

Index

- 3D reconstruction, 125
- 5+1-point algorithm, 284
- 5-point algorithm, 270
- 7-point algorithm, 265
- 8-point algorithm, 263

- affine point, 45
- affine transformation, 57
- affine transformation group, 57
- affine vector, 45
- algebraic distance, 39
- algebraic error, 39, 188
- algebraic errors, 188
- algebraic representation, 147
- algebraic representation of $SO(3)$, 149
- algebraically independent, 120
- analytic geometry, 16
- aperture, 95, 292
- associative operation, 348
- automatic camera calibration, 290
- auxiliary variables, 205, 228, 268, 303
- axis-angle representation, 150

- backward interpolation, 311
- barrel distortion, 295
- barycentric coordinates, 246
- baseline, 125
- blending, 313
- block diagonal matrix, 356
- block matrix, 355
- bookkeeping tables, 330
- bounding box, 110, 306
- Brown-Conrady distortion, 297
- bundle adjustment, 17, 328
 - incremental, 328

- C-normalized image coordinates, 100
- calibrated epipolar geometry, 123, 262
- calibration device, 300
- camera, 95
- camera calibration, 110, 224, 289
- camera center, 94
- camera centered coordinate systems, 96
- camera matrices from \mathbf{F} , 132
- camera matrix, 94
- camera normalized image coordinates, 100

- camera obscura, 95
- camera projection matrix, 94
- camera resectioning, 108
- canonical form, 30, 32, 65, 66, 70, 73
- canonical homogeneous coordinates, 90
- Cardano angles, 162
- Cartesian coordinate system, 21
- Cartesian representation, 22
- Cayley transform, 156
- central perspective, 93
- central projection, 93
- centroid, 175
- Closed form concatenation of rotations, 150
- Closed form inverse of a rotation, 150
- co-linear planes, 26
- co-linear points, 22, 26
- co-planar lines, 26
- co-planar points, 25
- collineation, 85
- column compression, 360
- commutative operation, 348
- complete representation, 149
- consensus set, 275
- consistency, 190
- consistent parameterization, 228
- consistent Plücker coordinates of 3D line, 72
- constraint enforcement, 229
 - fundamental matrix, 263
 - normalized camera matrix, 252
 - rotation matrix, 243
- corner points, 179
- correspondence, 123
- correspondence problem, 206, 207
- corresponding points, 123, 203
- cost function, 174
- cross product, 351
- cross product matrix, 351
- cross product operator, 351
- cross-correlation, 175

- D-normalization, 33
- data constraint, 190
- data degeneracy, 191, 209
- data error, 180
- data matrix, 36, 189
- decentering distortion, 297

- degeneracy
 - epipolar geometry estimation, 266
 - homography estimation, 209
 - method, 194
 - of data, 191
- degenerate configuration, 52
- degenerate data, 35
- degrees of freedom, 51, 190, 227
- depth, 99
- depth-of-field, 292
- descent direction, 376
- direct linear transformation, 119, 205
- directed line, 41
- direction, 45
- distibutive operation, 348
- distortion center, 298
- DL-normalization, 73
- DLT, 205
- double embedding of $SO(3)$, 159
- dual homogeneous coordinates, 32, 67
- dual line normalization, 33, 73
- dual Plücker coordinates, 49, 71
- dual transformation, 62
- duality, 50
- duality mapping, 72

- Eckart-Young (-Mirsky) theorem, 364
- ego-motion estimation, 328
- energy function, 174
- epipolar constraint, 120, 123, 128
- epipolar geometry, 123
 - degenerate, 266
- epipolar line, 126, 129
- epipolar plane, 126
- epipolar points, 125
- epipoles, 125
- equation of the line, 22
- equation of the plane, 25
- equilibrating transformation, 219
- equivalent cameras, 115
- error function, 174
- essential matrix, 123, 141
 - estimation
 - robust, 284
 - internal constraint, 142
- estimation
 - camera matrix, 223
 - epipolar geometry, 255
 - fundamental matrix, 262
 - homography, 203
 - introduction, 173
 - MAP, 199
 - maximum a posteriori probability, 199
 - rigid transformation, 245
 - rotations, 241
 - transforamtions, 203
- Euclidean geometry, 15
- Euclidean reconstruction, 136
- Euler angles, 162
- exterior orientation, 107, 245
- external camera parameters, 107

- feature point, 179
- FET, 296
- field of view, 121
- field of view model, 296
- fish-eye lens, 292
- fish-eye transform, 296
- focal length, 96
- focal point, 94
- forward interpolation, 311
- FOV, 296
- full rank pseudo-inverse, 353
- fundamental matrix, 123, 128
 - camera matrices from, 132
 - estimation, 262
 - robust, 283
 - internal constraint, 128

- Gauss-Newton method, 380
- general configuration, 52
- geometric distortion, 292
- geometric objects, 29
- gimbal lock, 169
- gold standard method, 268

- H-normalization, 219
- hand-eye calibration, 245
- Hartley normalization, 219
- homogeneous coordinates, 17, 28, 30, 65
- homogeneous method, 196
- homogeneous representation, 22
- homography, 85
- homography estimation
 - degeneracy, 209
 - robust, 282
- homography group, 87
- homography transformation, 85
- hybrid method, 380

- ICP, 247
- ideal data, 180
- ideal point, 16, 45
- identity element, 348
- identity rotation, 150
- IID, 181
- image coordinate system, 103
- image coordinates, 94
- image mosaic, 306

- image mosaicking, 306
- image plane, 94
- image point, 94
- incidence relations, 34
- incremental bundle adjustment, 328
- independent and identical distributions, 181
- indeterministic estimation method, 275
- inhomogeneous method, 193
- inliers, 183, 272
- inner derivatives, 230
- intercept, 24
- interest point, 179
- interior orientation, 107
- internal camera parameters, 107
- internal constraint, 190
 - essential matrix, 142
 - fundamental matrix, 128
 - normalized camera matrix, 101
 - of a rotation representation, 150
 - Plücker coordinates, 72
 - rotation matrix, 148
- invariances, 51
- inverse Cayley transform, 157
- inverse of a quaternion, 350
- involution, 59
- iterative closest point, 247

- Jacobian, 379
- Jacobian mask, 340, 384

- keystone effect, 88

- L-normalization, 70
- L_1 error, 185
- L_2 error, 185
- left inverse, 354
- left singular vectors, 357
- lens distortion, 292
- lens distortion function, 293
- lens effect, 292
- Levenberg-Marquardt method, 380
- likelihood, 200
- line at infinity, 46, 69
- line normalization, 70
- linear transformation, 347

- MAP, 199
- matrix exponential function, 366
- matrix logarithm, 367
- max-error, 186
- maximum a posteriori probability, 199
- Maximum Likelihood estimation, 200
- maximum likelihood estimation, 200
- mean, 175
- measurement error, 180
- measurement noise, 113, 180
- method degeneracies, 261
- method degeneracy, 194, 209
- mid-point method, 256
- minimal case estimation, 208
- minimal case of model estimation, 191
- minimal parameterization, 106, 132
- ML-estimation, 200
- model error, 181
- model estimation
 - minimal case, 191
 - over-determined case, 192
 - under-determined case, 191
- model parameters, 175, 189
- Moore-Penrose inverses, 354
- motion stereo, 125

- nearest neighbor interpolation, 113, 312
- Newton's method, 378
- non-linear optimization, 184, 375
- normalization constraint, 190
- normalized 8-point algorithm, 264
- normalized camera, 99
- normalized camera matrix, 100, 101
 - internal constraint, 101
- normalizing transformation, 216, 219

- objective function, 174
- observation, 179, 180
- omni-directional camera, 306
- one-first enumeration, 112
- OPP, 362
- optical axis, 96
- optical center, 94
- optical ray, 114
- optimal triangulation, 257
- orientation of a line, 44
- orthogonal Procrustes problem, 362
- outlier, 187
- outliers, 183, 272
- over-determined model estimation, 192
- over-fitting, 182

- P-normalization, 31
- P3P, 254
- panorama image, 307
- panorama stitching, 307
- parameter space, 149
- parameterization of a transformation, 52
- parametric representation, 23
- perspective n -point problem, 251
- photogrammetry, 17
- pin-cushion distortion, 295
- pinhole camera, 93, 95
- pinhole perspective, 93

- pixel coordinates, 103
- pixel density, 107
- pixel grid, 111
- pixel value, 111
- pixels, 95
- Plücker coordinates of 2D line, 48
- Plücker coordinates of 3D line, 69
 - consistent, 72
 - internal constraint, 72
- plumb bob distortion, 297
- PnP, 251
- point at infinity, 16, 44
- point cloud, 336
- point normalization, 31
- points of interest, 179, 207
- pose, 107
- pre-conditioning, 219
- principal axis, 96
- principal line, 96
- principal plane, 96
- principal point, 96
- probability density, 197
- probability density function, 180
- projection, 85
- projection line, 85, 114
- projection plane, 119
- projection point, 85
- projective elements, 346
- projective geometry, 16, 46
- projective group, 87
- projective plane, 16, 46
- projective reconstruction, 137
- projective space, 346
- projective spaces, 17
- projectivity, 85
- proper line, 69
- proper lines, 42
- proper points, 42
- pseudo-inverse, 353
 - full rank, 353
- pure quaternion, 350
- putative correspondences, 324

- quaternion, 348
 - inverse, 350
 - pure, 350
- quaternion sandwich product, 158
- quaternionic embedding of \mathbb{R}^3 , 158
- quaternionic embedding of $SO(3)$, 159

- radial distortion function, 294
- Random Sample Consensus, 276
- RANSAC, 276
- re-mapping of the residual vector, 231
- re-normalize, 215

- re-parameterization, 229
- reconstruction, 135
- rectified stereo rig, 125, 138
- rectifying homographies, 139
- reference image, 308
- registration, 247
- representative of a projective element, 345
- reprojection error, 327
- residual, 189, 379
- residual error, 175
- residual vector, 226
- right inverse, 354
- right singular vectors, 357
- rigid transformation, 55
 - estimation, 245
- rigid transformation group, 55
- robust errors, 273
- robust estimation, 271, 272
 - essential matrix, 284
 - fundamental matrix, 283
 - homography, 282
- Rodrigues' rotation formula, 151, 152
- rotation, 148
- rotation matrix
 - internal constraint, 148
- row compression, 360

- SAD, 185
- sandwich product, 84
- Schur complement, 356
- Schur complement trick, 341
- $SE(2)$, 55
- $SE(3)$, 81
- SfM, 325
- shearing, 60
- signed distance, 39
- similarity reconstruction, 137
- similarity transformations, 56
- singular value decomposition, 356
- singular values, 357
- singularity, 150
- skewing, 60
- slope, 24
- solution space, 190, 209
- SOPP, 243
- special Euclidean transformation group
 - in \mathbb{E}^2 , 55
 - in \mathbb{E}^3 , 81
- special orthogonal Procrustes problem, 243
- special QR-factorization, 372
- special SVD, 363
- SSD, 185
- SSVD, 363
- standard Plücker coordinates, 71

- step length, 376
- stereo camera, 123
- stereo rectification, 125
- stereo rig, 123, 125
- structure and motion, 325
- structure from motion, 325
- sum of absolute differences, 185
- sum of square differences, 185
- SVD, 356
- SVD profile, 211

- Tait-Bryan angles, 162
- thin-prism distortion, 297
- three-angle representation, 162
- total least squares, 177
- transfer, 130
 - of epipolar lines, 130
 - of points, 130
- translation group, 54
- trial set, 275
- triangulation, 17, 120, 125, 135, 255
- twisted pair, 166
- twisted rotations, 143, 166

- unbiased estimate, 221
- uncalibrated epipolar geometry, 123, 132
- under-determined model estimation, 191
- unique representation, 149
- unit quaternion, 350
- unperturbed data, 180

- variances, 175
- vector product, 351
- vectorization, 190, 206, 224
- virtual image plane, 99
- visibility function, 327
- visual appearance, 280
- visual odometry, 328

- Wahba's problem, 242
- world coordinate system, 100

- zero-first enumeration, 112