Index

A

A* algorithm 383
accelerometer 119
accuracy 1
action update 297
affine intensity changes 221
Aibo 31
Aircraft 52
aliasing 266, 268
Asimo (Honda) 28
Autonomous Map Building 348
averaging filter 196
averaging filters 198

B

bag of features 235
baseline 171
Bayer filter 146
Bayes rule 301
bearing sensor 151
bearing-only SLAM 355
behavior 32, 57, 58, 70, 74, 105, 107, 108, 111, 116, 128, 143, 144, 203, 208, 275, 276, 277, 278, 309, 342, 348, 370, 397, 398, 402, 411, 412, 413, 414, 415, 416, 418, 420, 421, 422
belief
  belief distributions 304
  multiple-hypothesis 278, 280, 282, 283, 296, 316, 322
  representation 12, 278, 279, 307
  single 278, 282
  single-hypothesis 278, 279, 280, 283
  state 282, 283, 287, 296, 298, 307, 308, 315, 316, 318, 319, 320, 321, 322, 323, 331, 336, 370, 371
  unique 280
belief representation 304
biped 13, 15, 20, 27, 29
blanking time 127
blob detectors 227
blooming 144, 267
blur circle 148, 149
bow leg 26, 27
breadth-first search 380
bubble band 399, 400, 401, 408
Bug 393, 394, 396, 397, 407
bundle adjustment 188

C

calibration 106, 270, 274
camera 155
  calibration 158
  center of projection 151
  central camera 161
  decentering distortion 157
  depth from focus 150
  extrinsic parameters 156
  geometry 169
  image formation 148
  image plane 151
  intrinsic parameters 156
  optical axis 151
  optics 144, 148, 149
  parameter 143, 144
  perspective projection 152
  pinhole model 150
  pixelization 154
  principal point 151
  radial distortion 156
  tangential distortion 157
camera obscura 150
catadioptric camera 159, 238, 239
caustic 163
CCD camera 102, 103, 104, 137, 143, 144, 145, 146, 211, 267, 344
center of mass (COM) 38, 39, 49
center of projection 151
central cameras 161
chassis 36, 38, 41, 43, 44, 45, 58, 59, 62, 63, 64, 65, 67, 68, 71, 73, 76, 77, 78, 79, 81, 82, 84, 85, 87, 90, 347, 396, 405, 410
cheirality constraint 186
chips 293, 419

chrominance 193
circle of confusion 148
closed-world assumption 284, 287, 290
clustering 194, 235
CMOS camera 103, 104, 137, 143, 144, 145, 146
cognition 2, 5, 10, 11, 17, 265, 267, 269, 277, 369, 417
color camera 146
color images 146
color sensing 193
color space 193
  RGB 193
  YUV 193
color tracking 192
completeness 316, 371, 375, 377, 379, 390
computer vision 142
condensation algorithms 315
conditional probability 301
configuration space 84, 290, 297, 307, 371, 372, 373, 374, 375, 387, 390, 403, 405, 406
conjugate pair 172
constraint
  rolling 64, 66, 67, 69, 70, 72, 73
  sliding 65, 67, 70, 73, 77, 81, 86
controllability 37, 38, 42, 43
convolution 197, 201, 308
corner detector 215
cornerness function 221
correlation 137, 197, 272
correspondence pair 172
correspondence problem 139, 174, 193
correspondence search
  area based 176
  feature based 176
corresponding points 170
cross-sensitivity 106, 107, 116, 128, 144, 145
curvature velocity 401, 408
cycle frequency 404
Cye 38, 39, 42, 290, 420

D

DARPA 32
dead reckoning 44, 47, 80, 116, 269, 344, 345
decomposition 287, 288, 316, 373, 376, 395, 411, 416
  approximate 290, 377, 378
  control 413, 414
  exact 284, 287, 376, 377
  fixed 288, 289, 291, 379
  parallel 415
  serial 414
  temporal 411, 412, 413, 417, 418, 422
  topological 291, 322
  variable-size 379
Deep Space One 417
degree 88
degree of freedom (DOF) 19, 20, 65, 68, 83, 88, 392
degree of maneuverability 82, 84, 87
degree of mobility 77, 81
depth from defocus 150
depth from focus 148, 149, 150, 172
depth of field 149
depth-first 382
Dervish 233, 316, 317, 318, 319, 320, 321, 322, 336
descriptor 230
differential degrees of freedom (DDOF) 85, 87
differential drive 39, 40, 61, 62, 73, 74, 78, 79, 81, 82, 83, 87
digital camera 142
Dijkstra's algorithm 382
dioptric camera 159
Dirac delta 304
disparity 139, 170, 171, 172
doppler 104, 140, 141
dynamic
  range 103, 105, 144, 145
  thresholding 205
dynamic stability 17
dynamic window 402, 403, 404, 408

E

edge detection 199, 200, 205
  Canny 200
  Prewitt 203, 204
  Roberts 203
  Sobel 204
effector noise 269
eight-point algorithm 184

elastic band 399, 408
encoder 269, 272, 298, 307, 317, 320, 322, 332, 347, 376, 417
capacitive 104
inductive 104
magnetic 104
optical 104, 115, 116
quadrature 103, 115
epipolar constraint 170, 183
epipolar geometry 164
epipolar line 170, 173
error
deterministic 106, 108, 269, 270, 274
nondeterministic 270, 272, 274, 298
random 106, 107, 108, 109, 111, 139, 144, 267, 268
systematic 106, 107, 108, 109, 116, 117, 270
error propagation law 109, 114, 272, 334
essential matrix 183
eight-point algorithm 184
five-point algorithm 184
executability 375
executive 418, 419, 420, 421, 422
expectation-maximization 256
Extended Kalman filter 324, 327
exteroceptive 101, 104, 106, 107, 116, 123, 297

F

FAST corner 226
feature 101, 111, 137, 199, 205, 206, 209, 210, 212, 213, 238, 239, 242, 243, 248, 260, 261, 267, 284, 285, 286, 287, 291, 293, 294, 295, 318, 319, 331, 332, 335, 338, 340, 351
feature detector 213
feature extraction 11, 208, 210, 211, 242, 248, 260, 319, 320, 332, 336, 420
features 212
affine invariance 224
blob detectors 227
C/C++ and Matlab code 234
corner detectors 215
descriptor 230
distinctiveness 213
FAST corner detector 226
GPU and FPGA implementations 233
Harris corner detector 216
invariance 220
Moravec corner detector 215
MSER detector 232
properties 213
repeatability 213
scale invariance 222
Shi-Tomasi corner detector 225
SIFT detector 227
SURF detector 232
SUSAN corner detector 225
feedback control 92
field 397
fingerprint image 209, 241
fisheye lenses 159
floor plane extraction 194, 195, 212
flux gate 116, 117
forward kinematic 58, 73
forward kinematics 61
framegrabber 146
frequency 105, 119, 127, 128, 130, 140, 141
Frobenius norm 184

G

gait 16, 19, 20, 21, 29, 31
Gaussian 108, 109, 111, 112, 113, 199, 200, 201, 202, 239, 244, 282, 283, 297, 324, 331, 333, 336
Gaussian filter 199
Genghis 34
GIST descriptor 240
global image feature 238
global localization 306
global positioning system (GPS) 122, 123, 124, 266, 295, 346
differential (DGPS) 124
pseudorange 124
GPU 233
gradient
convolution 201
covariance 114
edge detection 203, 204, 205, 241
intensity 199
optical flow 191
potential field 386
wavefront 405
gradient method 405

graph-based SLAM 361
grassfire 381, 404, 420
Great Flight Diagram 50
grid localization 343
gyroscope 116, 118, 269
  mechanical 118
  optical 119
H
Haar wavelets 232
Hall effect compass 117
Harris corner detector 216
  cornerness function 218
  scale and affine invariance 220
heap 382
hexapod 33
histogram 239
  angle 260, 345
  color, image 239, 241
  polar 398
  range 259
  vector field 397
holonomic 44, 85, 86, 87, 372, 399, 406, 409
homogeneous coordinates 153
hopping
  bow leg 27
  Raibert 26
  Ringrose 27
  single leg 26
Hough transform 205, 206, 241, 256
hypothesis
  multiple 278, 280, 282, 283, 286, 296, 316, 322
  single 278, 280, 283, 286
I
image buffer chip 146
image filtering 196
image fingerprint 240
Image formation 148
image histogram 241
image histograms 239
image plane 151
image processing 142
incremetal 251
inertial measurement unit (IMU) 121
inertial navigation system (INS) 121
instantaneous center of rotation (ICR) 77, 78
integral images 232
intrinsic parameter matix 155
Invariance 215
inverse kinematics 49
inverted file 236
iris 144, 149, 169
Iterative-End-Point-Fit 250
J
Jacobian 95, 114, 248, 273, 335, 339
K
Kalman filter 12, 282, 283, 297, 298, 299, 322, 323, 324, 331, 332, 336, 342
kernel 197, 203
kidnapped robot problem 306, 307
Kinect camera 139
kinematic 17, 35, 57, 58, 63, 68, 74, 79, 84, 94, 405, 407
  analysis 90
  constraints 58, 63, 71, 77, 78, 80, 82, 84, 85, 86, 87, 401, 402, 405
  control 91
  forward 58, 61, 73
  inverse 49
  limitations 398
  motion 77, 371
k-means 194, 235
L
lane curvature 402, 408
Laplacian 192
laser rangefinder 103, 106, 111, 125, 129, 133, 137, 169, 210, 336, 338, 375, 410
least-square 243, 244, 245, 246
lidar (light detection and ranging) 129
line extraction 244, 248, 286, 338
line fitting 243
line regression 250
linear filter 196
linearity 105, 144
localization 2, 5, 11, 115, 122, 265, 267, 268, 275, 277, 278, 282, 285, 291, 293, 294, 295, 297, 299, 344, 345, 409
  beacon 346
  control 410

global 345
Kalman filter 12, 297, 298, 299, 322, 324, 332, 336, 342
landmark-based 344
Markov 12, 297, 298, 299, 307, 309, 316, 318
probabilistic 297
representation 278
route-based 347
sensor 124, 125, 193, 239, 261, 295, 375
localization and mapping (SLAM) 418
location recognition 234
locomotion 13, 14, 16, 17
biological 14
biped 15
legged 17, 19, 25
mechanism 14, 49, 295
specific power 15
wheeled 35, 47
loop detection 351
lowpass filters 198

M

Mahalanobis 335, 340
maneuverability 35, 37, 38, 42, 44, 46, 47, 48, 58, 73, 77, 82, 84, 87
manipulator 1, 57, 371
Markov assumption 309
Markov localization 297, 298, 299, 307, 309, 316, 331
mask 197
matching 170, 176, 190, 207, 215, 227
NCC 207
SAD 207
SSD 207
stereo 176
mean square 110
measurement update 297
MEMS 120
minimum energy algorithm 241
mobility 2
monocular Visual SLAM 355
Monte Carlo 315
Monte Carlo localization 343
motion control 91, 92, 265, 275, 417
motion field 189, 190
motorization 90
MPEG 146
MSER detector 232

N

Nanokhod 47
navigation
behavior-based 275, 276, 277, 416
landmark-based 293, 344, 345
map-based 265, 277, 278
navigation architecture 369, 410, 411, 413, 418, 419, 422, 423
navigation competence 12, 369, 411
NCC 207
nearness diagram (ND) 405
NF1 381, 404, 406, 409
Nomad XR4000 40, 46
nonholonomic 85, 86, 87, 91, 372, 392, 397, 399, 406, 407, 409, 410
nonintegrable 85
nonlinearity 117
non-maxima suppression 202, 218
normal distribution 112
Normalized Cross Correlation 207

O

obstacle avoidance 150, 169, 172, 192, 208, 369, 393, 394, 396, 397, 398, 401, 402, 404, 405, 406, 409, 415, 417
occupancy grid 208, 211, 281, 289, 290, 291, 294, 397, 404, 420
omnidirectional 36, 38, 39, 40, 41, 42, 44, 45, 46, 68, 70, 71, 73, 75, 81, 87, 88, 404
omnidirectional camera
central 161
model 164
single effective viewpoint property 161
unified model for catadioptric and fish-eye cameras 168
unified model for catadioptric cameras 165
online SLAM 352
OpenCV 234
optical
flow 189, 190, 191, 192
flow constraint 191
gyroscope 119
radar 129

triangulation 125, 136, 137
optical axis 151
optical center 151
optics 148
orthogonal rotation matrix 59

P

particle filter 315
path planning 275, 369, 371, 373, 375, 386, 404, 409, 417
perception update 297, 319, 320, 344
Personal Rover 49
Perspective projection 152
pinhole 149, 151
Pioneer 4, 7
Place Recognition 234
planning
deferred 420
episodic 420, 421
integrated 370, 422, 423
Plustech 2, 3
polydioptric camera 159
pose 19, 57, 59, 64, 69, 81, 84, 85, 88, 90, 107, 267, 270, 274, 275, 295, 297, 342, 344
position tracking 306
position-sensitive device (PSD) 136, 138
potential field 386, 388, 389, 390, 396
extended 390, 391
rotation 390
task 390, 391
precision 1, 106, 107, 284, 299, 330
prediction 304
prediction update 297
preprocessing 199, 200, 239
principal point. 151
probability density function 109, 110, 111, 112, 282, 298, 316, 322
probability density functions 299
proprioceptive 101, 103, 104, 115, 116, 269, 297
Pygmalion 79, 336, 421

Q

quaternions 357

R

Radial distortion 156
Raibert 26
Random Sample Consensus 252
random variable 111, 112, 113, 243, 244
randomized sampling 315
range 103, 105, 107, 117, 125, 127, 128, 129, 130, 131, 132, 136, 137, 139, 141, 144, 169, 208, 259
rank 79, 80, 82
RANSAC 252
Rao-Blackwellized particle filters 363
Rapidly Exploring Random Trees 386
reference frame
global 58, 59, 60, 61, 63, 65, 86
inertial 118
local 61, 64, 65, 73, 74, 75, 76, 79, 107, 333
moving 294
resolution 105, 115, 117, 139, 269, 322, 378
RGB 193
road map 375, 376
Robox 5
rolling constraint 64, 66, 69, 70, 72, 73, 75, 76, 77, 86
rotation matrix 59, 60

S

SAD 207
Sagnac effect 119
saturation 144, 239
Scale invariant detection 222
Schlegel 404, 409
segmentation 248, 261
sensitivity 106, 145, 149, 239
sensor aliasing 268
sensor fusion 193, 268, 295, 296, 322, 331, 401, 404
sensor noise 267, 268, 280, 318
Shi-Tomasi corner 225
Shrimp 48, 49, 181
shutter 144, 149
Sick laser scanner 131, 133, 410
SIFT 212, 215, 227, 234
similarity measure 176
single effective viewpoint property 161
Singular Values Decomposition 184
SLAM 348, 349
Extended Kalman Filter SLAM 353
full SLAM problem 352
graph-based SLAM 361

Mathematical definition 351
sliding constraint 65, 67, 70, 72, 73, 74, 77, 79, 80, 81, 83, 86, 87
Smoothing filter 198
smoothing filter
filters 198
Gaussian filter 199
median filter 198
Sojourner 48
Sony Aibo 31
Sony Dream Robot (SDR-4X II) 28
Split-and-merge 249
Spring Flamingo 29, 30
SSD 207
stability 17, 35, 37, 38, 42, 43, 49, 87
motion controller 98
static 19, 26, 33, 38
standard deviation 107, 110, 111, 112, 113, 241, 282
steering
Ackermann 42, 44, 78
slip/skid 47, 80
stereo camera 153
stereo vision 108, 138, 169, 170, 171, 172, 193, 241
stereopsis 170
Structure from Motion 180
Sum of Absolute Differences 207
Sum of Squared Differences 207
SURF detector 232
SUSAN corner 225
synchro drive 39, 43, 44

T

teleoperated 2
theorem of total probability 301
tiered architecture 417, 418, 419
time-of-flight 104, 125, 126, 129
time-of-flight camera 135
topological 210, 279, 280, 281, 283, 291, 292, 293, 294, 295, 299, 316, 317, 318, 320, 321, 322, 373, 421
Tribolo 39, 45
two-steer 82, 83, 87, 90

U

ultrasonic beacon 346
ultrasonic sensor 103, 125, 126, 127, 128, 129, 133, 268, 319, 375, 410
Unscented Kalman Filter 343
unscented transform 343
up to a scale reconstruction 172
Uranus 38, 40, 43, 45, 46

V

variance 110, 111, 244, 245, 272, 330, 333, 336
vector field 397, 407
Vector Field Histogram (VFH) 407
vector field histogram (VFH) 397
velocity space 84, 401, 403
visibility graph 373, 374, 375
vision-based sensing 104, 145, 194, 210, 238, 245, 267, 293
visual odometry 187
Visual SLAM 356
visual vocabulary 235
visual words 235
vocabulary tree 235
Voronoi diagram 374, 375, 376
VTOL 52

W

Wabian 29, 30
wavefront 381, 405, 409
wavefront expansion algorithm 381
well depth 144
wheel
castor 36, 37, 38, 41, 42, 46, 66, 67, 68, 71, 79, 87
spherical 36, 38, 39, 41, 44, 45, 70, 71, 81, 83, 87
standard 36, 41, 64, 65, 66, 67, 68, 71, 72, 73, 75, 77, 79, 80, 81, 82, 83, 85, 86, 87
Swedish 36, 38, 39, 41, 42, 44, 45, 68, 69, 70, 71, 74, 75, 76, 79, 81, 83, 85, 87
white balance 147
workspace 16, 57, 63, 77, 84, 85, 86, 87, 88, 90, 266, 288, 372, 405, 406

Y

YUV 193

Z

zero motion line 77