Index

1-ring neighborhood 203
2D digital filter 31
2-manifold 201
3D Gaussian filters 257
3D SIFT 264

*a priori* information 299
abdominal scans 184
active appearance models (AAM) 417, 436, 440, 448
active contours 3, 275, 316
formulations 318
active shape models (ASM) 417, 448
admissible functions 347
affine 348
affine intensity transformations 234
affine-invariant 221, 223
affine tangent 280
affine transformation 245, 280, 352, 369
albedo model 444
albedo recovery 445
alignment 346, 361
amplitude-sampling 10
analog signal 10
anisotropic 353
anisotropic diffusion filtering 33
anisotropic Gibbs energy function 148
anisotropic model 146
anisotropic pairwise interaction model 149
arc-length 279
area 201
artificial markers 368
ASIFT 213, 239
autocorrelation 100
autocorrelation function 118
autobinomial model 147, 157
autocovariance function 120
average 91
axial planes 369
axioms 80

band-limited signals 10
bandpass filter 33
band-reject filters 33
bandwidth 18, 24, 67, 166
barycentric coordinates 201
biased estimator 167
basis functions 190, 191
Bayes’ rule 328
Bayesian maximum-*a-posteriori* (MAP) 301
Bayesian network 137
Bernstein polynomials 191, 192
bimodal image segmentation 342
binomial theorem 192
biological tissue 9
biomedical images 300
blood vessel segmentation 312
Boolean operators 186
Borel sets 85
boundary 185
Bremsstrahlung 41

Canny edge detector 215, 221
canonical orientation 262, 263
Cartesian space 190
categories 213
Cauchy theorem 31
causality 232
centroid 362
Chan and Vese model 319, 342
Chapman–Kolmogorov theorem 139
characteristic function 93
Chebyshev inequality 91
circular convolution 28, 29
classical deformable model 279
coding patterns 154
collimators 44, 50
composite product 359
computational geometry 183, 204
computed tomography (CT) 3, 14, 39, 43, 47, 369, 436, 444
<table>
<thead>
<tr>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>computer-aided design 185, 341</td>
</tr>
<tr>
<td>computer-assisted diagnosis 2, 3, 4</td>
</tr>
<tr>
<td>computer vision 3, 4, 213</td>
</tr>
<tr>
<td>computer-assisted radiology and surgery 5</td>
</tr>
<tr>
<td>conditional entropy 374</td>
</tr>
<tr>
<td>conditional probability 81, 145</td>
</tr>
<tr>
<td>conditional probability decomposition 149</td>
</tr>
<tr>
<td>congruence 186, 187</td>
</tr>
<tr>
<td>conservation law 287</td>
</tr>
<tr>
<td>constructive solid geometry (CSG) 186</td>
</tr>
<tr>
<td>continuous domains 85</td>
</tr>
<tr>
<td>continuous-time signal 10</td>
</tr>
<tr>
<td>contours 275, 282, 435</td>
</tr>
<tr>
<td>control points 191</td>
</tr>
<tr>
<td>convolution 101, 236</td>
</tr>
<tr>
<td>corners 215, 217</td>
</tr>
<tr>
<td>coronal planes 369</td>
</tr>
<tr>
<td>correlation coefficient 100, 423</td>
</tr>
<tr>
<td>correlation ratio 354</td>
</tr>
<tr>
<td>correspondences 225, 360</td>
</tr>
<tr>
<td>covariance 420</td>
</tr>
<tr>
<td>covariance matrix 260, 426</td>
</tr>
<tr>
<td>cross-correlation function 120</td>
</tr>
<tr>
<td>cross-multiplication, 37</td>
</tr>
<tr>
<td>cross product 189</td>
</tr>
<tr>
<td>cross-spectral density function 125</td>
</tr>
<tr>
<td>crucial landmarks 428</td>
</tr>
<tr>
<td>C-SIFT 240</td>
</tr>
<tr>
<td>cuboids 186</td>
</tr>
<tr>
<td>cumulative probability distribution function 85</td>
</tr>
<tr>
<td>curvature 202, 208, 279, 281, 287, 289, 417</td>
</tr>
<tr>
<td>curves 183, 191, 193, 196, 207, 279</td>
</tr>
<tr>
<td>curve parameterization 190</td>
</tr>
<tr>
<td>curve/surface 279</td>
</tr>
<tr>
<td>curve/surface modeling by level sets 326</td>
</tr>
<tr>
<td>curvedness 198, 199</td>
</tr>
<tr>
<td>cutoff frequency 18</td>
</tr>
<tr>
<td>cyclic ordering 200</td>
</tr>
<tr>
<td>databases 213</td>
</tr>
<tr>
<td>deformable objects 257</td>
</tr>
<tr>
<td>deformable models 3, 275, 286</td>
</tr>
<tr>
<td>snake model 282</td>
</tr>
<tr>
<td>deformation 184</td>
</tr>
<tr>
<td>delta and Heaviside functions 320</td>
</tr>
<tr>
<td>density 176, 177</td>
</tr>
<tr>
<td>density estimator 163</td>
</tr>
<tr>
<td>Derin–Elliott model 150</td>
</tr>
<tr>
<td>derivatives 217, 223</td>
</tr>
<tr>
<td>detectors 44</td>
</tr>
<tr>
<td>deterministic function 112</td>
</tr>
<tr>
<td>DICOM 17</td>
</tr>
<tr>
<td>difference of Gaussians (DOG) 222, 236</td>
</tr>
<tr>
<td>differentiable functions 193</td>
</tr>
<tr>
<td>differential geometry 203</td>
</tr>
<tr>
<td>diffusion equation 232</td>
</tr>
<tr>
<td>diffusion filters, 36</td>
</tr>
<tr>
<td>digital signal 10</td>
</tr>
<tr>
<td>Dirac delta function 11, 14, 15</td>
</tr>
<tr>
<td>directional derivative 23</td>
</tr>
<tr>
<td>discrete Fourier transform (DFT) 16, 23, 24</td>
</tr>
<tr>
<td>discrete random variable 83</td>
</tr>
<tr>
<td>discrete-time signal 10, 18</td>
</tr>
<tr>
<td>disjoint events 80, 81</td>
</tr>
<tr>
<td>dissimilarity measure 346</td>
</tr>
<tr>
<td>distance 189</td>
</tr>
<tr>
<td>distance function 291, 322</td>
</tr>
<tr>
<td>distance transform 342</td>
</tr>
<tr>
<td>distance-based rigid registration 345</td>
</tr>
<tr>
<td>distribution 163</td>
</tr>
<tr>
<td>mean 170</td>
</tr>
<tr>
<td>variance 170</td>
</tr>
<tr>
<td>Doppler shift 59, 61</td>
</tr>
<tr>
<td>edges 199, 217</td>
</tr>
<tr>
<td>edge-based regions (EBR) 221</td>
</tr>
<tr>
<td>eigenvalues 219, 355, 356, 366, 420, 421, 426, 432</td>
</tr>
<tr>
<td>eigenvalue decomposition 426, 432</td>
</tr>
<tr>
<td>eigenvectors 356, 366, 420, 421, 426, 432</td>
</tr>
<tr>
<td>Eikonal equation 322</td>
</tr>
<tr>
<td>elastic registration 324, 345</td>
</tr>
<tr>
<td>electronvolt 40</td>
</tr>
<tr>
<td>elementary outcomes 80</td>
</tr>
<tr>
<td>Elliott model 149</td>
</tr>
<tr>
<td>ellipse 224</td>
</tr>
<tr>
<td>EM algorithm 171, 172, 175, 178, 179, 303</td>
</tr>
<tr>
<td>empty set 80</td>
</tr>
<tr>
<td>entropy 66, 164, 223</td>
</tr>
<tr>
<td>epipolar lines 347</td>
</tr>
<tr>
<td>equi-affine 280</td>
</tr>
<tr>
<td>equivalence 187, 188</td>
</tr>
<tr>
<td>ergodicity 123</td>
</tr>
<tr>
<td>estimation 163, 179</td>
</tr>
<tr>
<td>estimator 170, 172</td>
</tr>
<tr>
<td>Euclidean distance 184, 279, 323, 336, 361</td>
</tr>
<tr>
<td>Euclidean norm 202</td>
</tr>
<tr>
<td>Euler angles 357</td>
</tr>
<tr>
<td>Euler equation 275</td>
</tr>
<tr>
<td>Euler formula 12</td>
</tr>
<tr>
<td>Euler transform 352</td>
</tr>
<tr>
<td>Eulerian formulation 286, 289</td>
</tr>
<tr>
<td>Eulerian framework 324</td>
</tr>
<tr>
<td>Euler–Lagrange formulation 275, 276, 277, 278, 292, 337</td>
</tr>
<tr>
<td>expectation 172</td>
</tr>
<tr>
<td>exponential value 91</td>
</tr>
<tr>
<td>exponential 165, 168</td>
</tr>
<tr>
<td>extended LBP 245</td>
</tr>
<tr>
<td>extrema 223, 224</td>
</tr>
<tr>
<td>false positive 240, 255</td>
</tr>
<tr>
<td>fast Fourier transform (FFT) 16, 24, 25, 28, 29, 36, 38, 164</td>
</tr>
</tbody>
</table>
features 213
feature descriptor 213, 237
filament 40
finite differences 283
finite elements 283
finite-impulse response (FIR) 31
first fundamental forms 197
floating volume 377
Fourier descriptors 424
Fourier methods 9
Fourier representation 17, 21
Fourier series 11, 12, 13, 21
Fourier transforms 11, 13, 14, 16, 31, 38, 46, 123
frequency spectrum 17
gamma distribution 168
Gaussian distribution 165, 168, 173, 198, 215, 217, 297, 302, 420
Gaussian curvature 203, 281
Gaussian intensity probability density function 327
Gaussian kernels 223, 232, 233, 236, 314
Gaussian model 320
Gaussian random variable 372
Gaussian weights 262
generalized Procrustes analysis (GPA) 419, 444
geodesics 281
godesic curvature 281
gestures 184
Gibbs distribution 305
Gibbs energy 144
Gibbs energy function 304
Gibbs models 141
Gibbs phenomena 37
Gibbs probability distribution 304
Gibbs sampler 149
global features 215
global registration 369, 419, 435
global shape registration 448
global transformation 352
gradient 283
gradient descent 369
approach 339
flow 278
vector-valued 318
gradient magnitude 262
gradient orientations 261, 262, 263, 264
graph 184, 190
graph cuts approach 314
optimal segmentation 305
gray-level
histogram 297, 298, 308
image 301
intensity distributions 298
marginal density 302
probabilistic model 305
Grossmann space 190
Haar wavelet 241
Hamilton–Jacobi 289
equation 287, 290
partial differential equation (PDE) 275
harmonic projection 443, 444
Harris 215, 217, 218
Harris corner 221
Harris–affine 219, 221
Harris–Laplace 219, 221
Heaviside functions 286, 318, 337
step function 337
Helmholtz hemispherical harmonics 441, 443
Hessian detector 221, 223
Hessian–affine 221, 223, 225
Hessian–Laplace 221, 223
hidden Markov model 140
higher-order derivatives 234
high-pass filter 33, 37
histograms 164, 214, 237
homogeneous coordinate system 190, 349
homography 347
homologous points 346
human brain 184
human colon 264
human jaw 4, 204, 441, 446
reconstruction of 441
hyperbolic conservation laws 290
hyper-pyramid 260
ICM algorithm 308
ICP algorithm 355
illumination 431
image analysis 275, 345
image modelling 299
image processing 299
image reconstruction 9
image segmentation 297, 299, 316, 320, 329, 342
image warping 428
image-guided interventions 345
imaging modalities 1, 366
implicit surface 286
independent random variables 170, 175
independent events 81
independent variables 109, 276
infinite-dimensional problem 276
infinite impulse response (IIR) 31
influence 203
information theory 371
initial condition 232
input signal 10
integral images 241
intensity-based image registration 345
intensity-based regions 223
intensity-based segmentation 336
internal energy 282
interpolation 190
inverse Fourier transforms 13, 38, 46
inverse mapping 83
inverse z-transform 31
isometries 183
isotropic scaling 353
iterated closest point 345
Jacobian 102
jaw see under human jaw
joint events 80
joint density estimation 382
joint distribution 301
joint entropy 374
joint Poisson distribution 110
joint probability 82
joint probability density function 373
joint probability distribution 107
jointly Gaussian 110
junction/corner 235
juxta-pleural nodules 334, 437, 439
Kendall’s shape definition 417
kernel density estimator 166
kernel-based techniques 166
keypoint 236
k-nearest neighbors 163
k-NN approach 168
Kolmogorov consistency conditions. 113
Kulback–Leibler distance 354
Lagrangian formulation 275
Lambertian counterpart 448
Laplacian 221
laser imaging, 39
LCG model 175
least square error (LSQR) 304
Leibnitz’s rule 276
level-set 275, 284, 286, 287, 291, 316, 318
approaches 316
framework 326
function 291, 292, 328, 336, 337
methods (LSM) 2, 3, 275, 316
methods
segmentation algorithm with shape prior 338
linear combination of Gaussians model (LCGM) 172, 173
linear convolution 29
linear discriminant analysis (LDA) 241
linear model 174
local binary pattern (LBP) 216, 241, 244, 245
local feature 213
localization 235, 236
local feature 213
low-dose CT (LDCT) 245
low-pass filter 18, 33
lung cancer 238
lung nodules 4, 417, 437
segmentation 334
machine learning 345
magnetic resonance angiography (MRA) 312, 332
magnetic resonance imaging
DCE-MRI 311
MRI 3, 9, 39, 64, 67, 70, 184, 366
Mahalanobis distance 264
marginal densities 175, 179
marginal probability distributions 97
Markov random field 137
Markov–Gibbs random field (MGRF) 297, 304, 314
mathematical domain 9
mathematicians 184
MATLAB 419, 421, 430, 432
maximally stable extremal regions (MSER) 223, 225
maximization (EM) 164, 171, 173
maximum-a-posteriori (MAP) 297
MAP image 314
maximum entropy-based method 148
maximum likelihood 164, 297
maximum likelihood estimator (MLE) 169, 171, 176, 177, 178, 303
mean 198, 420
mean shape 428
mean curvature 204
mean shift algorithm 308
medial axis 424
medical image analysis 5
medical image modalities 354
Medical Imaging, Computing and Computer-Assisted Intervention (MICCAI) 5
meshes, polygonal 199, 200
Metropolis algorithm 151
mixture-density 174
moment 93
monotonic 234
MRI see under magnetic resonance imaging
M-SIFT 240
multidimensional object 275
multimodal registration 354
multiple sclerosis (MS) 366
multi-scale 225, 229
multivariate kernel 166
Mumford–Shah energy formulation 318
mutual information 4, 345, 357, 377
computation 384
metric 376
mutually disjoint events 80
neighborhood 199, 213, 223
n-manifold 200
Nobel prize 39, 43
Index

nuclei 238, 239
nodule classification 334
nodule segmentation 339
non-adjacent segments 200
non-convex functions 278
non-invasive imaging 366
non-parametric 163, 166
non-rigid registration 446
norm 10, 197
normalization 230
normalized cross-correlation (NCC) 439
normalized event 91
n-space 188
nuclear medicine 3
numerical algorithm 290
numerical methods 287
numerical simulation of snakes 283
Nyquist rate 18
objects 213
object modelling 159
object recognition 345
objects-of-interest 175
occurrences 79
optimization 347
oral cavity 257
orientation 236, 237
orthogonal direction 217, 219
orthonormal basis 202
orthonormal coordinate 234
outcomes 79
output signal 10
panoramic view 251
parallelograms 183
parametric methods 163
parametric curves 191, 194, 275
parametric deformable models 284
parametric representation 190
parasagittal planes 369
Parzen 167, 168, 172
Parzen density 163
partial differential equations (PDE) 3, 284
partition function 144
patch 195, 196
pedestrians 215
perpendicular vectors 189
photometric features 213
photometric transformations 224, 225
photons 41
piecewise affine warping 428
piecewise linear 183
pixel 175
planar curves 279, 281
Planck’s constant 40
plane 190
pleural-tail nodules 334, 437, 439
point correspondences 346, 361
point cloud 203
point detection 215
point-based representation 184, 185
Poisson distribution 92
polygons 183, 200
positivity 229
positron emission tomography (PET) 39, 51, 52
posterior probability 303
post-repair 446
potential functions 145
power spectral density function 124
pre-repair 446
primitives 186
principal component analysis (PCA) 241, 419, 420, 421, 423, 425, 428, 448
principal component regression (PCR) 446
principal curvatures 204
prions 164
prior estimate 303
prior probability 327
prisms 186
probabilistic models 137
probability 80, 163
probability density function (PDF) 85, 163
probability distribution 354
probability space 107
process 163
Procrustes registration 418
Procrustes distance 418
product 197
projective transformation 246
prone scans 264
pseudo-landmarks 417
psychologists 184
pyramids 229, 230
quad-tree 225
quantization 16
quaternions 357, 365
radiation dose 41, 47
random field 131, 163
random field models 299
random process 79, 109, 131
random variable 94, 131, 373
RANSAC 240, 255
Rayleigh 165
real space 188
realizations 107
receiver operating characteristics 440
reference volume 376
reflexivity 188
region of convergence 30, 31
root mean square 446
registration 1, 2, 3, 4, 216, 275, 345
repeatability 225
Index

re-scaling 234
retrieval 213
right-hand orthonormal 202
rigid registration 345
rigid shapes 184
robot 171, 213
robustness 235
rotation 216, 279, 351
rotation invariance 233, 262, 263
rotation matrix 351
rubber-sheet geometry 186
sagittal plane 369
saliency 223
salient region 223
sample 165, 177
sample space 79
scalar multiplication 189
scalar product 197
scale 216, 221
scale-invariant 232
scale-space 232, 233, 236
scaling 349
scout images 368
second moment matrix 217
second-order derivatives 222
segmentation 1, 3, 4, 175, 275, 297, 298, 299, 300, 310, 312, 313, 316, 329, 336, 339
segmentation algorithm 314
segmented image 327
self-dissimilarity 223
sensor 1, 9, 39
sequence Fourier series (SFS) 18, 20, 21, 446
Shannon entropy 354
shape alignment 337
shape contour 338
shape from shading (SFS) 257
shape index 198, 199
shape models 2, 4, 325
shape modelling 322
shape priors 341
shape representation 324, 347
shape representation 183, 184, 205, 322
shape space 418
shape-based segmentation 324
shapes index 183, 204
SIFT 213, 216, 235, 236, 237, 239
sign distance 339
sign square distance 424
signal-to-noise ratio 47, 308
signals and systems 2, 9
simulated annealing 314
simulation of random variables 103
single photon emission computed tomography (SPECT) 51, 52
singular value decomposition (SVD) 250
singularities 234
smoothed signal 234
smoothly varying intensity 235
source 246, 345, 346
spatial interaction 313
spatial sampling 232
spatial support 215
spinal imaging 4
standard deviation 100
statistical approach 297
statistical experiments 79
statistical methods 1
statistical models 417
statistical appearance models 428
stereo 213
stiffness matrix 283
stitch segments 245, 252
stochastic approaches 299
stochastic expectation maximization algorithm (SEM) 327
stochastic process 113
stochastic system identification 163
sum squared distance (SSD) 418, 421
supine scans 264
SURF 213, 241
surface 193, 195, 196, 199, 205, 207
surface normal 281
surface registration 355
surface tangential vector 281
symmetric probability density 129
symmetry 188, 230
synthesis process 149
synthetic images 306
2D multimodal 307
tangent 279
tangent vector 279
target 246, 345, 346
taylor series 276
tensor product surfaces 194
texture 183
thermal infrared imaging 39
tensor 9
thin-plate splines 428, 429, 445, 446
warping 431
time average 121
time-sampling 10
topology 183, 204
total probability theorem 82
tracking 345
<table>
<thead>
<tr>
<th>Term</th>
<th>Page Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>transformation</td>
<td>221, 223</td>
</tr>
<tr>
<td>transition probabilities</td>
<td>139</td>
</tr>
<tr>
<td>transitivity</td>
<td>188</td>
</tr>
<tr>
<td>translation</td>
<td>216, 279, 349</td>
</tr>
<tr>
<td>translation-invariant</td>
<td>233</td>
</tr>
<tr>
<td>translational motion</td>
<td>45</td>
</tr>
<tr>
<td>trilinear interpolation</td>
<td>377</td>
</tr>
<tr>
<td>two-component mixture</td>
<td>172</td>
</tr>
<tr>
<td>two-dimensional signals</td>
<td>10</td>
</tr>
<tr>
<td>ultrasound imaging</td>
<td>3, 39, 53, 59</td>
</tr>
<tr>
<td>uniform distribution</td>
<td>101, 165, 372</td>
</tr>
<tr>
<td>unimodality</td>
<td>229</td>
</tr>
<tr>
<td>unit step function</td>
<td>11</td>
</tr>
<tr>
<td>University of Pennsylvania</td>
<td>39</td>
</tr>
<tr>
<td>University of Würzburg</td>
<td>39</td>
</tr>
<tr>
<td>variance</td>
<td>90, 165</td>
</tr>
<tr>
<td>variational methods</td>
<td>1, 2, 3, 275, 316, 326, 334, 345</td>
</tr>
<tr>
<td>variational segmentation without edges</td>
<td>318</td>
</tr>
<tr>
<td>variational shaped-based level sets</td>
<td>339</td>
</tr>
<tr>
<td>vascular nodules</td>
<td>334, 437, 439</td>
</tr>
<tr>
<td>vectors</td>
<td>163</td>
</tr>
<tr>
<td>vector distance</td>
<td>342</td>
</tr>
<tr>
<td>vector multiplication</td>
<td>189</td>
</tr>
<tr>
<td>velocity</td>
<td>279</td>
</tr>
<tr>
<td>vertebral bodies</td>
<td>310, 436</td>
</tr>
<tr>
<td>vertices</td>
<td>201</td>
</tr>
<tr>
<td>viscous conservation law</td>
<td>288</td>
</tr>
<tr>
<td>visualization</td>
<td>1, 183</td>
</tr>
<tr>
<td>volume interpolation</td>
<td>377</td>
</tr>
<tr>
<td>volume registration</td>
<td>367</td>
</tr>
<tr>
<td>volume-based methods</td>
<td>186</td>
</tr>
<tr>
<td>Voronoi region area</td>
<td>203</td>
</tr>
<tr>
<td>voxels</td>
<td>175, 186, 367</td>
</tr>
<tr>
<td>water voxel</td>
<td>42</td>
</tr>
<tr>
<td>warping</td>
<td>347</td>
</tr>
<tr>
<td>warping function</td>
<td>353</td>
</tr>
<tr>
<td>wavelets</td>
<td>36, 230, 231</td>
</tr>
<tr>
<td>weak solutions</td>
<td>287, 288</td>
</tr>
<tr>
<td>weighted average</td>
<td>190</td>
</tr>
<tr>
<td>well-circumscribed nodules</td>
<td>437, 439</td>
</tr>
<tr>
<td>white Gaussian noise</td>
<td>37</td>
</tr>
<tr>
<td>window</td>
<td>164, 167, 177</td>
</tr>
<tr>
<td>window function</td>
<td>33, 36, 37, 168</td>
</tr>
<tr>
<td>X-ray</td>
<td>3, 9, 39</td>
</tr>
<tr>
<td>X-ray beam</td>
<td>40, 41, 46</td>
</tr>
<tr>
<td>X-ray tube</td>
<td>40, 41, 44</td>
</tr>
<tr>
<td>z-transform</td>
<td>29, 30, 31</td>
</tr>
<tr>
<td>zero-derivative condition</td>
<td>276</td>
</tr>
<tr>
<td>zero-crossings</td>
<td>234, 235</td>
</tr>
<tr>
<td>zero-level set</td>
<td>275, 284, 323</td>
</tr>
<tr>
<td>Zygo Newview700s</td>
<td>443</td>
</tr>
</tbody>
</table>