



- A**
- abs, 112
 - Accumulator cells. *See* Hough Transform
 - Adaptive learning systems, 498
 - Adaptive median filter, 164
 - Adjacency, 408, 413, 427
 - adpmedian, 165
 - Affine, 183
 - transform (visualizing), 186
 - transformation matrix, 188
 - all, 46
 - Alpha-trimmed mean filter, 160
 - Alternating sequential filtering, 371
 - AND, 45, 337
 - ans, 48
 - any, 46
 - appcoef2, 261
 - applylut, 353
 - Arithmetic mean filter, 160
 - Arithmetic operators, 40
 - Array, 12
 - arithmetic operators, 41
 - dimensions, 37
 - editor, 8
 - indexing, 30
 - operations summary, 514–526
 - Artificial intelligence, 3
 - ASCII code, 294
 - @, 97
 - Average value, 138
 - axis, 78
- B**
- bar, 77
 - Basic rectangle, 456
 - Bayes classifier, 492
 - bayesgauss, 493
 - Between-class variance, 405
 - bin2dec, 300
 - Binary image, 24, 25
 - Bit depth, 194
 - blanks, 499
 - BLAS, definition of, 4
 - Blind deconvolution. *See* Restoration
 - blkproc, 321
 - BLPF, 129
 - BMP, 15
 - Book Web site, 6
 - Border. *See* Region
 - Bottomhat transformation. *See* Morphology
 - bound2eight, 434
 - bound2four, 434
 - bound2im, 435
 - boundaries, 434
 - Boundary, 426. *See also* Region descriptors, 455 segments, 452
 - break, 49
 - Brightness, 207
 - bsubsamp, 435
 - Butterworth. *See also* Filtering (frequency domain)
 - highpass filter, 136
 - lowpass filter, 129
 - bwdist, 418
 - bwhitmiss, 352
 - bwlabel, 361
 - bwmorph, 356
 - bwperim, 445
- C**
- C MEX-file, 305
 - Canny edge detector, 389
 - cart2pol, 451
 - Cartesian product, 335
 - cat, 195, 435
 - Catchment basin. *See* Morphology
 - CCITT, 21
 - CDF. *See* Cumulative distribution function

- ceil, 114
- Cell array, 48, 62, 427
- Cell indexing, 292
- cell, 292
- celldisp, 293, 428
- cellfun, 428
- cellplot, 293
- cellstr, 499
- Cellular. *See* Minimum perimeter polygon
 - complex, 440
 - mosaic, 440
- Chain codes. *See* Freeman chain codes
- changeclass, 26, 72
- char, 23, 24, 61, 499
- checkerboard, 167
- circshift, 433
- circular, 94
- Clearing border objects. *See* Morphology
- Close-open filtering. *See* Morphology
- Closing-by-reconstruction. *See* Morphology
- Code optimization, 55. *See also* Vectorizing
- Code words. *See* Compression
- Coding redundancy. *See* Compression
- col2im, 322
- colfilt, 96
- Colon, 31, 41
 - indexing, 43
- Color (image processing), 194–241
 - basics of processing, 215
 - bit depth, 194
 - brightness, 207
 - CMY color space, 206
 - CMYK color space, 206
 - color balancing, 224
 - color contrast, 222
 - color correction, 224
 - color cube, 195
 - color edge detection, 232
 - color mappings, 215
 - color pixels, 194
 - color segmentation, 237
 - color vector gradient, 232
 - colormap, 197, 199
 - colormap matrix, 197
 - colors, 195
 - component images, 194
 - conversion between color models, 204–215
 - function summary, 514, 520
 - histograms, 225
 - HSI color space, 207
 - HSV color space, 205
 - hue, 204, 207
 - image representation in MATLAB, 194
 - image sharpening, 230
 - image smoothing, 227
 - images, 12, 194–215
 - indexed images, 197
 - interactive color editing (ICE), 218, 527–551
 - IPT color functions, 199–204
 - NTSC color space, 204
 - number of RGB colors, 195
 - primary colors, 195
 - representation in MATLAB, 194
 - RGB color space, 195
 - RGB images, 194
 - saturation, 204, 207
 - secondary colors, 195
 - segmentation in RGB vector space, 237
 - sharpening, 231
 - smoothing, 227
 - spaces, 204
 - transformations, 215–227
 - vector processing, 215
 - YCbCr color space, 205
- colorgrad, 234
- colormap, 132
- colorseg, 238
- Column vector, 14
- Columns, 13
- Command
 - history, 7
 - History window, 9
 - line, 15
 - prompt, 8
 - Window, 7, 8, 15
- Comment lines, 40
- Comments, 39
- compare, 285
- Complement
 - image, 42, 67
 - set, 335
- Component images, 194
- Compression, 282–333
 - binary code, 289
 - block code, 290
 - blocking artifact, 323
 - code word, 286, 290
 - coding redundancy, 282, 286
 - compression ratio, 21, 283
 - decoder, 283
 - differential coding, 313
 - encoder, 283
 - entropy, 287, 288
 - error free, 285
 - first-order estimate, 288
 - Huffman coding and decoding, 289–309
 - implicit quantization, 327
 - improved gray-scale (IGS) quantization, 316
 - information preserving, 285
 - information theory, 287
 - instantaneous code, 290
 - interpixel redundancy, 282, 309, 310, 314
 - inverse mapper, 286
 - JPEG baseline coding system, 318
 - JPEG compression, 317–333
 - lossless, 285, 313
 - lossy compression, 285
 - mapper, 286
 - mappings, 310
 - packbits, 21
 - prediction error, 314

predictive coding, 310, 313
 predictor, 311
 previous pixel coding, 313
 psychovisual redundancy, 282, 315
 quantization, 315
 quantizer, 286
 redundancies, 282
 symbol coder, 286
 symbol decoder, 286
 transform coding, 318
 transform normalization array, 319
 uniquely decodable, 290
 variable-length coding, 282, 295, 310
 Computer vision, 3
 computer, 48
 Concave vertex, 441
 Connected component, 359, 360, 408, 422, 426. *See also* Morphology
 Connectivity, 408, 455
 minimally connected, 427
 connectpoly, 435
 Constants. *See* MATLAB
 Constrained least squares filtering, 173
 continue, 49
 Contour. *See* Region
 Contraharmonic mean filter, 160
 Contrast, 480
 enhancement, 373
 stretching transformation, 68
 Control points, 191, 217
 choosing interactively, 193
 conv, 94
 conv2, 257
 Converting
 between data classes, 25
 between image classes, 26
 between image types, 26
 colors from HSI to RGB, 211
 colors from RGB to HIS, 209
 to other color spaces, 204

Convex
 deficiency, 452
 hull, 452
 vertex, 441
 Convolution, 89, 90, 92, 115
 filter, 89
 kernel, 89
 mask, 89
 periodic functions, 116
 theorem, 115
 Conway's Game of Life, 354
 conwayLaws, 355
 Coordinate conventions, 13
 Coordinates, 12
 corr, 94
 Correlation, 90–95
 between pixels, 282
 mask, 490
 matching, 490
 template, 490
 Covariance matrix, 238, 475, 486
 covmatrix, 476
 cp2tform, 192
 cpselect, 193
 Cumulative distribution function, 81, 144, 220
 table of, 146
 cumsum, 82
 Current Directory, 7, 8, 15
 Current Directory window, 8
 Cygnus Loop, 416

D

Data classes, 23
 converting, 25
 Data matrix, 197
 DC component, 109
 average value, 109, 138
 DCT, 318
 dctmtx, 321
 dec2base, 508
 dec2bin, 298
 Decision. *See also* Recognition
 boundary, 488
 function, 488
 Decoder. *See* Compression
 deconvblind, 180
 deconvlucy, 177
 Deconvolution, 142
 blind, 166, 179, 180
 Wiener, 173
 deconvreg, 175
 deconvwnr, 171
 Degradation function, 142
 estimating, 166, 179
 modeling, 166
 Delimiter, 61
 Description, 455–483
 basic rectangle, 456
 boundary, 455
 boundary length, 455
 boundary segments, 452
 diameter, 456
 eccentricity, 456, 465
 end points, 456
 Fourier descriptors, 458
 IPT function regionprops, 463
 major axis, 456
 minor axis, 456
 moment invariants, 470–474
 principal components, 474–483
 shape numbers, 456
 statistical moments, 462
 texture, 464–470
 detcoef2, 261
 DFT, 108. *See* Discrete Fourier transform
 dftcorr, 491
 dftfilt, 122
 dftuv, 128
 diag, 239
 Diagonal neighbors, 359
 diameter, 456
 Diameter. *See* Description
 diff, 373
 DIFFERENCE, 337
 Difference of sets, 336
 Differential coding. *See* Compression
 Digital image. *See* Image

- Dilation. *See* Morphology
- dim, 37
- DIPUM
 defined, 514
 function summary, 514–521
- dir, 284
- Directories, 15
- Discrete cosine transform, 318
- Discrete Fourier transform
 (DFT), 108
 FFT, 112
 inverse, 110, 114
 origin of, 111
 padding, 91, 93, 116
 spectrum, 70, 109
 symmetry, 110
 zero padding, 116
- Discriminant function. *See*
 Recognition
- disp, 59
- Display pane, 9
- Displaying images, 16
- Distance
 computing, 485
 Euclidean, 17, 237–239, 456,
 485, 489
 Mahalanobis, 237–239, 486
 transform, 418
- dither, 199
- Dot notation, 40
- double, 24
- Dpi, 21
- DWT. *See* Wavelets
- dwtmode, 252
- Dynamic range, 16, 69, 114
 low, 16, 18
 manipulating, 69, 81, 474
 nominal, 326
- E**
- 8-adjacent, 359
- 8-connected path, 360
- 8-connectivity, 436
- 8-neighbors, 359
- Eccentricity. *See* Description
- Edge (detection), 384–393
 Canny edge detector, 389
 color, 232
 derivative approximations, 387
 direction, 384
 double, 385
 gradient, 384
 IPT function edge, 384
 Laplacian of Gaussian (LoG),
 388
 location, 385
 magnitude, 384
 masks, 387
 Prewitt detector, 100, 387
 Roberts detector, 388
 second-order derivative, 385
 Sobel detector, 126, 385
 zero crossings, 388
- edgetaper, 172
- edit, 40
- eig, 478
- Eigen axes, 450
- Eigenvalues, 475–476, 480
- Eigenvector, 475–476
 axis alignment, 483, 512
 principal components, 475
- EISPACK, definition of, 4
- Encoder. *See* Compression
- end, 31
- endpoints, 354
- Endpoints, 350, 358, 456. *See also*
 Description
- Enhancement, 65, 108, 141, 222,
 369, 373, 517
- Entropy, 287, 288, 314, 466. *See*
 also Compression
- eps, 48, 69, 70
- Erlang. *See* Probability density
 function
- Erosion. *See* Morphology
- error, 50
- Euclidean distance. *See*
 Distance
- eval, 501
- Exponential. *See* Probability
 density function
- Export, 23
- Extended
 minima transform, 424
 (padded) function, 116. *See*
 also Function
- External markers, 422. *See*
 Segmentation
- eye, 494
- F**
- 4-adjacent, 359
- 4-connected path, 360
- 4-connectivity, 436
- 4-neighbors, 359
- Faceted shading, 135
- false, 38
- false, 410
- fchcode, 437, 446
- feval, 415
- FFT, 112. *See* Discrete Fourier
 transform
- fft2, 112
- fftshift, 112
- fieldnames, 284
- Fields, 21, 63, 184, 430
- Figure callback functions, 545
- Figure window, 7
- figure, 18
- Filling holes, 365. *See also*
 Morphology
- Filter(ing) (frequency domain),
 115–139
 basic steps, 121
 Butterworth, lowpass, 129
 convolution theorem, 115
 convolution, 115
 extended functions, 116
 filter transfer function, 115
 finite-impulse-response (FIR),
 122
 from spatial filter, 122
 Gaussian highpass, 136
 Gaussian lowpass, 129
 generating directly, 127
 high frequency emphasis, 138

- highpass, 127, 136
 - ideal lowpass, 129
 - lowpass, 116, 127, 129
 - meshgrid arrays, 128
 - M-function for filtering, 122
 - obtaining from spatial filters, 122
 - padded functions, 116
 - periodic noise filtering, 166
 - plotting, 132
 - sharpening, 136–139
 - smoothing (lowpass filtering), 129–132
 - transfer function, 115
 - wraparound error, 116
 - zero-phase-shift, 122
 - Filter(ing) (spatial), 65, 89–107, 158–166
 - adaptive median filter, 164
 - alpha-trimmed mean filter, 160
 - arithmetic mean filter, 160
 - averaging filter, 100
 - conharmonic mean filter, 160
 - convolution, 89–94
 - correlation, 90–94
 - Gaussian filter, 100
 - generating filters with function `fspecial`, 99
 - geometric mean filter, 160
 - harmonic mean filter, 160
 - kernel, 89
 - Laplacian filter, 100
 - Laplacian of Gaussian (LoG) filter, 100
 - linear, 89, 99
 - mask, 89
 - max filter, 105, 160
 - mechanics of linear spatial filtering, 89
 - median adaptive filter, 164
 - median filter, 105, 160
 - midpoint filter, 160
 - min filter, 105, 160
 - motion filter, 100
 - nonlinear, 89, 96, 104
 - order-statistic filter, 104
 - Prewitt filter, 100
 - rank filter, 104
 - response of filter, 89, 379
 - Sobel filter, 100
 - supported by IPT, 99
 - template, 89
 - unsharp filter, 100
 - using IPT function `imfilter`, 99
 - window, 89
 - Filtering, 65, 89, 122
 - frequency domain. *See* Filter (frequency domain)
 - restoration. *See* Restoration spatial. *See* Filter (spatial)
 - `find`, 147, 432
 - First difference, 436, 456
 - Flat structuring elements, 343, 367–370
 - `flip1r`, 472
 - `flipud`, 472
 - `floor`, 114
 - Flow control, 49
 - Floyd-Steinberg algorithm, 199
 - Folders, 15
 - `for`, 49
 - Forming pattern vectors, 488
 - Formulation, 407
 - Fourier
 - coefficients, 109
 - descriptors, 458
 - spectrum, 70, 109. *See* Discrete Fourier transform
 - transform. *See* Discrete Fourier transform
 - `frdescp`, 459
 - Freeman chain codes, 436
 - Frequency
 - domain, 108
 - filter. *See* Filter (frequency domain)
 - rectangle, 109
 - response of FIR filter, 122
 - `freqz2`, 123
 - `fspecial`, 99, 120, 167
 - filter list, 100
 - `full`, 94, 396
 - Function. *See also* M-function
 - body, 39
 - categories, 514–521
 - definition line, 39
 - extended (padded), 91, 93, 116
 - handle, 97
 - IPT summary, 514–521
 - MATLAB summary, 521–526
 - optimization, 55
 - padding, 91, 93, 116
 - zero padding, 116
 - Fuzzy logic, 4
 - FWT. *See* Wavelets
- ## G
- Gamma, 67, 72, 148. *See also* Erlang
 - Gaussian, 38, 86, 100, 129, 136, 148
 - expressions for, 146, 388
 - highpass filter, 136–138
 - Laplacian of, 388
 - lowpass filter, 129
 - multivariate PDF, 493
 - noise, 143, 148
 - spatial filter, 100
 - `gca`, 78
 - `gcf`, 540
 - Generator equation, 145
 - Geometric mean filter, 160
 - Geometric transformations, 182–193
 - affine transform (visualizing), 186
 - affine transformation matrix, 188
 - forward mapping, 187
 - inverse mapping, 187
 - registration, 191
 - `get`, 218
 - `getfield`, 540
 - `getsequence`, 342

- GIF, 15
 - Global thresholding, 404, 405. *See also* Segmentation
 - global, 292
 - GLPF, 129
 - Gradient, 232, 384
 - definition, 232, 384
 - detectors. *See* Edge detection, Filter (spatial)
 - in color vector space, 233
 - in watershed segmentation, 420
 - morphological, 369
 - Granulometry. *See* Morphology
 - Graphical user interface (GUI), 59, 527–551
 - Graphics formats, 15
 - Graphs, 498
 - Gray level. *See* Intensity
 - gray2ind, 200, 201
 - Gray-scale. *See also* Intensity images. *See* Image. *See* Morphology
 - grayscale, 200, 201
 - graythresh, 406
 - grid, 132
 - gscale, 76
 - GUI, 59, 527–551
 - gui_mainfcn, 533
 - guidata, 539
- H**
- H1 line, 10, 39
 - Handle, 218
 - Harmonic mean filter, 160
 - help, 39
 - Help, 9
 - browser, 9
 - navigator pane, 9
 - obtaining, 9
 - page, 10
 - text, 40
 - text block, 10
 - High frequency emphasis filtering, 138
 - Higher-level processes, 3
 - Highpass filtering, 136
 - hist, 150
 - histsc, 299
 - histeq, 82
 - Histogram, 76
 - equalization, 81
 - mappings, 225
 - matching, 84
 - processing, 76
 - specification, 84
 - histroi, 156
 - Hit-or-miss transformation, 350
 - h-minima transform, 374
 - hold on, 81
 - Hotelling transform, 475
 - Hough transform, 393
 - accumulator cells, 395
 - line detection and linking, 401
 - peak detection, 399
 - hough, 396
 - houghlines, 401
 - houghpeaks, 399
 - houghpixels, 401
 - hpfilt, 136
 - HSI color space, 207
 - hsi2rgb, 213
 - HSV color space, 205
 - hsv2rgb, 206
 - HTML, 9
 - Hue, 204, 207
 - huff2mat, 301
 - Huffman, 290. *See also* Compression
 - codes, 289
 - decoding, 301
 - encoding, 295
 - Hurricane Andrew, 491
- I**
- i, 48
 - ice, 218
 - Interactive color editing (ICE), 218, 527–551
 - ice_OpeningFcn
 - ice_OutputFcn
 - Ideal lowpass filter, 129
 - Identity matrix, 494
 - if, 49
 - ifft2, 114
 - ifftshift, 114
 - ifrdescp, 459
 - IGS. *See* Compression
 - ILPF, 129
 - im2bw, 26, 406
 - im2col, 321
 - im2double, 26
 - im2jpeg, 319
 - im2jpeg2k, 327
 - im2uint16, 26
 - im2uint8, 26
 - imabsdiff, 42
 - imadd, 42
 - imadjust, 66
 - imag, 115
 - Image, 2, 12, 335
 - analysis, 3, 334
 - arithmetic operators, 42
 - as a matrix, 14
 - background, 426
 - binary, 24, 25
 - blur, 166, 167
 - color. *See* Color image processing
 - compression. *See* Compression
 - converting, 26
 - coordinates, 12
 - deblurring. *See* Restoration
 - description. *See* Description
 - digital, 2, 13
 - display options, 514
 - displaying, 16
 - element, 14
 - enhancement, 65
 - formats, 15
 - gray-scale, 66, 94, 199, 200, 204
 - indexed, 24, 197
 - intensity. *See* Intensity
 - monochrome, 12, 24, 66, 222, 408
 - morphology. *See* Morphology
 - multispectral, 479, 492, 496
 - noise. *See* Noise

- origin, defined, 13
 - processing, 2, 3
 - recognition. *See* Recognition
 - registration, 191
 - registration, 191–193
 - representation, 12. *See also* Representation
 - restoration. *See* Restoration
 - segmentation. *See* Segmentation
 - transforms. *See* Transforms
 - types, 24
 - Image Processing Toolbox. *See also* MATLAB
 - background, 1, 4, 12
 - complementary toolboxes, 4
 - coordinate convention, 13
 - function summary, 514–521
 - image representation, 13
 - imapprox, 198
 - imbothat, 373
 - imclearborder, 366
 - imclose, 348
 - imcomplement, 42, 67
 - imdilate, 340
 - imdivide, 42
 - imerode, 347
 - imextendedmin, 424
 - imfill, 366, 432
 - imfilter, 92
 - options for, 94
 - imfinfo, 18
 - imhist, 77
 - imhmin, 374
 - imimposemin, 424
 - imlincomb, 42, 159
 - immultiply, 42
 - imnoise, 106, 143
 - options for, 143
 - imnoise2, 148
 - imnoise3, 152
 - imopen, 348
 - Improved gray-scale (IGS)
 - quantization, 316
 - Impulse, 92, 122, 151, 166
 - imratio, 283
 - imread, 14
 - imreconstruct, 363, 410
 - imregionalmin, 422
 - imrotate, 472
 - imshow, 16
 - imstack2vectors, 476
 - imsubtract, 42
 - imtophat, 373
 - imtransform, 188
 - imwrite, 18
 - ind2gray, 200, 201
 - ind2rgb, 200, 202
 - Indexed images. *See* Image
 - Indices, 32, 42, 56, 147
 - inpolygon, 446
 - input, 60
 - Input, interactive, 59
 - int16, 24
 - int2str, 506
 - int32, 24
 - int8, 24
 - Intensity, 2, 12. *See also* Histogram
 - image type, 24
 - in HSI color model, 207
 - in indexed images, 197
 - in pseudocolor, 216
 - in set theory view, 335
 - PDF, 155
 - scaling, 75
 - transformations, 65–76
 - Interactive I/O, 59
 - Interior
 - angle, 441
 - point, 427
 - Internal markers, 422
 - interp1q, 217
 - Interpixel redundancy. *See* Compression
 - Interpolation, 472
 - bicubic, 188, 472
 - bilinear, 188, 472
 - cubic spline, 217
 - in faceted shading, 135
 - nearest neighbor, 188, 190, 472
 - Intersection. *See* Set operations
 - intline, 436
 - intrans, 73
 - inv, 41, 403
 - Inverse mapping, 85, 187, 220
 - invmoments, 472
 - IPT1. *See* Image Processing Toolbox
 - is*, 48
 - iscell, 48
 - iscellstr, 501
 - islogical, 25
- ## J
- j, 48
 - Joint Photographic Experts Group, 15
 - JPEG2000, 282, 325, 331
 - JPEG Compression. *See* Compression
 - JPEG, 15, 323
 - JPEG, 323
 - jpeg2im, 322
 - jpeg2k2im, 330
- ## K
- Kernel, 89, 243, 245, 367
- ## L
- Label matrix, 361
 - Labeling connected components, 359
 - LAPACK, definition of, 4
 - Laplacian, 100, 174, 230, 385
 - of a Gaussian (LoG), 388
 - operator, 175
 - length, 51
 - Length
 - of array, 51
 - of boundary, 455
 - of string, 499
 - Line
 - detection, 381–384
 - detection and linking, 403
 - joining two points, 436

Linear

2-D filter design, 517
 and spatial invariance, 142
 combination, 42, 159
 conformal transformation, 188
 frequency domain filtering. *See* Filter (frequency domain)
 indexing, 35
 linear process, 142
 motion, 100
 spatial filtering. *See* Filter (spatial)
 systems and convolution, 115

LINPACK, definition of, 4
 linspace, 32, 185

Local
 gradient, 389
 maxima of gradient, 386
 maximum operator, 367
 minimum operator, 368
 thresholding, 405, 407
 variables, 292

log, 68
 log10, 68
 log2, 68

Logarithm transformation, 68, 70

logical, 25

Logical, 23
 functions, 45, 46
 operators, 45

Lognormal. *See* Probability density function

lookfor, 10, 40

Lookup tables, 353

Loop, 51, 52. *See* Vectorizing

lower, 62

Low-level processes, 3

Lowpass filter. *See* Filter (frequency domain)

lpc2mat, 312

lpfilter, 131

Lucy-Richardson algorithm, 176

Luminance, 204

M

magic, 38

Mahalanobis distance. *See* Distance

Major axis, 456. *See* Description

makelut, 353

maketform, 183
 transformations supported, 192

manualhist, 87

Mapping
 color, 216, 223
 forward, 187
 in compression. *See* Compression
 in indexed images, 197
 intensities. *See* Intensity transformations
 inverse, 187
 inverse, 220
 in set theory, 335

Marker
 in morphological reconstruction, 362
 in plots, 79
 in region segmentation, 414
 in watershed segmentation, 422

Mask, 89, 362, 379. *See also* Filter (spatial)

mat2lpc, 312

mat2gray, 26, 43

mat2huff, 298

mat2str, 507

Matching. *See also* Recognition
 correlation, 490
 regular expression, 502
 string, 508

MAT-files, 11

MathWorks web site, 5

MATLAB
 array indexing, 30
 background, 4
 command line, 15
 constants, 48
 definition of, 4
 desktop, 7
 editor, 9
 environment, 7
 function summary, 521–526
 fundamentals, 12–64
 help, 9
 M-function. *See* M-function
 number representation, 49
 operators. *See* Operators
 plotting. *See* Plotting
 predefined colormaps, 200
 programming, 38–64
 prompt, 15
 retrieving work session, 10
 saving work session, 10
 string manipulation, 499
 variables, 48

Matrix. *See also* Array
 arithmetic operations, 40
 dimensions, 37
 indexing, 30, 32

max, 42

Maximum-likelihood estimation (MLE), 180

Mean, 147, 153, 158, 466

Mean vector, 475

mean, 362

mean2, 75

medfilt2, 106

Median axis, 453

Median filter, 105, 160
 adaptive, 164

median, 105

mesh, 132

meshgrid, 55, 185

Metacharacters, 501, 502

mexErrMsgTxt, 307

MEX-file, 305

M-file, 4

mfilename, 533

M-file. *See* M-function

M-function, 4
 components, 10
 editing, 9
 help, 10
 listings, 552–593
 programming, 38–64

Mid-level processes, 3
 Midpoint filter, 160
 min, 42
 Minima imposition, 424
 Minimally connected, 427
 Minimum-perimeter polygons, 439–449
 cellular complex, 440
 cellular mosaic, 440
 Minor axis, 456
 minperpoly, 447
 MLE, 180
 Moment
 about the mean, 155, 464
 central, 155
 invariants, 463, 470–474
 order, 155, 470
 Monochrome image. *See* Image
 Monospace font, 14
 Morphology, Morphological, 334–377
 adjacency, 359
 alternating sequential filtering, 371
 bottomhat transformation, 373
 clearing border objects, 366
 close-open filtering, 371
 closing gray-scale images, 369
 closing, 348
 closing-by-reconstruction, 375
 connected component, 359–362
 Conway’s Game of Life, 354
 dilation, 338
 erosion, 345
 filling holes, 365
 flat structuring elements, 343, 367–370
 function `bwmorph`, 356
 function `strel`, 341
 gradient, 369
 granulometry, 373
 gray-scale dilation, 366
 gray-scale erosion, 368
 gray-scale morphological reconstruction, 374

gray-scale morphology, 366–377
 hit-or-miss transformation, 350
 h-minima transform, 374
 labeling connected components, 359
 look-up tables, 353
 marker, 362
 mask, 362
 open-close filtering, 371
 opening, 347
 opening by reconstruction, 363
 opening gray-scale images, 369
 operations, table of, 357
 parasitic components, 358
 pruning, 358
 reconstruction, 362
 reconstruction, gray-scale images, 374
 reflection of structuring element, 336
 skeletonizing, 356, 358
 strel object, 342
 structuring element, 334, 338
 structuring element decomposition, 341
 thinning, 356
 tophat-by-reconstruction, 376
 watershed. *See* Segmentation
 Motion, 100
 Multiresolution, 244
`mxArray`, 307
`mxMalloc`, 307
`mxCreate`, 307
`mxGet`, 307

N

NaN, 48
 nan, 48
`nargchk`, 71
`nargin`, 71
`nargout`, 71
`ndims`, 37
 Negative image, 67
 Neighbor, 359

Neighborhood, 65, 104
 gradient, 232
 implementation, 90
 in color images, 216
 processing, 89
 Neural network, 4, 498
`nextpow2`, 117
`nlfilter`, 96
 Noise
 2-D sinusoid, 150
 Erlang, 145, 146
 estimating parameters, 153
 exponential, 148
 filtering. *See* Filtering
 frequency filters. *See* Filter (frequency domain)
 Gaussian, 143, 148
 generating, 143, 148, 152
 lognormal, 148
 models, 143
 periodic, 150, 152, 166
 Poisson, 143
 Rayleigh, 148
 salt & pepper, 107, 143, 148
 spatial filters. *See* Filter (spatial)
 speckle, 143
 uniform, 148
 Norm (Euclidean), 485
 norm, 485
 Normalized histogram, 76
 NOT, 45, 337
 NTSC color space. *See* Color
`ntsc2rgb`, 205
 Number representation, 49
`numel`, 51

O

Object, 359. *See also* Connected component
 callback functions, 549
 recognition, 484
 ones, 38
 Opening and closing. *See* Morphology

- Opening by reconstruction. *See* Morphology
- Operator. *See also* Filter (spatial)
- arithmetic, 40
 - concatenate, 195
 - derivative, 101
 - expected value, 170
 - identity, 142
 - Laplacian, 174
 - logical, 45
 - relational, 44
- Optical transfer function (OTF). *See* Restoration
- Optimum statistical classifiers, 492
- OR, 45, 337
- Order-statistic filters. *See* Filter (spatial)
- ordfilt2, 105
- Origin
- image, 13, 66, 90, 93
 - Fourier transform, 111, 112
 - structuring element, 336, 338–339, 343
- Orthogonality, 245
- of eigenvectors, 475
- OTF. *See* Restoration
- otf2psf, 142
- Otsu's method, 405
- Oversegmentation, 420, 422
- P**
- padarray, 97
- paddedsz, 117
- Padding. *See* Function
- Parameter space. *See* Hough transform
- Parasitic components, 358
- patch, 196
- Path
- between pixels, 360
 - MATLAB, 8
- Pattern. *See* Recognition
- PDF. *See* Probability density function
- Pel, 14
- Pepper noise, 162
- Periodic
- noise. *See* Noise sequence, 119
- Periodicity, 110
- permute, 486
- persistent, 353
- Phase angle, 109
- pi, 48
- Picture element, 14
- Pixel, 14
- pixeldup, 168
- pixval, 17
- plot, 37, 80
- Plotting
- 1-D functions, 37, 76–81
 - 2-D functions, 132–135
- PNG, 15
- Point detection, 379
- Poijnt spread function (PSF). *See* Restoration
- Poisson. *See* Noise
- pol2cart, 451
- polyangles, 510
- Polygonal approximation, 439
- PNG, 15
- pow2, 300
- Power spectrum, 109, 170
- Predicate, 408
- Prewitt edge detector. *See* Edge
- Primary color. *See* Color
- Principal components transform, 475
- princomp, 477
- print, 23
- Probability density function (PDF), 81, 144
- Erlang, 146
 - estimating parameters, 153
 - exponential, 146
 - Gaussian, 38, 86, 143, 146, 493
 - generating random numbers, 144, 148
 - histogram equalization, 81
 - in color transformations, 220
 - lognormal, 146
 - multivariate, 493
 - Rayleigh, 146
 - salt & pepper, 146
 - table of, 146
 - uniform, 146
- prod, 98
- Prompt, 15
- Pruning. *See* Morphology
- Pseudocolor. *See* Color
- psf2otf, 142
- Psychovisual redundancy. *See* Compression
- Q**
- qtdecomp, 413
- qtgetblk, 413
- Quadimages, 412
- Quadregions, 412
- Quadtree, 412
- Quality, in JPG images, 19
- Quantization, 13. *See also* Compression
- R**
- rand, 38, 144, 145
- randn, 38, 144, 147
- Random number, 145
- randvertex, 510
- Rayleigh. *See* Probability density function
- Reading images, 14
- real, 115
- realmax, 48
- realmin, 48
- Recognition, 484–513
- adaptive learning, 498
 - Bayes classifier, 492
 - correlation, 490
 - decision boundary, 488
 - decision function, 488
 - decision-theoretic methods, 488
 - discriminant function, 488
 - distance measures, 485

- matching regular expressions, 502
 - matching, 489–492, 502,
 - minimum-distance classifier, 489
 - neural networks, 498
 - pattern class, 484
 - pattern vectors, 488
 - pattern, 484
 - regular expressions, 501
 - string matching, 508
 - string representation, 499
 - string similarity, 508
 - structural methods, 498
 - structural, 498–512
 - training, 488
 - References, organization of, 11
 - Reflection of structuring element, 336
 - regex, 502
 - regexp, 503
 - regprep, 503
 - Region, 3, 426. *See also*
 - Description
 - border, 426
 - boundary, 426
 - classifying in multispectral imagery, 495
 - contour, 426
 - of interest (ROI), 156
 - Region-based segmentation, 407
 - regiongrow, 409
 - Region growing, 408–411
 - adjacency, 408, 413
 - regionprops, 463
 - Region splitting and merging, 412–417
 - adjacency, 408, 413
 - Registered images, 476
 - Regular expressions, 501. *See* Recognition
 - Regularized filtering. *See* Restoration
 - Relational operators. *See* Operators
 - rem, 256
 - replicate, 94
 - repmat, 264
 - Representation, 436–455
 - boundary segments, 452
 - convex deficiency, 452
 - convex hull, 452
 - Freeman chain codes, 436
 - minimum perimeter polygons, 439
 - polygonal, 439
 - signatures, 449
 - skeletons, 453
 - reshape, 300
 - Resolution, 21
 - Response, of filter, 89, 379
 - Restoration, 141–193
 - blind deconvolution, 179
 - constrained least squares filtering, 173
 - deconvolution, 142, 179
 - degradation modeling, 142, 166–169
 - geometric transformations, 182–190
 - image registration, 191–193
 - inverse filter, 169
 - inverse filtering, 169
 - iterative techniques, 176–182
 - Lucy-Richardson algorithm, 176
 - noise generation and modeling, 143–158
 - noise reduction, 158–166
 - nonlinear, iterative, 176
 - optical transfer function (OTF), 142
 - point spread function (PSF), 142
 - regularized filtering, 173
 - Richardson-Lucy algorithm, 176
 - using spatial filters, 158
 - Wiener deconvolution, 173
 - Wiener filter, parametric, 171
 - Wiener filtering, 170
 - Retrieving a work session, 10
 - return, 49
 - RGB. *See* Color
 - RGB color space. *See* Color
 - rgb2gray, 20, 202
 - rgb2hsi, 212
 - rgb2hsv, 206
 - rgb2ind, 200, 201
 - rgb2ntsc, 204
 - rgb2ycbcr, 205
 - rgbcube, 195
 - Richardson-Lucy algorithm, 176
 - Rms (root-mean-square) error, 285
 - Roberts edge detector. *See* Edge
 - ROI. *See* Region
 - roipoly, 156
 - rot90, 94
 - round, 22
 - Row vector, 14
 - Rows, 13
 - Rubber-sheet transformation, 182
- ## S
- Salt & pepper noise. *See* Noise
 - salt noise, 162
 - same, 94
 - Sampling, 13
 - Saturation. *See* Color
 - save, 301
 - Saving a work session, 10
 - Scalar, 14
 - Scaling, 18
 - Screen capture, 17
 - Search path, 9
 - Secondary color. *See* Color
 - Second-order derivatives, 385
 - Seed points, 408
 - Segmentation, 378–425
 - color, 237
 - double edges, 385
 - edge detection, 384–393. *See also* Edge
 - edge location, 385
 - extended minima transform, 424

- Segmentation (*cont.*)
 external markers, 422
 global thresholding, 404–407
 Hough transform, 393–404. *See*
 also Hough transform
 in RGB Vector Space, 237
 line detection, 381
 local thresholding, 407
 point detection, 379
 region growing, 408
 region splitting and merging, 412
 region-based, 407–417
 watershed segmentation,
 417–425
 watershed transform, 417
 Self-intersecting polygon, 441
 Semicolon, 15
 Set operations, 335, 337
 complement, 335
 difference, 336
 intersection, 335
 union, 335
 Set path, 9
 set, 78
 setfield, 546
 shading interp, 135
 Shape numbers, 456
 Sharpening frequency domain
 filters, 136
 Sharpening, 101
 Sifting, 92
 sign, 326
 Signal processing, 4
 signature, 450
 Signatures, 449
 Similarity, 237, 408, 489, 508
 Simple polygon, 440
 Single subscript, 35
 single, 24
 Singleton dimension, 37
 size, 13, 15
 Skeletons, 453. *See*
 Representation
 Slope, 69
 Smoothness, 466
 Sobel. *See* Edge, Filtering (spatial)
 sort, 293
 sortrows, 433
 Sparse matrices, 395
 sparse, 395
 Spatial
 coordinates, 2, 14
 domain, 109
 filter. *See* Filter (spatial)
 invariance, 142
 processing, 65, 215
 Speckle noise. *See* Noise
 Spectral measures of texture, 468
 Spectrum features, 468
 Spectrum, 70, 109
 specxture, 469
 Speed comparisons, 57
 spfilt, 159
 spline, 218
 splitmerge, 414
 sprintf, 52
 Standard arrays, 37
 Standard deviation, 86, 100, 130,
 148, 388, 466
 Statistical error function, 170
 Statistical moments, 462
 statmoments, 155
 statxture, 467
 stem, 79
 str2num, 60
 strcmp, 504
 strcmp, 62
 strcmpi, 316
 strcmpi, 504
 Strel object, 342
 strel, 341
 strfind, 505
 Strings, 498
 manipulation functions, 500
 matching, 508
 measure of similarity, 508
 strjust, 505
 strmatch, 505
 strncmp, 504
 strncmpi, 505
 stread, 61
 strep, 506
 strsimilarity, 509
 strtok, 506
 Structural recognition. *See*
 Recognition
 Structures, 21, 48, 63, 430
 Structuring element. *See*
 Morphology
 strvcats, 504
 subplot, 249
 surf, 134
 Surface area. *See* Morphology
 switch, 49
 symmetric, 94
- ## T
- Tagged Image File Format, 15
 Template, 89
 text, 79
 Texture. *See* Description
 Tform structure, 183
 tformfwd, 184
 tforminv, 184
 Thinning. *See* Morphology
 Thresholding. *See* Segmentation
 tic, 57
 Tie points, 191
 TIFF, 15
 title, 79
 toc, 57
 Tophat. *See* Morphology
 Transform coding. *See*
 Compression
 Transforms
 Discrete cosine, 318
 Fourier. *See* Discrete Fourier
 Wavelet. *See* Wavelets
 Transpose operator. *See*
 Operators
 Trees, 498
 true, 38, 410
 try...catch, 49
 twomodegauss, 86

U

uicontrol, 534
 uint16, 24
 uint32, 24
 uint8, 16
 uint8, 24
 uiresume, 540
 uiwait, 540
 Unary
 minus, 41
 plus, 41
 Uniform
 linear motion, 167
 random numbers. *See* PDF
 uniform noise. *See* Noise
 Union. *See* Set operations
 unique, 433
 unravel.c, 305
 unravel.m, 306
 Unsharp, 100
 upper, 62

V

varargin, 72
 varargout, 72
 Variable
 number of inputs, 71
 number of outputs, 71
 Variables. *See* MATLAB
 Variance, 38, 143, 146, 147, 153,
 155, 158, 466
 Vector
 complex conjugate, 41
 Euclidean norm, 174
 indexing, 30
 transpose, 41
 Vectorizing, 36, 52, 55
 speed comparison, 57
 loops, 55
 version, 48
 view, 132
 vistformfwd, 185

W

wfilters, 246
 warning, 159
 Watershed, 417. *See*
 Segmentation
 waveback, 272
 wavecut, 264
 wavedec2, 249
 wavefast, 255
 wavefilter, 252
 wavefun, 247
 waveinfo, 247
 Wavelets, 242–281
 decomposition structures,
 259
 discrete wavelet transform
 (DWT), 243
 displaying decomposition
 coefficients, 266
 editing decomposition
 coefficients, 262
 expansion coefficients, 243
 fast wavelet transform, FWT,
 245
 forward and inverse
 transformation kernels,
 243
 FWT using Haar filters, 250
 FWTs Using the Wavelet
 Toolbox, 246
 FWTs without the Wavelet
 Toolbox, 252
 in image processing, 276
 inverse fast wavelet transform,
 271
 kernel properties, 244
 kernel, 244
 mother wavelet, 244
 progressive reconstruction,
 279
 Toolbox, 4, 242
 waverec2, 271

wavework, 262
 wavezero, 277
 Web site
 book, 6
 MathWorks, 5
 while, 49
 whitebg, 198
 whos, 16
 Wiener. *See* Restoration
 Wireframe plotting, 132. *See also*
 Plotting
 Work session, saving and
 retrieving, 10
 Workspace, 8
 browser, 7, 8, 10, 11
 variables, 10
 Wraparound error, 116
 Writing images, 18

X

X Window Dump, 15
 x2majoraxis, 457
 xlabel, 79
 xlim, 80
 xor, 46
 xtick, 78
 XWD, 15

Y

YCbCr color space. *See*
 Color
 ycbcr2rgb, 205
 ylabel, 79
 ylim, 80
 ytick, 78

Z

Zero-crossings detector, 388
 Zero-padding, 91, 93, 116
 Zero-phase-shift filters, 122
 zeros, 38