

## A

Absorption images, 5, 6f  
 AC. *See* Alternating current  
 Activity dominant vector selection (ADVS), 828  
 Adaptive cluster techniques, in neural network research, 527–528  
 Adaptive wavelet transforms, 703–705, 703f, 705f  
 Additive image offset, in linear point operations, 25–26, 25f, 26f  
 Additive operator splitting (AOS), 622  
 ADIR system  
   advantages of, 1327  
   dot-finding of, 1327–1328, 1329f  
   four-color FISH images captured by, 1333  
   hardware, 1322  
   software, 1322  
 Advanced Research Projects Agency (ARPA), of DOD, 1031  
 Advanced simple profile (ASP), of MPEG-2 part 2, 865  
 Aerial image segmentation, statistical methods for, 447, 449, 449f, 450f  
 Affine invariance, of shape scale space, 574–575  
 Agglomerations, images as, 522  
 Airy diffraction pattern, 222, 222f  
 Algorithm development environments, 629, 630–636, 631f, 633f, 635f, 640. *See also specific software products*  
 Aliasing, 899  
   phenomenon of, 9, 422–423, 428  
   spatial, 64  
   in video sampling, 914  
 ALMOT 2D DSP, 80, 81f, 82f  
 ALOE feature, in computer-aided mammography, 1198  
 Alphabet extension  
   in JPEG-LS, 739  
   in JPEG-LS part 2, 741  
 Alternating sequential filters (ASFs), 139–140  
 AM-FM image modeling  
   emerging trends in, 390–393, 391f, 392f  
   perfect reconstruction filterbanks, 390–392, 391f, 392f  
   perfect reconstruction FM algorithm, 392–393  
   practical techniques for, 382–390, 385f–388f  
   channelized components analysis, 387–388, 387f, 388f  
   dominant component analysis, 385–387, 385f, 386f  
   filterbank design considerations in, 384–385, 385f  
   filtered demodulation, 383–384  
   postfiltering, 389, 389f  
   postprocessing, 389–390  
   reconstruction in, 388–389  
 AM-FM image models, 377  
   and DFT, 377–380, 378f, 379f  
   two-dimensional analytic image in, 381–382  
   two-dimensional energy separation in, 380–381

Amplitude modulation (AM), 377. *See also* AM-FM image models  
 Analog-to-digital (A/D) conversion, 6  
 Angiography  
   in coronary artery analysis, 1176–1179, 1176f, 1178f, 1179f  
   in heart chamber analysis, 1184–1185, 1184f  
 Angular radial transform, 870, 870f  
 ANN. *See* Artificial neural network  
 AOD. *See* Average Optical Density  
 AOS. *See* Additive operator splitting  
 Apparent motion, 253, 261  
 Arbitrary slice order (ASO), 858  
 Area opening, in morphological filtering, 140  
 Arithmetic coding, 651–653, 652f, 652t  
   in JPEG2000, 727, 729  
   in JPEG-LS part 2, 741  
   for lossless compression, 736  
 ARPA. *See* Advanced Research Projects Agency  
 ARPANET (Advanced Research Projects Agency Network), 1031  
 ARQ. *See* Automatic repeat request  
 Artificial intelligence, 519  
 Artificial neural network (ANN)  
   characteristics of, 520–522  
   defined, 520  
   feedforward, 520–521, 520f  
   image segmentation techniques for, 519  
 ASO. *See* Arbitrary slice order  
 ASP. *See* Advanced simple profile  
 Astronomy  
   imaging, 29–30  
   video enhancement and restoration in, 275  
 Asymptotics, in target recognition, 1352  
 Asynchronous Transfer Mode (ATM) networks,  
   1043–1048, 1044t, 1045f–1047f  
   asynchronous application layer-1 (AAL-1),  
   1044–1046, 1045f, 1046f  
   asynchronous application layer-5 (AAL-5),  
   1046–1048, 1046f, 1047f  
 ATM networks. *See* Asynchronous Transfer Mode networks  
 Audio marker, defined, 1015, 1015f  
 Audio signals, compared with visual signals, 1285  
 Audio track, in video indexing, 1002  
 Audiovisual information fusion  
   in ASR, 1269–1270  
   classifiers in speech applications, 1270–1271  
   speech classes in, 1270, 1270t  
 Audiovisual information system, feature and classifier fusion in, 1271–1273, 1272f, 1273f  
 Audiovisual object (AVO), concept of, 850–851, 851f  
 Audiovisual scene, in MPEG-4, 850–851, 851f  
 Audiovisual signal processing, joint, 1286. *See also* Visual signals  
 Audiovisual speaker recognition systems, 1282–1285, 1282f, 1283f, 1285t  
 Audiovisual speech synthesis, 1275–1276  
   coarticulation modeling in, 1276  
   facial animation in, 1276–1278, 1277f

speech-to-video, 1279–1281, 1279f  
 visual speech evaluation in, 1281–1282, 1281f  
 visual text-to-speech in, 1278–1279, 1278f  
 Authentication methods. *See also* Identity characterization  
   algorithm for, 1104  
   watermarking techniques for, 1085  
 Autofocusing  
   of ADIR computerized microscopy system, 1322–1323  
   in computer-assisted microscopy systems  
     autofocus speed, 1317  
     focus functions, 1316–1317  
     two-phase approach to, 1318f  
 Automated Cellular Imaging System (ACIS), 1337  
 Automated imaging, commercial interest in, 1337  
 Automated target recognition (ATR), 1341. *See also* Automatic target recognition  
 Automatic face recognition  
   biometric perspective on, 1235–1236, 1236t  
   experimental perspective on, 1236, 1236f  
   theoretical perspective on, 1236–1239, 1237f–1239f  
   unified approach to, 1239  
 Automatic gain control (AGC), 28  
 Automatic repeat request (ARQ), 1072, 1077  
 Automatic speech recognition (ASR), 1263  
   analysis of visual signals in, 1265–1269, 1266f–1269f  
   audiovisual, 1264, 1273–1275, 1274f  
   bimodal corpora for, 1274, 1274f  
   experimental results, 1274–1275, 1274t, 1275t  
   audiovisual information fusion in, 1269–1273, 1270t, 1272f, 1273f  
   audiovisual speaker recognition in, 1282–1285, 1282f, 1283f, 1285t  
   audiovisual speech synthesis in, 1275–1282  
   interactions in, 1264, 1264f  
   transcription accuracy of, 1269  
 Automatic target recognition (ATR)  
   Bayesian framework for, 1346–1347  
   and clutter models, 1345–1346  
   performance analysis for, 1342  
   and pose location estimation and performance, 1347–1350, 1349f, 1350f  
   and sensor modeling, 1344–1345  
   target recognition and performance in, 1350–1352  
   and target representations, 1342–1344, 1343f, 1344f  
 Autoregressive conditional heteroskedastic (ARCH) models, 437  
 Average Optical Density (AOD)  
   computation of, 22  
   gray-scale center K/2 in, 26  
 AVO. *See* Audiovisual object

## B

Bandwidth, 15  
 Barbara image, 701, 702f, 703, 704, 704f  
 Bayesian framework, 1346–1347

- Bayesian methodologies
    - reconstruction methods, 1170–1171, 1171f
    - recovery methods based on, 773
  - Bayesian object tracking, 502–503
    - in Kalman filters, 503–505
    - in particle filters, 505
  - BCS. *See* Boundary contour system
  - Bessel K forms, 1345–1346
  - Bessel parameters, 1346
  - Bias cancellation
    - in JPEG-LS, 738
    - in JPEG-LS part 2, 741
  - Bilinear interpolation, 37f
  - Binary Hopfield model, 521
  - Binary image morphology
    - boundary detection in, 53
    - logical operations, 45–46
    - morphological filters, 47–53, 47f, 48f–52f
    - windows, 46–47, 47f
  - Binary image processing, 39
    - binary image morphology, 45–53, 47f–53f
    - image thresholding, 16, 17, 40–43, 41f–44f
    - region labeling, 45, 45f
    - representation and compression, 53–55, 54f
  - Binary images
    - creation of, 39
    - display of, 39, 40f
    - simple device for, 40f
  - Binary median filter, 52–53, 52f
  - Bioengineering, 79. *See also* Education, image processing
  - Biometrics, 1219
  - BI-RADS. *See* Breast Imaging Reporting and Data System
  - Bit-plane encoding passes, in JPEG2000, 726–727
  - Bit planes, 10
  - Bit rate, 15
  - Bit rate control, in video transcoding, 829–830
  - Blackboard educational system, 84
  - Blind embedding schemes, for watermarking, 1086
  - Blocking artifacts
    - of JPEG compression, 761
    - in wavelet shrinkage, 162
  - Block layer, in H.261 video encoder, 795
  - Block matching algorithms
    - estimation criterion for, 269
    - search methods, 270
  - Block transform coding, with discrete cosine transform, 787–788, 788f, 789f
  - Block truncation coding (BTC), 88
    - applications of, 667, 669
    - basics of, 662–666, 662f–665f
    - development of, 669
    - history of, 661–662
    - with hybrid techniques, 669
    - and moment preserving quantization, 666–667, 668t
  - Blotches
    - defined, 276
    - detection and removal, 282–287, 283f–288f
    - detectors for, 283
    - and motion vector repair, 285–287, 287f
    - properties of, 283
    - video frame with, 284f
  - Bluetooth wireless network, 1042
  - Blur identification
    - algorithms for, 178–179
    - goal of, 167
  - Blur image
    - diffraction, 222–223, 222f, 223f
    - and multi-frame restoration, 221–223, 221f–223f
  - Blurred signal-to-noise ratio (BSNR), 238
  - Blurring
    - and atmospheric turbulence, 170–171
    - defined, 167
    - maximum likelihood estimation for, 179–181, 181f
    - models for, 169–171, 170f
    - out-of-focus, 170, 170f
    - spectral estimation, 179
  - Body animation, in MPEG-4, 855
  - Boolean filters, 47–53, 47f, 48f–52f
  - Boundary contour system (BCS), in edge-based segmentation, 523–524
  - Boundary detection, in image segmentation, 443
  - Boundary value problem, in image restoration, 178
  - Breast cancer, 1195. *See also* Mammography, screening
  - Breast cancer computer-aided detection/
    - computer-aided diagnosis, 1211–1213
  - Breast Imaging Reporting and Data System (BI-RADS), 1195–1196, 1213
  - Broadcast monitoring, watermarking techniques for, 1084
  - Browsing, video, 1013, 1014f
    - and retrieval, 1017–1018
    - scene-based video ToC representation, 1018–1022, 1019f
  - BTC. *See* Block truncation coding
  - Butterworth filter, 104
- C**
- CABAC. *See* Context based Adaptive Binary Arithmetic Coder
  - Cable systems, video transmission via, 15
  - Cable television system, 1039
  - Cable TV (CATV) networks, MPEG-2 used in, 847
  - CADx Medical Systems, 1210
  - Calibration, color I/O device, 425–426
  - CALIC (Context-based, Adaptive, Lossless Image Codec), 657, 657f, 657t
  - Cameras
    - digital, 431, 877, 878f
    - FLIR, 1342, 1345
    - interpreting motion of, 996, 997
    - mathematical model for color sensor of, 418
    - and object motion detection, 997, 998f
  - Canadian RADARSAT-1 satellite, 1134, 1134f
  - CANDIDE face model, 507
  - Canny edge detector, 548–549, 550f, 615
  - Cardiac chamber analysis
    - angiography, 1184–1185, 1184f
    - CT imaging in, 1185–1186, 1185f, 1186f
    - echocardiography, 1186–1188, 1187f
    - with MRI, 1188
  - Cardiac image processing
    - cardiac mechanics and shape analysis, 1183–1184
    - chamber analysis, 1184–1188, 1184f, 1187f
    - myocardial wall, 1188–1190, 1189f
    - coronary artery analysis, 1176–1183, 1176f, 1178f–1179f, 1181f–1183f
    - electrocardiography, 1190, 1191f
    - of myocardial blood flow, 1190, 1190f
    - techniques, 1175–1176
    - technological advances in, 1191
  - Cartesian form, of Gabor function, 458, 458f
  - Cauchy-Riemann equations, in AM-FM modeling, 381
  - CBR. *See* Constant bit rate
  - CCD. *See* Charge coupled devices
  - CCIR. *See* International Consultative Committee for Radio
  - CCS. *See* Curvature scale space
  - CDMA. *See* Code-division multiple access
  - CD-ROM devices, storage capacity of, 643
  - Cells, confocal microscopy of, 1299–1304, 1299f, 1302f
  - Cellular phone, 877, 878f
  - Center-on-surround-off (COSO) filter, 905
  - Center weighted median (CWM) smoothers. *See also* Weighted median smoothers
    - impulse noise cleaning with, 121f–122f
    - realization of, 112–113, 113f
  - Central Limit Theorem, 401
  - Centroid condition, in VQ design, 676
  - Chain coding, in binary image processing, 53, 54–55, 55f
  - Chamfer metrics, weighted distance transform (WDT) based on, 606
  - Change detection, image differencing for, 34–35, 35f
  - Channel coding
    - forward error coding (FEC), 1072, 1073–1074, 1073f
    - retransmission, 1074–1075, 1074f
    - techniques, 1072
  - Channel encoding, 1080
  - Channel models
    - Internet, 1070–1071
    - wireless channel, 1071
  - Channels, multiple, 203, 204f
  - Channel state information (CSI), in JSCC, 1068–1069
  - Charge coupled devices (CCDs), 783, 896
    - in noise models, 405–406
    - sampling grid spacing of, 783
  - Charge injection devices (CIDs), 896
  - Checkmark, copyright protection watermarking, 1092
  - Chip architecture, in embedded video codec development, 882
  - Chirp-scaling algorithm (CSA), in SAR, 1142
  - Chroma-keying
    - in object tracking, 495, 496f
    - in video segmentation, 484
  - Chrominance, 11
  - CID. *See* Charge injection devices
  - CIELab space, 424
  - CIEluv transformation, 424
  - CIF. *See* Common Interchange Format
  - Close filter, morphological, 50
  - Close-open filter, 51–52, 51f
  - Clustering
    - for image segmentation, 527–528
    - spectral, 528
  - Clutter objects, and target recognition, 1345–1346
  - CMOS devices, 896
  - CMTIA, duplication pattern for, 1332, 1332f
  - CMYK. *See* Cyan, magenta, yellow, and black colors
  - Coded block pattern (CBP) parameter, in H.261 video encoder, 796
  - Code-division multiple access (CDMA), 1041
    - origins of, 1041
    - W-CDMA, 1041
    - in wireless networks, 1040–1041
  - Coding. *See also* Block truncation coding; Entropy coding

- lossless
  - basics, 644–646, 644f, 645f
  - CALIC, 657, 657f, 657t
  - JBIG and JBIG2 standards, 655
  - JPEG standard, 655–656
  - JPEG2000 standard, 656
  - LOCO-I, 656
  - perceptually-based, 657–659, 658f
  - standards, 654–656
  - symbol coding schemes for, 646–655, 649f, 650t, 652f, 652t, 654t
  - techniques, 643
- Coding delay, defined, 645
- Coding efficiency, defined, 778
- Coding primitives, in JPEG2000, 726
- Coiflet-based filterbank, 393
- Collision warning (CW) systems, 446
- Color descriptors, in MPEG-7, 868–869, 869f
- Color images, 11, 12f
  - edge detection for, 549–551
  - multivariate medians for, 126f
  - sharpening process for, 128
  - weighted median filters for, 117–119
- Colorimetry, 417–418
  - color aliasing in, 422–423, 428
  - and color sampling, 418–419, 418f
  - CRT calibration, 426
  - definitions and terminology, 425–426
  - discrete representation of color matching, 419–420, 419f, 420f
  - example, 427–428, 428f
  - and nonlinearity of eye, 423
  - and printers, 427
  - and properties of color matching functions, 420–422, 421f
  - scanners and cameras, 426–427
  - uniform color spaces in, 423–424
- Color information, in region-based object tracking, 495
- Color matching, properties of, 420–422, 421f
- Color palette design, in quantization, 934
- Color printing, 925–926
- Color quantization, 926, 933–935
- Colors
  - in multispectral images, 747
  - perception of, 11
  - primary, 11
- Color sampling, 418–419, 418f
- Common Interchange Format (CIF), 785
- Communication, and human face visibility, 1264. *See also* Face recognition
- Complex spatial-spectral transform, for multispectral images, 749
- Compression, 689. *See also* Wavelet image compression
  - compared with processing, 259
  - and halftoning, 933
  - JPEG-LS, 736, 737f
    - alphabet extension, 739
    - bias cancellation in, 738
    - context formation, 738
    - near-lossless compression, 739–740
    - prediction step in, 736–737
    - Rice-Golomb coding, 738–739
  - lossless, 693
    - and arithmetic coding, 736
    - band ordering, 756
    - comparison of standards for, 744
    - efficiency in, 645
    - error modeling and coding, 757–758
    - goal of, 643–644
    - inter-band prediction, 756–757
    - JPEG-LS part 2, 740–742
    - of multispectral images, 759
    - near-lossless compression, 758
    - original standards, 734–736, 734f, 734t
    - predictive techniques, 756
    - reversible transform based techniques, 758
  - lossy
    - alternative modes of operation, 718
    - coefficient-to-symbol mapping and coding in, 715–717, 715f, 716f
    - discrete cosine transform used in, 712–713, 712f
    - image data format and components in, 717–718
    - JPEG codec structure, 710–712, 711f
    - of medical images, 755
    - of multispectral images, 750–755, 752f, 754f
    - of photographic images, 755
    - quantization, 713–715, 713f, 714f
    - quantization table design, 714–715
    - of RGB color images, 750–751, 751f
    - of multispectral images, 748
    - need for, 940
    - of postprocessing, 761
    - problem of, 431, 692–693
    - segmentation for, 450–451, 451f
    - techniques, 877, 963
    - visual models for image quality, 943–956, 944f, 948f–952f, 954t
- Compression ratio, defined, 778
- Compression standards, video, 890
- Computational mathematics, 519
- Computed tomography, 167
- Computed tomography (CT), 167
  - in cardiac image processing, 1175
  - for coronary artery analysis, 1179–1180, 1181f
  - 3D image reconstruction
    - cone-beam tomography, 1166–1168, 1166f
    - with missing data, 1165–1166
  - examples, 1159, 1160f
  - extracting 2D data from 3D in, 1163
  - first generation systems, 1156
  - in heart chamber analysis, 1185–1186, 1185f, 1186f
  - image reconstruction
    - fan-beam filtered backprojection for, 1161–1162, 1161f
    - Fourier space and filtered backprojection methods, 1159–1161, 1160f
  - iterative reconstruction methods for
    - Bayesian reconstruction methods, 1170–1171, 1171f
    - finite dimensional formulations and ART, 1168–1169, 1168f
    - maximum likelihood methods, 1169–1170
    - statistical formulations, 1169
  - mathematical preliminaries for, 1159
  - nuclear imaging using, 1157–1159, 1157f–1159f
  - rebinning methods in 3D PET, 1164–1165, 1164f
  - spiral, 1163–1164, 1163f
  - x-ray, 1155–1157, 1156f
- Computer-aided detection (CAD), 1197
  - of mammographic abnormalities, 1197–1198, 1211
  - architectural distortions in, 1211
  - calcifications, 1203–1205, 1205t, 1206t
  - commercial, 1210–1211
  - detection of masses, 1198–1203, 1199f, 1201f, 1203t
- Computer-aided detection/computer-aided diagnosis
  - clinical applications, 1213
  - evaluation methodologies, 1212–1213
  - multiview, multimodality, 1212
- Computer-aided diagnosis
  - of mammographic abnormalities
    - all lesion types, 1211–1212
    - calcifications, 1208–1209, 1209t
    - masses, 1206–1208, 1207f
- Computer-aided microscopy
  - ADIR system, 1322
  - clinical cytogenetic applications
    - detection of gene duplications, 1326–1332, 1327f, 1329f–1332f
    - fetal cell screening in maternal blood, 1323–1324, 1324f, 1338
    - FISH for aneuploidy screening, 1333
    - performance, 1332–1333
    - STFISH, 1324–1326
    - thick-specimen imaging, 1335–1336, 1336f, 1337f, 1338
  - commercially available, 1337–1338
  - components of, 1312–1313, 1312f
  - function of, 1311–1312
  - hardware
    - filter control, 1313–1314
    - illumination source, 1313
    - image sensors, 1314–1315
    - X, Y stage positioning and Z-axis motors, 1314
  - image processing and analysis software for
    - background subtraction in, 1318–1320, 1319f
    - color compensation with, 1320
    - segmentation for object identification, 1320–1321
    - and user interface, 1321–1322
  - imaging software for, 1315–1316
  - software for hardware control
    - autofocusing, 1316–1317
    - automated slide scanning, 1316
    - image capture in, 1317–1318
- Computer assisted tomography (CAT). *See* computed tomography
- Computer graphics, and motion tracking, 492
- Computers, wearable, 819
- Computer science, 79. *See also* Education, image processing
- Cone-beam tomography, 1166–1168, 1166f
- Cones, of eye, 11. *See also* Visual system
- Conferencing, video, 819, 865–866, 878f
- Confocal microscope
  - concept of, 1291
  - features of, 1291–1292
  - types of, 1295–1296, 1296f
- Confocal microscopy
  - biological applications of, 1308
  - cells and tissues, 1299–1304, 1299f
  - microvascular networks, 1304–1308, 1305f–1307f
  - quantitative analysis of 3-D confocal images, 1298–1299
  - fluorescence, 1295
  - image formation in, 1291–1292, 1292f
  - depth resolution for, 1294, 1294f
  - with lateral resolution, 1292–1293, 1293f
  - laser scanning, 1299

- Confocal microscopy [*Continued*]  
 limitations of, 1296–1298, 1297f  
 two-photon laser scanning, 1296–1298, 1297f
- Conjugate epipolar lines, 298
- Conjugate Quadrature Filters (CQFs), 351–352
- Connected operators, 140
- Constant bit rate (CBR) algorithms, 881
- Constrained least-squares filter, 174
- Context based Adaptive Binary Arithmetic Coder (CABAC), 802, 807
- Context formation  
 in JPEG2000, 726  
 in JPEG-LS, 738  
 in JPEG-LS part 2, 741
- Context-modeling method, 164
- Continuous-state models, in random field studies, 368–370
- Continuous-valued image, 9
- Contour images, 54–55, 55f
- Contraction mapping theorem, 248
- Contrast response, of cortical cells, 335, 337–338
- Contrast sensitivity function (CSF), 940, 945
- Contrast stretch, 28
- Copyright protection watermarking, 1088–1103.  
*See also* Watermarking
- Coring functions, 281f, 282f
- Coronary artery analysis  
 biplane angiography and 3-D reconstruction, 1177–1179, 1178f, 1179f  
 intravascular ultrasound imaging in, 1181–1182, 1182f, 1183f  
 MRI for, 1180–1181, 1182f  
 single-plane angiography, 1176–1177, 1176f  
 virtual angiography, 1182–1183, 1186f  
 x-ray CT imaging for, 1179–1180, 1181f
- Cortical cells  
 and motion, 338–340, 339f  
 and stereopsis, 340–342, 343f
- COSOF. *See* Center-on-surround-off filters
- Covariance statistics, in image segmentation, 446
- Cross-layer design, 1080
- Cryptographical security, in copyright protection, 1089
- CSF. *See* Contrast sensitivity function
- CSI. *See* Channel state information
- Curvature flows, morphologic representation of, 600–601
- Curvature scale space (CCS) representation, in shape descriptors, 870–871, 870f
- Curve evolution, 608  
 analytic representation of, 598–599  
 weighted distance transform (WDT) based on, 606–607
- CWM. *See* Center weighted median smoothers
- Cyan, magenta, yellow, and black (CMYK) colors, 747
- Cyclic convolution property, of DFT, 64
- Cytogenetics, clinical  
 detection of gene duplications, 1326–1332, 1327f, 1329f–1332f  
 fetal cell screening, 1323–1324, 1324f, 1338  
 performance, 1332–1333  
 STFISH, 1324–1326, 1338
- Cytometry, computer-assisted, 1311
- Data. *See also* Compression  
 size of image, 12–13  
 standardization of digital, 849
- DCA. *See* Dominant component analysis
- DCT. *See* Discrete cosine transform
- DDL. *See* Description definition language
- Decoding, watermark, 1087–1088, 1088f
- Decompositions, multiscale image, 358  
 Gaussian pyramid, 347, 348f, 349, 350  
 Laplacian pyramid, 348f, 350–351  
 wavelet decomposition, 348f, 349
- Deconvolution, 1338
- Defense Advanced Research Projects Agency (DARPA), 1134, 1135
- Deformable template theory, 1342
- Degradation, spatially invariant  
 basic algorithm in, 236–237  
 convergence, 237–238, 237f  
 degradation model, 236  
 experimental results, 238–241, 240f–241f  
 reblurring, 238
- Degradation process  
 and recovery problem, 235  
 video, 275
- Deinterlacing, in sampling structure conversion, 921
- Delayed frame memory  
 in intraframe encoding mode, 780  
 motion compensation, 780  
 motion estimation, 780
- Delft University of Technology, digital signal coding at, 91
- DeMorgan's Laws, 49
- Denoising  
 with GSM model, 164  
 linear filtering, 157–158  
 nonlinear filtering, 157–158  
 problem of, 157  
 using natural scene statistics, 162–164
- Denoising techniques, wavelet-based  
 discrete wavelet transform in, 158, 158f  
 Donoho-Johnstone method of, 158–159, 160
- Density-weighted contrast-enhancement (DWCE) filter, 1200–1201
- Description definition language (DDL), in MPEG-7, 872–873
- Desktop printers, 903
- Detection, watermark, 1087–1088, 1088f
- DFD. *See* Displaced frame differences
- DFT. *See* Discrete Fourier transform
- Difference measures  
 absolute difference, 994–995, 995f  
 histogram, 995, 996f
- Difference of Gaussian (DoG) filter  
 to detect masses, 2052  
 in edge detection, 546–548
- Differential entropy, in quality assessment, 979
- Differential equations, partial, 555. *See also* Partial differential equations
- Differential morphology, 590
- Differential pulse code modulation (DPCM), 92, 733
- Differentiated services (DiffServ), 1062–1063, 1063f
- Diffraction patterns, 222, 222f
- DiffServ. *See* Differentiated services
- Diffusion  
 anisotropic, 556–557, 570  
 applications, 565–568, 566f–568f  
 diffusion coefficient, 557–558, 558f, 559f  
 diffusion partial differential equation, 558, 560–561  
 multiresolution diffusion, 562–563  
 multispectral, 563, 564f  
 quantitative evaluation of edge detection by, 566–568, 567f, 568f  
 speckle reducing, 563–565, 564f, 565f  
 variational formulation, 561–562  
 defined, 555  
 isotropic, 556
- Digital camcorders, 877, 878f
- Digital cameras, 431, 877, 878f
- Digital content, 993
- Digital data, standardization of, 849
- Digital image, 157
- Digital image processing (DIP), 21. *See also* Image processing  
 microscope images for, 1312  
 multidisciplinary nature of, 73  
 principles of, 73
- Digital images, 3, 157, 411  
 creation of negative, 27  
 sequence, 778–779, 778f  
 storage required for, 12, 13t
- Digital image signals  
 one-dimensional (1D), 961  
 two-dimensional (2D), 961
- Digital still cameras (DSCs), 877, 878f
- Digital television, MPEG-2 used in, 847
- Digital terrain elevation data (DTED), 1149
- Digital transmission providers, Quality of Services (QoS), 777
- Digital video, 3. *See also* Video  
 applications and technology, 778  
 emerging applications, 13  
 formats, 784–785  
 signals and formats, 782–785, 784f, 785t  
 storage required for, 12–13
- Digital video devices (DVDs)  
 MPEG-2 used in, 847  
 universal access to, 820
- Digital Video Disc (DVD) players, processors employed by, 629
- Digital video industry  
 conformance testing efforts of, 866  
 new standards for, 849
- Digital video processing, 13
- Digital watermarking, development of, 1083.  
*See also* Watermarking techniques
- Digitized images, estimating depth from, 297
- Dilate filter, in binary image processing, 47–48, 47f, 48f
- Dilation and translation-invariant (DTI) systems, 591
- Dilation flows, 600
- Dilation partial differential equations, slope transforms and, 595
- Dirac delta function, 169
- Direct memory access (DMA) controller, in embedded video codecs, 880
- Direct-sequence spread-spectrum (DSSS), of CDMA, 1041
- Discrete cosine transform (DCT), 250, 644, 689, 787–788, 788f, 789f  
 and compression schemes, 994  
 computation of, 850  
 JPEG, 764, 764f  
 in lossy image compression, 710, 712–713, 712f  
 CHECK

## D

Daly's model, 947

Dark current, 406

- in MPEG-2, 843
- and POCS, 764–765, 764f, 765f
- and Watson's model, 950–953
- Discrete cosine transform (DCT)-based coders, perceptual threshold matrices for, 952
- Discrete-domain signals, 150
- Discrete Fourier transform (DFT), 377–380, 379f, 387f, 788
  - computation of, 65–66
  - cyclic convolution property of, 63–64
  - displaying, 66–67, 66f, 67f
  - image analysis using, 86, 88f
  - image frequencies and, 67–72, 68f–71f
  - image periodicity implied by, 63
  - linear convolution using, 64–65, 65f
  - linearity and invertibility of, 62
  - periodicity of, 62–63
  - symmetry of, 62
  - two-dimensional, 61–62
- Discrete Memoryless Source (DMS), 786
- Discrete morphological gradient, 147
- Discrete-space Fourier transform (DSFT), 58–61, 59f
  - convolution and, 61
  - inversion of, 60
  - linearity of, 60
  - magnitude and phase of, 60
  - pair, 59
  - symmetry of, 60
  - translation of, 60
- Discrete-state models, in random field studies, 368
- Discrete-valued image, 9
- Discrete wavelet transform (DWT), 1070
  - basics of, 158, 158f
  - disadvantage of, 159
  - in JPEG2000 standard, 724, 725t, 743–744, 743t
  - video encoding method based on, 780
- Disparity, 341
- Displaced frame differences (DFD), 801
- Displacement vector field (DVF), in image restoration, 209
- Distance transforms
  - of binary images and approximations, 602
  - chamfer, 602–603, 603f
  - as slope filters, 603–604
  - and wave propagation, 601–602
- Distortion
  - correcting, 16
  - and VQ, 687
- Distortion model, for quality assessment, 978, 979f, 980f
- Divergence penalty, in maximum-likelihood estimation, 226
- DMA. *See* Direct memory access
- DMS. *See* Discrete Memoryless Source
- Documentary video, formats for, 994
- Dome/basin extraction, in feature detection, 149–150
- Dominant component analysis (DCA), in AM-FM modeling, 385–387, 385f, 386f
- Dominant motion segmentation, 475–476
- Donoho-Johnstone method, of denoising, 158–159, 160
- Dot-finding, in computer-assisted microscopy, 1327–1328, 1329f
- DPCM. *See* Differential pulse code modulation
- DSSS. *See* Direct-sequence spread-spectrum
- DTI. *See* Dilation and translation-invariant
- DVD. *See* Digital video disc players
- DWT. *See* Discrete wavelet transform
- Dye sublimation, 925
- Dynamic programming
  - disadvantages of, 304
  - explained, 301
- Dynamic shape algorithm
  - description, 575
  - implementation, 575–576
  - properties, 576, 576f, 577f
- E**
- EBCOT. *See* Embedded block coding with optimized truncation
- ECC. *See* Error correction code
- Echocardiography, in heart chamber analysis, 1186–1188, 1187f
- Edge detection
  - algorithms for, 536
  - application of anisotropic diffusion to, 565–568, 566f–568f
  - Canny's method, 548–549, 550f
  - in 1-D continuous case, 536, 536f, 537
  - defined, 535
  - errors in, 536–537
  - in feature detection, 145–148
  - Gaussian approach, 552
  - gradient-based methods, 536
    - continuous gradient, 536, 537–540, 538f–540f
    - discrete gradient operators, 540–542, 543f
  - gray-level, 552
  - in image analysis, 130–132
  - from image features, 566, 566f
  - Laplacian-based methods, 536
    - continuous Laplacian, 543–544, 544f
    - and difference of Gaussian, 546–548
    - with discrete Laplacian operators, 544–545
    - Laplacian of Gaussian, 545–546, 552
  - morphological, 146–148
  - for multispectral images, 550
  - perceptual grouping and, 522–524, 522f, 523f
  - process, 130f
  - quantitative evaluation of, 566–568, 567f, 568f
- Edge detectors
  - comparisons of, 552
  - directional, 538–539, 540f
  - and geometric evolutions, 615–617
- Edge-directed interpolation, 904–907, 905f, 906f
- EdgeFlow, segmentation using, 464, 464f, 465f
- Edge location errors, 552
- Edge profile, example of, 861f
- Edge response, of ideal LPF, 105
- Edges
  - and anisotropic diffusion, 555–556
  - defined, 535, 536, 555–556
  - physical, 536
  - scales for, 556
  - using parametric active contours to locate, 568–569, 569f, 608
  - using vector diffusion to locate, 569–570, 570f
- Education, image processing, 73
  - IP-LAB, 74–78, 76f
  - Java-based educational software and two-dimensional signal processing, 78–83
  - practical applications, 94
  - SIVA, 83–91, 85f, 86t, 87f, 88f
  - at Univ. of Texas Austin, 84–85, 89–91
  - VcDemo, 90–94, 92f–93f
- Eigenface approach, to face recognition, 1237
- Eigenfaces, sample, 500f
- Eikonal, defined, 605
- Electrocardiography, in cardiac image processing, 1175, 1190, 1191f
- Electromagnetic spectrum, 4, 4f
- Electron micrographs, 167. *See also* Microscopy
- Ellipse fitting, in computer-assisted microscopy, 1330–1331, 1331f
- Embedded block coding with optimized truncation (EBCOT), 706, 725
- Embedded video codecs
  - algorithms for, 883–885
  - applied programming interfaces, 885–886, 885f
  - and block-based video coding, 878–879, 879f
  - concurrent processing, 888–889, 888f
  - design flow, 882–887, 883f–885f
  - developing, 880
  - Golden C in, 886–887
  - kernel optimization and integration, 887–888
  - overall optimization for, 889–890
  - platform-specific development for, 887
  - stress and conformance testing of, 890
- Embedded video features, content-based, 1003
- Embedded wavelet image coders, 753
- Embedded zero block coder (EZBC), 799, 800f
  - context modeling, 809–810, 810f
  - definitions, 808–809
  - packetization and, 810f, 811
  - and scalability, 810–811, 810f
- Embedded zerotree wavelet (EZW) coding, 698–701, 699f
- Embedding
  - of information, 935, 935f
  - watermark, 1087–1088, 1088f
- Emission images, 5, 6f
- Emotion recognizers, audio-only, 1286
- Engineering, 79. *See also* Education, image processing
- Enhancement
  - algorithms for, 157
  - application of video, 275
  - image sharpening for, 127–130, 129f, 130f
  - image sharpening technique, 127–130, 129f, 130f
  - linear filtering for, 102–107, 104f–108f
  - morphological filters for, 135, 139–143, 139f–143f
  - via wavelet shrinkage, 160–162
- Enhancement of legacy systems, watermarking techniques for, 1085
- Enhancement resolution, example of, 251f
- Entropy, defined, 693
- Entropy-based estimators, 1347
- Entropy coding, 645
  - context-based, 648–649
  - in H.264/AVC, 862
  - for JPEG2000, 725–729, 726f–728f
  - in lossy image compression, 716–717
  - in transform coding paradigm, 697
- Environment for Visualizing Images (Envi), 639
- Epipolar geometry, non-parallel, 299
- Epipolar lines, 298
- Erode and dilate filter, in binary image processing, 48–49, 49f
- Erosion and translation-invariant (ETI) systems, 591, 593
  - ideal-cutoff spatial slope filter, 594
  - space dynamics of, 593
- Error correction code (ECC), in H.261 video encoder, 793

- Error detection, in embedded video decoders, 881–882
- Error diffusion  
and color quantization, 932f, 934–935  
in halftoning, 929–932, 931f
- Error resilience  
in MPEG-4, 855–856  
techniques, 1065
- Estimation theory, in noise models, 399–400
- Ethernet systems, video transmission via, 15
- ETI. *See* Erosion and translation-invariant
- Euclidean distance transform, and PDEs, 607
- Euler-Lagrange equations, 258, 271
- Eye. *See also* Visual system  
human, 418  
nonlinearity of, 423
- Eyeball, optics of, 327–328, 328f
- F**
- Face animation, in MPEG-4, 854–855, 854f, 855f
- Face detection, in ASR, 1265–1266
- Face recognition, from video sequences, 1244–1248, 1246f, 1247t, 1248f. *See also* Automatic face recognition
- Face recognition test protocol (FERET), 1236
- Face tracking technique, template-based, 501–502
- Face visibility, and speech perception, 1264
- Facial action coding system (FACS), 1285
- Facial animation, in audiovisual speech synthesis, 1276–1278, 1277f
- Facial animation parameters (FAPs)  
standard for, 854  
as visual features, 1267
- Facial definition parameters (FDPs), 854–855, 855f
- Facial recognition, visual features in, 1266–1268, 1267f, 1268f. *See also* Automatic face recognition
- Fast Fourier transform (FFT), 66
- Fast marching method (FMM), 607, 610
- FDPs. *See* Facial definition parameters
- FDVS. *See* Forward dominant vector selection
- Feature detection, 135  
morphological operators for, 145–150  
peak/valley blob detection, 148–150, 151f
- Feature extraction, in video retrieval, 1024
- Features, image and video  
access and browsing, 1008–1009, 1010f  
compressed domain, 999–1000, 1000f  
content-based, 1000–1003, 1000f–1002f  
and content retrieval, 1010–1011, 1011f  
and high-level semantics, 1004–1006  
and MPEG-7 standard, 1010–1011, 1011f  
retrieval techniques, 1006–1008, 1007f  
statistical, 994–999, 995f, 996f, 998f
- FEC. *See* Forward error coding
- Fetal cell screening, in maternal blood, 1323–1324, 1324f, 1338
- Fiber optics, 1042
- Field, defined, 850
- Field prediction  
in field-pictures, 842–843  
in frame-pictures, 842
- Figure-background reversal principle, 574, 582
- Film, layered structure of, 288f
- Filtering, in visual system, 332–334. *See also specific filters*
- Filtering-based techniques, for postprocessing, 761
- Filters. *See also specific filters*  
multi-resolution, 281, 282f, 283f  
order-statistic, 279–281, 280f
- Filter sidelobes, 106
- Fingerprint-based automatic identity authentication system  
feature enhancement in, 1225–1227, 1226f, 1227f, 1229t  
feature extraction in, 1223, 1224f, 1225  
fingerprint representation, 1223, 1223f  
fingerprint sensing in, 1221–1222, 1221f  
system architecture, 1220–1221, 1221f
- Fingerprint image compression, wavelet-based  
standard for, 689, 705
- Fingerprints  
as biometric, 1220, 1221f  
classification of, 1227–1229, 1228f, 1229f, 1229t  
history of, 1220  
matching, 1229–1232, 1230f–1232f, 1232t  
uniqueness of, 1220  
widespread use of, 1232
- Finite-state VQ (FSVQ), 687
- Fisher color distance, 447, 447f, 448f
- Fisherface approach, to face recognition, 1237
- Fixed-length coding, in JPEG-LS part 2, 741
- Fixed-threshold hypothesis testing, in motion detection algorithms, 256
- Flat zones, of image signal, 140
- Floyd-Steinberg error, in error diffusion, 931
- Fluorescence resonance energy transfer (FRET)  
imaging, 1311, 1338
- Fluorescent in situ hybridization (FISH), four-color  
image acquisition in, 1333  
spectral overlap in, 1333
- Fluorescent in situ hybridization (FISH) images,  
duplicated genes represented in, 1331
- Flying spot scanners, 909
- Focal plane arrays, 909
- Focal plane mosaic, in image capture, 896
- Foliage penetration (FOPEN), and SAR, 1135, 1135f
- Forensic sciences, video enhancement and restoration in, 275
- Forward dominant vector selection (FDVS), 828
- Forward error coding (FEC), 1072, 1073–1074, 1073f
- Forward error correction, 1076–1077, 1076f, 1077
- Forward-looking infrared (FLIR) camera, 1342, 1345
- Forward-looking infrared (FLIR) imaging system, 229
- Fourier analysis  
of image capture, 898–901, 899f–901f  
in linear image enhancement, 102
- Fourier space, in CT image reconstruction, 1159
- Fourier statistics, in image segmentation, 446, 451
- Fourier transform analysis, 16, 31, 72  
discrete-space, 58–61, 59f  
fast, 66  
and sinusoidal functions, 16, 57–58  
in spatiotemporal sampling structures, 912–913  
two-dimensional discrete, 61–67, 64f–67f
- Fovea, of eye, 11. *See also* Visual system
- Frame, defined, 850
- Frame/field adaptive coding, in H.264/AVC, 862–863, 863f
- Frame-rate conversion, in video sampling, 916
- Frei-Chen operator, 542
- Frequency, two-dimensional, 57
- Frequency-domain analysis, 16, 57
- Frequency masks, zero-one image, 71
- Frequency modulation (FM), 377. *See also* AM-FM image models
- Front end, 327
- FRQA. *See* Full-reference quality assessment
- Frustrated total internal reflection (FTIR), in fingerprint sensing, 1222
- Full-reference (FR) quality assessment (QA) paradigm, 975–976
- Full-scale histogram stretch, 28–29
- Fusion techniques, in AV information systems, 1272
- G**
- Gabor filter, modulation transfer function of, 1225
- Gabor functions  
in AM-FM models, 384, 385f, 393  
analytic, 457–458  
cortical simple cell modeled as, 335, 336f, 338f  
Gabor wavelets, 459  
in image texture classification, 456–457  
one-dimensional, 457  
in texture-based segmentation, 524, 526
- Gabor space, transformation into, 459–461
- Gaussian filters  
application of, 107f  
in linear image enhancement, 106–107, 107f, 108f
- Gaussian mixture models (GMMs), 437, 439, 439f, 1004  
anomaly detection of, 372, 372f  
applications, 372–374, 372f  
description, 371  
multiresolution texture modeling, 372–374, 373f  
in noise models, 402  
for non-Gaussian random variables, 370–371  
texture motif, 468  
for wavelet coefficients, 164
- Gaussian model, of image statistics, 432–434, 432f–434f
- Gaussian noise, 103, 400–401, 401f  
maximum-likelihood for, 226  
and multi-frame blind restoration, 230  
wavelet shrinkage, 161–162, 161f, 163
- Gaussian pyramid, 347, 348f, 349, 350  
in isotropic diffusion, 562  
in spatial change detection, 473
- Gaussian scale mixture (GSM) model  
for natural image sources, 977  
for wavelet coefficients, 164
- Gaussian scale space, 556
- Gaussian statistics  
in image restoration, 194  
in image segmentation, 449
- Gauss-Jacobi mechanical quadrature problem, 666, 667
- Gauss-Markov random fields (GMRFs)  
causal, 364, 364f  
in GIS application, 449, 449f  
noncausal, 365  
Toroidally Stationary, 364–365, 365f
- Gene duplications, detection of, 1326–1332, 1327f, 1329f–1332f
- Generalized likelihood ratio, in target recognition, 1352
- Geodesic active contour model  
alignment term for, 616, 616f  
calculus of variations for, 617–620  
defined, 615  
efficient numeric schemes, 622–623

- examples, 623, 623f, 624f
  - gradient descent in level set formulation in, 620–622, 620f
  - for image segmentation, 613–614
  - minimal variance, 616–617
  - notations and problem formulation, 614–615, 615f
  - weighted region, 616
  - Geographical information systems (GIS), 447
  - Geomatica software, 639
  - Geometric active contour model, and related work, 623–625
  - Geometric image operations, 35–37, 37f
    - bilinear interpolation, 36, 37f
    - in gray-level digital image processing, 21
    - image rotation, 36
    - image translation, 36
    - image zoom, 36–37, 37f
    - nearest neighbor interpolation, 36, 37f
  - Geometry
    - parallel, 298, 298f, 299
    - three-dimensional imaging, 311f
  - Gestalt phenomenon, 522
  - Gibbs distribution, 483
  - Gibbs phenomena, 104
  - Gibbs random fields (GRFs), 365–366, 366f
    - estimation, 367
    - in motion segmentation, 477
    - parameter estimation for, 366
    - sampling, 367
  - Gigabit Ethernet networks, 13
  - GIS. *See* Geographical information systems
  - Global clustering, in video retrieval, 1024, 1025f
  - Global motion
    - computation of, 310
    - problems of, 309
  - Global motion compensation (GMC), in motion estimation, 267–269, 268f
  - Global motion models
    - feature-based, 312
    - flow-based, 312–314
  - GMMs. *See* Gaussian mixture models
  - GMRFs. *See* Gauss-Markov random fields
  - Golomb codes, in JPEG-LS, 739
  - Gradient-based techniques
    - of edge detection, 537–543, 538f, 540f, 543f
    - in motion estimation, 266
  - Granularity, 68–70, 68f–70f
  - Graph cuts, 304–306, 304f, 306f
    - expansion algorithm for, 305–306
    - swap algorithm for, 305
  - Gray-level co-occurrence matrix method (GLCM), in computer-aided mammography, 1204
  - Gray-level difference method (GLDM), in computer-aided mammography, 1204
  - Gray-level image processing, 21
    - arithmetic operations between images in, 21, 32–35
    - geometric image operations, 35–37, 37f
    - image histogram in, 22–20.1–6
    - linear point operations, 24
    - morphological filters for, 136–137
    - nonlinear point operations, 29–32, 30f, 31f
    - notation for, 22
  - Gray-level range, 9, 22
  - Gray-level run-length method (GLRLM), in computer-aided mammography, 1204
  - Gray-scale alpha planes, in MPEG-4, 853
  - Gray-scale plot, for monochrome images, 413, 413f
  - Greedy minimization approach, to halftoning, 932
  - GRFs. *See* Gibbs random fields
  - Gridless halftoning, and PDEs, 607
  - Ground penetration (GPEN), and SAR, 1135, 1135f
  - Grouping
    - images as, 522
    - perceptual, 522
  - Group of blocks (GOB) layer, in H.261 video encoder, 794
  - Group-of-frames/group-of-pictures color descriptor, in MPEG-7, 869
  - Groups of pictures (GOPs), in MPEG-1, 835–837, 835f
- ## H
- Hadamard definition, of ill-posed problem, 186
  - Halftoning, 903
    - and compression, 933
    - error diffusion, 929–932, 931f
    - optimization techniques, 932–933
    - ordered dithering, 928–929, 929f
    - process of, 928
    - techniques, 928
  - Halftoning framework, for VC, 1112
  - Hamming distance, in iris recognition, 1255, 1255f, 1257, 1257f, 1259, 1259f
  - Hand-eye coordination, 536
  - Handheld products, consumer electronic, 877–878, 878f, 890
  - Hardcopies of images, 925
  - HDTV terrestrial transmission, 777
  - Head, cylindrical representation of human, 507. *See also* Object tracking
  - Heat equation on curves
    - in calculus of variations, 617
    - description, 577
    - implementation, 577–578
    - properties, 577–578, 578f
  - Height flooding, in watershed segmentation, 609
  - Hewlett-Packard proposal LOCO- $I_{1p}$ , and JPEG lossless compression standard, 733
  - HFC. *See* Hybrid fiber-coax network
  - Hidden Markov models (HMMs), 1025
    - and ASR, 1271–1273, 1273f
    - in speech-to-video synthesis, 1280–1281
  - Hierarchical variable-size block (HVSBM), 801
  - Highest confidence first (HCF) algorithm, 266–267, 483
  - Highlight candidate, defined, 1015, 1015f
  - Highlight group, defined, 1015, 1015f
  - Highlights extraction
    - audio marker detection, 1022, 1022f
    - audio-visual markers, 1023
    - finer-resolution highlights, 1023–1024, 1023t, 1024t
    - visual marker detection, 1022–1023, 1022f, 1023f
  - High-range resolution radar (HRR), in sensor modeling, 1345
  - Hilbert-Schmidt bounds (HSBs), 1348
  - Hilbert-Schmidt estimator, 1347
  - Hilbert-Schmidt norm, 1352
  - Hilbert transform
    - in AM-FM modeling, 381, 393
    - in image statistics, 437
  - Histogram approaches
    - bimodal, 40–41, 41f
    - calculation for, 22
    - effects of multiplicative image scaling on, 27f
    - expansion and contraction of, 26–27, 27f
    - in image statistics, 437, 437f
    - multimodal, 42f
  - Histogram equalization, 30–32, 31f
    - applications, 31f
    - digital, 30
  - Histogram flattening, 31
  - Histogram shaping, 32, 32f
  - HMMs. *See* Hidden Markov models
  - Homography, in global motion models, 312
  - Hopfield model, binary, 521
  - Hough transform methods
    - in feature-based object tracking, 499
    - in motion segmentation, 478
  - H.323 protocol stack, 1059–1060, 1060f, 1060t
  - H.261 standard, compared with MPEG-1, 837–838, 838t
  - H.261 video encoder, 786, 793–797, 800
    - data hierarchy in, 795
    - implementation, 793, 794f
  - H.263 encoder, 822
  - H.264/AVC
    - block transform coding used by, 861
    - coding performance, 864, 865f
    - in digital video market, 873
    - in-loop deblocking filter, 860–861, 861f
    - intraprediction in, 858f
    - multireference picture prediction in, 860f
    - visual profiles of, 863, 863t
  - H.264/AVC video coding layer
    - enhanced motion-compensation prediction model, 859–861, 859f–861f
    - slices and slice groups, 858
    - spatial directional intraprediction, 858–859, 858f
    - technical overview, 857–858, 858f
  - Hubble Space Telescope, 221f, 222
  - Hue-Saturation components, 495
  - Huffman coding, 733, 744
    - defined, 716
    - modified, 786
    - procedures, 734–736, 735t
    - technique, 649–651, 649f, 650t
  - Human body
    - cylinder-based volumetric representation of, 511f
    - hierarchic representation, 508f
    - polygonal representation of, 510f
    - stick model of, 510f
  - Human-computer interaction (HCI)
    - future scenarios for, 1263
    - and visual and audio signals, 1285
  - Human-machine interfaces, 491
  - Human Visual Subspace (HVSS), 421
  - Human visual system (HVS), 163. *See also* Visual system
    - amplitude nonlinearity in, 941
    - contrast masking in, 942, 943f
    - and contrast sensitivity function, 941–942, 942f
    - and image quality, 939
    - and natural image signals, 961
    - and psychophysics, 941
    - and quantization tables, 715
    - temporal masking in, 942–943, 943f, 944f
    - top-down vs. bottom-up philosophy of, 973
    - and video compression techniques, 780
    - video quality metrics, 955–956
  - Human visual system model, for quality assessment, 978–979, 986
  - HVS. *See* Human visual system
  - HVSBM. *See* Hierarchical variable-size block

- Hybrid block-based motion-compensated (HBMC) (R)?, 1069, 1070f
- Hybrid coders, 815
- Hybrid fiber-coax (HFC) network, 1039–1040
- Hypothesis testing
  - with adaptive threshold, 257–258
  - with fixed threshold, 256–257
  - in motion detection, 254
- I**
- IBLOCKS, directional, 806, 806f
- IDCT. *See* Inverse discrete cosine transform
- Ideal observer model, 331–332
- Identification, blur, 178–179
- Identification, positive
  - applications for, 1219–1220
  - with fingerprint as biometric, 1220
- Identity, problem of, 1219
- Identity characterization. *See also* Automatic face recognition; Fingerprint-based automatic identity authentication system; Iris recognition
  - from group of still images, 1242–1244, 1244f, 1245f, 1245t
  - probabilistic, 1240–1241
  - recognition setting and issues in, 1241–1242
  - from video sequence, 1244–1248, 1246f, 1247t, 1248f
- Identity equation, in face recognition, 1245
- IDL. *See* Interactive Data Language
- IEC. *See* International Electrotechnical Commission
- IFC. *See* Information fidelity criterion
- Illumination phenomenon, in face recognition, 1237, 1238f
- Illumination spectrum, in color matching, 421
- Image, defined, 939
- ImageAccess
  - canny edge detector in, 77, 78f
  - of IP-LAB, 75–76, 76f
  - and MIP, 76
  - moving-average filter in, 77
  - wavelet transforms, 77, 79f
- Image analysis, mathematical morphology for, 135
- Image averaging, for noise reduction, 33–34, 34f
- Image binarization, 16
- Image capture, 895
  - Fourier analysis of, 898–901, 899f–901f
  - general model for, 898–900, 899f, 900f
  - model for general process of, 897, 897f
  - and sampling rate conversion, 901–903
  - systems for, 909
  - technologies, 896, 896f
- Image differencing, for change detection, 34–35, 35f
- Image focus assessment, in iris recognition, 1252
- Image formation processor (IFP), in SAR, 1133
- Image frames, multiple, 203, 204f
- Image frequency, 57
  - and DFT, 67–72, 68f–71f
  - granularity, 68–70, 68f–70f
  - orientation, 70–72, 70f–72f
- Image histogram. *See also* Histogram approaches
  - cumulative normalized, 30
  - defined, 22
  - normalized, 30
  - poor use of gray-scale range, 23, 24f
  - skewed, 22, 23, 23f
- ImageI, of IP-LAB, 75
- Image luminance field, temporal variation in, 309
- ImageMagick, 639
- Image noise cleaning, 119. *See also* Noise
- Image plane, global motion models in, 311–312, 311f
- Image prior, in postprocessing of compressed images, 771–772
- Image processing, 3. *See also* Gray-level image processing
  - algorithms for, 16
  - applications, 4f, 438–439
    - automated target recognition, 1341–1353
    - automatic speech processing, 1263–1289
    - cardiac imaging, 1175–1193
    - computed tomography, 1155–1173
    - computer-assisted microscopy, 1311–1340
    - confocal microscopy, 1291–1309
    - face recognition, 1235–1250
    - fingerprint classification and matching, 1219–1234
    - iris recognition, 1251–1262
    - mammography, 1195–1218
    - synthetic aperture radar, 1131–1154
  - in everyday life, 925
  - as science, 157
  - two-dimensional, 16
- Image reconstruction algorithm, in postprocessing of compressed images, 772. *See also* Reconstruction
- Image restoration, problems of, 183–185. *See also* Restoration
- Imagery, time-varying, 911
- Images, 16. *See also* Multispectral images
  - binary, 39, 40f
  - color, 11, 12f
  - defined, 3
  - described by function, 411
  - digitization of, 5
  - dimension of, 5, 7f
  - display of, 412–414, 412f, 413f
  - interpolation of, 903–909, 903f–908f
  - mathematical morphology for, 135
  - nature of, 411
  - in point operations, 27–28
  - presentation of, 412
  - quantized, 9–10, 9f–16f
  - sampled, 7–8, 7f
  - scale of, 5
  - two-dimensional functions for, 412
  - types of, 4–5
- Image sequence analysis, 309
  - algorithms for, 314–316
  - biologic motivation in, 311
  - global motion models in, 311–314
  - motion superresolution in, 318–320
  - two-dimensional stabilization in, 316–317
- Image sequences
  - processing of, 309
  - three-dimensional stabilization in analysis of, 320
- Image sharpening, 127–130, 128f, 129f, 130f
  - by high frequency emphasis, 127f, 128f
  - using weighted median filter, 129f
- Image smoothing, noise suppression and, 139–140, 139f, 140f
- Image stimulus synthesis, for performance comparison, 970–973, 970f–973f
- Image synthesis, and probability, 431. *See also* Probability
- Image thresholding, 16, 40–43, 41f–44f
- Image zooming, 123, 125–127, 127f, 128f
- Imaging process, 3-D to 2-D representation of, 535. *See also* Image processing
- Implementation, of lossless image coding, 646
- Improvement SNR, 239
- Impulse function, two-dimensional, 99
- Impulse noise, and morphological openings and closings, 139
- Impulse response, 100, 101, 116
- Impulse response shaping, 116
- IMSL libraries, 636
- Inclusion principle, in shape smoothing, 574
- Independent component analysis (ICA), in face recognition, 1237
- Indexes
  - in video design, 1025–1027, 1025f–1027f, 1026t, 1027t
  - in video retrieval, 1024
- Information embedding, 926
- Information fidelity criterion (IFC) (R), 981–982, 989
  - and human visual system-based meth, 982–983, 983f
  - properties of, 982
  - validation of, 986
- Information-fidelity problem, 976, 976f
- Information theory, and lossless image coding, 646–648
- Informed coding/embedding schemes, for watermarking, 1086
- Inkjet printing, 925–926
- Insect navigation
  - control of flight speed, 310–311
  - stabilization, 310–311
- Insects
  - centering behavior of, 310
  - collision avoidance in, 310
  - flight navigation of, 310
- Integrated Services Digital Network (ISDN)
  - basis for, 1042–1043
  - video transmission via, 15
- Intel library, 636
- Intelligent cruise control (ICC) systems, 446
- Intelligent Systems Software, Inc. (ISSI), 1210
- Intelligent transportation systems (ITS), 446
- Intelligent vehicle highway systems (IVHS), 446
- Intensity flicker
  - correction of, 289–292, 290f
  - defined, 276
  - and parameter estimation, 289–291
  - sequences with motion and, 291–292
- Intensity histogram equalization, 289
- Interactive Data Language (IDL), 632, 633f, 640
- Interband correlations, in JPEG-LS part 2, 741–742
- Interlaced scanning, 14, 14f
- International Consultative Committee for Radio (CCIR), 785, 785t
- International Electrotechnical Commission (IEC), standards of, 792
- International Standards Organization (ISO), 638, 733, 785, 792
- International Telecommunications Union (ITU), 785, 792
- Internet
  - evolution of, 1031
  - Internet 2, 1032
  - viewing video over, 819
- Internet protocol networks
  - development of, 1048



- DiffServ, 1062–1063, 1063f
- H.323 protocol stack, 1059–1060, 1060f, 1060t
- multicast backbone, 1049–1050
- real-time streaming protocol, 1059, 1060t
- real-time transport control protocol, 1054–1059, 1055t, 1056f–1058f
- real-time transport protocol, 1050–1054, 1050f, 1052f, 1052t, 1053f, 1054f
- resource reservation protocol, 1061–1062, 1062f
- session initiation protocol, 1060t, 1061
- Interpolation, 17
  - bilinear, 37f
  - motion-compensated, 919–920, 919f, 920f
  - motion-compensated temporal, 921
  - nearest-neighbor, 37f
  - pure temporal, 919
  - spatiotemporal, 919, 921
- Interpolation image
  - linear filtering approaches to, 903–904, 903f, 904f
  - model-based approaches to, 904–909, 905f–908f
- Intershape coding, in MPEG-4, 853, 853f
- Intrashape coding, in MPEG-4, 853
- Inverse discrete cosine transform (IDCT), 788
- Inverse filter, in image restoration, 172, 172f
- Inverse operators, in intraframe encoding mode, 779–780
- Ion ratio imaging, 1338
- IP-LAB
  - computer laboratories of, 77–78
  - description of, 75
  - development of, 74–75
  - foundation of, 75
  - ImageAccess of, 75–76, 76f
  - sessions at, 76
- Iris patterns, diversity among, 1260. *See also* Visual system
- Iris recognition
  - decision environment for, 1259–1260, 1259f
  - development of, 1251–1252, 1252f
  - failing test of statistical independence in, 1258–1259, 1258t
  - imaging system for, 1252
  - size, position and orientation in, 1256–1258, 1257f
  - speed performance in, 1260, 1260t
  - test of statistical independence in, 1255f, 1254–1256, 1256f
  - two-dimensional wavelet demodulation in, 1253–1254, 1253f, 1254f
  - video frame rate in, 1260–1262, 1262f
- ISDN. *See* Integrated Services Digital Network
- ISO. *See* International Standards Organization
- ISO/IEC JTC1/SC29 technical committee, Working Group 11 of, 709. *See also* Moving Picture Experts Group
- Isotropy, in shape smoothing, 574
- Iterated affine erosion
  - description, 579
  - implementation, 579–581
  - properties, 581, 581f
- Iterated conditional mode (ICM), in motion estimation, 271–272
- Iterated weighted median filter
  - description, 576–577
  - with image partial differential equation, 576–577
  - implementation of, 576
  - properties of, 577
- Iterative filters
  - advantages and disadvantages, 176–178
  - in image restoration, 175–178, 176f
- ITU. *See* International Telecommunications Union
- J**
- Java-based educational software
  - ALMOT 2D DSP, 80, 81f, 82f
  - at Arizona State University, 78–80
  - J-DSP, 80–83, 83f, 84t
  - and two-dimensional signal processing, 78–83
- Java Digital Signal Processing (J-DSP), 80–83, 83f, 84t
- Java Language, used by IP-LAB, 75
- JBIG. *See* Joint Binary Image Experts Group
- JFIF. *See* JPEG file interchange format
- JND. *See* Just-noticeable distortion
- Joint Binary Image Experts Group (JBIG), coding standards of, 655
- Joint Photographic Experts Group (JPEG)
  - coding standards of, 638, 655–656
  - and discrete cosine transform (DCT), 160
  - lossless image compression standards of, 733
  - standards, 17
- Joint Photographic Experts Group (JPEG) standard, 709–710
  - coefficient-to-symbol mapping unit in, 711
  - DCT, 711
  - decoder structure in, 712
  - encoder structure in, 710–711, 711f
  - entropy coding unit in, 711
  - hierarchic mode for, 719–720, 720f
  - image data format and components in, 717–718
  - JPEG2000, 722–729, 724f, 725t, 726f–728f
  - JPEG Part 3, 720–723
  - progressive mode for, 718–719
  - quantizer in, 711
  - source of information on, 729–730
- Joint source-channel coding (JSCC), 1066, 1080
  - channel models, 1070–1071
  - and end-to-end distortion, 1067–1068
  - error resilient source coding, 1072
  - illustration of, 1068, 1068f
  - and Internet video transmission, 1076–1077, 1076f
  - and power adaptation, 1078, 1080
  - and practical constraints in video communications, 1067–1068
  - in problem formulation, 1075–1076
  - and rate-distortion theory, 1067, 1067f
  - and wireless video transmission, 1077–1080, 1078f, 1079f
- Joint source coding
  - and data rate adaptation, 1080
  - and forward error correction, 1076–1077, 1076f, 1077
  - and hybrid forward error correction, 1077
  - and power adaption, 1077–1078, 1078f, 1079f
- Jordan curve, 614, 620
- JPEG. *See* Joint Photographic Experts Group
- JPEG file interchange format (JFIF), 710
- JPEG-LS part 2 standard, 736, 737f, 740–742
  - alphabet extension in, 741
  - arithmetic coding in, 741
  - baseline algorithm for, 736, 737f, 740
  - bias cancellation in, 741
  - context formation in, 741
  - fixed-length coding in, 741
  - interband correlations in, 741–742
  - near-lossless mode in, 741
  - prediction in, 740–741
- JPEG Part 3 standard
  - tiling capability of, 722, 722f
  - variable quantization in, 720–721, 721f
- JPEG2000 standard, 722–723, 744
  - bitstream organization in, 727–728
  - coding architecture, 723–724, 724f
  - discrete wavelet transform, 724, 725t
  - entropy coding technique, 725–729, 726f–728f
  - extensions, 729
  - and integration of lossless and lossy compression, 742–744
  - lossless coding in, 742, 743f
  - performance, 729
  - precincts and codeblocks, 725
  - preprocessing in, 723–724
  - quantization and inverse quantization, 724–725
  - ranging, 744
  - reversible color transform in, 742–743
  - reversible discrete wavelet transform, 743–744, 743t
  - source of information on, 730
- JSCC. *See* Joint source-channel coding
- Just-noticeable distortion (JND), 658
- K**
- Kalman filters
  - in Bayesian object tracking, 503–505
  - extended, 508
  - for occlusion handling, 505
- Kanizsa subjective triangle, 522, 522f
- Karhunen-Loeve transform (KLT), 530, 748, 753, 787
- Key frame, defined, 1014, 1015f
- Kinescope moiré phenomenon
  - during film-to-video transfer, 276
  - removal of, 292–293, 293f
- KL transform *see* Karhunen-Loeve transform. *See also* Karhunen-Loeve transform
- K-means method, as segmentation strategy, 477–478
- L**
- Label statistics, in image segmentation, 446
- LabVIEW, 632–634, 635f
- LabVIEW Development Environment, 85, 85f, 89
- Landweber weight function, 197, 197f, 198f
- Lane departure warning (LDW) systems, 446
- Laplacian, defined, 543
- Laplacian density, in face recognition, 1247
- Laplacian methods
  - continuous, 543–544, 544f
  - with discrete operators, 544–545
  - and DoG, 546–548
  - Laplacian of Gaussian, 545–546, 547f
- Laplacian pyramid, 338, 348f, 350–351
- Laser printing, 925, 926
- Laser scanning confocal microscopy (LSCM), 1299. *See also* Confocal microscopy
- Lateral geniculate nucleus (LGN) of thalamus, 332
  - cells of, 326, 330t
  - magnocellular layers of, 334
  - parvocellular layers of, 334
- Lattice, in video sampling, 912, 913f, 914, 916, 918f
- Lattice theory, morphological operators and, 138–139
- Layered coding, 843–845, 844f, 845f
- Layered coding with transport prioritization, 1072
- LBG. *See* Linde, Buzo, and Gray Design
- Learned Vector Quantization (LVQ), 528

- Learning. *See also* Education  
 active, 1006  
 off-line, 1004–1005  
 on-line, 1005–1006
- Least-squares filters, in image restoration, 172–175, 173t, 175f
- Legal path, in dynamic processing, 302
- Legendre-Fenchel “slope” transforms, 589
- Lempel-Ziv coding technique, 653–654, 654t
- Lena image, 428, 428f, 658f, 669f, 690f, 692, 693f, 698, 699f, 701, 702f, 712, 712f, 721f, 765f, 768f, 770f, 772, 773f, 985f, 1126f
- Level sets formulation, 599–600
- Lexicographic ordering, 242
- LGN. *See* Lateral geniculate nucleus
- Likelihood, in postprocessing of compressed images, 771
- Likelihood ratio test, 42, 145
- Linde, Buzo, and Gray Design (LBG) algorithm, in VQ design, 677–678, 678f
- Linear discriminant analysis (LDA), in face recognition, 1237
- Linear edge operators, in feature detection, 146
- Linear filtering  
 application of, 99, 107–108  
 frequency response, 101, 102  
 and image interpolation, 903–904, 903f, 904f  
 impulse response, 100, 101  
 limitations of, 108  
 linear convolution, 100–101  
 for linear image enhancement, 102–107, 104f–108f  
 using Sobel operator, 131
- Linear filters  
 limitations of, 108  
 temporally averaging, 277–278, 278f, 280f  
 temporally recursive, 278–279
- Linear minimum mean square error (LMMSE) estimation, 205
- Linear prediction coefficients (LPCs), in speech-based HCI, 1268
- Linear system analysis, in vision science, 337
- Linear system theory, 99
- Lip tracking, in ASR, 1265–1266
- Liquid toner laser transfer, 925
- Lloyd algorithm, for optimum quantizer, 927
- Lloyd-Max quantizers, 927
- LMDS *see* Local Multipoint Distribution Service
- Local feature analysis (LFA), in face recognition, 1237
- Local inclusion principle, in shape smoothing, 574
- Localization descriptors, in MPEG-7, 872
- Local Multipoint Distribution Service (LMDS), 1042
- Logarithmic point operations, 29–30, 30f
- Lossy image compression, 709. *See also* Compression;  
 Joint Photographic Experts Group standard;  
 JPEG2000 standard
- Lossy operations, 778
- Low-pass filtering  
 application of, 106f  
 in linear image enhancement, 103, 104–106, 106f
- Lubin’s model, 947
- Luminance  
 changes, 964  
 human eye’s sensitivity to, 939  
 in visual system, 333
- Luminance levels, qualitative description of, 417, 417t
- LZ coding. *See* Lempel-Ziv coding
- M**
- Machine-readable travel document (MRTD), 1235
- Macroblock-based coding technique, 879
- Macroblock layer, in H.261 video encoder, 794–795
- Magnetic resonance imaging (MRI), 748, 1155  
 in cardiac image processing, 1175  
 for coronary artery analysis, 1180–1181, 1182f  
 in heart chamber analysis, 1188
- Mahalanobis distance, in object tracking, 502
- Majority filter, 52–53, 52f
- Mammography, screening, 1195, 1196f  
 abnormalities found in, 1195, 1196f  
 computer-aided detection of abnormalities with, 1197–1206, 1197f–1199f, 1201f, 1203t, 1206t  
 computer-aided diagnosis of abnormalities with, 1206–1210, 1209t  
 early detection via, 1196  
 image thresholding in, 42, 44f  
 positive predictive value of, 1197
- MAP. *See* Maximum a posteriori estimation; Median adaptive predictor
- Mapping. *See* Geographical information systems
- Mapping AC coefficient, in lossy image compression, 716
- Maps, SSIM index, 968, 969f
- Marginal kurtosis criterion, optimizing, 435f
- Marginal Weighted Multichannel Median (Marginal WMM), 119
- Marginal WM filter, 117
- Markov assumption, in image modeling, 431
- Markovianity, 363
- Markov random field (MRF) models, 254–255, 361  
 hypothesis testing combined with, 257  
 for modeling texture, 527  
 neural network techniques and, 527  
 texture descriptors derived from, 456  
 in video segmentation, 481–482, 481f
- Marr-Hildreth operator, 545–546
- Marr-Hildreth paradigm, 556
- Masses, computer-aided detection of. *See also*  
 Mammography  
 classification as mass in, 1202  
 in suspicious regions, 1198–1202, 1199f, 1201f  
 using multiple images, 1202–1203, 1203t
- Masses, computer-aided diagnosis of, 1206–1208, 1207f  
 classification of, 1207–1208  
 feature extraction, 1207  
 segmentation, 1207
- MATLAB software, 412, 413, 414, 630–631, 631f, 640
- Matrix-vector formulation  
 basic iteration, 242  
 constrained least-squares iteration, 243–246, 245f, 246f  
 experimental results, 244–246, 245f, 246f  
 least-squares iteration, 242–243  
 spatially adaptive iteration, 246–247
- Maximum a posteriori (MAP) estimation  
 and image segmentation, 447, 448f, 450f, 451, 480–481  
 in motion detection, 255, 258  
 in multi-frame restoration, 227
- Maximum a posteriori (MAP) methodologies, in recovery-based postprocessing, 762
- Maximum a posteriori probability (MAP), and Bayesian framework, 1347
- Maximum entropy regularization, 192, 192f
- Maximum intensity projection (MIP), using ImageAccess, 76
- Maximum-likelihood (ML) estimation, 480  
 in multi-frame restoration, 225–226  
 penalized, 226–227  
 and segmentation, 449, 449f, 450f, 480, 487f  
 sieve-constrained, 226
- MBONE. *See* Multicast Backbone
- MCD. *See* Multispectral high definition Color Description
- MCTF. *See* Motion-compensated temporal filter
- MDS. *See* Multimedia description scheme
- Mean square error (MSE), 693
- Median adaptive predictor (MAP), in JPEG-LS, 737
- Median edge detection (MED) predictor, in JPEG-LS, 736–737
- Medical imaging. *See also* Computed tomography;  
 Magnetic resonance imaging  
 developments in, 4  
 multichannel reconstruction in, 215–216, 215f, 216f  
 multispectral, 748, 755  
 software for, 632  
 video enhancement and restoration in, 275
- Mel-frequency cepstral coefficients (MFCCs), in speech-based HCI, 1268
- Memory allocation, in embedded video codecs, 880, 890
- Mesh object coding, in MPEG-4, 854, 854f
- Metaphase finding, in clinical cytogenetics, 1326
- Metropolis algorithm, used in MAP segmentation, 481
- Mexican hat neighborhood connections, 529–530, 530f
- Micrograph of cellular specimens, binarized image for, 42, 43f
- Microscanning, 219
- Microscopy, advances in, 1311. *See also*  
 Computer-aided microscopy; Confocal microscopy
- Microvascular networks, confocal microscopy of, 1304–1305  
 data acquisition in, 1305, 1305f  
 density determination in, 1304  
 3-D representation of, 1305, 1305f  
 morphology in, 1305–1308, 1306f, 1307f
- Microwave imaging, potential of, 1152
- Minimum absolute error (MAE), and Bayesian framework, 1347
- Minimum mean squared error (MMSE) estimator, 1347, 1348
- Minkowski error metric, 961–963, 962f, 963f, 966–967, 967f
- ML. *See* Maximum-likelihood estimation
- MLP. *See* Multi-layered perceptron
- MMDS. *See* Multichannel Multipoint Distribution Service
- MMS. *See* Multimedia message service
- Mobile phones, 819
- MoCA. *See* Movie Content Analysis
- Model-based coding, in MPEG-4, 854–855
- Modulation transfer function (MTF), of Gabor filter, 1225
- Moment preserving quantization, and BTC, 666–667, 668t
- Monochrome images, 157, 413
- Monte Carlo Markov chain, in identity characterization, 1241

- Morphological filtering
  - and contrast enhancement, 142–143
  - hit-miss transformation, 145
  - multiscale, 588
  - research directions in, 155
  - for smoothing and simplification, 140–142, 141f
- Morphological filters, 47–53, 47f, 48f–52f
  - for binary images, 136
  - indications for using, 155
  - optimal design of, 150–155
  - stack filters, 138
- Morphological image operators
  - for feature detection, 145–150
  - for gray-level images, 136–137
  - and lattice theory, 138–139
  - rank filter, 137–138
  - for template matching, 143–145
  - universality of, 137
- Morphological image processing, 136
- Morphological/rank/linear (MRL) filters, 151–152
- Morphologic systems, multidimensional, 590–591
- Morphometry, computer-assisted, 1311
- Mosaicking, 317, 319, 320–321
- Mosaics
  - generation of, 317–318
  - types of, 317
- Motion
  - capture of, 253
  - and cortical cells, 338–340, 339f
  - notation for, 254–256
- Motion analysis
  - human, 491
  - in video indexing, 996–997
- Motion blur, linear, 169–170, 170f
- Motion-compensated embedded zero block coder (MC-EZBC), 799
  - block models in, 806, 806f
  - comparison of different interpolation filters, 804, 805f
  - improvements for, 814–815
  - motion estimation in, 807
  - and overlapped block motion compensation, 806
  - rate-distortion curves of, 804–805, 805f
  - visual results with, 814, 815f
- Motion-compensated interpolation, 919–920, 919f, 920f
- Motion-compensated (MC) subband/wavelet transform (SWT), 799
- Motion-compensated (MC) temporal filtering
  - bidirectional, 805–806
  - invertible half-pixel accurate, 803
  - and lifting implementation, 803–804
  - noninvertible approach to, 802–803
  - with OBMC, 806–807
  - and sub-pixel interpolation, 803–804
- Motion-compensated prediction (MCP), 1069
  - bi-directional, 834–835, 834f
  - frame-based and field-based, 842–843, 842f, 843f
  - with half-pixel accuracy, 835, 835f
  - in H.264/AVC, 859
- Motion-compensated temporal filtering (MCTF), 706, 799, 800f
- Motion compensation, DCT domain inverse, 823–825, 825f
- Motion constraint equation, 263
- Motion descriptors, in MPEG-7, 871–872, 871f
- Motion detection, 253
  - comparison of methods of, 259, 260f
  - goal of, 256
  - hypothesis testing in, 254, 256–258
  - MAP in, 255, 258–259
  - MRF in, 254–255
  - temporal integration in, 474
- Motion estimation, 253, 800
  - algorithms for, 259–261, 880–881
    - block matching, 269–270
    - dense motion, 271–272
    - global, 267–269, 268f
    - optical flow via regularization, 271
    - phase correlation, 270–271
  - comparing methods of, 272–273, 272f
  - criteria
    - Bayesian, 266
    - frequency-domain, 265
    - pixel-domain, 264–265, 264f
    - regularization of, 265
    - search strategies, 266
  - and detection of covered and uncovered pixels, 801–802
  - in embedded video codecs, 880–881
  - goals of, 259
  - models
    - observation, 263–264
    - spatial, 261
    - temporal, 261–262
  - regions of support in, 262–263, 262f
  - using color components for, 802
  - variational formulations for, 255–256
- Motion field, 254
- Motion Picture Experts Group (MPEG)
  - encoding standards of, 777
  - MPEG-1 coding, 792
  - MPEG-1 standard, 777
    - background and structure of, 833–834
    - compared with H.261, 834–835, 834f, 835f
    - compared with MPEG-2, 846
    - simulation model, 838
    - target applications and requirements, 834–835, 834f
  - MPEG-2 standard, 777, 792, 800, 1034–1038, 1035f, 1036t, 1037f
    - background and structure of, 839–840
    - compared with MPEG-1, 841–843, 841f, 842f, 846
    - data partitioning, 845
    - data structure and syntax, 846f
    - and discrete cosine transform (DCT), 160
    - elementary stream, 1035, 1035f, 1036t
    - input resolutions and formats, 841
    - packetized elementary stream, 1035–1036, 1036t, 1037f
    - part 2, 850–856, 851f–856f, 863–864, 864f
    - profiles and levels, 840–841, 841t
    - program stream, 1036
    - target applications and requirements, 840
    - test models developed in, 846
    - and tools for error-resilience, 845–846
    - transport stream, 1036–1038, 1038f, 1038t
    - visual profiles, 856, 856t
  - MPEG-4 standard, 777, 792, 873
    - characteristics of, 849
    - compression performance, 863–864
    - part 10, 864, 865f
    - Part 10: H.264/AVC, 857–863, 857f–861f, 863f
    - release of, 1034
    - technical description, 850–856, 851f–856f
    - temporal integration procedure adopted by, 474
    - video applications, 864–866
  - MPEG-7 standard, 777, 792, 873
    - characteristics of, 849
    - DDL in, 872–873
    - MDS in, 872, 872f
    - technical description, 866–873, 866f–872f
    - terminal block diagram, 867f
    - video applications, 873
  - MPEG-1 video
    - bit-stream structures of, 838–839, 838f
    - compared with H.261, 837–838, 838t
    - structure of, 835–837, 835f, 836f
  - MPEG-2 video, and system bit stream structures, 846
    - standards of, 792
    - video encoding and decoding of, 94
- Motion pictures, preserving, 275
- Motion problems, 309
- Motion segmentation, 253, 474–482, 481f
  - dominant, 475–476
  - multiple, 476–477
- Motion superresolution algorithms, 318–320
- Motion tracking, in digital video, 491. *See also* Object tracking
- Motion transition equation, in face recognition, 1244–1245
- Motion vector, scan/spatial prediction for, 807
- Motion vector coding
  - layered structure of, 808
  - in MPEG-4, 851
  - scalable, 807–808
- Motion vector estimation
  - for spatial resolution reduction, 827, 827f
  - for temporal resolution reduction, 827–828, 828f
- Motion vector repair, 285–287, 287f
- Motion vector symbols, alphabet general partition, 807–808
- Mouth, in ASR, 1265–1266, 1266f
- Movie Content Analysis (MoCA), 1009
- Moving-average filter, 103–104, 104f, 105f
- MPEG. *See* Motion Picture Experts Group
- MPEG video compression, 93, 93f
- MRF models. *See* Markov random field models
- MRI. *See* Magnetic resonance imaging
- MRL filters
  - applications, 153–155, 155f
  - designing optimal, 153
- MSE. *See* Mean square error
- Multicast Backbone (MBONE), 1032
- Multichannel image, 203
  - astronomical, 208f
  - implicit approach to recovery of, 211–216, 215f, 216f
  - linear minimum mean square error (LMMSE)
    - estimation for, 205
  - LMMSE for, 205
  - recovery approaches for, 207–211, 208f
  - regularized weighted least-squares (RWLS)
    - estimation for, 205
- Multichannel image recovery, 204
- Multichannel imaging
  - model for, 204–205
  - numerical experiment in, 207–209, 208f
  - regularization in, 206–207, 208f
  - transformation of the model for, 212–214
- Multichannel Multipoint Distribution Service (MMDS), 1042
- Multicomponent (color) constraint, 264

Multi-frame blind deconvolution, 220  
 Multi-frame imaging process  
   mathematical models, 221–224  
   and nuisance parameters, 228–229  
   problem of, 224–228  
   and undersampled image sequences, 229  
 Multi-layered perceptron (MLP), in ANNs,  
   520–521, 526  
 Multimedia analysis, 1027  
 Multimedia applications, handheld, 880  
 Multimedia databases  
   queries in, 1008, 1008t  
   testing and evaluation, 1008, 1009f  
 Multimedia description scheme (MDS), in MPEG-7,  
   872, 872f  
 Multimedia message service (MMS), 877  
 Multimedia products, 877, 878f  
 Multimodal analysis, 1013, 1016  
 Multiple bit watermarking systems, 1086  
 Multiplicative image scaling, 26–9, 26–27, 27f, 29f  
 Multiscale image analysis, 588  
 Multiscale morphologic filtering, implementations  
   of, 588  
 Multispectral high definition Color Description  
   (MCD), 749, 749f, 755  
 Multispectral images, 747  
   compression algorithms for, 749, 749f  
   defined, 758–759  
   lossless compression of, 755–759  
   lossy compression of, 750–755, 751f, 752f, 754f  
   remotely sensed, 751–755, 752f, 754f  
   RGB color, 747  
 Mutual information, notion of, 980

## N

National Solar Observatory, 232  
 National Television Systems Committee (NTSC), 785  
 Natural image signals, 961  
 Natural scene statistics (NSS), 163  
 Natural scene statistics (NSS) model, 976, 977  
 Naval Air Warfare Center (NAWC), 1135  
 NCP. *See* Network Control Protocol  
 Nearest-neighbor interpolation, 37f  
 Nearest neighbor rule, in VQ design, 676  
 Near-lossless compression  
   in JPEG-LS, 739–740  
   in JPEG-LS part 2, 741  
   of multispectral images, 758  
 Network Control Protocol (NCP), 1031  
 Neural networks, 532. *See also* Artificial neural  
   network  
 Neural oscillations, in image segmentation, 528–530  
 Neuroscience, computational, 963. *See also* Artificial  
   neural network  
 NEWPRED, 856  
 Next-generation Internet (NGI), 1032  
 Node, in dynamic processing, 302  
 Noise. *See also* Speckle  
   and CCD imaging, 405–406  
   cleaning, 119–123, 121f–126f, 126t  
   defined, 397–398  
   denoising examples, 438, 439f  
   types of  
     Gaussian noise, 400–401, 401f  
     heavy tailed, 401–403, 402t  
     photographic grain, 405  
     photon counting, 404–405, 405f

    Poisson, 404–405, 405f  
     quantization, 403–404, 404f  
     salt and pepper, 403, 403f  
     uniform noise, 403–404, 404f  
 Noise amplification, 201. *See also* Regularization  
 Noise filtering, spatio-temporal, 277–282, 278f,  
   280f–282f  
 Noise leakage, 103  
 Noiseless Source Coding Theorem, 786  
 Noise models  
   estimation theory in, 399–400  
   and multi-frame restoration, 224  
   and notions of probability, 398–399  
   speckle in, 406–409, 408f  
 Noise reduction. *See also* Denoising  
   and feature preservation, 2.1–14–2.1–17  
   image averaging for, 34–35, 35f  
 Noisy images  
   and Gaussian filters, 107  
   and low-pass filter, 106, 106f  
   and moving-average filter, 103, 105f  
 Nonlinear filtering, 109, 132. *See also* Weighted  
   median smoothers  
   edge detection, 130–132  
   and image noise cleaning, 119–123, 121f–126f, 126t  
   in image sharpening, 127–130, 129f, 130f  
   and multivariate filtering structure, 118–119  
 Nonlinear point operations, 29–50, 30f, 31f. *See also*  
   Point operations  
 Non-quadratic regularization, 191–192  
 Non-separable filtering, 77  
 Normalized cross-correlation, 300  
 Normalized SSD, 300  
 NSFNET, 1031, 1032  
 NSS. *See* Natural scene statistics  
 NTSC. *See* National Television Systems Committee  
 Numerical filtering, 189–190, 190f  
 Numerical recipes, 638  
 Nyquist Sampling Theorem, 783

## O

Object-based representation, in MPEG-4, 850–851  
 Object detection, 491  
   articulated objects, 1002  
   captions and graphics, 1000, 1000f  
   human subjects, 1000, 1000f  
 Object tracking  
   algorithms for, 491  
   applications for, 491–492  
   articulated, 508–509, 508f  
     3D example techniques, 512  
     3D modelling of, 510–511, 510f  
     image cues, 511  
     kinematic and motion constraints, 510–511  
     three-dimensional, 509–512, 510f, 511f  
     two-dimensional, 512–513  
   Bayesian, 502–505  
   contour-based, 497–498  
   3D rigid, 506–508, 507f, 508f  
   feature-based, 498–500, 499f  
   methods for, 493  
   model-based coding in, 492  
   occlusion handling in, 505–506  
   region-based, 494–497, 495f, 496f  
   videophone application, 507–508  
 Observation likelihood, in face recognition, 1245  
 Off-line learning systems, 1004–1005  
 Offset printing, 925  
 One-dimensional processes, in image representation  
   discrete system representation, 415–416  
   practical sampling for, 414–415  
 On-line learning systems, 1005–1006  
 Open-close filters, 50, 51–52, 51f  
 Open filter, morphological, 50  
 Open systems interconnection (OSI), in video  
   transmission system, 1068–1069  
 Optical cues, insects' use of, 310  
 Optical flow  
   computation of, 315–316  
   measuring distance by integrating, 311–312  
 Optical flow segmentation, 474–482, 481f  
 Optics. *See also* Visual system  
   of eyeball, 327–328, 328f  
   of human vision, 325  
 Optimality, and VQ, 687  
 Optimark, copyright protection watermarking,  
   1092–1093  
 Optimization halftoning techniques, 932–933  
 Optimization techniques  
   dynamic programming, 306  
   graph cuts, 306  
 Ordered dithering, 928–929, 929f  
 Order-statistic (OS) filters, 279–281, 280f  
 Orthogonality, of transform coding paradigm, 695  
 Osher-Sethian level-set formulation, 614, 620  
 Outliers, 268  
 Out-of-focus blur, uniform, 170, 170f  
 Owner identification, watermarking techniques for,  
   1084. *See also* Identity characterization

## P

Pairwise nearest neighbor (PNN) algorithm, in VQ  
   design, 678  
 Parallel-beam projections, in CT image  
   reconstruction, 1159  
 Parametric active contours, to locate edges, 568–569,  
   569f  
 Partial differential equations (PDEs), 555  
   continuous models based on, 587  
   for diffusion, 556  
   eikonal, 604  
     applications of, 607–610, 608f, 609f  
     arrival time and level sets, 605  
     numeric algorithms for, 606–607  
   generating openings and closings, 597  
   image segmentation via, 625  
   and morphologic operations, 587, 589  
   for multiscale dilations and erosions, 594–595  
   for multiscale reconstruction filters, 597–598, 598f  
   numerical algorithms for dilation, 595–597, 596f  
   and shape shifting algorithms, 578  
 Partitioning, and VQ, 687  
 Pattern recognition system, 519. *See also* Object  
   tracking  
   classification in, 531–532  
   in feature extraction, 530–531  
   specific techniques to, 532  
 PCA. *See* Principal Component Analysis  
 PC/UNIX, 887  
 PDAs. *See* Personal digital assistants  
 PDEs. *See* Partial differential equations  
 pdf. *See* Probability density function  
 Peak signal-to-noise ratio (PSNR), 693, 703, 986, 988t  
   in JPEG2000, 729

- in nonlinear filtering, 120
  - Perception
    - computational theory of visual, 326
    - grouping mechanisms in, 522, 522f
    - models of visual, 956
    - threshold of, 940
  - Perception, human. *See also* Human visual system; Visual system
    - and compression, 943–956, 944f, 948f–952f, 954t
    - and image quality, 941–943, 941f, 942f
  - Perceptual image coder (PIC), 658–659
  - Perceptual metrics, 953, 954t
    - and image quality, 939–940, 940f
    - for image quality, 943–944
    - models for, 944–947
    - Safranek-Johnston PIC, 947–950, 948f–950f
    - and video quality, 955–956
    - Watson's DCT-based metric, 950–953, 951f, 952t
  - Persistent item identification, watermarking
    - techniques for, 1085
  - Personal computers (PCs), 12
  - Personal digital assistants (PDAs), 819, 877, 878f
  - Personal identification numbers, 1235
  - Pfinder, tracking system, 496
  - Phase correlation method, 270–271
  - Phase demodulation process, in iris patterns, 1253f
  - Phase-diverse speckle (PDS), 231–232, 232f
  - Photoconductor storage tubes, 783–784
  - Photographic grain noise, 405
  - Photographic images
    - multispectral, 755
    - statistical modeling of, 431
      - Gaussian, 432–434, 432f–434f
      - wavelet joint, 436–438, 436f–439f
      - wavelet marginal, 434–436, 434f, 435f
  - Photoreceptor density, 329f, 331
  - Picture, use of term, 850
  - Picture layer, in H.261 video encoder, 794
  - Pixel, 8
    - quantized, 9, 9f
    - replication, 47
  - “Plaid” stimulus, 340, 341f
  - Play and break, defined, 1014–1015, 1015f
  - PNN. *See* Pairwise nearest neighbor
  - Poincare index, in fingerprint enhancement, 1228
  - Point operations, 21
  - Point operations, linear
    - additive image offset, 25–26, 25f, 26f
    - full-scale histogram stretch, 28–29
    - image negative in, 27
    - multiplicative image scaling, 26–27, 27f, 28f
  - Point operations, nonlinear
    - in gray-level digital image processing, 30–33, 31f, 32f
    - histogram equalization, 29–32, 30f, 31f
    - histogram shaping, 32, 32f
    - logarithmic, 29–30, 30f
  - Point-spread function, 222–223, 223f
    - Airy, 222–223, 223f
    - diffraction, 222–223, 223f
    - in image restoration, 168
    - turbulence-induced, 223, 223f
  - Poisson noise, 404–405, 405f
    - maximum-likelihood for, 226
    - and multi-frame blind restoration, 230
  - Polar form, of Gabor function, 458–459, 458f
  - Polar format algorithm (PFA), in SAR, 1142
  - Pose, in ATR, 1341
  - Position, statistical analysis of, 997, 998f, 999
  - Positive Boolean functions (PBFs), 115–116
  - Positron emission tomography (PET), 1155
    - in cardiac image processing, 1175
    - myocardial perfusion in, 1190
    - nuclear imaging using, 1157–1159, 1158f
    - reconstruction of time-sequences in, 215, 215f, 216f
  - Postprocessing of compression images
    - MAP estimation for
      - basics of, 770–771
      - of JPEG-compressed images, 771–773
      - objective of, 761
      - POCS for, 763–770, 764f–766f, 768f, 770f
  - Power-complementary filters, 352, 352f
  - Power spectral estimates, for photographic images, 433, 433f
  - Prewitt edge gradient operator, 542
  - Primitive path, in dynamic processing, 302
  - Principal component analysis (PCA)
    - for face recognition, 1237
    - for feature extraction, 530
  - Printers, calibration of, 427
  - Printing technologies, 925–926
  - Probability
    - in noise models, 398–399
    - and noise problem, 431
  - Probability density function (pdf), 483
    - likelihood, 447, 451
    - a posteriori maximizing of, 480
    - a priori, 447, 451, 483
  - Probability model, for images, 431
  - Probability theory, and information theory, 646–648
  - Progressive scanning, 14, 14f
  - Projection onto convex sets (POCS)
    - basic theory of, 762–763
    - in recovery-based postprocessing, 762
    - theory of, 250
  - PSNR. *See* Peak signal-to-noise ratio
  - PSTN. *See* Public switched telephone network
  - Psychophysics, 326
    - and physiology, 344
    - quantitative models in, 342
  - Public switched telephone network (PSTN), 1040
  - Pupils, in iris recognition, 1253. *See also* Visual system
  - PVRG code, 744
  - Pyramidal principle, in shape smoothing, 574
  - Pyramid representations, 361
    - decimation and interpolation, 349–350
    - Gaussian pyramid, 350
    - Laplacian pyramid, 350–351
- Q**
- QIM. *See* Quantization Index Modulation
  - QM coder, in lossless compression, 736
  - Quadrature amplitude modulation (QAM), 1039
  - Quadrature integration, in target recognition, 1351
  - Quadrature Mirror Filters (QMFs), 351, 352f
  - Quality, image
    - baseline contrast sensitivity model for, 945
    - coder-specific models, 947–954, 956
    - contrast/texture masking in, 946
    - Daly model, 947
    - error pooling in, 946–947
    - evaluation of, 939
    - frequency analysis model for, 944–945
    - and human perception, 941
    - Lubin model, 947
    - luminance masking model for, 945
    - Minkowski error metric, 961–963, 962f, 963f
    - perceptual metric for, 943–944
    - Safranek-Johnston PIC, 947–950, 948f–950f
    - suprathreshold models, 954–955
    - Teo and Heeger model, 947
    - Watson's wavelet metric, 953, 954t
  - Quality assessment
    - distortion model for, 978, 979f, 980f, 985–986
    - full-reference, 975–976
    - and human visual system model, 978–979, 986
    - implementation issues, 984–986
    - information fidelity for, 976, 976f, 980–984
    - and natural scene statistics, 976, 977f
    - source model for, 977–979, 984–985
    - and SSIM, 946f, 963–967, 965f, 967f
    - structural image in, 974
    - structural similarity-based methods, 963
    - theoretic approaches to, 975
    - using structural similarity index, 967–970, 968f, 969f
    - validating measures for, 970–973, 970f–973f, 986–988, 987f, 988f, 988t
    - calibration of objective score, 987–988, 987f, 988f, 988t
    - simulation details, 987
    - subjective experiments for, 987
    - variance-weighted weighting function in, 969–970
  - Quantization, 673, 925. *See also* Vector quantization
    - in A/D conversion, 6
    - basics, 926, 926f
    - color, 926, 933–935
    - defined, 895
    - distortion criteria and, 927–928, 928f
    - of images, 9–10, 9f–11f
    - and JSCC, 1069
    - optimum, 927
  - Quantization Index Modulation (QIM), for
    - information embedding, 1102, 1102f
  - Quantizer, in intraframe encoding mode, 779
  - Quantum electrodynamics (QED), 224
  - Quarter Common Interchange Format (QCIF), 272f, 785
  - Queries, in multimedia databases, 1008, 1008t
  - Query concept learner, 1005–1006
- R**
- Radar, 1131
  - Radar image, 1131
  - RADARSAT-1 SAR, 1134, 1134f
  - Radial Basis Function Network (RBFN), for realizing
    - static maps, 521
  - Radial openings, in morphological filtering, 140
  - Radiation, image derived from, 4
  - Random field model
    - function of, 361
    - nonlinear/non-Gaussian, 370–374
  - Random fields
    - early studies, 361, 362f
    - Gauss-Markov, 364–365, 364f, 365f
    - Gibbs, 365–367, 366f
    - Markov, 363–364, 363f, 364f
    - multiresolution/multiscale models for, 361–362
    - multiscale, 367–370, 368f–371f
    - overview of, 362–363
  - Range image, 939
  - Range spheres, in SAR, 1138, 1138f

- Rank filtering, 137–138, 145
- Rank-order difference (ROD) detector, 283–285
- Rate control, in embedded video codecs, 881
- Rate-distortion (R-D) bounds, 694
- Rate-distortion (R-D) theory, 694
- RCT. *See* Reversible color transform
- R-D bounds. *See* Rate-distortion bounds
- R-D optimization, in embedded video encoder, 881
- Real-time streaming protocol (RTSP), 1059, 1060t
- Real-time transport control protocol (RTCP), 1054–1059, 1055t, 1056f–1058f
- Real-time transport protocol (RTP), 1050–1054, 1050f, 1052f, 1052t, 1053f, 1054f
- Recognition principle, 1251
- Recognition systems, 519. *See also* Automatic face recognition; Automatic speech recognition; Automatic target recognition; Segmentation
- Reconstruction, problems of, 185, 201. *See also* Regularization
- Reconstruction opening
  - dome/basin extraction with, 149–150
  - in feature detection, 149–150
  - in morphological filtering, 141
- Recovery, image, 207
  - defined, 203
  - implicit approach to multichannel, 211–216, 215f, 216f
  - POCS-based, 763–770, 764f–766f, 768f, 770f
    - adaptive processing, 768–769
    - constraints based on prior knowledge, 766–767
    - constraint set based on transform coefficients, 765–766
    - determination of constant  $\lambda$  in projector  $P_w$ , 770
    - JPEG discrete cosine transform algorithm, 764–765, 764f, 765f
    - methodology, 763
    - recovery algorithm, 700, 767–768, 768f
    - vector notation, 765
  - space-variant, 203, 209
  - techniques, 203
- Recovery, multichannel, 207
  - implicit approach to, 211–216, 215f, 216f
  - space-variant, 209
- Recovery-based techniques, for postprocessing, 761–762
- Red, green, blue (RGB) color images, lossy
  - compression of, 750–751, 751f
- Reed-Solomon (RS) codes, 1073, 1073f
- Reflection images, 4, 5, 6f
- Refresh rate, for video scanning, 14
- Region correction algorithms, to binarized image, 43
- Region labeling
  - algorithm, 44
  - in binary image processing, 43–44
  - minor region removal algorithm, 45, 45f
  - region counting algorithm, 44–45
- Region of interest (ROI) coding, in JPEG2000, 728–729, 728f
- Regularization
  - discrepancy principle in, 200
  - and generalized cross-validation, 201
  - L-curve in, 200–201, 200f
  - multichannel, 206–207, 208f
  - statistical approaches to, 201
  - visual inspection in, 199
- Regularization methods, 188–189
  - formally defined, 188
  - iterative, 196–199, 197f–199f
  - maximum entropy, 192, 192f
  - non-quadratic, 191–192, 193–194
  - parameter choice, 199–201, 200f
  - parametric, 196
  - statistical, 194–196
  - Tikhonov, 190–191, 191f, 195
  - total variation, 192–193, 193f
  - truncated SVD, 189–190, 190f
- Regularized estimation criterion, optical flow via, 271
- Regularized weighted least-squares (RWLS)
  - estimation for, 205–206, 214
  - for multichannel imaging, 205–206, 214
- Relaxation labeling, 522
- Relaxation techniques, in motion estimation, 266
- Relevance feedback, in text retrieval, 1005
- Remote sensing
  - of multispectral data, 747–748
  - of multispectral images, 751–755, 752f, 754f
- Renormalized heat equation on curves
  - description, 578
  - implementation, 578–579
  - properties, 579, 579f
- Representation, image, 411
  - analog images as physical functions, 417, 417t
  - colorimetry, 417–424, 418f–421f
  - color I/O device calibration for, 425–428, 428f
  - multidimensional system, 416–417
  - one-dimensional processes, 414–416
  - and sampling of color signals and sensors, 424–425, 424f, 425f
- Resolution enhancement. *See also* Enhancement
  - example, 251f
  - and probability, 431
- Resolution of image, 347
- Resource reservation protocol (RSVP), 1061–1062, 1062f
- Restoration, 201. *See also* Regularization
  - algorithms for, 167–168, 171–178
  - direct regularization methods for, 189–196
  - generalized solution, 186–187, 188f, 189f
  - least-squares solution for, 186
  - mathematical models for, 221–224, 221f–223f
  - methods, 168
  - multichannel image recovery in, 209–211, 210f–213f
  - need for regularization in, 187–189
  - problems of, 183–185
  - space-invariant, 214
- Restoration, image. *See also* Regularization, 201
  - algorithms for, 167–168, 171–178
  - direct regularization methods for, 189–196
  - generalized solution, 186–187, 189f, CHECK 188f
  - hierarchical bayesian, 249–250, 251
  - least-squares solution for, 186
  - methods, 168
  - need for regularization in, 187–189
  - problems of, 183–185
  - space-invariant, 214
- Restoration, iterative image
  - algorithms for, 235, 249
  - applications, 249–251
  - matrix-vector formulation, 241–247
  - use of constraints, 247–248, 248f
- Restoration, multi-frame
  - goal of, 219, 220f
  - linear methods for, 227–228
  - mathematical models for, 221–224, 221f–223f
  - nonlinear (iterative) methods for, 228
  - nuisance parameters, 228–229
  - as optimization problem, 225
  - problem of, 224–228
- Restoration, multi-frame blind
  - and atmospheric turbulence, 230–231, 231f
  - with ground-based solar imaging, 231–233–232f
  - for undersampled image sequences, 229, 230, 230f
- Restoration, video
  - in difficult object motion, 286–287
  - objective of, 275
- Retina. *See also* Visual system
  - and DoG bandpass filters, 548
  - ganglion cells of, 332
  - parallel projections from, 334
  - sampling by, 328, 329f, 331
- Retinal plane, global motion models in, 311–312, 311f
- Retrieval image, using texture, 464–465, 466f, 467f
- Retrieval systems, image/video, 1011, 1014, 1017, 1018, 1024
  - aspects of, 993
  - content categories, 994
  - index categories, 1024
  - research in, 1013, 1014f
  - storage and compression, 994
- Retrieval techniques
  - content-based, 1006–1008, 1007f
  - feature-based, 1006
  - multimedia databases, 1008
- Reversible color transform (RCT), in JPEG2000, 742–743
- Reversible variable-length coding (RVLC), 1072
  - in embedded video decoders, 882
  - in error resilient source coding, 1072
- RGB. *See* Red, green, blue color
- RGB color coordinate system, 11, 12f
- Rice codes, in JPEG-LS, 739
- Rice-Golomb coding, in JPEG-LS, 738–739
- Richardson-Lucy method, 220–221
- Ringing artifacts
  - with ideal LPF, 105
  - of lossy compression, 761
  - in spatially invariant degradation, 239–241, 240f–241f
- RLC. *See* Run-length coding
- Roberts operator, 541
- Robustness
  - in copyright protection, 1089–1090
  - of lossless image coding, 646
- Rods, of eye, 11. *See also* Human visual system
- Round-trip time (RTT), in JSCC, 1069
- RS. *See* Reed-Solomon codes
- RSVP. *See* Resource reservation protocol
- RTCP. *See* Real-time transport control protocol
- RTP. *See* Real-time transport protocol
- RTSP. *See* Real-time streaming protocol
- RTT. *See* Round-trip time
- R2 Technology, Inc., 1210
- Rule-based features, content-based, 1003
- Run-length coding (RLC)
  - in binary image processing, 53, 54, 54f
  - and symbol conversion, 644, 645f
- Run-length coding (RLC) primitives, in JPEG2000, 726
- RVLC. *See* Reversible variable-length coding

## S

- Safranek-Johnston perceptual subband image coder (PIC), 947–950, 948f–950f
- Sakar-Boyer filter, 546
- Sample, use of term, 850
- Sampled image
- downsampling and decimation, 901–902, 902f
  - effect of undersampling on, 899, 899f, 900f
  - with nonrectangular lattices, 900–901, 901f
  - representations for, 895–896
  - spectrum of, 898, 899f
  - upsampling and interpolation, 902–903, 903f
- Sampled video, 13–15, 14f
- Sampling, 17
- in A/D conversion, 6
  - color, 418–419, 418f
  - detector, 221f, 223–224
  - different densities for, 8f
  - insufficient, 8
  - and multi-frame restoration, 221f, 223–224
  - process of, 7, 7f, 895
- Sampling, video
- and continuous time-varying imagery, 913–916, 914f, 915f, 917f
  - effects caused by, 911
  - and spatiotemporal structure conversion, 920–921
  - spatiotemporal structures, 911–913, 912f, 913f
  - and structure conversion, 916–921, 917f–921f, 918t
- SAR. *See* Synthetic aperture radar
- Sarnoff model, 986
- Sarnoff's JND-Matrix 8.0, 988
- Satellite broadcasting, MPEG-2 used in, 847
- Scalability
- hybrid, 845
  - of lossless image coding, 646
  - in MPEG-4, 855–856
  - MPEG-2 SNR, 844, 844f
  - spatial, 844, 845f
  - temporal, 844–845
- Scalable coding, 843–845, 844f, 845f
- Scalable color descriptor, in MPEG-7, 868
- Scalar quantization, 926–928, 926f
- Scalar quantizers, 789, 926
- Scale
- concept of, 347
  - in EdgeFlow segmentation, 347
- Scale-invariance, in image modeling, 432
- Scale space property, Gaussian filter, 108f
- Scanning
- meaning of term, 895
  - video, 14, 14f, 17
- Scanning confocal microscope, 1295. *See also* Confocal microscope
- Scripted/Unscripted Content, defined, 1014, 1015, 1015f
- SDMI. *See* Secure Digital Music Initiative
- SDRAM, 888, 888f
- Search algorithms, text-based, 993
- Search strategies, in block matching, 270
- Secret sharing (SS), visual
- for arbitrary monotone structures, 1115
  - and arbitrary structures, 1119
  - basis matrices, 1114
  - formal definitions, 1112–1114, 1113f
  - halftone, 1116, 1117f, 1118–1122, 1118f
  - halftone vs. combinatorial, 1122
  - for threshold access structures, 1115
- Secret sharing (SS) protocol, 1111
- Secure Digital Music Initiative (SDMI), 1084
- Security, image, 926
- and embedding of information, 935, 935f
  - watermarking, 935, 935f
- Segmentation. *See also* Geodesic active contour model
- biologically oriented approaches to, 528–530
  - in computer-assisted software, 1320–1321
  - defined, 443, 444f, 471
  - edge-based, 519, 522–524, 522f, 523f
  - geodesic active contour model, 613–614
  - goal of, 613
  - importance of, 443
  - mathematical problem of, 445
  - model-based methods, 519
  - and object recognition, 530
  - oscillation based, 527f, 528–530, 530f
  - region-based methods, 519, 524–527, 525f, 526f
  - statistical methods for, 443–444
    - aerial image segmentation, 447, 449, 449f, 450f
    - algorithms, 452
    - covariance statistics, 446
    - Fourier statistics, 446
    - Gaussian statistics, 445–446
    - image compression, 450–451, 451f
    - label statistics, 446
    - multivariate optimization problem, 452
    - vehicle segmentation, 446–447, 447f, 448f
  - using texture, 463–464, 464f, 465f
    - adaptive multi-channel modelling for, 524–527, 525f, 526f
    - BCS approach to, 524
    - optimization framework for, 527
    - SAWTA network for, 525f
    - via adaptive clustering, 527–528
    - video, 995–996, 996f
    - watershed, 607–610, 608f, 609f
    - WDT-based, 606
- Segmentation, video
- change detection methods in, 473–474
  - choosing methods for, 471–472
  - motion segmentation, 474–482, 481f
    - automatic, 485–486, 486f–487f
    - maximum a posteriori (MAP) (R) segmentation, 480–481
    - maximum-likelihood segmentation, 478–480
    - region-based label assignment, 4, 480–481
    - and scene change detection problem, 472–473
    - and simultaneous motion estimation and, 482–484
- Sensor modeling, statistical models for, 1344–1345
- Separable filtering, 77
- Session initiation protocol (SIP), 1060t, 1061
- Set partitioning in hierarchical trees (SPIHT) coding, 698, 699, 700f, 700t
- Shape analysis
- morphological filters for, 155
  - statistical, 997, 998f, 999
- Shape coding, in MPEG-4, 852–853, 853f
- Shape descriptors, in MPEG-7, 870–871, 870f
- Short-time-Fourier-transform (STFT), 691
- SIF. *See* Standard Input Format
- Sifting property, in linear filtering, 99
- Signal, Image and Video Audio-Visualization Gallery (SIVA), 83–91, 85f, 86t, 88f
- binary image processing in, 85–86, 86f
  - histogram and point operations, 86, 88f
  - image and video processing demos in, 85, 86t
  - image compression, 88, 89f
  - image filtering in, 86, 88, 88f
  - video processing demos, 88–89, 89f
- Signal processing techniques, multiscale, 358
- Signal recovery, 762
- Signal transformation unit, in JPEG standard, 711
- Signature, digital, 1105
- Signature, identity
- continuous, 1241
  - discrete, 1241
- Simoncelli pyramid decomposition scheme, 282f
- Single-photon emission computed tomography (SPECT), 1155
- in cardiac image processing, 1175
  - myocardial perfusion in, 1190
  - nuclear imaging using, 1157–1159, 1157f
  - reconstruction of time-sequences in, 215, 216f
- Sinusoidal functions, 57–58
- Slide scanning, in ADIR computerized microscopy, 1323
- Smoothed impulse, 152
- SMP. *See* Software Motion Pictures
- Sobel linear operator, 131, 132
- Software Motion Pictures (SMP), DECs, 669
- Software products, for video conferencing
- applications, 866
- Source compression, 1065
- Space-frequency segmentation, 698, 703, 705, 705f
- Space-invariant blur, 221–223, 221f
- Space Shuttle Discovery, 230–231
- Space variant apodization (SVA), in SAR, 1147
- Spatial aliasing, 64
- Spatial operator, in intraframe encoding mode, 779
- Spatial restoration algorithms, classification of, 287
- Spatial-spectral transform, for multispectral images, 749
- Spatial summation, 334, 338, 343f
- Spatio-temporal filtering, 332, 333, 333f, 336f
- Spatio-temporal frequency, 337f, 340, 342, 343f, 343f CHECK
- Spatio-temporal windows, 280f
- Speaker detection and tracking, 1286
- Speaker recognition, audiovisual, 1282–1285, 1282f, 1283f, 1284. *See also* Automatic speaker recognition
- Speckle. *See also* Noise
- atmospheric, 408–409
  - in coherent light imaging, 406–408
  - defined, 406–409, 408f
- Spectral representations, for discrete and continuous-space signals, 898
- Spectral-spatial transform methods, for multispectral images, 749, 752
- Speech, computer processing of, 1263
- Speech-to-video synthesis systems, 1279–1281, 1279f
- SPIHT. *See* Set partitioning in hierarchical trees
- Spotlight mode, in SAR, 1142–1143, 1143f
- Sprite coding, in MPEG-4, 853, 854f
- SSIM index, 974
- Stabilization, 320–321
- image, 316
  - in insect navigation, 310–311
  - two-dimensional, 316–317
- Stabilization algorithms
- feature-based, 310–311
  - flow-based, 314–316
- Stack filters, 138
- Stacking constraints, 115
- Standard Input Format (SIF), 785

- Statistical features
    - alternative, 997, 998f, 999
    - hierarchical video structure, 999
    - image difference, 994–995
    - motion analysis, 996–997
    - video segmentation, 995–996, 996f
  - Statistical modeling
    - Gaussian, 432–434, 432f–434f
    - wavelet joint, 436–438, 436f–439f
    - wavelet marginal, 434–436, 434f, 435f
  - Steganography, visual
    - combinatorial techniques, 1115–1116
    - half-toning techniques, 1116–1122
    - simulation results, 1122–1127, 1122f–1126f
  - Stein's Unbiased Risk Estimate (SURE), 159
  - Stereo correspondence algorithms, 299–300
    - taxonomy of
      - global methods, 301–306, 301f–303f
      - local methods, 300–301
  - Stereopsis, and cortical cells, 340–342, 343f
  - Stereo vision, computational, 297
    - background of, 298–299
    - mathematical foundation of, 298
  - STFT. *See* Short-time Fourier-transform
  - Still texture coding, in MPEG-4, 855, 856f
  - Still-to-still face recognition, 1247–1248
  - StirMark, copyright protection watermarking, 1092
  - Stripe bit-plane scanning pattern, in entropy coding, 725, 726f
  - Stripmap mode, in SAR, 1140–1142, 1141f, 1142f
  - Structural similarity (SSIM) index, 946f, 963–967, 965f, 967f
  - Subband coding (SBC), 93
  - Subband/wavelet transform (SWT), 799
  - Subspace analysis, in identity characterization, 1242
  - Subspace density, in face recognition, 1247
  - Subspace identity encoding, in identity characterization, 1242
  - Subtelomeric fluorescent in situ hybridization (SFISH) assay, 1325
    - for detection of cryptic translocations, 1324–1326, 1338
    - metaphase finding in, 1326
    - user interface in, 1325–1326, 1326f
  - Successive approximations algorithm, 236
  - Successive over-relaxation (SOR), 291
  - Summarization, video, 1013, 1014
    - and scene-based representation, 1018–1022
    - unified framework for, 1025–1027, 1025f, 1027
    - video highlights extraction, 1022–1024, 1022f, 1023f, 1024t
  - Sum of absolute differences (SAD), 300
  - Sum of squared difference (SSD), 300
  - Support Vector Machine (SVM), 1004
  - Surface fitting, in computer-assisted microscopy, 1328, 1329f
  - Surrounding region-dependence method (SRDM), in computer-aided mammography, 1204
  - SVM. *See* Support Vector Machine
  - Swiss Federal Institute of Technology in Lausanne (EPFL), 74
  - Switching filter, 279
  - SWT. *See* Subband/wavelet transform
  - Symbols, in lossless image coding, 644–645
  - Symmetry, in SSIM, 965
  - Synthetic aperture radar (SAR)
    - advances in, 1152
    - development of, 1131–1132
    - fine detail detected by, 1136, 1136f
    - frequency bands of, 1132f
    - image data of, 1137–1139, 1138f
    - image enhancement in, 1131, 1146–1148, 1146f, 1147f, 1149f
      - autofocus algorithms for, 1144–1146, 1147f, 1148f
      - geometric distortion correction, 1148
      - intensity remapping, 1148
    - image exploitation in, 1148–1149
      - moving target detection, 1149–1151, 1150f
      - SAR interferometry, 1151–1152, 1151f
    - image formation processing
      - history of, 1139
      - problems of, 1139–1140, 1140f
      - in spotlight mode, 1142–1143, 1143f
      - in stripmap mode, 1140–1142, 1141f, 1142f
    - of image quality parameters, 1139
    - image resolution, 1132–1133, 1133f
    - imagery from, 1134–1136, 1134f–1136f
    - imaging modes for, 1133–1134, 1133f
    - signal data of, 1136–1137, 1137f
  - System and environmental blur, 221
- T**
- Table-of-Contents (ToC), in video summarization, 1014
  - Tail probabilities, in noise models, 402, 402t
  - “Talking head” image, 1000, 1000f
  - Tamper-proofing, watermarking techniques for, 1085
  - Tandem scanning optical microscope (TSOM), 1295–1296, 1296f
  - Target representations, statistical models for, 1342–1344, 1343f, 1344f
  - TBRs. *See* Tree-based resolution synthesis
  - TCQ. *See* Trellis-coded quantization
  - TDMA. *See* Time-division multiple access
  - Teager-Kaiser Energy Operator (TKEO), 378
  - Telecommunications technology, visual information content in, 13
  - Telemedicine, skin tones in, 747. *See also* Medical imaging
  - Telephone industry, 1040
  - Telephone lines (POTS), video transmission via, 15
  - Television
    - digital, 847
    - HDTV, 15
    - images on, 411
    - image statistics for, 432–434
  - Television broadcasting, scanning standard, 911
  - Templates, for target representations, 1342–1343
  - Teo and Heeger model, 947
  - Terabit Ethernet networks, 13
  - Text retrieval engines, 1005
  - Text-to-speech (TTS) systems, 1263, 1264
  - Texture, 456, 462–463, 462t
    - classification of, 456
    - experimental results with, 462, 463f
    - image retrieval using, 464–465, 466f, 467f
    - image segmentation using, 463–464, 464f, 465f
    - local frequency estimation, 460
    - macrofeatures of, 461–462, 461f
    - macromodel for, 462
    - microfeature representation of
      - transformation into, 460–461
      - transformation into Gabor space, 459–461
    - micromodel for, 461
    - research in, 468
    - statistical analysis of, 997, 998f, 999
    - and texture motifs, 465, 468, 468f, 469f
  - Texture coding, in MPEG-4, 851–852, 852f
  - Texture descriptors, 869–870, 869f
  - Texture motif, defined, 468
  - Texture synthesis, constrained, 288f
  - Thermal noise, 406
  - Thermal wax transfer, 925
  - Thick-specimen imaging
    - deblurring, 1335, 1335f
    - image fusion, 1335–1336
    - wavelet design, 1336, 1336f
    - wavelet fusion, 1336, 1337f
  - Threading operation, 314
  - Threshold decomposition, 114–116
  - Tikhonov regularization methods, 190–191, 191f, 195
  - Tiling representations
    - of several expansions, 704, 704f
    - time-frequency, 691, 691f
  - Time-division multiple access (TDMA), in wireless networks, 1040–1041
  - Tissues, confocal microscopy of, 1299–1304, 1299f, 1302f
  - TMS320C6X, 882, 887, 888
  - TMS320C54X DSP architecture, 882–883, 883f
  - Toeplitz structure, 184
  - Tomography. *See also* Computed tomography
    - defined, 1155
    - and regularization methods, 196
  - Top-hat transformation, in feature detection, 148–149
  - Total least squares (TLS) method, 202, 314
  - Training set, in VQ design, 676
  - Transaction tracking, watermarking techniques for, 1084
  - Transformations
    - in lossless image coding, 644
    - for target representations, 1343
  - Transform coding paradigm, 694–696, 694f, 695f
    - entropy coding, 697
    - quantization, 696
    - transform structure, 696
  - Translation-invariance, in image modeling, 432
  - Transmission, video, 1065. *See also* Video transmission
  - Transmission requirements, of video compression system, 782
  - Transport control protocol, in retransmission, 1074
  - Tree-based resolution synthesis (TBRs), 907–909, 907f, 908f
  - Tree-structured vector quantization, 679–680, 679f
  - Trellis-coded quantization (TCQ), 683–687, 684f, 685f
  - Trichromatic theory, 326
  - Truncated SVD (TSVD), 189–190, 190f
  - Turbulence
    - atmospheric, 170–171
    - imaging through, 222, 223f
  - 2-D images
    - enhancement and restoration of, 275–276
    - multi-resolution representation of, 281
  - 2-D motion, 253, 261
- U**
- Ultrasound imaging
    - in cardiac image processing, 1175
    - in coronary artery analysis, 1181–1182, 1182f, 1183f



- Uncertainties, correcting, 16
  - Uncertainty theorem, 691
  - Undecimated DWT (UDWT), 159–160
  - Undersampling
    - explained, 8
    - resolution improvement in, 219, 219f
  - Uniform Scalar Quantizer, 789
  - Unique maximum, in SSIM, 965
  - Unsharp contrast enhancement, 143
  - Usage control, watermarking techniques for, 1084–1085
  - User-interface, for slide-scanning algorithm, 1325–1326, 1326f
  - US-VISIT system, 1235
- V**
- Variable-length coding (VLC), 645, 716
    - in intraframe encoding mode, 779
    - in lossless compression, 645, 716
  - Variable length decoding (VLD), 826
  - Vascular networks. *See* microvascular networks
  - VC. *See* Visual cryptography
  - VcDemo
    - balance between versatility and efficiency with, 91–92
    - compression modules, 92–93, 92f
    - description, 90, 93
    - supporting functions, 92
    - workspace provided by, 91–92, 91f
  - Vector quantization (VQ)
    - conceptual notion of, 673
    - field of, 694
    - gain-shape, 680–681, 681f
    - implementations, 678–679
    - mean-removed, 680–681, 681f
    - multistate, 681–683, 682f, 683f
    - predictive, 685–686, 685f
    - structured, 679–680, 679f
    - theory of, 674–676, 674f–676f
    - and transform coding paradigm, 694
    - trellis-coded, 683–687, 684f, 685f
    - variable-rate, 686–687
  - Vector quantization (VQ) approaches, to multispectral images, 753
  - Vector quantizers, design of, 675, 676–678, 677f, 678f
  - Vector WM filter (WVM), 117–118
  - Vehicle segmentation, statistical modeling in, 446–447, 447f, 448f. *See also* Segmentation
  - Velocity field, 254
  - Very large scale integration (VLSI) technology, 878
  - Video
    - accessing content of, 1013
    - defined, 3, 275, 911
    - digital, 13 (*see also* Digital video)
    - dimensionality of, 5, 7f
    - sampled, 13–15, 14f
    - text detection in, 1001f
  - Video analysis, 16
    - audio marker detection, 1016
    - key frame extraction, 1016
    - play/break segmentation, 1016
    - shot boundary detection, 1015–1016
    - video marker detection, 1016
  - Video artifacts, removal of, 276, 276f
  - Video codecs, embedded, 877, 879–882
  - Video coding, 777
    - block-based, 878–879, 879f
    - interlaced, 842–843, 842f
    - MPEG-1 standard, 834–835, 834f
      - background and structure of, 833–834
      - compared with H.261, 834–835, 834f
      - GOP and I-B-P pictures, 835–837, 835f
      - slice, macroblock, and block structures, 837, 837f
      - for source input format, 835, 835f
      - target applications and requirements, 834
    - MPEG-2 standard
      - background and structure of, 839–840
      - compared with MPEG-1, 841–843, 841f, 842f
      - input resolutions and formats, 841–843, 841f, 842f
      - profile and levels, 840–841, 841t
      - target applications and requirements, 840
    - scalable coding, 843–845, 844f, 845f
  - Video coding, scalable, 799
    - cross-check method of comparing, 811–813, 812f, 813f
    - embedded bit streams produced by, 815
    - and MCTF, 802–806, 803f–806f
    - and motion estimation, 800–802, 801f, 802f
    - multiple adaptations in, 813–814, 813f, 814f
  - Video Coding Experts Group (VCEG), 849
  - Video communications networks
    - Asynchronous Transfer Mode (ATM) networks, 1043–1048, 1044t, 1045f–1047f
    - digital subscriber loop, 1040
    - fiber optics in, 1042
    - future of, 1033
    - hybrid fiber-coax networks, 1039–1040
    - Integrated Services Digital Network (ISDN), 1042–1043
    - proliferation of, 1038
    - wireless networks, 1040–1042
  - Video compression, 17. *See also* Compression
    - application requirements for, 781–782, 783t
    - basics of, 1069–1070
    - block transform coding, 787–788, 788f, 789f
    - DPCM predictive encoder, 787
    - encoding standards, 792–797
    - entropy coding, 786
    - importance of, 781
    - international standards for, 778
    - motion compensation and estimation, 790–792
    - quantization, 789–790
    - techniques, 785–792, 788f, 789f, 791f, 792f
  - Video compression standards
    - MPEG-2, 1034–1038, 1035f, 1036t, 1037f
    - overview, 1033–1034
  - Video compression systems
    - characteristics and performance, 782
    - design and selection of, 781–782
    - generalized, 778–779, 778f
  - Video conferencing, 1065
    - industry, 865–866
    - portable, 878f
  - Video content description, for MPEG-7, 866
  - Video description scheme (DS), in MPEG-7, 872, 872f
  - Video descriptors, in MPEG-7, 867–872, 867f–871f
  - Video design, access components of, 1014
  - Video elementary stream format, 1035, 1035f, 1036t
  - Video encoder, design and selection, 777
  - Video engineering, 777
  - Video frames, noise filters for, 276
  - Video group, defined, 1014, 1015f
  - Video imager, in sensor modeling, 1345
  - Video marker, defined, 1015, 1015f
  - Video object coding, in MPEG-4, 851, 852f
  - Video object plane (VOP), 851
  - Video object (VO), 851
  - Video on Demand (VoD), 819
  - Video quantization, 13
  - Video representation, 1013
    - for scripted content, 1016–1017
    - for unscripted content, 1017
  - Video scanning, 14, 14f
  - Video scene, defined, 1014, 1015f
  - Video sequences
    - advantages over still images of, 253
    - face recognition from, 1238, 1244–1248, 1246f, 1247t, 1248f
  - Video shot
    - defined, 1014, 1015f
    - and visual index, 1025–1027, 1025f–1027f, 1026t, 1027t
  - Video signals
    - dimensions of, 778
    - sampling of analog, 782–784, 784f
    - temporal sampling of, 783
  - Video streaming, 1065
  - Videotelephony, 1065
  - Video transcoding, 820
    - bit rate control in, 829–830
    - for bit rate reduction, 820–825, 820f–825f
    - error-resilient, 830
    - fast architectures for, 822–823
    - heterogeneous, 825–829, 826f–828f
      - and macroblock coding type decision, 829
      - and spatial resolution reduction, 827, 827f, 828–829, 829f
      - and temporal resolution reduction, 827–828, 828f
    - of inter-coded frame, 822
    - of intra-coded frame, 821–822, 821f
    - operations, 820, 820f
    - research in, 830
  - Video transmission, 1068–1069, 1069f
    - channel models, 1070–1071
    - OSI in, 1068–1069
    - system architecture for, 1069f
    - via cable systems, 15
    - via POTS, 15
    - worldwide standards for, 15
  - VIF. *See* Visual information fidelity
  - Vinegar syndrome
    - appearance of, 287–288
    - defined, 276
    - removal of, 287–289, 288f–290f
  - Virtual endoscopy, in coronary artery analysis, 1182–1183, 1186f
  - Vision, human
    - computational models of, 325
    - early study of, 325–326
  - Vision science. *See also* Optics
    - linear system analysis in, 337
    - stereopsis in, 340–342
  - Visual behavior, models of, 326
  - Visual cortex, 325
    - cells of, 326–327, 327f, 330t
    - input, 332
    - neurons of, 334–338, 336f, 338f
  - Visual cryptography (VC), 1111
    - combinatorial framework for, 1111–1112
    - halftoning framework for, 1112
  - Visual format, digital, 3

- Visual impression, 11
  - Visual information fidelity (VIF) measure, 976, 983, 989, 989f
    - HVS-based quality assessment methods, 984
    - properties of, 984
    - validation of, 986
  - Visual processing
    - binocular, 340
    - human, 326, 327f
  - Visual signals
    - amount of data in, 13
    - analysis of, 1285
    - and audio signals, 1285
    - of face, 1265–1266
    - and feature extraction systems, 1268–1269, 1269f
    - lip tracking, 1265–1266
    - mouth, 1265–1266, 1266f
    - visual features in, 1266–1268, 1267f, 1268f
  - Visual system, 297. *See also* Human visual system
    - analysis of, 342
    - early parallel representations in, 334
    - front end of, 327
    - and ideal observer model, 332
    - sampling, 328, 329f, 331
    - spatio-temporal filtering in, 332, 333, 333f, 336f, 336f CHECK
  - Visual text-to-speech synthesis systems (VTTS), 1278f, 1279
  - VLC. *See* Variable-length coding
  - VLD. *See* Variable length decoding
  - VLSI. *See* Very large scale integration
  - VO. *See* Video object
  - VoD. *See* Video on demand
  - VOP. *See also* Video object plane
  - VQ. *See* Vector quantization
- W**
- Watermarking, 926
    - authentication, 1103–1106, 1106f
    - copyright protection
      - attacks against, 1090–1091
      - benchmarking of, 1091–1093
      - requirements and metrics, 1088–1090
    - halftone, 935, 935f
    - heuristic approaches, 1084
    - with side information
      - informed coding, 1100–1102
      - informed embedding, 1099–1100, 1099f
      - perceptual masking, 1102–1103
    - spread spectrum
      - and blind additive embedding, 1093–1094
      - chaotic watermarks, 1094–1095
      - involving optimal detectors, 1098–1099
      - special structure watermarks, 1097–1098
      - template watermarks, 1096–1097
      - transformed watermarks, 1095–1096
  - Watermarking techniques, 1084–1085
    - algorithms for, 1085–1087
    - development of, 1083
  - Watermarks, detection procedure for, 1087
  - Watson's DCT-based metric, 950–953, 951f, 952t
  - Watson's wavelet metric, 953, 954t
  - Wavelet-based denoising techniques, discrete
    - wavelet transform in, 158, 158f
  - Wavelet coefficients, models for marginal
    - distributions with, 163–164
  - Wavelet coefficient tree, 698
  - Wavelet decomposition
    - and multiresolution texture modeling, 373, 373f
    - subimages from, 348f, 349
  - Wavelet image compression
    - EZW coding, 698–701, 699f
    - high level characterization, 701–703
    - JPEG2000, 706
    - as subband coding, 697–698, 698f
    - and transform coding paradigm, 694–696, 694f, 695f
    - wavelet packets, 703–705, 703f, 705f
  - Wavelet image representation, multiresolution, 692, 693f
  - Wavelet joint model, of image statistics, 436–438, 436f–439f
  - Wavelet marginal model, of image statistics, 434–436, 434f, 435f
  - Wavelet packets, 357
  - Wavelet representations, 356, 361
    - applications, 357
    - continuous wavelet bases, 354–356, 355f
    - discrete wavelet bases, 352–354, 354f
    - filter banks, 351–352, 351f
    - geometric wavelets, 357–358, 358f
    - and human visual system, 356–357, 356–357 CHECK
    - wavelet decomposition, 352, 353f
  - Wavelets
    - defined, 689
    - role in image coding, 690
  - Wavelet scalar quantization (WSQ) standard, 704–705, 705f CHECK
  - Wavelet shrinkage
    - Donoho-Johnstone method of, 158–159, 160
    - drawbacks of, 163
    - examples of, 161–162, 161f, 162f
    - removal of blocking artifacts in DCT-coded images for, 160
    - shift-invariant, 159–160, 159f
    - success of, 160
    - suppression of additive noise in, 160
  - Wavelet theory, 692
  - Wavelet transform, 963
    - and cortex model, 338
    - undecimated, 357
  - WebCT educational system, 84
  - Weber's Law, 941
  - WebTV, 819
  - Weighted median filters, 116–117, 119
    - color images for, 117–119
    - computation for, 116–117
    - image sharpening, 129f
    - multichannel median, 119
  - Weighted Multichannel Median (WMM), 119
  - Weighted medians (WMs)
    - marginal WM filter, 117
    - principles of, 110
  - Weighted median (WM) smoothers, 132
    - center, 112–113, 113f, 121f–122f
    - computation for, 111–112
    - permutation, 113–115
    - running median smoothers, 110–111, 110f
    - and threshold decomposition, 114–116
  - Weighted Multichannel Median (WMM), 119
  - Wiener restoration, 174
  - Windows, in binary image morphology, 46–47, 47f
  - Wireless networks, 1040–1042
  - World Wide Web, 3, 993, 1031
  - WSQ. *See* wavelet scalar quantization
- X**
- X-ray radiography, 1155–1156
- Y**
- YIQ color coordinate system, 11
  - Yule-Walker equations, 173t
- Z**
- Zero bit watermarking systems, 1086
  - Zero-padding, in linear convolution, 65, 65f
  - Zerotree-based framework
    - embedded wavelet image coders based on, 753
    - and EZW coding, 698–701, 699f, 700f, 700t, 703
  - Zig-zag scan procedure, in lossy image compression, 715, 715f
  - Zoom. *See* Scale invariance
  - Zooming
    - bilinear interpolation of, 127, 128f
    - image, 123, 125–127, 127f, 128f
    - median interpolation of, 127, 128f