -2 & 1 \\ -1 & -1 & 1 \end{bmatrix}$$

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29. PREWITT_COMPASS_S

$$\frac{1}{5}\begin{bmatrix} 1 & 1 & 1 \\ 1 & -2 & 1 \\ -1 & -1 & -1 \end{bmatrix}$$

30. PREWITT_COMPASS_SE

$$\frac{1}{5}\begin{bmatrix} 1 & 1 & 1 \\ 1 & -2 & -1 \\ 1 & -1 & -1 \end{bmatrix}$$

31. KIRSCH_E

$$\frac{1}{15}\begin{bmatrix} 5 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & -3 & -3 \end{bmatrix}$$

32. KIRSCH_NE

$$\frac{1}{15}\begin{bmatrix} -3 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & 5 & -3 \end{bmatrix}$$

33. KIRSCH_N

$$\frac{1}{15}\begin{bmatrix} -3 & -3 & -3 \\ -3 & 0 & -3 \\ 5 & 5 & 5 \end{bmatrix}$$

34. KIRSCH_NW

$$\frac{1}{15}\begin{bmatrix} -3 & -3 & -3 \\ -3 & 0 & 5 \\ -3 & 5 & 5 \end{bmatrix}$$

35. KIRSCH_W

$$\frac{1}{15}\begin{bmatrix} -3 & -3 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & 5 \end{bmatrix}$$

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36. KIRSCH_SW

$$\frac{1}{15}\begin{bmatrix} -3 & 5 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & -3 \end{bmatrix}$$

37. KIRSCH_S

$$\frac{1}{15}\begin{bmatrix} 5 & 5 & 5 \\ -3 & 0 & -3 \\ -3 & -3 & -3 \end{bmatrix}$$

38. KIRSCH_SE

$$\frac{1}{15}\begin{bmatrix} 5 & 5 & -3 \\ 5 & 0 & -3 \\ -3 & -3 & -3 \end{bmatrix}$$

39. ROBERTS_3_LEVEL_E

$$\frac{1}{3}\begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}$$

40. ROBERTS_3_LEVEL_NE

$$\frac{1}{3}\begin{bmatrix} 0 & -1 & -1 \\ 1 & 0 & -1 \\ 1 & 1 & 0 \end{bmatrix}$$

41. ROBERTS_3_LEVEL_N

$$\frac{1}{3}\begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

42. ROBERTS_3_LEVEL_NW

$$\frac{1}{3}\begin{bmatrix} -1 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix}$$

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43. ROBERTS_3_LEVEL_W

$$\frac{1}{3}\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

44. ROBERTS_3_LEVEL_SW

$$\frac{1}{3}\begin{bmatrix} 0 & 1 & 1 \\ -1 & 0 & 1 \\ -1 & -1 & 0 \end{bmatrix}$$

45. ROBERTS_3_LEVEL_S

$$\frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

46. ROBERTS_3_LEVEL_SE

$$\frac{1}{3}\begin{bmatrix} 1 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -1 \end{bmatrix}$$

47. ROBERTS_5_LEVEL_E

$$\frac{1}{4}\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$$

48. ROBERTS_5_LEVEL_NE

$$\frac{1}{4}\begin{bmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{bmatrix}$$

49. ROBERTS_5_LEVEL_N

$$\frac{1}{4}\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

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50. ROBERTS_5_LEVEL_NW

$$\frac{1}{4}\begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix}$$

51. ROBERTS_5_LEVEL_W

$$\frac{1}{4}\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

52. ROBERTS_5_LEVEL_SW

$$\frac{1}{4}\begin{bmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{bmatrix}$$

53. ROBERTS_5_LEVEL_S

$$\frac{1}{4}\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

54. ROBERTS_5_LEVEL_SE

$$\frac{1}{4}\begin{bmatrix} 2 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -2 \end{bmatrix}$$

55. UNWEIGHTED_LINE_1

$$\frac{1}{6}\begin{bmatrix} -1 & 2 & -1 \\ -1 & 2 & -1 \\ -1 & 2 & -1 \end{bmatrix}$$

56. UNWEIGHTED_LINE_2

$$\frac{1}{6}\begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}$$

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57. UNWEIGHTED_LINE_3

$$\frac{1}{6}\begin{bmatrix} -1 & -1 & -1 \\ 2 & 2 & 2 \\ -1 & -1 & -1 \end{bmatrix}$$

58. UNWEIGHTED_LINE_4

$$\frac{1}{6}\begin{bmatrix} -1 & -1 & 2 \\ -1 & 2 & -1 \\ 2 & -1 & -1 \end{bmatrix}$$

59. WEIGHTED_LINE_1

$$\frac{1}{8}\begin{bmatrix} -1 & 2 & -1 \\ -2 & 4 & -2 \\ -1 & 2 & -1 \end{bmatrix}$$

60. WEIGHTED_LINE_2

$$\frac{1}{8}\begin{bmatrix} 2 & -1 & -2 \\ -1 & 4 & -1 \\ -2 & -1 & 2 \end{bmatrix}$$

61. WEIGHTED_LINE_3

$$\frac{1}{8}\begin{bmatrix} -1 & -2 & -1 \\ 2 & 4 & 2 \\ -1 & -2 & -1 \end{bmatrix}$$

62. WEIGHTED_LINE_4

$$\frac{1}{8}\begin{bmatrix} -2 & -1 & 2 \\ -1 & 4 & -1 \\ 2 & -1 & -2 \end{bmatrix}$$

63. SPOT_4_CONNECTED

$$\frac{1}{4}\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

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64. SPOT_8_CONNECTED

$$\frac{1}{8}\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

65. DECORRELATE

$$\frac{1}{8}\begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix}$$

66. LAPLACIAN_1

$$\frac{1}{4}\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

67. LAPLACIAN_2

$$\frac{1}{8}\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

68. LAPLACIAN_3

$$\frac{1}{8}\begin{bmatrix} -2 & 1 & -2 \\ 1 & 4 & 1 \\ -2 & 1 & -2 \end{bmatrix}$$

69. CHEBYSHEV_1

$$\frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

70. CHEBYSHEV_2

$$\frac{1}{6}\begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

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71. CHEBYSHEV_3

$$\frac{1}{6}\begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}$$

72. CHEBYSHEV_4

$$\frac{1}{6}\begin{bmatrix} 1 & 1 & 1 \\ -2 & -2 & -2 \\ 1 & 1 & 1 \end{bmatrix}$$

73. CHEBYSHEV_5

$$\frac{1}{4}\begin{bmatrix} 1 & 0 & -1 \\ 0 & 0 & 0 \\ -1 & 0 & 1 \end{bmatrix}$$

74. CHEBYSHEV_6

$$\frac{1}{6}\begin{bmatrix} 1 & -2 & 1 \\ 1 & -2 & 1 \\ 1 & -2 & 1 \end{bmatrix}$$

75. CHEBYSHEV_7

$$\frac{1}{4}\begin{bmatrix} 1 & 0 & -1 \\ -2 & 0 & 2 \\ 1 & 0 & -1 \end{bmatrix}$$

76. CHEBYSHEV_8

$$\frac{1}{4}\begin{bmatrix} 1 & -2 & 1 \\ 0 & 0 & 0 \\ -1 & 2 & -1 \end{bmatrix}$$

77. CHEBYSHEV_9

$$\frac{1}{4}\begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix}$$

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78. LAWS_1

$$\frac{1}{36}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

79. LAWS_2

$$\frac{1}{12}\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

80. LAWS_3

$$\frac{1}{12}\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$$

81. LAWS_4

$$\frac{1}{12}\begin{bmatrix} 1 & 2 & 1 \\ -2 & -4 & -2 \\ 1 & 2 & 1 \end{bmatrix}$$

82. LAWS_5

$$\frac{1}{4}\begin{bmatrix} 1 & 0 & -1 \\ 0 & 0 & 0 \\ -1 & 0 & 1 \end{bmatrix}$$

83. LAWS_6

$$\frac{1}{12}\begin{bmatrix} 1 & -2 & 1 \\ 2 & -4 & 2 \\ 1 & -2 & 1 \end{bmatrix}$$

84. LAWS_7

$$\frac{1}{12}\begin{bmatrix} 1 & 0 & -1 \\ -2 & 0 & 2 \\ 1 & 0 & -1 \end{bmatrix}$$

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85. LAWS_8

$$\frac{1}{12}\begin{bmatrix} 1 & -2 & 1 \\ 0 & 0 & 0 \\ -1 & 2 & -1 \end{bmatrix}$$

86. LAWS_9

$$\frac{1}{4}\begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix}$$

87. PIXEL_STACK

$$\frac{1}{256}\begin{bmatrix} 16 & 32 & 64 \\ 8 & 256 & 128 \\ 4 & 2 & 1 \end{bmatrix}$$

88. UNIFORM_5x5

$$\frac{1}{25}\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

89. PYRAMID_5x5

$$\frac{1}{35}\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 2 & 2 & 2 & 1 \\ 1 & 2 & 3 & 2 & 1 \\ 1 & 2 & 2 & 2 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

90. BOXCAR_5x5_HORIZONTAL

$$\frac{1}{10}\begin{bmatrix} 1 & 1 & 0 & -1 & -1 \\ 1 & 1 & 0 & -1 & -1 \\ 1 & 1 & 0 & -1 & -1 \\ 1 & 1 & 0 & -1 & -1 \\ 1 & 1 & 0 & -1 & -1 \end{bmatrix}$$

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91. BOXCAR_5x5_VERTICAL

$$\frac{1}{10}\begin{bmatrix} -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

92. TRUNCATED_PYRAMID_5x5_HORIZONTAL

$$\frac{1}{13}\begin{bmatrix} 1 & 1 & 0 & -1 & -1 \\ 1 & 2 & 0 & -2 & -1 \\ 1 & 2 & 0 & -2 & -1 \\ 1 & 2 & 0 & -2 & -1 \\ 1 & 1 & 0 & -1 & -1 \end{bmatrix}$$

93. TRUNCATED_PYRAMID_5x5_VERTICAL

$$\frac{1}{13}\begin{bmatrix} -1 & -1 & -1 & -1 & -1 \\ -1 & -2 & -2 & -2 & -1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 2 & 2 & 2 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

94. NEVATIA_0

$$\frac{1}{1000}\begin{bmatrix} 100 & 100 & 0 & -100 & -100 \\ 100 & 100 & 0 & -100 & -100 \\ 100 & 100 & 0 & -100 & -100 \\ 100 & 100 & 0 & -100 & -100 \\ 100 & 100 & 0 & -100 & -100 \end{bmatrix}$$

95. NEVATIA_30

$$\frac{1}{1102}\begin{bmatrix} 100 & -32 & -100 & -100 & -100 \\ 100 & 78 & -92 & -100 & -100 \\ 100 & 100 & 0 & -100 & -100 \\ 100 & 100 & 92 & -78 & -100 \\ 100 & 100 & 100 & 32 & -100 \end{bmatrix}$$

96. NEVATIA_60

$$\frac{1}{1102}\begin{bmatrix} -100 & -100 & -100 & -100 & -100 \\ 32 & -78 & -100 & -100 & -100 \\ 100 & 92 & 0 & -92 & -100 \\ 100 & 100 & 100 & 78 & -32 \\ 100 & 100 & 100 & 100 & 100 \end{bmatrix}$$

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97. NEVATIA_90

$$\frac{1}{1000}\begin{bmatrix} -100 & -100 & -100 & -100 & -100 \\ -100 & -100 & -100 & -100 & -100 \\ 0 & 0 & 0 & 0 & 0 \\ 100 & 100 & 100 & 100 & 100 \\ 100 & 100 & 100 & 100 & 100 \end{bmatrix}$$

98. NEVATIA_120

$$\frac{1}{1102}\begin{bmatrix} -100 & -100 & -100 & -100 & -100 \\ -100 & -100 & -100 & -78 & 32 \\ -100 & -92 & 0 & 92 & 100 \\ -32 & 78 & 100 & 100 & 100 \\ 100 & 100 & 100 & 100 & 100 \end{bmatrix}$$

99. NEVATIA_150

$$\frac{1}{1102}\begin{bmatrix} -100 & -100 & -100 & -32 & 100 \\ -100 & -100 & -92 & 78 & 100 \\ -100 & -100 & 0 & 100 & 100 \\ -100 & -78 & 92 & 100 & 100 \\ -100 & 32 & 100 & 100 & 100 \end{bmatrix}$$

100. NEVATIA_180

$$\frac{1}{1000}\begin{bmatrix} -100 & -100 & 0 & 100 & 100 \\ -100 & -100 & 0 & 100 & 100 \\ -100 & -100 & 0 & 100 & 100 \\ -100 & -100 & 0 & 100 & 100 \\ -100 & -100 & 0 & 100 & 100 \end{bmatrix}$$

101. NEVATIA_210

$$\frac{1}{1102}\begin{bmatrix} -100 & 32 & 100 & 100 & 100 \\ -100 & -78 & 92 & 100 & 100 \\ -100 & -100 & 0 & 100 & 100 \\ -100 & -100 & -92 & 78 & 100 \\ -100 & -100 & -100 & -32 & 100 \end{bmatrix}$$

102. NEVATIA_240

$$\frac{1}{1102}\begin{bmatrix} 100 & 100 & 100 & 100 & 100 \\ -32 & 78 & 100 & 100 & 100 \\ -100 & -92 & 0 & 100 & 100 \\ -100 & -100 & -100 & -78 & 32 \\ -100 & -100 & -100 & -100 & -100 \end{bmatrix}$$

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103. NEVATIA_270

$$\frac{1}{1000}\begin{bmatrix} 100 & 100 & 100 & 100 & 100 \\ 100 & 100 & 100 & 100 & 100 \\ 0 & 0 & 0 & 0 & 0 \\ -100 & -100 & -100 & -100 & -100 \\ -100 & -100 & -100 & -100 & -100 \end{bmatrix}$$

104. NEVATIA_300

$$\frac{1}{1102}\begin{bmatrix} 100 & 100 & 100 & 100 & 100 \\ 100 & 100 & 100 & 78 & -32 \\ 100 & 92 & 0 & -92 & -100 \\ 32 & -78 & -100 & -100 & -100 \\ -100 & -100 & -100 & -100 & -100 \end{bmatrix}$$

105. NEVATIA_330

$$\frac{1}{1102}\begin{bmatrix} 100 & 100 & 100 & 32 & -100 \\ 100 & 100 & 92 & -78 & -100 \\ 100 & 100 & 0 & -100 & -100 \\ 100 & 78 & -92 & -100 & -100 \\ 100 & -32 & -100 & -100 & -100 \end{bmatrix}$$

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G.2 Dither Arrays

The following is a set of dither arrays.

1. DITHER_2x2

$$\frac{1}{4}\begin{bmatrix} 0 & 2 \\ 3 & 1 \end{bmatrix}$$

2. DITHER_4x4

$$\frac{1}{16}\begin{bmatrix} 0 & 8 & 2 & 10 \\ 12 & 4 & 14 & 6 \\ 3 & 11 & 1 & 9 \\ 15 & 7 & 13 & 5 \end{bmatrix}$$

3. DITHER_8x8

$$\frac{1}{64}\begin{bmatrix} 0 & 32 & 8 & 40 & 2 & 34 & 10 & 42 \\ 48 & 16 & 56 & 24 & 50 & 18 & 58 & 26 \\ 12 & 44 & 4 & 36 & 14 & 46 & 6 & 38 \\ 60 & 28 & 52 & 20 & 62 & 30 & 54 & 22 \\ 3 & 35 & 11 & 43 & 1 & 33 & 9 & 41 \\ 51 & 19 & 59 & 27 & 49 & 17 & 57 & 25 \\ 15 & 47 & 7 & 39 & 13 & 45 & 5 & 37 \\ 63 & 31 & 55 & 23 & 61 & 29 & 53 & 21 \end{bmatrix}$$

4. DITHER_16x16

$$\frac{1}{256}\begin{bmatrix} 0 & 128 & 32 & 160 & 8 & 136 & 40 & 168 & 2 & 130 & 34 & 162 & 10 & 138 & 42 & 170 \\ 192 & 64 & 224 & 96 & 200 & 72 & 232 & 104 & 194 & 66 & 226 & 98 & 202 & 74 & 234 & 106 \\ 48 & 176 & 16 & 144 & 56 & 184 & 24 & 152 & 50 & 178 & 18 & 146 & 58 & 186 & 26 & 154 \\ 240 & 112 & 208 & 80 & 248 & 120 & 216 & 88 & 242 & 114 & 210 & 82 & 250 & 122 & 218 & 90 \\ 12 & 140 & 44 & 172 & 4 & 132 & 36 & 164 & 14 & 142 & 46 & 156 & 6 & 134 & 38 & 166 \\ 204 & 76 & 236 & 108 & 96 & 68 & 228 & 100 & 206 & 78 & 220 & 92 & 198 & 70 & 230 & 102 \\ 60 & 188 & 28 & 156 & 52 & 180 & 20 & 148 & 62 & 190 & 30 & 158 & 54 & 182 & 22 & 150 \\ 252 & 124 & 220 & 92 & 244 & 116 & 212 & 84 & 254 & 126 & 222 & 94 & 246 & 118 & 214 & 86 \\ 3 & 131 & 35 & 163 & 11 & 139 & 43 & 171 & 1 & 128 & 33 & 161 & 9 & 132 & 41 & 169 \\ 195 & 67 & 227 & 99 & 203 & 75 & 235 & 107 & 193 & 65 & 225 & 97 & 201 & 73 & 233 & 105 \\ 51 & 179 & 19 & 147 & 59 & 187 & 27 & 155 & 49 & 177 & 17 & 145 & 57 & 185 & 25 & 153 \\ 243 & 115 & 211 & 83 & 251 & 123 & 219 & 91 & 242 & 113 & 209 & 81 & 249 & 121 & 217 & 89 \\ 15 & 143 & 47 & 175 & 7 & 135 & 39 & 167 & 13 & 141 & 45 & 173 & 5 & 133 & 37 & 165 \\ 207 & 79 & 239 & 111 & 199 & 71 & 128 & 103 & 205 & 77 & 237 & 109 & 197 & 69 & 229 & 101 \\ 63 & 191 & 31 & 159 & 55 & 183 & 23 & 151 & 61 & 189 & 29 & 157 & 53 & 181 & 21 & 149 \\ 255 & 127 & 223 & 95 & 247 & 119 & 215 & 87 & 253 & 125 & 221 & 93 & 245 & 117 & 213 & 85 \end{bmatrix}$$

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G.3 Colour conversion matrices

Point Linear Colour Conversion Matrices — Colourmetric Match

1. Linear CCIR Illuminant D65 RGB To Linear CIE Illuminant E RGB

$$\begin{bmatrix} 0.77509391 & 0.14875744 & -0.08266281 \\ 0.09259316 & 0.84655687 & 0.09428281 \\ 0.01858302 & 0.11179613 & 0.95908549 \end{bmatrix}$$

2. Linear CCIR Illuminant D65 RGB To Linear EBU Illuminant C RGB

$$\begin{bmatrix} 0.91360609 & 0.04024419 & 0.00000000 \\ 0.00000000 & 1.02615213 & 0.00000000 \\ 0.00000000 & -0.01083262 & 0.91833396 \end{bmatrix}$$

3. Linear CCIR Illuminant D65 RGB To Linear EBU Illuminant D65 RGB

$$\begin{bmatrix} 0.95780869 & 0.04219131 & 0.00000000 \\ 0.00000000 & 1.00000000 & 0.00000000 \\ 0.00000000 & -0.01193675 & 1.01193675 \end{bmatrix}$$

4. Linear CCIR Illuminant D65 RGB To Linear NTSC Illuminant C RGB

$$\begin{bmatrix} 0.66885159 & 0.26786882 & 0.03232325 \\ 0.01848455 & 1.07427730 & -0.06028377 \\ 0.01622201 & 0.04317549 & 0.85500261 \end{bmatrix}$$

5. Linear CCIR Illuminant D65 RGB To Linear NTSC Illuminant D65 RGB

$$\begin{bmatrix} 0.69021822 & 0.27642595 & 0.03335583 \\ 0.01790309 & 1.04048437 & -0.05838746 \\ 0.01774061 & 0.04721728 & 0.93504211 \end{bmatrix}$$

6. Linear CCIR Illuminant D65 RGB To Linear SMPTE Illuminant D65 RGB

$$\begin{bmatrix} 1.06538719 & -0.05540962 & -0.00997757 \\ -0.01962947 & 1.03635627 & -0.01672680 \\ 0.00163216 & 0.00441333 & 0.99395451 \end{bmatrix}$$

7. Linear CCIR Illuminant D65 RGB To UVW

$$\begin{bmatrix} 0.27489899 & 0.23840092 & 0.12030009 \\ 0.21261719 & 0.71520276 & 0.07218005 \\ 0.12241596 & 0.95360368 & 0.49323037 \end{bmatrix}$$

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8. Linear CCIR Illuminant D65 RGB To XYZ

$$\begin{bmatrix} 0.41234849 & 0.35760138 & 0.18045013 \\ 0.21261719 & 0.71520276 & 0.07218005 \\ 0.01932884 & 0.11920046 & 0.95037071 \end{bmatrix}$$

9. Linear CIE Illuminant E RGB To Linear CCIR Illuminant D65 RGB

$$\begin{bmatrix} 1.31667378 & -0.24959345 & 0.13801931 \\ -0.14302828 & 1.22390542 & -0.13264340 \\ -0.00883943 & -0.13782889 & 1.05544731 \end{bmatrix}$$

10. Linear CIE Illuminant E RGB To Linear EBU Illuminant C RGB

$$\begin{bmatrix} 1.19716513 & -0.17877501 & 0.12075716 \\ -0.14676878 & 1.25591315 & -0.13611231 \\ -0.00656818 & -0.13983105 & 0.97068999 \end{bmatrix}$$

11. Linear CIE Illuminant E RGB To Linear EBU Illuminant D65 RGB

$$\begin{bmatrix} 1.25508704 & -0.18742460 & 0.12659970 \\ -0.14302828 & 1.22390542 & -0.13264340 \\ -0.00723765 & -0.15408357 & 1.06962925 \end{bmatrix}$$

12. Linear CIE Illuminant E RGB To Linear NTSC Illuminant C RGB

$$\begin{bmatrix} 0.84206082 & 0.15645005 & 0.09089890 \\ -0.12878104 & 1.31850904 & -0.20357092 \\ 0.00762605 & -0.06905026 & 0.89892221 \end{bmatrix}$$

13. Linear CIE Illuminant E RGB To Linear NTSC Illuminant D65 RGB

$$\begin{bmatrix} 0.86896066 & 0.16144788 & 0.09380268 \\ -0.12473005 & 1.27703345 & -0.19716730 \\ 0.00833995 & -0.07551427 & 0.98307317 \end{bmatrix}$$

14. Linear CIE Illuminant E RGB To Linear SMPTE Illuminant D65 RGB

$$\begin{bmatrix} 1.41078072 & -0.33235460 & 0.14386293 \\ -0.17392601 & 1.27560688 & -0.15782932 \\ -0.00726820 & -0.13200153 & 1.04870649 \end{bmatrix}$$

15. Linear CIE Illuminant E RGB To UVW

$$\begin{bmatrix} 0.32679084 & 0.20658636 & 0.13328947 \\ 0.17701522 & 0.81232418 & 0.01066060 \\ 0.02042971 & 1.06858510 & 0.41098519 \end{bmatrix}$$

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16. Linear CIE Illuminant E RGB To XYZ

$$\begin{bmatrix} 0.49018626 & 0.30987954 & 0.19993420 \\ 0.17701522 & 0.81232418 & 0.01066060 \\ 0.00000000 & 0.01007720 & 0.98992280 \end{bmatrix}$$

17. Linear EBU Illuminant C RGB To Linear CCIR Illuminant D65 RGB

$$\begin{bmatrix} 1.09456363 & -0.04292719 & 0.00000000 \\ 0.00000000 & 0.97451437 & 0.00000000 \\ 0.00000000 & 0.01149532 & 1.08892847 \end{bmatrix}$$

18. Linear EBU Illuminant C RGB To Linear CIE Illuminant E RGB

$$\begin{bmatrix} 0.84838960 & 0.11074343 & -0.09001388 \\ 0.10134910 & 0.82209088 & 0.10266724 \\ 0.02034030 & 0.11917421 & 1.04437550 \end{bmatrix}$$

19. Linear EBU Illuminant C RGB To Linear EBU Illuminant D65 RGB

$$\begin{bmatrix} 1.04838256 & 0.00000000 & 0.00000000 \\ 0.00000000 & 0.97451437 & 0.00000000 \\ 0.00000000 & 0.00000000 & 1.10192674 \end{bmatrix}$$

20. Linear EBU Illuminant C RGB To Linear NTSC Illuminant C RGB

$$\begin{bmatrix} 0.73210063 & 0.23270166 & 0.03519771 \\ 0.02023252 & 1.04541220 & -0.06564472 \\ 0.01775602 & 0.05120729 & 0.93103668 \end{bmatrix}$$

21. Linear EBU Illuminant C RGB To Linear NTSC Illuminant D65 RGB

$$\begin{bmatrix} 0.75548776 & 0.24013537 & 0.03632211 \\ 0.01959607 & 1.01252726 & -0.06357977 \\ 0.01941822 & 0.05600097 & 1.01819398 \end{bmatrix}$$

22. Linear EBU Illuminant C RGB To Linear SMPTE Illuminant D65 RGB

$$\begin{bmatrix} 1.16613407 & -0.09984625 & -0.01086486 \\ -0.02148570 & 1.01059444 & -0.01821428 \\ 0.00178650 & 0.01565661 & 1.08234537 \end{bmatrix}$$

23. Linear EBU Illuminant C RGB To UVW

$$\begin{bmatrix} 0.30089444 & 0.22190737 & 0.13099819 \\ 0.23272304 & 0.68867804 & 0.07859892 \\ 0.13399205 & 0.92971536 & 0.53709259 \end{bmatrix}$$

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24. Linear EBU Illuminant C RGB To XYZ

$$\begin{bmatrix} 0.45134166 & 0.33286105 & 0.19649729 \\ 0.23272304 & 0.68867804 & 0.07859892 \\ 0.02115664 & 0.12625764 & 1.03488572 \end{bmatrix}$$

25. Linear EBU Illuminant D65 RGB To Linear CCIR Illuminant D65 RGB

$$\begin{bmatrix} 1.04404983 & -0.04404983 & 0.00000000 \\ 0.00000000 & 1.00000000 & 0.00000000 \\ 0.00000000 & 0.01179594 & 0.98820406 \end{bmatrix}$$

26. Linear EBU Illuminant D65 RGB To Linear CIE Illuminant E RGB

$$\begin{bmatrix} 0.80923666 & 0.11363960 & -0.08168772 \\ 0.09667187 & 0.84359031 & 0.09317065 \\ 0.01940160 & 0.12229087 & 0.94777218 \end{bmatrix}$$

27. Linear EBU Illuminant D65 RGB To Linear EBU Illuminant C RGB

$$\begin{bmatrix} 0.95385028 & 0.00000000 & 0.00000000 \\ 0.00000000 & 1.02615213 & 0.00000000 \\ 0.00000000 & 0.00000000 & 0.90750135 \end{bmatrix}$$

28. Linear EBU Illuminant D65 RGB To Linear NTSC Illuminant C RGB

$$\begin{bmatrix} 0.69831439 & 0.23878730 & 0.03194197 \\ 0.01929879 & 1.07275196 & -0.05957267 \\ 0.01693659 & 0.05254647 & 0.84491705 \end{bmatrix}$$

29. Linear EBU Illuminant D65 RGB To Linear NTSC Illuminant D65 RGB

$$\begin{bmatrix} 0.72062221 & 0.24641542 & 0.03296236 \\ 0.01869172 & 1.03900701 & -0.05769873 \\ 0.01852208 & 0.05746551 & 0.92401241 \end{bmatrix}$$

30. Linear EBU Illuminant D65 RGB To Linear SMPTE Illuminant D65 RGB

$$\begin{bmatrix} 1.11231731 & -0.10245744 & -0.00985987 \\ -0.02049415 & 1.03702363 & -0.01652949 \\ 0.00170406 & 0.01606606 & 0.98222988 \end{bmatrix}$$

31. Linear EBU Illuminant D65 RGB To UVW

$$\begin{bmatrix} 0.28700824 & 0.22771072 & 0.11888104 \\ 0.22198294 & 0.70668844 & 0.07132862 \\ 0.12780836 & 0.95402939 & 0.48741225 \end{bmatrix}$$

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32. Linear EBU Illuminant D65 RGB To XYZ

$$\begin{bmatrix} 0.43051237 & 0.34156608 & 0.17832155 \\ 0.22198294 & 0.70668844 & 0.07132862 \\ 0.02018027 & 0.12955955 & 0.93916019 \end{bmatrix}$$

33. Linear NTSC Illuminant C RGB To Linear CCIR Illuminant D65 RGB

$$\begin{bmatrix} 1.50741434 & -0.37252467 & -0.08325323 \\ -0.02746442 & 0.93501527 & 0.06696352 \\ -0.02721337 & -0.04014799 & 1.16778515 \end{bmatrix}$$

34. Linear NTSC Illuminant C RGB To Linear CIE Illuminant E RGB

$$\begin{bmatrix} 1.16655167 & -0.14633238 & -0.15110014 \\ 0.11376031 & 0.75326510 & 0.15908182 \\ -0.00115806 & 0.05910310 & 1.12594497 \end{bmatrix}$$

35. Linear NTSC Illuminant C RGB To Linear EBU Illuminant C RGB

$$\begin{bmatrix} 1.37607764 & -0.30271188 & -0.07336576 \\ -0.02818267 & 0.95946791 & 0.06871476 \\ -0.02469345 & -0.04699793 & 1.07169138 \end{bmatrix}$$

36. Linear NTSC Illuminant C RGB To Linear EBU Illuminant D65 RGB

$$\begin{bmatrix} 1.44265580 & -0.31735785 & -0.07691539 \\ -0.02746442 & 0.93501527 & 0.06696352 \\ -0.02721038 & -0.05178827 & 1.18092538 \end{bmatrix}$$

37. Linear NTSC Illuminant C RGB To Linear NTSC Illuminant D65 RGB

$$\begin{bmatrix} 1.03194524 & 0.00000000 & 0.00000000 \\ 0.00000000 & 0.96854357 & 0.00000000 \\ 0.00000000 & 0.00000000 & 1.09361317 \end{bmatrix}$$

38. Linear NTSC Illuminant C RGB To Linear SMPTE Illuminant D65 RGB

$$\begin{bmatrix} 1.60777324 & -0.44829128 & -0.10405900 \\ -0.05759747 & 0.97699294 & 0.05149898 \\ -0.02470972 & -0.03638677 & 1.16088497 \end{bmatrix}$$

39. Linear NTSC Illuminant C RGB To UVW

$$\begin{bmatrix} 0.40456537 & 0.11567204 & 0.13356260 \\ 0.29889531 & 0.58662247 & 0.11448223 \\ 0.14491894 & 0.82622882 & 0.62965224 \end{bmatrix}$$

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40. Linear NTSC Illuminant C RGB To XYZ

$$\begin{bmatrix} 0.60684805 & 0.17350805 & 0.20034389 \\ 0.29889531 & 0.58662247 & 0.11448223 \\ 0.00000000 & 0.06609831 & 1.11620169 \end{bmatrix}$$

41. Linear NTSC Illuminant D65 RGB To Linear CCIR Illuminant D65 RGB

$$\begin{bmatrix} 1.46075032 & -0.38462356 & -0.07612676 \\ -0.02661422 & 0.96538277 & 0.06123145 \\ -0.02637095 & -0.04145192 & 1.06782287 \end{bmatrix}$$

42. Linear NTSC Illuminant D65 RGB To Linear CIE Illuminant E RGB

$$\begin{bmatrix} 1.13043951 & -0.15108498 & -0.13816599 \\ 0.11023871 & 0.77772970 & 0.14546443 \\ -0.00112221 & 0.06102265 & 1.02956420 \end{bmatrix}$$

43. Linear NTSC Illuminant D65 RGB To Linear EBU Illuminant C RGB

$$\begin{bmatrix} 1.33347932 & -0.31254338 & -0.06708566 \\ -0.02731024 & 0.99062958 & 0.06283279 \\ -0.02392903 & -0.04852433 & 0.97995471 \end{bmatrix}$$

44. Linear NTSC Illuminant D65 RGB To Linear EBU Illuminant D65 RGB

$$\begin{bmatrix} 1.39799646 & -0.32766503 & -0.07033144 \\ -0.02661422 & 0.96538277 & 0.06123145 \\ -0.02636804 & -0.05347025 & 1.07983830 \end{bmatrix}$$

45. Linear NTSC Illuminant D65 RGB To Linear NTSC Illuminant C RGB

$$\begin{bmatrix} 0.96904366 & 0.00000000 & 0.00000000 \\ 0.00000000 & 1.03247808 & 0.00000000 \\ 0.00000000 & 0.00000000 & 0.91440011 \end{bmatrix}$$

46. Linear NTSC Illuminant D65 RGB To Linear SMPTE Illuminant D65 RGB

$$\begin{bmatrix} 1.55800247 & -0.46285092 & -0.09515156 \\ -0.05581447 & 1.00872379 & 0.04709067 \\ -0.02394480 & -0.03756854 & 1.06151334 \end{bmatrix}$$

47. Linear NTSC Illuminant D65 RGB To UVW

$$\begin{bmatrix} 0.39204151 & 0.11942884 & 0.12212965 \\ 0.28964261 & 0.60567484 & 0.10468256 \\ 0.14043278 & 0.85306315 & 0.57575407 \end{bmatrix}$$

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48. Linear NTSC Illuminant D65 RGB To XYZ

$$\begin{bmatrix} 0.58806226 & 0.17914326 & 0.18319448 \\ 0.28964261 & 0.60567484 & 0.10468256 \\ 0.00000000 & 0.06824505 & 1.02065495 \end{bmatrix}$$

49. Linear SMPTE Illuminant D65 RGB To Linear CCIR Illuminant D65 RGB

$$\begin{bmatrix} 0.93953487 & 0.05018923 & 0.01027590 \\ 0.01776942 & 0.96579923 & 0.01643136 \\ -0.00162170 & -0.00437073 & 1.00599243 \end{bmatrix}$$

50. Linear SMPTE Illuminant D65 RGB To Linear CIE Illuminant E RGB

$$\begin{bmatrix} 0.73100514 & 0.18293248 & -0.07274908 \\ 0.10188442 & 0.82183906 & 0.10970935 \\ 0.01789060 & 0.10471338 & 0.96686066 \end{bmatrix}$$

51. Linear SMPTE Illuminant D65 RGB To Linear EBU Illuminant C RGB

$$\begin{bmatrix} 0.85907990 & 0.08472099 & 0.01004939 \\ 0.01823413 & 0.99105693 & 0.01686107 \\ -0.00168175 & -0.01447592 & 0.92365902 \end{bmatrix}$$

52. Linear SMPTE Illuminant D65 RGB To Linear EBU Illuminant D65 RGB

$$\begin{bmatrix} 0.90064438 & 0.08882001 & 0.01053561 \\ 0.01776942 & 0.96579923 & 0.01643136 \\ -0.00185316 & -0.01595140 & 1.01780457 \end{bmatrix}$$

53. Linear SMPTE Illuminant D65 RGB To Linear NTSC Illuminant C RGB

$$\begin{bmatrix} 0.63311685 & 0.29213537 & 0.04379145 \\ 0.03655392 & 1.03872739 & -0.04280324 \\ 0.01462179 & 0.03877604 & 0.86100228 \end{bmatrix}$$

54. Linear SMPTE Illuminant D65 RGB To Linear NTSC Illuminant D65 RGB

$$\begin{bmatrix} 0.65334192 & 0.30146770 & 0.04519037 \\ 0.03540407 & 1.00605274 & -0.04145680 \\ 0.01599059 & 0.04240598 & 0.94160343 \end{bmatrix}$$

55. Linear SMPTE Illuminant D65 RGB To UVW

$$\begin{bmatrix} 0.26231834 & 0.24351859 & 0.12776306 \\ 0.21235295 & 0.70109788 & 0.08654917 \\ 0.13115917 & 0.92497788 & 0.51311295 \end{bmatrix}$$

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56. Linear SMPTE Illuminant D65 RGB To XYZ

$$\begin{bmatrix} 0.39347752 & 0.36527789 & 0.19164460 \\ 0.21235295 & 0.70109788 & 0.08654917 \\ 0.01873702 & 0.11194000 & 0.95822298 \end{bmatrix}$$

57. UVW To Linear CCIR Illuminant D65 RGB

$$\begin{bmatrix} 4.11396087 & -0.04155516 & -0.99732385 \\ -1.39146656 & 1.75121888 & 0.08310615 \\ 1.66918590 & -3.37546482 & 2.11430214 \end{bmatrix}$$

58. UVW To Linear CIE Illuminant E RGB

$$\begin{bmatrix} 2.84373542 & 0.50732308 & -0.93543113 \\ -0.63965541 & 1.16041034 & 0.17735107 \\ 1.52178123 & -3.04235208 & 2.01855417 \end{bmatrix}$$

59. UVW To Linear EBU Illuminant C RGB

$$\begin{bmatrix} 3.70254126 & 0.03251134 & -0.90781660 \\ -1.42785638 & 1.79701698 & 0.08527956 \\ 1.54794333 & -3.11877427 & 1.94073521 \end{bmatrix}$$

60. UVW To Linear EBU Illuminant D65 RGB

$$\begin{bmatrix} 3.88167969 & 0.03408432 & -0.95173909 \\ -1.39146656 & 1.75121888 & 0.08310615 \\ 1.70572014 & -3.43666076 & 2.13854802 \end{bmatrix}$$

61. UVW To Linear NTSC Illuminant C RGB

$$\begin{bmatrix} 2.43285230 & 0.33219670 & -0.57645898 \\ -1.51940105 & 2.08401232 & -0.05661414 \\ 1.43381778 & -2.81109561 & 1.79514340 \end{bmatrix}$$

62. UVW To Linear NTSC Illuminant D65 RGB

$$\begin{bmatrix} 2.51057036 & 0.34280880 & -0.59487410 \\ -1.47160612 & 2.01845673 & -0.05483326 \\ 1.56804201 & -3.07425119 & 1.96319246 \end{bmatrix}$$

63. UVW To Linear SMPTE Illuminant D65 RGB

$$\begin{bmatrix} 4.44340743 & -0.10762779 & -1.08823652 \\ -1.55073010 & 1.87216308 & 0.07033902 \\ 1.65966850 & -3.34739761 & 2.10025914 \end{bmatrix}$$

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64. UVW To XYZ

$$\begin{bmatrix} 1.50000000 & 0.00000000 & 0.00000000 \\ 0.00000000 & 1.00000000 & 0.00000000 \\ 1.50000000 & -3.00000000 & 2.00000000 \end{bmatrix}$$

65. XYZ To Linear CCIR Illuminant D65 RGB

$$\begin{bmatrix} 3.24130250 & -1.53754093 & -0.49866192 \\ -0.96919745 & 1.87587811 & 0.04155308 \\ 0.05563953 & -0.20401161 & 1.05715107 \end{bmatrix}$$

66. XYZ To Linear CIE Illuminant E RGB

$$\begin{bmatrix} 2.36353918 & -0.89582361 & -0.46771557 \\ -0.51511248 & 1.42643694 & 0.08867553 \\ 0.00524373 & -0.01452082 & 1.00927709 \end{bmatrix}$$

67. XYZ To Linear EBU Illuminant C RGB

$$\begin{bmatrix} 2.92226914 & -1.32921356 & -0.45390830 \\ -0.99454403 & 1.92493632 & 0.04263978 \\ 0.06159461 & -0.20767146 & 0.97036761 \end{bmatrix}$$

68. XYZ To Linear EBU Illuminant D65 RGB

$$\begin{bmatrix} 3.06365601 & -1.39352432 & -0.47586955 \\ -0.96919745 & 1.87587811 & 0.04155308 \\ 0.06787275 & -0.22883873 & 1.06927401 \end{bmatrix}$$

69. XYZ To Linear NTSC Illuminant C RGB

$$\begin{bmatrix} 1.91013102 & -0.53249177 & -0.28822949 \\ -0.98462697 & 1.99909111 & -0.02830707 \\ 0.05830682 & -0.11838052 & 0.89757170 \end{bmatrix}$$

70. XYZ To Linear NTSC Illuminant D65 RGB

$$\begin{bmatrix} 1.97115062 & -0.54950235 & -0.29743705 \\ -0.95365411 & 1.93620684 & -0.02741663 \\ 0.06376511 & -0.12946249 & 0.98159623 \end{bmatrix}$$

71. XYZ To Linear SMPTE Illuminant D65 RGB

$$\begin{bmatrix} 3.50638988 & -1.73998257 & -0.54411826 \\ -1.06898958 & 1.97767161 & 0.03516951 \\ 0.05631610 & -0.19700891 & 1.05012957 \end{bmatrix}$$

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72. XYZ To UVW

$$\begin{bmatrix} 0.66666667 & 0.00000000 & 0.00000000 \\ 0.00000000 & 1.00000000 & 0.00000000 \\ -0.50000000 & 1.50000000 & 0.50000000 \end{bmatrix}$$

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Point Linear Colour Conversion Matrices — Appearance Match

73. Linear CCIR Illuminant D65 RGB To Linear CIE Illuminant E RGB

$$\begin{bmatrix} 0.81734069 & 0.25664443 & -0.07398512 \\ 0.08531340 & 0.82174918 & 0.09293742 \\ 0.01706302 & 0.10221783 & 0.88071915 \end{bmatrix}$$

74. Linear CCIR Illuminant D65 RGB To Linear EBU Illuminant C RGB

$$\begin{bmatrix} 0.92262406 & 0.06429103 & 0.01308491 \\ -0.00286813 & 1.01653687 & -0.01366875 \\ 0.00176759 & -0.00027143 & 0.99850383 \end{bmatrix}$$

75. Linear CCIR Illuminant D65 RGB To Linear NTSC Illuminant C RGB

$$\begin{bmatrix} 0.67484846 & 0.28360777 & 0.04154378 \\ 0.01555260 & 1.06401864 & -0.07957123 \\ 0.01788096 & 0.05294295 & 0.92917609 \end{bmatrix}$$

76. Linear CIE Illuminant E RGB To Linear CCIR Illuminant D65 RGB

$$\begin{bmatrix} 1.26348678 & -0.41323258 & 0.14974580 \\ -0.13011370 & 1.27565697 & -0.14554327 \\ -0.00937751 & -0.14004907 & 1.14942658 \end{bmatrix}$$

77. Linear CIE Illuminant E RGB To Linear EBU Illuminant C RGB

$$\begin{bmatrix} 1.15723546 & -0.30107756 & 0.14384209 \\ -0.13576104 & 1.29985185 & -0.16409081 \\ -0.00709484 & -0.14091620 & 1.14801104 \end{bmatrix}$$

78. Linear CIE Illuminant E RGB To Linear EBU Illuminant D65 RGB

$$\begin{bmatrix} 1.20468896 & -0.34197612 & 0.13728716 \\ -0.13011370 & 1.27565697 & -0.14554327 \\ -0.00793632 & -0.15694799 & 1.16488431 \end{bmatrix}$$

79. Linear CIE Illuminant E RGB To Linear NTSC Illuminant C RGB

$$\begin{bmatrix} 0.81537127 & 0.07709869 & 0.10753004 \\ -0.11804673 & 1.36203983 & -0.24399311 \\ 0.00699039 & -0.06998220 & 1.06299181 \end{bmatrix}$$

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80. Linear CIE Illuminant E RGB To Linear NTSC Illuminant D65 RGB

$$\begin{bmatrix} 0.83580200 & 0.06273258 & 0.10146541 \\ -0.11221343 & 1.32808011 & -0.21586668 \\ 0.00750304 & -0.07804972 & 1.07054668 \end{bmatrix}$$

81. Linear CIE Illuminant E RGB To Linear SMPTE Illuminant D65 RGB

$$\begin{bmatrix} 1.35340575 & -0.50953902 & 0.15613327 \\ -0.15948887 & 1.33248921 & -0.17300033 \\ -0.00783285 & -0.13424697 & 1.14207982 \end{bmatrix}$$

82. Linear EBU Illuminant C RGB To Linear CCIR Illuminant D65 RGB

$$\begin{bmatrix} 1.08368101 & -0.06854161 & -0.01513940 \\ 0.00303179 & 0.98354398 & 0.01342423 \\ -0.00191755 & 0.00038869 & 1.00152886 \end{bmatrix}$$

83. Linear EBU Illuminant C RGB To Linear CIE Illuminant E RGB

$$\begin{bmatrix} 0.88665654 & 0.19637048 & -0.08302702 \\ 0.09476567 & 0.80241507 & 0.10281926 \\ 0.01711194 & 0.09970854 & 0.88317952 \end{bmatrix}$$

84. Linear EBU Illuminant C RGB To Linear EBU Illuminant D65 RGB

$$\begin{bmatrix} 1.03808700 & -0.02415274 & -0.01393426 \\ 0.00303179 & 0.98354398 & 0.01342423 \\ -0.00197663 & -0.01134698 & 1.01332362 \end{bmatrix}$$

85. Linear EBU Illuminant C RGB To Linear NTSC Illuminant D65 RGB

$$\begin{bmatrix} 0.74875048 & 0.22458138 & 0.02666814 \\ 0.02266773 & 1.02211234 & -0.04478007 \\ 0.01757532 & 0.04558775 & 0.93683693 \end{bmatrix}$$

86. Linear EBU Illuminant C RGB To Linear SMPTE Illuminant D65 RGB

$$\begin{bmatrix} 1.15439100 & -0.12752503 & -0.02686597 \\ -0.01809800 & 1.02064090 & -0.00254291 \\ -0.00012384 & 0.00461518 & 0.99550866 \end{bmatrix}$$

87. Linear EBU Illuminant D65 RGB To Linear CIE Illuminant E RGB

$$\begin{bmatrix} 0.85334441 & 0.21976799 & -0.07311240 \\ 0.08907144 & 0.81908743 & 0.09184113 \\ 0.01781464 & 0.11185512 & 0.87033024 \end{bmatrix}$$

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88. Linear EBU Illuminant D65 RGB To Linear EBU Illuminant C RGB

$$\begin{bmatrix} 0.96326549 & 0.02380395 & 0.01293056 \\ -0.00299447 & 1.01650198 & -0.01350751 \\ 0.00184546 & 0.01142901 & 0.98672554 \end{bmatrix}$$

89. Linear EBU Illuminant D65 RGB To Linear NTSC Illuminant C RGB

$$\begin{bmatrix} 0.70457541 & 0.25437086 & 0.04105373 \\ 0.01623769 & 1.06239493 & -0.07863262 \\ 0.01866861 & 0.06311580 & 0.91821558 \end{bmatrix}$$

90. Linear NTSC Illuminant C RGB To Linear CCIR Illuminant D65 RGB

$$\begin{bmatrix} 1.49353473 & -0.39309507 & -0.10043966 \\ -0.02387841 & 0.94213022 & 0.08174819 \\ -0.02738086 & -0.04611637 & 1.07349724 \end{bmatrix}$$

91. Linear NTSC Illuminant C RGB To Linear CIE Illuminant E RGB

$$\begin{bmatrix} 1.21662422 & -0.07608820 & -0.14053603 \\ 0.10525175 & 0.73637252 & 0.15837572 \\ -0.00107144 & 0.04897955 & 0.95209189 \end{bmatrix}$$

92. Linear NTSC Illuminant C RGB To Linear EBU Illuminant D65 RGB

$$\begin{bmatrix} 1.42951309 & -0.33676017 & -0.09275292 \\ -0.02387841 & 0.94213022 & 0.08174819 \\ -0.02742267 & -0.05791283 & 1.08533550 \end{bmatrix}$$

93. Linear NTSC Illuminant C RGB To Linear NTSC Illuminant D65 RGB

$$\begin{bmatrix} 1.02335096 & -0.01243038 & -0.01092058 \\ 0.00349248 & 0.97592677 & 0.02058076 \\ -0.00023352 & -0.00560967 & 1.00584319 \end{bmatrix}$$

94. Linear NTSC Illuminant C RGB To Linear SMPTE Illuminant D65 RGB

$$\begin{bmatrix} 1.59278905 & -0.47054140 & -0.12224766 \\ -0.05360584 & 0.98487018 & 0.06873566 \\ -0.02488303 & -0.04232124 & 1.06720427 \end{bmatrix}$$

95. Linear NTSC Illuminant D65 RGB To Linear CIE Illuminant E RGB

$$\begin{bmatrix} 1.18905134 & -0.06354155 & -0.12550979 \\ 0.10030051 & 0.75663652 & 0.14306296 \\ -0.00102104 & 0.05560899 & 0.94541204 \end{bmatrix}$$

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96. Linear NTSC Illuminant D65 RGB To Linear EBU Illuminant C RGB

$$\begin{bmatrix} 1.34566728 & -0.29333990 & -0.05232738 \\ -0.03088350 & 0.98301693 & 0.04786657 \\ -0.02374226 & -0.04233179 & 1.06607405 \end{bmatrix}$$

97. Linear NTSC Illuminant D65 RGB To Linear NTSC Illuminant C RGB

$$\begin{bmatrix} 0.97714155 & 0.01250537 & 0.01035309 \\ -0.00350120 & 1.02450174 & -0.02100055 \\ 0.00020733 & 0.00571663 & 0.99407603 \end{bmatrix}$$

98. Linear SMPTE Illuminant D65 RGB To Linear CIE Illuminant E RGB

$$\begin{bmatrix} 0.77260048 & 0.28921206 & -0.06181254 \\ 0.09460620 & 0.79752033 & 0.10787347 \\ 0.01641939 & 0.09572890 & 0.88785171 \end{bmatrix}$$

99. Linear SMPTE Illuminant D65 RGB To Linear EBU Illuminant C RGB

$$\begin{bmatrix} 0.86795868 & 0.10834082 & 0.02370050 \\ 0.01539073 & 0.98168632 & 0.00292295 \\ 0.00003662 & -0.00453762 & 1.00450100 \end{bmatrix}$$

100. Linear SMPTE Illuminant D65 RGB To Linear NTSC Illuminant C RGB

$$\begin{bmatrix} 0.63901583 & 0.30759671 & 0.05338746 \\ 0.03364824 & 1.02875673 & -0.06240497 \\ 0.01623371 & 0.04796851 & 0.93579778 \end{bmatrix}$$

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Point Nonlinear Colour Conversion Matrices

101. Gamma EBU Illuminant C RGB To EBU Illuminant C YUV

$$\begin{bmatrix} 0.29900000 & 0.58700000 & 0.11400000 \\ -0.14740700 & -0.28939100 & 0.43679800 \\ 0.61477700 & -0.51479900 & -0.09997800 \end{bmatrix}$$

102. Gamma EBU Illuminant D65 RGB To EBU Illuminant D65 YUV

$$\begin{bmatrix} 0.29900000 & 0.58700000 & 0.11400000 \\ -0.14740700 & -0.28939100 & 0.43679800 \\ 0.61477700 & -0.51479900 & -0.09997800 \end{bmatrix}$$

103. Gamma NTSC Illuminant C RGB To NTSC Illuminant C YIQ

$$\begin{bmatrix} 0.29889531 & 0.58662247 & 0.11448223 \\ 0.59597799 & -0.27417610 & -0.32180189 \\ 0.21147017 & -0.52261711 & 0.31114694 \end{bmatrix}$$

104. Gamma NTSC Illuminant D65 RGB To NTSC Illuminant D65 YIQ

$$\begin{bmatrix} 0.29889531 & 0.58662247 & 0.11448223 \\ 0.59597799 & -0.27417610 & -0.32180189 \\ 0.21147017 & -0.52261711 & 0.31114694 \end{bmatrix}$$

105. Gamma SMPTE Illuminant D65 RGB To SMPTE Illuminant D65 YCbCr

$$\begin{bmatrix} 0.29900000 & 0.58700000 & 0.11400000 \\ -0.16900000 & -0.33100000 & 0.50000000 \\ 0.50000000 & -0.41900000 & -0.08100000 \end{bmatrix}$$

106. EBU Illuminant C YUV To Gamma EBU Illuminant C RGB

$$\begin{bmatrix} 1.00000000 & 0.00000000 & 1.14025086 \\ 1.00000000 & -0.39393070 & -0.58080921 \\ 1.00000000 & 2.02839757 & 0.00000000 \end{bmatrix}$$

107. EBU Illuminant D65 YUV To Gamma EBU Illuminant D65 RGB

$$\begin{bmatrix} 1.00000000 & 0.00000000 & 1.14025086 \\ 1.00000000 & -0.39393070 & -0.58080921 \\ 1.00000000 & 2.02839757 & 0.00000000 \end{bmatrix}$$

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108. NTSC Illuminant C YIQ To Gamma NTSC Illuminant C RGB

$$\begin{bmatrix} 1.00000000 & 0.95608445 & 0.62088850 \\ 1.00000000 & -0.27137664 & -0.64860590 \\ 1.00000000 & -1.10561724 & 1.70250126 \end{bmatrix}$$

109. NTSC Illuminant D65 YIQ To Gamma NTSC Illuminant D65 RGB

$$\begin{bmatrix} 1.00000000 & 0.95608445 & 0.62088850 \\ 1.00000000 & -0.27137664 & -0.64860590 \\ 1.00000000 & -1.10561724 & 1.70250126 \end{bmatrix}$$

110. SMPTE Illuminant D65 YCbCr To Gamma SMPTE Illuminant D65 RGB

$$\begin{bmatrix} 1.00000000 & -0.00092674 & 1.40168676 \\ 1.00000000 & -0.34369538 & -0.71416904 \\ 1.00000000 & 1.77216042 & 0.00099022 \end{bmatrix}$$

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Von Kries Transformation Matrices — XYZ To XYZ Transformations

111. Illuminant C To Illuminant D50

$$\begin{bmatrix} 1.01327993 & 0.04581042 & -0.06371821 \\ 0.00503195 & 0.99626434 & -0.00101428 \\ 0.00000000 & 0.00000000 & 0.69770786 \end{bmatrix}$$

112. Illuminant C To Illuminant D65

$$\begin{bmatrix} 0.99726964 & -0.00941528 & -0.01539969 \\ -0.00103420 & 1.00076680 & 0.00020929 \\ 0.00000000 & 0.00000000 & 0.92100144 \end{bmatrix}$$

113. Illuminant C To Illuminant E

$$\begin{bmatrix} 1.01338690 & 0.04617587 & -0.03383609 \\ 0.00507209 & 0.99623559 & -0.00102325 \\ 0.00000000 & 0.00000000 & 0.84580902 \end{bmatrix}$$

114. Illuminant D50 To Illuminant C

$$\begin{bmatrix} 0.98711953 & -0.04538992 & 0.09008277 \\ -0.00498576 & 1.00397892 & 0.00100418 \\ 0.00000000 & 0.00000000 & 1.43326464 \end{bmatrix}$$

115. Iluminant D50 To Illuminant D65

$$\begin{bmatrix} 0.98447128 & -0.05471874 & 0.06775553 \\ -0.00601047 & 1.00479571 & 0.00121175 \\ 0.00000000 & 0.00000000 & 1.32003879 \end{bmatrix}$$

116. Illuminant D50 To Illuminant E

$$\begin{bmatrix} 1.00010378 & 0.00036204 & 0.04283900 \\ 0.00003977 & 0.99996930 & -0.00000927 \\ 0.00000000 & 0.00000000 & 1.21226815 \end{bmatrix}$$

117. Illuminant D65 To Illuminant C

$$\begin{bmatrix} 1.00274762 & 0.00943392 & 0.01676439 \\ 0.00103625 & 0.99924353 & -0.00020974 \\ 0.00000000 & 0.00000000 & 1.08577463 \end{bmatrix}$$

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118. Illuminant D65 To Illuminant D50

$$\begin{bmatrix} 1.01611150 & 0.05533497 & -0.05220621 \\ 0.00607815 & 0.99555818 & -0.00122587 \\ 0.00000000 & 0.00000000 & 0.75755349 \end{bmatrix}$$

119. Illuminant D65 To Illuminant E

$$\begin{bmatrix} 1.01621916 & 0.05570115 & -0.01975924 \\ 0.00611838 & 0.99552982 & -0.00123494 \\ 0.00000000 & 0.00000000 & 0.91835798 \end{bmatrix}$$

120. Illuminant E To Illuminant C

$$\begin{bmatrix} 0.98701891 & -0.04574867 & 0.03942976 \\ -0.00502517 & 1.00401156 & 0.00101361 \\ 0.00000000 & 0.00000000 & 1.18230000 \end{bmatrix}$$

121. Illuminant E To Illuminant D50

$$\begin{bmatrix} 0.99989625 & -0.00036202 & -0.03533423 \\ -0.00003976 & 1.00003071 & 0.00000905 \\ 0.00000000 & 0.00000000 & 0.82490000 \end{bmatrix}$$

122. Illuminant E To Illuminant D65

$$\begin{bmatrix} 0.98437131 & -0.05507681 & 0.02110550 \\ -0.00604980 & 1.00482875 & 0.00122105 \\ 0.00000000 & 0.00000000 & 1.08890000 \end{bmatrix}$$

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Annex H (normative)

PIKS image resampling

PIKS defines a global resampling capability that is applicable to most geometric operators and to those non-geometric operators that are subject to match point translation control. This annex specifies the PIKS image resampling functionality.

Image resampling is an interpolation process in which pixels in a destination image are generated by a weighted combination of source pixels within a neighbourhood of a reference pixel whose coordinates are computed by a geometric transformation. Figure H-1 illustrates the neighbourhood relationship for two-dimensional resampling.

When pixels accessed for resampling lie outside the image extent, image data is reflected about each image edge following the same technique defined in the *convolve_2d* operator for the key pixel, reflected exterior mode.

PIKS supports the following global resampling options:

support 1 constant
support 2 linear
support 2 lookup table
support 2 sinc
support 4 truncated sinc
support 4 cubic B-spline
support 4 cubic convolution
support 4 Lagrangian
support 4 lookup table
support 8 truncated sinc
support 8 lookup table

The term "support N" indicates the number of pixel sample intervals in each image dimension involved in the interpolation process.

Image resampling functions range from one-dimensional to five-dimensional. The analytic one-dimensional interpolation functions are defined below.

Support 1 constant:

$$R(u) = 1 \qquad \text{for } -\frac{1}{2} \le u \le \frac{1}{2}$$

Support 2 linear:

$$R(u) = u + 1 \qquad \text{for } -1 \le u < 0$$

$$R(u) = 1 - u \qquad \text{for } 0 \le u \le 1$$

Support 2 sinc:

$$R(u) = \frac{\mathrm{SIN}\{\pi u\}}{\pi u} \qquad \text{for } -1 \le u \le 1$$

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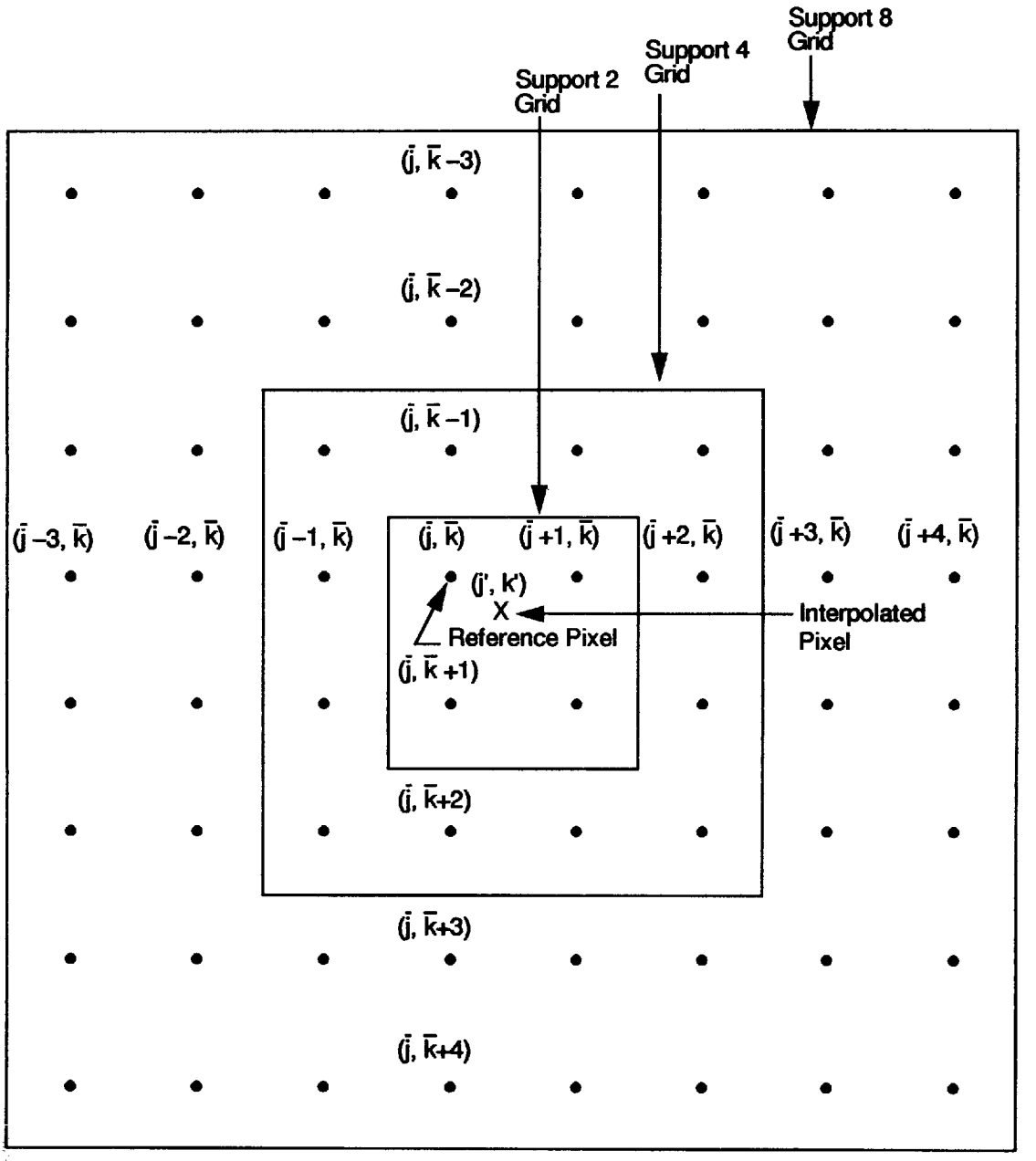

Figure H-1 – Two-dimensional resampling

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Support 4 sinc:

$$R(u) = \frac{SIN\{\pi u\}}{\pi u} \qquad \text{for } -2 \le u \le 2$$

Support 4 cubic B-spline:

$$R(u) = \frac{2}{3} + \frac{1}{2}|u|^3 - (u)^2 \qquad \text{for } 0 \le |u| < 1$$

$$R(u) = \frac{1}{6}[2 - |u|]^3 \qquad \text{for } 1 \le |u| < 2$$

Support 4 cubic convolution:

$$R(u) = \frac{3}{2}|u|^3 - \frac{5}{2}|u|^2 + 1 \qquad \text{for } 0 \le |u| < 1$$

$$R(u) = -\frac{1}{2}|u|^3 + \frac{5}{2}|u|^2 - 4|u| + 2 \qquad \text{for } 1 \le |u| \le 2$$

Support 4 Lagrangian:

$$R(u) = \frac{1}{2}|u|^3 - |u|^2 - \frac{1}{2}|u| + 1 \qquad \text{for } 0 \le u \le 1$$

$$R(u) = -\frac{1}{6}|u|^3 + |u|^2 - \frac{11}{6}|u| + 1 \qquad \text{for } 1 \le u \le 2$$

Support 8 truncated sinc:

$$R(u) = \frac{SIN\{\pi u\}}{\pi u} \qquad \text{for } -4 \le u \le 4$$

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The lookup table representations of the interpolation functions involve the quantization of each unit sampling interval into eight equi-spaced slices in which the interpolation function is a constant amplitude over the slice. The lookup table interpolation functions are defined below.

Support 2 lookup table:

$$R(u) = C(e) \qquad \text{for } -1+\frac{e}{8} \le u \le -1+\frac{e+1}{8}$$

where C(e) represents the interpolation function amplitude for the e-th cell of the lookup table and $0 \le e \le 15$.

Support 4 lookup table:

$$R(u) = C(e) \qquad \text{for} + -2+\frac{e}{8} \le u \le -2+\frac{e+1}{8}$$

where $0 \le e \le 31$.

Support 8 lookup table:

$$R(u) = C(e) \qquad \text{for} + -4+\frac{e}{8} \le u \le -4+\frac{e+1}{8}$$

where $0 \le e \le 63$.

Interpolation functions of order greater than one are generated by the product of identical one-dimensional interpolation functions. For example, a third order interpolation function is obtained by the construction

$$R(u, v, w) = R(u)R(v)R(w)$$

The following are the analytic relationships between an operator input image S(j, k, l, m, n) and an operator output image D(j, k, l, m, n) for a general geometric transformation involving support 1 (nearest neighbour) image resampling.

1D support 1 resampling:

For all j, k, l, m, n

$$D(j, k, l, m, n) = S(j', k, l, m, n)$$

where

$$S(j', k, l, m, n) = S(\tilde{j}, k, l, m, n)$$

The term j' is a source image coordinate, which, in general, is not integer valued. It is computed by a geometrical transformation

$$j' = G_j\{j, k, l, m, n\}$$

from the destination image corrdinate set (j, k, l, m, n), where $G_j\{.\}$ denotes the transformation function.

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The term

$$\bar{j} = \mathrm{LIV}\{j'\}$$

is an integer obtained by rounding down j'.

2D support 1 resampling:

For all j, k, l, m, n

$$D(j, k, l, m, n) = S(j', k', l, m, n)$$

where

$$S(j', k', l, m, n) = S(\bar{j}, \bar{k}, l, m, n)$$

and

$$j' = G_j\{j, k, l, m, n\}$$

$$k' = G_k\{j, k, l, m, n\}$$

$$\bar{j} = \mathrm{LIV}\{j'\}$$

$$\bar{k} = \mathrm{LIV}\{k'\}$$

3D support 1 resampling:

For all j, k, l, m, n

$$D(j, k, l, m, n) = S(j', k', l', m, n)$$

where

$$S(j', k', l', m, n) = S(\bar{j}, \bar{k}, \bar{l}, m, n)$$

and

$$j' = G_j\{j, k, l, m, n\}$$

$$k' = G_k\{j, k, l, m, n\}$$

$$l' = G_l\{j, k, l, m, n\}$$

$$\bar{j} = \mathrm{LIV}\{j'\}$$

$$\bar{k} = \mathrm{LIV}\{k'\}$$

$$\bar{l} = \mathrm{LIV}\{l'\}$$

4D support 1 resampling:

For all j, k, l, m, n

$$D(j, k, l, m, n) = S(j', k', l', m', n)$$

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where

$$S(j', k', l', m', n) = S(\tilde{j}, \tilde{k}, \tilde{l}, \tilde{m}, n)$$

and

$$j' = G_j\{j, k, l, m, n\}$$

$$k' = G_k\{j, k, l, m, n\}$$

$$l' = G_l\{j, k, l, m, n\}$$

$$m' = G_m\{j, k, l, m, n\}$$

$$\tilde{j} = LIV\{j'\}$$

$$\tilde{k} = LIV\{k'\}$$

$$\tilde{l} = LIV\{l'\}$$

$$\tilde{m} = LIV\{m'\}$$

5D support 1 resampling:

For all j, k, l, m, n

$$D(j, k, l, m, n) = S(j', k', l', m', n')$$

where

$$S(j', k', l', m', n') = S(\tilde{j}, \tilde{k}, \tilde{l}, \tilde{m}, \tilde{n})$$

and

$$j' = G_j\{j, k, l, m, n\}$$

$$k' = G_k\{j, k, l, m, n\}$$

$$l' = G_l\{j, k, l, m, n\}$$

$$m' = G_m\{j, k, l, m, n\}$$

$$n' = G_n\{j, k, l, m, n\}$$

$$\tilde{j} = LIV\{j'\}$$

$$\tilde{k} = LIV\{k'\}$$

$$\tilde{l} = LIV\{l'\}$$

$$\tilde{m} = LIV\{m'\}$$

$$\tilde{n} = LIV\{n'\}$$

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The following are the analytic relationships between an operator input image S(j, k, l, m, n) and an operator output image D(j, k, l, m, n) for a general geometric transformation involving support 2, 4, and 8 image resampling.

1D support 2, 4, and 8 resampling:

For all j, k, l, m, n

$$D(j, k, l, m, n) = S(j', k, l, m, n)$$

where

$$S(j', k, l, m, n) = \sum_{i_j} S(\bar{j} + i_j, k, l, m, n) R(j' - \bar{j} - i_j)$$

The summation limits are

$$1 - \frac{s}{2} \le i_j \le \frac{s}{2}$$

where s is the support size of the interpolation function.

2D support 2, 4, and 8 resampling:

For all j, k, l, m, n

$$D(j, k, l, m, n) = S(j', k', l, m, n)$$

where

$$S(j', k', l, m, n) = \sum_{i_j} \sum_{i_k} S(\bar{j} + i_j, \bar{k} + i_k, l, m, n) R(j' - \bar{j} - i_j) R(k' - \bar{k} - i_k)$$

The summation limits are

$$1 - \frac{s}{2} \le i_j \le \frac{s}{2}$$

$$1 - \frac{s}{2} \le i_k \le \frac{s}{2}$$

3D support 2, 4, and 8 resampling:

For all j, k, l, m, n

$$D(j, k, l, m, n) = S(j', k', l', m, n)$$

where

$$S(j', k', l', m, n) = \sum_{i_j} \sum_{i_k} \sum_{i_l} S(\bar{j} + i_j, \bar{k} + i_k, \bar{l} + i_l, m, n) \times R(j' - \bar{j} - i_j) R(k' - \bar{k} - i_k) R(l' - \bar{l} - i_l)$$

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The summation limits are

$$1 - \frac{s}{2} \le i_j \le \frac{s}{2}$$

$$1 - \frac{s}{2} \le i_k \le \frac{s}{2}$$

$$1 - \frac{s}{2} \le i_l \le \frac{s}{2}$$

4D support 2, 4, and 8 resampling:

For all j, k, l, m, n

$$D(j, k, l, m, n) = S(j', k', l', m', n)$$

where

$$S(j', k', l', m', n) = \sum_{i_j} \sum_{i_k} \sum_{i_l} \sum_{i_m} S(\bar{j} + i_j, \bar{k} + i_k, \bar{l} + i_l, \bar{m} + i_m, n)$$

$$\times R(j' - \bar{j} - i_j)\, R(k' - \bar{k} - i_k)\, R(l' - \bar{l} - i_l)\, R(m' - \bar{m} - i_m)$$

The summation limits are

$$1 - \frac{s}{2} \le i_j \le \frac{s}{2}$$

$$1 - \frac{s}{2} \le i_k \le \frac{s}{2}$$

$$1 - \frac{s}{2} \le i_l \le \frac{s}{2}$$

$$1 - \frac{s}{2} \le i_m \le \frac{s}{2}$$

5D support 2, 4, and 8 resampling:

For all j, k, l, m, n

$$D(j, k, l, m, n) = S(j', k', l', m', n')$$

where

$$S(j', k', l', m', n') = \sum_{i_j} \sum_{i_k} \sum_{i_l} \sum_{i_m} \sum_{i_n} S(\bar{j} + i_j, \bar{k} + i_k, \bar{l} + i_l, \bar{m} + i_m, \bar{n} + i_n)$$

$$\times R(j' - \bar{j} - i_j)\, R(k' - \bar{k} - i_k)\, R(l' - \bar{l} - i_l)\, R(m' - \bar{m} - i_m)\, R(n' - \bar{n} - i_n)$$

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The summation limits are

$$1 - \frac{s}{2} \le i_j \le \frac{s}{2}$$

$$1 - \frac{s}{2} \le i_k \le \frac{s}{2}$$

$$1 - \frac{s}{2} \le i_l \le \frac{s}{2}$$

$$1 - \frac{s}{2} \le i_m \le \frac{s}{2}$$

$$1 - \frac{s}{2} \le i_n \le \frac{s}{2}$$

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Annex J (normative)

PIKS error codes

The following are listings of the PIKS error codes.

001 to 100: General element data type, structure, identifier, and functionality errors

001
Cause: Element input data parameter is incorrect data type
Reaction: Abort operation and issue warning

002
Cause: Enumerated option parameter is out of range
Reaction: Abort operation and issue warning

003
Cause: Signed integer option parameter is out of range
Reaction: Abort operation and issue warning

004-010 unused

011
Cause: Image identifier is invalid
Reaction: Abort operation and issue warning

012
Cause: Non-image identifier is invalid
Reaction: Abort operation and issue warning

013
Cause: Identifier is not to an image
Reaction: Abort operation and issue warning

014
Cause: Identifier is not to a non-image
Reaction: Abort operation and issue warning

015-020 unused

021
Cause: Mismatch between source image and element input structure
Reaction: Abort operation and issue warning

022
Cause: Mismatch between source non-image and element input structure
Reaction: Abort operation and issue warning

023
Cause: Mismatch between destination image and element output structure
Reaction: Abort operation and issue warning

024
Cause: Mismatch between destination non-image and element output structure
Reaction: Abort operation and issue warning

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025
Cause: Mismatch between source image and destination image structure
Reaction: Abort operation and issue warning

026
Cause: Mismatch between source non-image and destination non-image structure
Reaction: Abort operation and issue warning

027
Cause: Mismatch between multiple source image structures
Reaction: Abort operation and issue warning

028
Cause: Mismatch between multiple source non-image structures
Reaction: Abort operation and issue warning

029
Cause: Mismatch between multiple destination image structures
Reaction: Abort operation and issue warning

030
Cause: Mismatch between multiple destination non-image structures
Reaction: Abort operation and issue warning

031-040 unused

041
Cause: Mismatch between source image and element input data type
Reaction: Abort operation and issue warning

042
Cause: Mismatch between source non-image and element input data type
Reaction: Abort operation and issue warning

043
Cause: Mismatch between destination image and element output data type
Reaction: Abort operation and issue warning

044
Cause: Mismatch between destination non-image and element output data type
Reaction: Abort operation and issue warning

045
Cause: Mismatch between source image and destination image data type
Reaction: Abort operation and issue warning

046
Cause: Mismatch between source non-image and destination non-image data type
Reaction: Abort operation and issue warning

047
Cause: Mismatch between multiple source image data types
Reaction: Abort operation and issue warning

048
Cause: Mismatch between multiple source non-image data types
Reaction: Abort operation and issue warning

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049
Cause: Mismatch between multiple destination image data types
Reaction: Abort operation and issue warning

050
Cause: Mismatch between multiple destination non-image data types
Reaction: Abort operation and issue warning

051
Cause: Mismatch between destination image and destination non-image data types
Reaction: Abort operation and issue warning

052
Cause: Mismatch between source image and source non-image data type
Reaction: Abort operation and issue warning

053
Cause: Mismatch between destination image and source non-image data type
Reaction: Abort operation and issue warning

054
Cause: Mismatch between source image and element input colour space
Reaction: Abort operation and issue warning

055
Cause: Mismatch between destination image and element output colour space
Reaction: Abort operation and issue warning

056-060 unused

061
Cause: Element does not support heterogeneous bands
Reaction: Abort operation and issue warning

062
Cause: Element is not chainable
Reaction: Abort operation and issue warning

063-070 unused

071
Cause: Specified integer size exceeds implementation integer size
Reaction: Abort operation and issue warning

072
Cause: Specified real arithmetic size exceeds implementation real arithmetic size
Reaction: Abort operation and issue warning

073
Cause: Specified image size exceeds implementation image size
Reaction: Abort operation and issue warning

074
Cause: Specified array size exceeds implementation array size
Reaction: Abort operation and issue warning

075-100 unused

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101 to 200: Element functional errors

101
Cause: Element input data parameter is out of range
Reaction: Abort operation and issue warning

102
Cause: Upper parameter bound is smaller than lower parameter bound
Reaction: Abort operation and issue warning

103
Cause: Source image contains pixel of zero or negative amplitude
Reaction: Abort operation and issue warning

104-110 unused

111
Cause: Array row dimension is not a positive integer
Reaction: Abort operation and issue warning

112
Cause: Array column dimension is not a positive integer
Reaction: Abort operation and issue warning

113
Cause: Array row dimension is not a positive odd integer
Reaction: Abort operation and issue warning

114
Cause: Array column dimension is not a positive odd integer
Reaction: Abort operation and issue warning

115
Cause: Array row dimension is not a positive even integer
Reaction: Abort operation and issue warning

116
Cause: Array column dimension is not a positive even integer
Reaction: Abort operation and issue warning

117
Cause: Number of TRUE state mask array elements is not a positive odd integer
Reaction: Abort operation and issue warning

118-120 unused

121
Cause: Lookup table segment value is out of range
Reaction: Abort operation and issue warning

122
Cause: Lookup table index is out of range
Reaction: Abort operation and issue warning

123
Cause: Lookup table size is insufficient
Reaction: Abort operation and issue warning

124-130 unused

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131
Cause: Seed pixel is not in FALSE state
Reaction: Abort operation and issue warning

132
Cause: Block size dimensions not a power of two
Reaction: Abort operation and issue warning

133
Cause: j-k pixel plane sizes are not integer multiples of the block size
Reaction: Abort operation and issue warning

134
Cause: Covariance matrix is not symmetric
Reaction: Abort operation and issue warning

135-150 unused

151
Cause: Illegal internal data type conversion
Reaction: Abort operation and issue warning

152
Cause: Illegal import data type conversion
Reaction: Abort operation and issue warning

153
Cause: Illegal export data type conversion
Reaction: Abort operation and issue warning

154-160 unused

161
Cause: Composite image arrays are of different length
Reaction: Abort operation and issue warning

162
Cause: Composite image lists are of different length
Reaction: Abort operation and issue warning

163
Cause: Composite image records are of different length
Reaction: Abort operation and issue warning

164
Cause: Composite image list is empty
Reaction: Abort operation and issue warning

165
Cause: Composite image record is empty
Reaction: Abort operation and issue warning

166
Cause: Composite names are not unique
Reaction: Abort operation and issue warning

167-170 unused

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171
Cause: Histogram bin overflow
Reaction: Abort operation and issue warning

172
Cause: Attempted division by zero-valued constant
Reaction: Abort operation and issue warning

173-200 unused

201 to 300 Chaining and virtual register errors:

201
Cause: Chain type is invalid
Reaction: Abort operation and issue warning

202
Cause: Chain identifier is invalid
Reaction: Abort operation and issue warning

203
Cause: Chain identifier is not to an image
Reaction: Abort operation and issue warning

204
Cause: Chain resource type parameter invalid
Reaction: Abort operation and issue warning

205
Cause: Chain parameter is invalid
Reaction: Abort operation and issue warning

206
Cause: Chain already executing
Reaction: Abort operation and issue warning

207
Cause: Chain already deleted
Reaction: Abort operation and issue warning

208
Cause: Chain is not executing
Reaction: Abort operation and issue warning

209
Cause: Chain definition incomplete
Reaction: Abort operation and issue warning

210
Cause: Chain previously defined
Reaction: Abort operation and issue warning

211
Cause: Not in CHAIN_BUILD state
Reaction: Abort operation and issue warning

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212
Cause: Attempt to begin a chain in CHAIN_EXECUTE state
Reaction: Abort operation and issue warning

213
Cause: Selector less than one or greater than number of chain elements
Reaction: Abort operation and issue warning

214
Cause: Next chainable PIKS element does not match selected element built into chain
Reaction: Abort operation and issue warning

215
Cause: Chain is presently on the asynchronous queue or is in execution
Reaction: Abort operation and issue warning

216-250 unused

251
Cause: Mismatch between source and destination virtual register data types
Reaction: Abort operation and issue warning

252
Cause: Virtual register is not in VREG_SET state
Reaction: Abort operation and issue warning

253-300 unused

301 to 400 PIKS system and state errors:

301
Cause: State is PIKS_OPEN when PIKS_CLOSED is expected
Reaction: Log the error, abort operation, invoke *close_piks_emergency*

302
Cause: State is PIKS_CLOSED when PIKS_OPEN is expected
Reaction: Return to the calling PIKS element to resume execution with the error flag parameter set to 'error' whether or not a prior error has been recorded

303
Cause: PIKS initialization failure
Reaction: Log the error, abort operation, invoke *close_piks_emergency*

304
Cause: PIKS closure failure
Reaction: Abort operation and issue warning

305
Cause: Unsupported default state for parameter
Reaction: Log the error, abort operation, invoke *close_piks_emergency*

306
Cause: Invalid default state
Reaction: Abort operation and issue warning

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307
Cause: Element is not in implementation conformance profile
Reaction: Abort operation and issue warning

308-400 unused

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Annex K (informative)

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Annex L (informative)

Alphabetical listings of PIKS elements by profile

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L.1 Alphabetical listing of PIKS elements in the Foundation profile

No.	*Element name*
2	accumulator
8	allocate_histogram
9	allocate_image
10	allocate_lookup_table
11	allocate_matrix
12	allocate_neighbourhood_array
14	allocate_roi
16	allocate_tuple
19	alpha_blend_constant
21	array_to_lut
23	bind_roi
24	bit_shift
34	close_piks
35	close_piks_emergency
36	colour_conversion_linear
37	colour_conversion_matrix
39	colour_conversion_subtractive
41	complement
59	convert_array_to_image
60	convert_image_datatype
61	convert_image_to_array
63	convert_roi_to_image
64	convolve_2d
66	copy_window
68	create_tuple
70	deallocate_data_object
71	define_sub_image
73	diffuse
74	dither

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75 draw_pixels

77 dyadic_arithmetic

79 dyadic_logical

81 dyadic_predicate

90 error_handler

91 error_logger

92 error_test

93 export_histogram

94 export_image

95 export_lut

96 export_matrix

97 export_neighbourhood_array

100 export_tuple

102 extract_pixel_plane

104 extrema

119 flip_spin_transpose

122 get_colour_pixel

124 get_pixel

125 get_pixel_roi

126 get_pixel_array

127 get_pixel_array_roi

133 histogram_1d

139 image_constant

143 import_histogram

144 import_image

145 import_lut

146 import_matrix

147 import_neighbourhood_array

150 import_tuple

159 impulse_rectangular

161 input_object (Foundation - IIf Capable only)

164 inquire_elements

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165 inquire_image
167 inquire_non_image_object
168 inquire_piks_implementation
169 inquire_piks_status
170 inquire_repository
171 inquire_resampling
172 insert_pixel_plane
178 lookup
180 luminance_generation
182 moments
183 monadic_arithmetic
185 monadic_logical
187 morphic_processor
195 open_piks
197 output_object (Foundation - IIF Capable only)
203 put_colour_pixel
204 put_pixel
206 put_pixel_array
210 rescale
211 rescale_roi
212 resize
213 resize_roi
214 return_repository_id
218 roi_rectangular
219 rotate
220 rotate_roi
225 set_globals
226 set_image_attributes
231 split_image
232 subsample
236 threshold
241 translate

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242 translate_roi

243 unary_integer

243 window_level

266 zoom

267 zoom_roi

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L.2 Alphabetical listing of PIKS elements in the Technical profile

No.	*Element name*
2	accumulator
8	allocate_histogram
9	allocate_image
10	allocate_lookup_table
11	allocate_matrix
12	allocate_neighbourhood_array
13	allocate_pixel_record
14	allocate_roi
15	allocate_static_array
16	allocate_tuple
19	alpha_blend_constant
20	alpha_blend_variable
21	array_to_lut
22	bind_match_point
23	bind_roi
24	bit_shift
34	close_piks
35	close_piks_emergency
36	colour_conversion_linear
37	colour_conversion_matrix
38	colour_conversion_nonlinear
39	colour_conversion_subtractive
40	colour_lookup_interpolated
41	complement
42	complement_roi
43	complex_composition
44	complex_conjugate
45	complex_decomposition
46	complex_magnitude

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58 constant_predicate

59 convert_array_to_image

60 convert_image_datatype

61 convert_image_to_array

62 convert_image_to_roi

63 convert_roi_to_image

64 convolve_2d

65 convolve_5d

66 copy_window

67 copy_window_roi

68 create_tuple

70 deallocate_data_object

71 define_sub_image

72 difference_measures

73 diffuse

74 dither

75 draw_pixels

76 draw_pixels_roi

77 dyadic_arithmetic

78 dyadic_complex

79 dyadic_logical

80 dyadic_logical_roi

81 dyadic_predicate

85 equal_predicate

86 erosion_dilation_boolean

87 erosion_dilation_boolean_roi

88 erosion_dilation_grey

90 error_handler

91 error_logger

92 error_test

93 export_histogram

94 export_image

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95 export_lut

96 export_matrix

97 export_neighbourhood_array

98 export_roi_array

99 export_static_array

100 export_tuple

102 extract_pixel_plane

103 extract_pixel_plane_roi

104 extrema

106 fill_region

107 fill_region_roi

108 filter_butterworth

109 filter_gaussian

113 filter_zonal

115 filtering_linear

116 filtering_median

119 flip_spin_transpose

120 flip_spin_transpose_roi

121 gamma_correction

122 get_colour_pixel

123 get_pixel

124 get_pixel_roi

125 get_pixel_array

126 get_pixel_array_roi

127 get_pixel_record

128 get_pixel_record_roi

133 histogram_1d

135 hit_or_miss

136 hit_or_miss_roi

138 image_bar_chart

139 image_constant

141 image_grey_scale

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143 import_histogram

144 import_image

145 import_lut

146 import_matrix

147 import_neighbourhood_array

148 import_roi_array

149 import_static_array

150 import_tuple

155 impulse_elliptical

156 impulse_gaussian

159 impulse_rectangular

161 input_object (Technical - IIF Capable only)

164 inquire_elements

165 inquire_image

166 inquire_index_assignment

167 inquire_non_image_object

168 inquire_piks_implementation

169 inquire_piks_status

170 inquire_repository

171 inquire_resampling

172 insert_pixel_plane

173 insert_pixel_plane_roi

178 lookup

179 lookup_interpolated

180 luminance_generation

182 moments

183 monadic_arithmetic

184 monadic_complex

185 monadic_logical

186 monadic_logical_roi

187 morphic_processor

188 morphic_processor_roi

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189 morphology

190 morphology_roi

195 open_piks

196 outlier_removal

197 output_object (Technical - IIF Capable only)

198 paint_pixels

201 power_law_scaling

202 pseudocolour

203 put_colour_pixel

204 put_pixel

205 put_pixel_roi

206 put_pixel_array

207 put_pixel_array_roi

208 put_pixel_record

209 put_pixel_record_roi

210 rescale

211 rescale_roi

212 resize

213 resize_roi

214 return_repository_id

215 roi_coordinate

216 roi_elliptical

217 roi_polygon

218 roi_rectangular

219 rotate

225 set_globals

226 set_image_attributes

231 split_image

232 subsample

233 subsample_roi

236 threshold

237 transform_cosine

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238 transform_fourier

241 translate

242 translate_roi

243 unary_integer

244 unary_real

245 unsharp_mask

255 wallis_statistical_differencing

256 warp_control_point

257 warp_lut

258 warp_polynomial

263 window_level

266 zoom

267 zoom_roi

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L.3 Alphabetical listing of PIKS elements in the Scientific profile

No.	*Element name*
1	abort_asynchronous_execution
2	accumulator
3	adaptive_histogram_equalization
5	allocate_composite_identifier_array
6	allocate_composite_identifier_list
7	allocate_composite_identifier_record
8	allocate_histogram
9	allocate_image
10	allocate_lookup_table
11	allocate_matrix
12	allocate_neighbourhood_array
13	allocate_pixel_record
14	allocate_roi
15	allocate_static_array
16	allocate_tuple
17	allocate_value_bounds
19	alpha_blend_constant
20	alpha_blend_variable
21	array_to_lut
22	bind_match_point
23	bind_roi
24	bit_shift
25	cartesian_to_polar
32	classifier_bayes
33	classifier_nearest_neighbour
34	close_piks
35	close_piks_emergency
36	colour_conversion_linear
37	colour_conversion_matrix

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38 colour_conversion_nonlinear

39 colour_conversion_subtractive

40 colour_lookup_interpolated

41 complement

42 complement_roi

43 complex_composition

44 complex_conjugate

45 complex_decomposition

46 complex_magnitude

47 composite_identifier_array_equal

48 composite_identifier_array_get

49 composite_identifier_array_put

50 composite_identifier_list_empty

51 composite_identifier_list_equal

52 composite_identifier_list_get

53 composite_identifier_list_insert

54 composite_identifier_list_remove

55 composite_identifier_record_equal

56 composite_identifier_record_get

57 composite_identifier_record_put

58 constant_predicate

59 convert_array_to_image

60 convert_image_datatype

61 convert_image_to_array

62 convert_image_to_roi

63 convert_roi_to_image

64 convolve_2d

65 convolve_5d

66 copy_window

67 copy_window_roi

68 create_tuple

69 cross_correlation

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70 deallocate_data_object

71 define_sub_image

72 difference_measures

73 diffuse

74 dither

75 draw_pixels

76 draw_pixels_roi

77 dyadic_arithmetic

78 dyadic_complex

79 dyadic_logical

80 dyadic_logical_roi

81 dyadic_predicate

82 edge_detection_orthogonal_gradient

83 edge_detection_second_derivative

84 edge_detection_template_gradient

85 equal_predicate

86 erosion_dilation_boolean

87 erosion_dilation_boolean_roi

88 erosion_dilation_grey

89 error_function_scaling

90 error_handler

91 error_logger

92 error_test

93 export_histogram

94 export_image

95 export_lut

96 export_matrix

97 export_neighbourhood_array

98 export_roi_array

99 export_static_array

100 export_tuple

101 export_value_bounds

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102 extract_pixel_plane

103 extract_pixel_plane_roi

104 extrema

105 false_colour

106 fill_region

107 fill_region_roi

108 filter_butterworth

109 filter_gaussian

110 filter_inverse

111 filter_matched

112 filter_wiener

113 filter_zonal

114 filtering_homomorphic

115 filtering_linear

116 filtering_median

117 filtering_pseudomedian

118 filtering_rank_order

119 flip_spin_transpose

120 flip_spin_transpose_roi

121 gamma_correction

122 get_colour_pixel

123 get_pixel

124 get_pixel_roi

125 get_pixel_array

126 get_pixel_array_roi

127 get_pixel_record

128 get_pixel_record_roi

129 histogram_modification

130 histogram_scaling

131 histogram_shape_1d

132 histogram_shape_2d

133 histogram_1d

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134 histogram_2d

135 hit_or_miss

136 hit_or_miss_roi

137 hough_transform

138 image_bar_chart

139 image_constant

140 image_gaussian

141 image_grey_scale

142 image_random_number

143 import_histogram

144 import_image

145 import_lut

146 import_matrix

147 import_neighbourhood_array

148 import_roi_array

149 import_static_array

150 import_tuple

151 import_value_bounds

152 impulse_boxcar

153 impulse_derivative_of_gaussian

154 impulse_difference_of_gaussians

155 impulse_elliptical

156 impulse_gaussian

157 impulse_laplacian_of_gaussian

158 impulse_pyramid

159 impulse_rectangular

160 impulse_sinc

161 input_object (Scientific - IIF Capable only)

164 inquire_elements

165 inquire_image

166 inquire_index_assignment

167 inquire_non_image_object

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168 inquire_piks_implementation

169 inquire_piks_status

170 inquire_repository

171 inquire_resampling

172 insert_pixel_plane

173 insert_pixel_plane_roi

174 label_objects

175 laws_texture_features

176 level_slice

177 line_profile

178 lookup

179 lookup_interpolated

180 luminance_generation

181 markov_spectrum

182 moments

183 monadic_arithmetic

184 monadic_complex

185 monadic_logical

186 monadic_logical_roi

187 morphic_processor

188 morphic_processor_roi

189 morphology

190 morphology_roi

191 neighbour_count

192 noise_combination

193 open_close

194 open_close_roi

195 open_piks

196 outlier_removal

197 output_object (Scientific - IIF Capable only)

198 paint_pixels

199 perimeter_code_generator

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200 polar_to_cartesian

201 power_law_scaling

202 pseudocolour

203 put_colour_pixel

204 put_pixel

205 put_pixel_roi

206 put_pixel_array

207 put_pixel_array_roi

208 put_pixel_record

209 put_pixel_record_roi

210 rescale

211 rescale_roi

212 resize

213 resize_roi

214 return_repository_id

215 roi_coordinate

216 roi_elliptical

217 roi_polygon

218 roi_rectangular

219 rotate

220 rotate_roi

221 rubber_band_scaling

222 sequence_average

223 sequence_karhunen_loeve

224 sequence_running_measures

225 set_globals

226 set_image_attributes

227 set_image_attributes

228 shape_metrics

229 spatial_moments_invariant

230 spatial_moments_scaled

231 split_image

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232 subsample

233 subsample_roi

234 synchronize

235 template_match

236 threshold

237 transform_cosine

238 transform_fourier

239 transform_hadamard

240 transform_hartley

241 translate

242 translate_roi

243 unary_integer

244 unary_real

245 unsharp_mask

246 value_bounds

255 wallis_statistical_differencing

256 warp_control_point

257 warp_control_point_roi

258 warp_lut

259 warp_lut_roi

260 warp_polynomial

261 warp_lut_roi

262 windowing_function

263 window_level

264 window_statistics

265 z_merge

266 zoom

267 zoom_roi

268 3d_slice

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L.4 Alphabetical listing of PIKS elements in the Full profile

No.	*Element name*
1	abort_asynchronous_execution
2	accumulator
3	adaptive_histogram_equalization
4	allocate_chain
5	allocate_composite_identifier_array
6	allocate_composite_identifier_list
7	allocate_composite_identifier_record
8	allocate_histogram
9	allocate_image
10	allocate_lookup_table
11	allocate_matrix
12	allocate_neighbourhood_array
13	allocate_pixel_record
14	allocate_roi
15	allocate_static_array
16	allocate_tuple
17	allocate_value_bounds
18	allocate_vreg
19	alpha_blend_constant
20	alpha_blend_variable
21	array_to_lut
22	bind_match_point
23	bind_roi
24	bit_shift
25	cartesian_to_polar
26	chain_abort
27	chain_begin
28	chain_delete
29	chain_end

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30 chain_execute

31 chain_reload

32 classifier_bayes

33 classifier_nearest_neighbour

34 close_piks

35 close_piks_emergency

36 colour_conversion_linear

37 colour_conversion_matrix

38 colour_conversion_nonlinear

39 colour_conversion_subtractive

40 colour_lookup_interpolated

41 complement

42 complement_roi

43 complex_composition

44 complex_conjugate

45 complex_decomposition

46 complex_magnitude

47 composite_identifier_array_equal

48 composite_identifier_array_get

49 composite_identifier_array_put

50 composite_identifier_list_empty

51 composite_identifier_list_equal

52 composite_identifier_list_get

53 composite_identifier_list_insert

54 composite_identifier_list_remove

55 composite_identifier_record_equal

56 composite_identifier_record_get

57 composite_identifier_record_put

58 constant_predicate

59 convert_array_to_image

60 convert_image_datatype

61 convert_image_to_array

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62 convert_image_to_roi

63 convert_roi_to_image

64 convolve_2d

65 convolve_5d

66 copy_window

67 copy_window_roi

68 create_tuple

69 cross_correlation

70 deallocate_data_object

71 define_sub_image

72 difference_measures

73 diffuse

74 dither

75 draw_pixels

76 draw_pixels_roi

77 dyadic_arithmetic

78 dyadic_complex

79 dyadic_logical

80 dyadic_logical_roi

81 dyadic_predicate

82 edge_detection_orthogonal_gradient

83 edge_detection_second_derivative

84 edge_detection_template_gradient

85 equal_predicate

86 erosion_dilation_boolean

87 erosion_dilation_boolean_roi

88 erosion_dilation_grey

89 error_function_scaling

90 error_handler

91 error_logger

92 error_test

93 export_histogram

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94 export_image

95 export_lut

96 export_matrix

97 export_neighbourhood_array

98 export_roi_array

99 export_static_array

100 export_tuple

101 export_value_bounds

102 extract_pixel_plane

103 extract_pixel_plane_roi

104 extrema

105 false_colour

106 fill_region

107 fill_region_roi

108 filter_butterworth

109 filter_gaussian

110 filter_inverse

111 filter_matched

112 filter_wiener

113 filter_zonal

114 filtering_homomorphic

115 filtering_linear

116 filtering_median

117 filtering_pseudomedian

118 filtering_rank_order

119 flip_spin_transpose

120 flip_spin_transpose_roi

121 gamma_correction

122 get_colour_pixel

123 get_pixel

124 get_pixel_roi

125 get_pixel_array

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126 get_pixel_array_roi

127 get_pixel_record

128 get_pixel_record_roi

129 histogram_modification

130 histogram_scaling

131 histogram_shape_1d

132 histogram_shape_2d

133 histogram_1d

134 histogram_2d

135 hit_or_miss

136 hit_or_miss_roi

137 hough_transform

138 image_bar_chart

139 image_constant

140 image_gaussian

141 image_grey_scale

142 image_random_number

143 import_histogram

144 import_image

145 import_lut

146 import_matrix

147 import_neighbourhood_array

148 import_roi_array

149 import_static_array

150 import_tuple

151 import_value_bounds

152 impulse_boxcar

153 impulse_derivative_of_gaussian

154 impulse_difference_of_gaussians

155 impulse_elliptical

156 impulse_gaussian

157 impulse_laplacian_of_gaussian

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158 impulse_pyramid

159 impulse_rectangular

160 impulse_sinc

161 input_object (Full - IIF Capable only)

162 inquire_chain_environment

163 inquire chain_status

164 inquire_elements

165 inquire_image

166 inquire_index_assignment

167 inquire_non_image_object

168 inquire_piks_implementation

169 inquire_piks_status

170 inquire_repository

171 inquire_resampling

172 insert_pixel_plane

173 insert_pixel_plane_roi

174 label_objects

175 laws_texture_features

176 level_slice

177 line_profile

178 lookup

179 lookup_interpolated

180 luminance_generation

181 markov_spectrum

182 moments

183 monadic_arithmetic

184 monadic_complex

185 monadic_logical

186 monadic_logical_roi

187 morphic_processor

188 morphic_processor_roi

190 morphology

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191 morphology_roi

192 neighbour_count

193 noise_combination

194 open_close

195 open_piks

196 outlier_removal

197 output_object (Full - IIF Capable only)

198 paint_pixels

199 perimeter_code_generator

200 polar_to_cartesian

201 power_law_scaling

202 pseudocolour

203 put_colour_pixel

204 put_pixel

205 put_pixel_roi

206 put_pixel_array

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218 roi_rectangular

219 rotate

220 rotate_roi

221 rubber_band_scaling

222 sequence_average

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223 sequence_karhunen_loeve

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240 transform_hartley

241 translate

242 translate_roi

243 unary_integer

244 unary_real

245 unsharp_mask

246 value_bounds

247 vreg_alter

248 vreg_clear

249 vreg_conditional

250 vreg_copy

251 vreg_delete

252 vreg_get

253 vreg_set

254 vreg_wait

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255 wallis_statistical_differencing

256 warp_control_point

257 warp_control_point_roi

258 warp_lut

259 warp_lut_roi

260 warp_polynomial

261 warp_polynomial_roi

262 windowing_function

263 window_level

264 window_statistics

265 z_merge

266 zoom

267 zoom_roi

268 3d_slice

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