Abramson, N., 83	Advanced audio coding (AAC), MPEG,
Absolute difference measure, 198	527–533
AC coefficient of transforms, 400, 413–414	Advanced prediction mode,
Action units (AUs), 590	H.263 standard, 600
Adaptive arithmetic coding, 112	Advanced Television Systems Committee
Adaptive codebook, FS 1016 standard, 551	(ATSC), 533
Adaptive dictionary techniques	AEP. See Asymptotic equipartition
LZ77 approach, 121–125	property
LZ78 approach, 125–127	Affine wavelets, 480
LZW algorithm, 127–133	A lattices, 309
Adaptive DPCM, 337	Algorithmic information theory, 35–36
G.722 standard, 461–462	Algorithms
ITU and ITU-T standards, 345, 347–349,	adaptive Huffman, 58–65
461–462	Adaptive TRansform Acoustic Coding
prediction, 339–342	(ATRAC), 535
quantization, 338–339	arithmetic coding, 92, 107
Adaptive Huffman coding, 58	Burrows-Wheeler Transform (BWT),
decoding procedure, 63–65	152–157
encoding procedure, 62–63	cluster compression, 284
update procedure, 59-61	dictionary techniques, 121–133
Adaptive model, 17	CALIC (Context Adaptive Lossless
Adaptive scalar quantization	Image Compression), 166–170
backward/on-line, 246–248	compression versus reconstruction, 3–4
forward/off-line, 244–246	deflate, 133
Jayant, 249–253	differential encoding, 328–332
Adaptive spectral enhancement filter, 557	dynamic Markov compression, 158–160
Adaptive TRansform Acoustic Coding	embedded zerotree coder, 497–505
(ATRAC) algorithm, 535	FS 1016, 550–551
Adaptive vector quantization, 315–316	generalized BFOS, 303
Addition, vector, 358	H.261 standard, 582–588
Additive noise model of a quantizer, 231	H.263 standard, 598-603
Adjoint matrix, 635–636	Huffman coding, 41–54
Adler, Mark, 133	Jayant, 247, 249–253
Admissibility condition, 479	JBIG, 183–188
ADPCM. See Adaptive DPCM	JBIG2, 189–190
•	

Algorithms (Continued)	Analysis filters, 539-540
JPEG lossless old standard, 164–166	Analysis/synthesis schemes
JPEG-LS, 170-172	background of, 537-538
least mean squared (LMS), 342	image compression, 559–568
Levinson-Durbin, 530, 547	speech compression, 539–559
Linde-Buzo-Gray (LBG), 282-299	Anchor frames, 592
Lloyd, 283–284	APCO. See Association of Police
Lloyd-Max, 254–257	Communications Officers
LPC-10, 544-545	Arimoto, S., 212
LZ77, 121–125	Arithmetic coding, 54
LZ78, 125–127	adaptive, 112
LZW, 127–133	algorithm implementation, 96–102
MH (Modified Huffman), 180, 187-188	applications, 112–113
mixed excitation linear prediction,	binary code, generating, 92–109
555–557	bit sliced, 533
model-based coding, 588-590	decoding, 106-109
MPEG-1 algorithm, 580	defined, 81
origin of term, 3	encoding, 102-106
packet video, 610, 612-613	floating-point implementation, 102-109
pairwise nearest neighbor (PNN),	Graphics Interchange Format (GIF),
292–294	133–134
ppma, 144, 149–150	Huffman coding compared with, 81-83
ppmz, 151	109–112
prediction with partial match (ppm), 26,	JBIG, 183–188
143–149	JBIG2, 189–190
set partitioning in hierarchical trees,	sequences, 83–92
505–512	syntax-based and H.263 standard, 600
subband, 436–438	tags, deciphering, 91–93
trellis-coded, 316–321	tags, generating, 84-91, 97-99
Tunstall, 69–71	uniqueness and efficiency of, 93-96
videoconferencing and videophones,	ARJ, 125
582–590	ARMA (moving average model, 218, 223
Viterbi, 317	AR(N) model, 219–222
Aliasing, 376	Association of Police Communications
filters, 429, 443	Officers (APCO), 555
time domain, 417	Associative coder of Buyanovsky (ACB),
Al-Khwarizmi, 3	157–158
All pole filter, 218	Associativity axiom, 358
Alphabet	Asymmetric applications, 590–591
defined, 16, 27	Asymptotic equipartition property (AEP),
extended, 52	305–306
AMDF. See Average magnitude difference	Atal, B. S., 550
function	ATM (asynchronous transfer mode)
Analog-to-digital (A/D) converter, 228	networks, 610-611
Analysis filter bank, 436–437	Atomic blocks, 566

ATRAC. See Adaptive TRansform	Bandwidth, 371
Acoustic Coding	Barnsley, Michael, 561
ATSC. See Advanced Television Systems	Barnwell, T. P., III, 449
Committee	Basis matrices, 400
AU. See Action units	Basis vectors, 356–357
Audio coding	Basis vector spaces, 360-361
See also MPEG audio coding	Bayes' rule, 616-617
Dolby AC3, 533–534	Bell Laboratories, 3
hearing principles, 516	Bennett, W. R., 263
psychoacoustic model, 518–519	Bennett integral, 263, 267
spectral masking, 517	Bidirectionally predictive coded (B)
temporal masking, 517–518	frames, 592–594
Audio compression	BIFS. See Binary Format for Scenes
Huffman coding and, 75–77	Binary code, generating
masking, 201	in arithmetic coding, 92-109
subband coding and, 462-463	in transform coding, 396
transform coding and, 416-419	Binary codewords, pruned tree-structure
Auditory perception, 200–201	and, 303
Autocorrelation approach, 546	Binary entropy function, 212
Autocorrelation function	Binary Format for Scenes (BIFS), 609
AR(N) model, 219–222	Binary images
differential pulse code modulation, 333,	coding schemes, comparing, 188
334	facsimile encoding, 178–190
differential pulse code modulation,	JBIG, 183–188
adaptive, 339-340	JBIG2, 189–190
of a random process, 628	Markov model and, 24-25
Autocovariance approach, 546	Binary sources, rate distortion function
Autoregressive model	and, 212–214
AR(N) model, 219–222	Binary symmetric channel, 617
moving average model (ARMA),	Binary trees
218, 223	adaptive Huffman coding and, 58
speech compression algorithms, 223	external (leaves), 31
Average information	Huffman coding and, 45–46
derivation of, 18–22	internal nodes, 31
mutual, 204–205	prefix code, 31
Average magnitude difference function	sibling property, 58
(AMDF), 544–545	Bit allocation
Axiomatic approach, 618–620	Dolby AC3, 534–535
Axioms, probability, 618	subband coding, 437, 438, 459–461
	threshold coding, 409-410
Backward adaptive prediction in DPCM	transform coefficients, 399, 407–410
(DPCM-APB), 340–342	zonal sampling, 408–409
Backward/on-line adaptive scalar	Bit reservoir, 526
quantization, 246–248	Bits, 14
Band-pass filters, 371, 428	Bit sliced arithmetic coding (BSAC), 533

Bitstreams, 519–521	See also International
constrained parameter, 594	Telecommunications Union (ITU-T)
order, 593	Recommendation V.42, 136
Black-and-white television, 576–578	CCSDS. See
Blahut, R. E., 212	Consultative Committee on Space Data
Block, 59	Standards
Block-based motion compensation, 574	CD-audio. See Audio compression
Block diagrams	cdf. See Cumulative distribution function
channel vocoder, 539	CELP. See Code excited linear prediction
companded scalar quantization, 258-259	CFDM. See Constant factor adaptive delta
delta modulation, 343	modulation
differential encoding, 331	Chaitin, G., 35
Dolby AC3, 534	Channel vocoder, 538, 539–542
generic compression, 197	Characteristic equation, 636
G.728, 553	Chen, O.TC., 612
H.261 standard, 583	Chen, WH., 409, 410, 413, 414
H.263 standard, 599	Cholesky decomposition, 548
linear predictive coder, 543	Chou, P. A., 303
mixed excitation linear prediction,	Chrominance components, 578–579
555–557	CIF. See Common Interchange Format
MPEG audio coding, 519	Classified vector quantization, 313
subband coding system, 436	Clear code, 134
Block switching, MPEG-2 AAC, 528–529	Cleary, J. G., 143, 144, 149
Bloom, Charles, 151	Cloning, dynamic Markov compression
Boundary gain, 304, 307	(DMC), 158–160
Braille code, 2	Cluster compression algorithm, 284
Breiman, L., 303	Codebook design
BSAC. See	defined, 282
Bit sliced arithmetic coding	Hilbert approach, 284, 291
Burrows-Wheeler Transform (BWT),	image compression and, 294–299
152–157	initializing Linde-Buzo-Gray algorithm, 287–294
Buyanovsky, George, 157–158	pairwise nearest neighbor (PNN)
Buzo, A., 283, 284	algorithm, 292–294
	splitting technique, 288–291
CALIC. See Context Adaptive Lossless	two-dimensional vector quantization,
Image Compression	284–287
Canadian Space Agency (CSA), 2	Codebooks
Capon model, 179	bits per sample, 275
CBP. See Coded block pattern	bits per vector, 275
CCIR (International Consultative	defined, 274, 282
Committee on Radio), 601-2	FS 1016, 551
standard, 579–582	vector, 274
CCITT (Consultative Committee on	Coded block pattern (CBP), 587
International Telephone and	Code excited linear prediction (CELP),
Telegraph)	539, 549–552

Codes (coding)	Coefficients
See also Arithmetic coding; Audio	autocorrelation approach, 546
coding; Subband coding; Transforms	autocovariance approach, 546
and transform coding	Coiflet, 491, 493
clear, 134	covariance method, 548
comparison of binary, 188	Daubechies, 491, 492
defined, 6, 27	discrete Fourier series, 377–378
delay, 551	expansion, 373
dictionary, 9–10	filter, 430
digram, 119–121	parcor, 339-340, 531, 547
embedded, 505	periodic function, 377
fixed-length, 27	quadrature mirror, 432, 433, 434,
Golomb, 65–67	447–449
H.261 standard, 586–587	reflection, 547
H.264 standard, 608	set partitioning in hierarchical trees,
Huffman, 41–77	505–512
instantaneous, 29	Smith-Barnwell, 432, 434-435
JPEG, 413–416	transform, 399, 407-410
Kraft-McMillan inequality, 32–35	wavelets, 480, 488-491
make-up, 180	Coiflet filters, 491, 493
model-based, 588-590	Color television, 578
modified Huffman (MH), 180	Column matrix, 632
move-to-front (mtf), 153, 156–157	Comfort noise, 559
predictive, 7–9	Common Interchange Format (CIF), 580
prefix, 31–32	Commutativity axiom, 358
rate, 27–28	Companded scalar quantization, 257-259
Relative Element Address Designate	Compendious Book on Calculation, The
(READ), 181	(Al-Khwarizmi), 3
Rice, 67–69	Composite source model, 27
run-length, 179–180	compress command, UNIX, 133
terminating, 180	Compression
threshold, 409–410	See also Audio compression; Image
transform, 391-420	compression; Speech compression;
Tunstall, 69–71	Video compression; Wavelet-based
unary, 65–66	compression
uniquely decodable, 28-31	algorithm, 3–4
Code-vectors, 274	ratio, 5
Codewords	techniques, 3-6
dangling suffix, 30-31	Compressor function, 258
defined, 27	Compressor mapping, 259-260
Huffman, 41–77	CompuServe Information Service, 133, 134
Kraft-McMillan inequality, 32-35, 49-51	Conditional entropy, 202-204
in optimum prefix codes, 48-49	Conditional probabilities, 204
Tunstall, 69–71	Constant factor adaptive delta modulation
unique, 28	(CFDM), 343–345

Constrained parameter bitstream Cross product, matrix, 634 (CPB), 594 CSA. See Canadian Space Agency Consultative Committee on International Cumulative distribution function (cdf) defined, 83 Telephone and Telegraph (CCITT). joint, 627 See International overview of, 621-622 Telecommunications Union (ITU-T) sequences, 83-92 Consultative Committee on Space Data tag generating, 84–91, 97–99 Standards (CCSDS), 67-69 Cutoff frequency, 428 Context adaptive binary arithmetic code Cutoffs, filter, 371–372 (CABAC), 608 CVSDM. See Continuously variable slope Context Adaptive Lossless Image delta modulation Compression (CALIC), 166–170 CWT. See Continuous wavelet transform Context adaptive variable length code (CAVLC), 608 Dadson, ?FIRST NAME, 516 Context-based compression and models Dangling suffix, 30–31 associative coder of Buyanovsky (ACB), Data compression 157–158 applications, 1–2 Burrows-Wheeler Transform (BWT), packages, 125 152 - 157techniques, 3–6 dynamic Markov compression, 158-160 Data-dependent transforms, finite, 25-26 Karhunen-Loéve transform, 401–402 JBIG standard, 183-184 Data-independent transforms prediction with partial match (ppm), discrete cosine transform, 402-404, 143–152 410-411, 416-419, 580 zero frequency problem, 26 discrete sine transform, 404 Continuously variable slope delta discrete Walsh-Hadamard transform, modulation (CVSDM), 345 404, 406 Continuous wavelet transform (CWT), Daubechies filters, 491, 492 479-480 DC coefficient of transforms, 400, 414–415 Contouring, 237 DCT. See Discrete cosine transform Contours of constant probability, 304 DDVPC. See Defense Department Voice Convolution Processing Consortium filter, 431 Deblocking filter mode, 601 Z-transform discrete, 387–389 Decibels, 198 Convolution theorem, 367 Decimation, 436, 438 Conway, J. H., 638 Deciphering tags, 91–93 Cormack, G. V., 158 Decision boundaries Covariance method, 548 defined, 231 CPB. See Constrained parameter bitstream Lloyd algorithm, 283 CRC bit, 520-521 mean squared quantization error, Critical band frequencies, 201 231-233 Critically decimated filter bank, 454 pdf-optimized, 254–257 Crochiere, 448 quantizer rate, 232-233 Croisier, A., 432 Decision tree, vector quantization, 302

Decoding procedures	Dictionary techniques
adaptive Huffman coding and, 63-65	adaptive, 121–133
arithmetic coding and, 106-109	applications, 133-138
Burrows-Wheeler Transform (BWT),	digram coding, 119-121
155–156	LZ77 approach, 121-125
generic, 189–190	LZ78 approach, 125-127
G.728 standard, 551–552	LZW algorithm, 127-133
halftone region, 190	purpose of, 117–118
instantaneous, 29	static, 118–121
JBIG, 183–188	Difference distortion measures, 198
JBIG2, 189–190	Difference equation, 24
JPEG standard, 413-416	Differential encoding
LZ77 approach, 121-125	adaptive DPCM, 337–342
LZ78 approach, 125–127	basic algorithm, 328–332
LZW algorithm, 130-133	block diagram, 331
symbol region, 190	defined, 325–326
vector quantization, 274–275	delta modulation, 342–345
Decomposition	dynamic range, 326
Cholesky, 548	image coding, 349–351
of images, 465–467	ITU and ITU-T standards, 345, 347–349
model-based coding, 588–590	performance, 336
polyphase, 454–459	prediction in DPCM, 332–337
Defense Department Voice Processing	quantization error accumulation, 329–330
Consortium (DDVPC), 555	sinusoidal example, 326, 330–331
Deflate algorithm, 133	speech coding, 334–337, 345–349
Delivery Multimedia Integration	Differential entropy, 205–208
Framework (DMIF), 609	Differential pulse code modulation
Delta function	(DPCM)
dirac, 370–371	adaptive, 337–342
discrete, 387	backward adaptive prediction with,
Delta modulation (DM), 342	340–343
block diagram, 343	basic algorithm, 328–332
constant factor adaptive, 343–345	block diagram, 331
continuously variable slope, 345	defined, 325–326
granular regions, 343	delta modulation, 342–345
slope overload regions, 343	development of, 331
syllabically companded, 345	forward adaptive prediction and, 339–340
Deprettere, E. F., 550	noise feedback coding, 346
Derivation of average information, 18–22	prediction in, 332–337
Determinant, matrix, 635	speech coding, 345–349 Digital Theater Systems (DTS), 535
DFS. See Discrete Fourier series	
DFT. See Discrete Fourier transform	Digital-to-analog (D/A) converter, 229 Digram coding, 119–121
Dictionary compression, 9–10	Dirac delta function, 370–371
Dictionary ordering, 87	Direct Broadcast Satellites (DBS), 533
Dividing diacring, 0/	Direct Director Datellites (DDD), 333

Discrete convolution, Z-transform,	probability density function (pdf), 205,
387–389	622–23
Discrete cosine transform (DCT), 402-404,	Distributivity axiom, 358
410–411	Dithering, 237
modified, 416-419	D lattices, 309
video compression and, 580	DM. See Delta modulation
Discrete delta function, 387	DMIF. See Delivery Multimedia
Discrete Fourier series (DFS), 377-378	Integration Framework
Discrete Fourier transform (DFT),	Dolby AC3, 533–534
376–378, 402–403	Domain blocks, 561
Discrete sine transform (DST), 404	Dot product, 357, 634
Discrete time Markov chain, 24	Downsampling, 436, 438, 440-442
Discrete time wavelet transform	DPCM. See Differential pulse code
(DTWT), 480	modulation
Discrete Walsh-Hadamard transform	DST. See Discrete sine transform
(DWHT), 404, 406	DTWT. See Discrete time wavelet
Discrete wavelet transform (DWT), 480	transform
Display order, 593	Dudley, Homer, 3, 538
Distortion	DVDs, 533
aliasing, 376	DWHT. See Discrete Walsh-Hadamard
auditory perception, 200-201	transform
Bennett integral, 263, 267	DWT. See Discrete wavelet transform
control loop, 526	Dynamic Markov compression (DMC),
criteria, 197–201	158–160
defined, 6, 196	Dynamic range, differential encoding, 326
difference distortion measures, 198	
high-rate entropy-coded quantization,	EBCOT (embedded block coding with
266–269	optimized truncation), 512
human visual system, 199–200	Edge blocks, 563
Linde-Buzo-Gray (LBG), 282–299	Eigenvalues, 636
Lloyd, 283–284	Elias, Peter, 83
mean squared quantization error,	Embedded block coding with optimized
231–233	truncation (EBCOT), 512
quantizer, 231	Embedded coding, 505
rate distortion theory, 196, 208–215	Embedded zerotree wavelet (EZW),
scalar versus vector quantization,	497–505, 610
276–282	Empty cell problem, 294
trellis-coded quantization, 316-321	Encoding procedures
uniform quantization for uniformly	See also Differential encoding
distributed sources, 234–236	adaptive Huffman coding and, 62-63
vector versus scalar quantization,	arithmetic coding and, 102-106
276–282	associative coder of Buyanovsky (ACB)
Distribution functions	157–158
cumulative distribution function (cdf),	Burrows-Wheeler Transform (BWT),
83–92, 97–99, 621–622, 627	152–157

digram coding, 119–121	Exclusion principle, 151–152
facsimile, 178–190	Expander function, 258–259
G.728 standard, 551-552	Expectation operator, 623
H.261 standard, 586-587	Extended alphabet, 52
Huffman coding and, 62-63	Extended Huffman codes, 51-54
JBIG, 183–188	External nodes, 31
JBIG2, 189–190	EZW. See Embedded zerotree wavelet
JPEG, 164–166, 413–416	
LZ77 approach, 121-125	Facsimile encoding
LZ78 approach, 125–127	binary coding schemes, comparing, 188
LZW algorithm, 127-133	groups, 178–179
minimum variance Huffman codes,	Group 3 and 4 (recommendations T.4
46-48	and T.6), 180–183
vector quantization, 274-275	JBIG, 183–188
End-of-block (EOB) symbol, 410, 414, 415	JBIG2, 189–190
Ensemble, stochastic process, 627	MH (Modified Huffman), 180, 187-188
Entropy	modified modified READ (MMR) code,
average mutual information, 204-205	187–188
binary entropy function, 212	modified READ (MR) code, 181,
conditional, 202-204	187–188
defined, 16	Relative Element Address Designate
differential, 205–208	(READ) code, 181
estimating, 16–17	run-length coding, 179-180
extended Huffman codes, 51-54	Faller, N., 58
first-order, 16	Families of wavelets, 491–493
Markov model, 24–25	Fano, Robert, 41, 83
rate distortion theory, 196, 208-215	Fast Fourier transform (FFT), 378
reducing, 17	FBI fingerprint image compression, 512
run-length coding, 179–180	FCC (Federal Communications
of the source, 16	Commission), 597–598
Entropy-coded scalar quantization,	Federal standards. See standards
264–269	Fenwick, P., 157
Entropy-constrained quantization, 265–266	FFT. See Fast Fourier transform
EOB. See End-of-block symbol	Fidelity
Equitz, W. H., 292	See also Distortion
Error magnitude, maximum value of the,	defined, 6
199	Fields, television, 577–578
Escape symbol, 149–150	File compression,
Esteban, D., 432	UNIX compress command, 133
Euler's identity, 363	Filter banks
European Space Agency (ESA), 2	analysis, 436–437
Exception handler, LZW algorithm, 132	design of, 438–444
Excitation signal	M-band QMF, 451–454
channel vocoder synthesis, 541-542	perfect reconstruction using two-channel
sinusoidal coders, 552–554	444–451

Filters	LZ77 approach, 121–125
adaptive spectral enhancement, 557	quantizer output, 231
all pole, 218	uniform quantization, 236
analysis filter bank, 436–437	Fletcher, H., 516
anti-aliasing, 429, 443	Fletcher-Munson curves, 201
band-pass, 371, 428	Floating-point implementation, arithmetic
bandwidth, 371	coding and, 102–109
coefficients, 430	Format frequencies, 540
Coiflet, 491, 493	Format vocoders, 541
convolution, 431	FORTRAN, 74
cutoffs, 371–372	Forward adaptive prediction in DPCM
Daubechies, 491, 492	(DPCM-APF), 339–340
defined, 371, 428	Forward/off-line adaptive scalar
finite impulse response, 430, 449–451	quantization, 244–246
high-pass, 371, 428	Forward transform, 396
H.261 loop, 584-586	Fourier, Jean Baptiste Joseph, 362
impulse response, 430–431	Fourier series, 362–364
infinite impulse response, 430	discrete, 377
interpolation, 443	Fourier transform
linear systems and, 371–372	average analysis, 474
low-pass, 371, 428	convolution theorem, 367
magnitude transfer function, 428-429	defined, 365–366
mechanical, 428	discrete, 376-378, 402-403
passband, 371	fast, 378
quadrature mirror, 432, 433, 434,	inverse, 366
447–449	modulation property, 366–367
Smith-Barnwell, 432, 434–435	Parseval's theorem, 366
stopband, 371	periodic extension, 365
subband, 428–435	short-term, 474–476
synthesis, 443	time and, 474
taps, 430	Fractal compression, 560–568
vocal tract filter, 545–548	Fractional pitch refinement, 556
wavelet, 486–493	Frames
Fine quantization assumption, 332, 333	anchor, 592
Finite context models, 25–26	bidirectionally predictive coded (B),
Finite context models, 23–20 Finite impulse response (FIR) filters	592–594
defined, 430	
,	H.263 standard and improved, 600
power symmetric and perfect	I, 591–593
reconstruction, 449–451	MPEG, 591–594
FIR. See Finite impulse response filters	predictive coded (P), 592, 593
First-order entropy, 16	television, 577–578
First-order Markov model, 24	Freidman, J. H., 303
Fischer, T. R., 306	Frequencies
Fixed-length code	formats, 540
defined, 27	short-term Fourier transform and, 474

Frequency domain view, sampling, Grand Alliance HDTV, 597–598 373-374 Granular error/noise, 240, 307 Frequency of occurrence, description of, Granular regions, 343 615-616 Graphics Interchange Format (GIF), FS 1016 standard, 550-551 133–134 Fundamental theorem of expectation, 624 Gray, R. M., 275, 283, 284, 303 Gray-scale images, CALIC (Context Adaptive Lossless Gabor transform, 474 Image Compression), 166–170 Gailly, Jean-loup, 133 Groups of blocks (GOBs), 587, 598 Gain-shape vector quantization, 306, 311 Galand, C., 432 Groups of pictures (GOPs), 592 G.722 standard, 461-462 Gallagher, R. G., 58 G.722.2 standard, 558-559 Gamma distribution, 217 mismatch effect, 244 G.726 standard, 347–349 G.728 standard, 551–552 overview, 626 gzip, 125, 133 Gaussian distribution, 216 contours of constant probability, 306 Haar scaling function, 481–485 Gabor transform, 474 Hadamard matrices, 406 Laplacian distribution model versus, Halftone region decoding, 190 242-243 Hartleys, 14 mismatch effect, 244 output entropies, 265 HDTV, 533, 597-598 High-pass coefficients of transforms, 399 overview, 626 High-pass filters, 371, 428 pdf-optimized quantization, 257 High profile, 594 polar and spherical vector quantization, 306-307 High-rate quantizers uniform quantization of nonuniform entropy-coded quantization, 266–269 source, 239-240 properties of, 261–264 Hilbert, E. E., 284 Gaussian sources differential entropy, 206–208 Hilbert approach, 284, 291 rate distortion function and, 214–215 HINT (Hierarchical INTerpolation), 173 Homogeneity, linear systems and, 368 Generalized BFOS algorithm, 303 Horizontal mode, 182 Generalized Lloyd algorithm (GLA). See Linde-Buzo-Gray (LBG) algorithm Horspool, R.N.S., 158 Generic decoding, 189–190 Hotelling, H., 395 Geometric transformation, 562 Hotelling transform, 401–402 H.261 standard, 582 Gersho, Allen, 254, 275, 459 GIF. See Graphics Interchange Format block diagram, 583 Gish, H., 266 coded block pattern, 587 Global motion, 590 coding, 586–587 GOBs. See Groups of blocks group of blocks, 587 Golomb, Solomon, 66 loop filter, 584–586 Golomb codes, 65–67, 608 motion compensation, 583–584 GOPs. See Group of pictures MPEG-1 video standard compared to,

591-594

Government standards. See Standards

H.261 standard (Continued)	dynamic Markov compression (DMC), 158–160
quantization, 586–588 rate control, 588	facsimile encoding, 178–190
transform, 586	
	Graphics Interchange Format (GIF), 133–134
H.263 standard, 598–603	
H.264 standard, 603–608	Huffman coding and, 72–74
Huang, JY., 395	JPEG-LS, 170–172
Huffman, David, 41	JPEG old standard, 164–166
Huffman coding, 2	MRC-T.44, 190–193
adaptive, 58–65	multiresolution models, 172–178
algorithm, 41–54	Portable Network Graphics (PNG),
arithmetic coding compared with, 81-83,	134–136
109–112	Image compression, lossy
applications, 72–77	analysis/synthesis schemes, 559–568
decoding procedure, 63–65	differential encoding, 349–351
design of, 42–46	fractal compression, 560-568
encoding procedure, 62–63	JBIG2, 189–190
extended, 51–54	JPEG, 410–416
Golomb codes, 65–67	Linde-Buzo-Gray (LBG) algorithm and,
length of codes, 49–51	294–299
minimum variance, 46–48	subband coding and, 463–470
modified, 180, 187-188	uniform quantization and, 236-237
nonbinary, 55–57	wavelet, 494-496
optimality of, 48–49	Imaging, 443
redundancy, 45	Improved MBE (IMBE), 555
Rice codes, 67–69	Impulse function, 370
Tunstall codes, 69–71	Impulse response
update procedure, 59–61	of filters, 430–431
Human visual system, 199–200	linear systems and, 369-370
HV partitioning, 567	Independent, identically distributed (iid), 627
	Independent events, 617
Identity matrix, 631	Inequalities
IEC. See International Electrotechnical	Jensen's, 50
Commission	Kraft-McMillan, 32-35, 49-51
IEEE Transactions on Information	Infinite impulse response (IIR) filters,
Theory, 254	430–432
I frames, 591–593	Information theory
Ignorance model, 23	algorithmic, 35–36
iid (independent, identically	average mutual information, 204-205
distributed), 627	conditional entropy, 202–204
IIR. See Infinite impulse response filters	derivation of average information, 18–22
Image compression, lossless	differential entropy, 205–208
CALIC (Context Adaptive Lossless	lossless compression and overview of,
Image Compression), 166–170	13–22, 35–36

lossy compression and, 201–208 Isometries, fractal compression, 562 self-information, 13-14 ITU-R recommendation BT.601-2, Inner product, 357, 361, 634 569-582 Instantaneous codes, 29 ITU-T. See International Integer implementation, arithmetic coding Telecommunications Union and, 102-109 Inter mode, 586 Jacquin, Arnaud, 561 Internal nodes, 31 Jain, A. K., 448 International Consultative Committee on Japanese Space Agency (STA), 2 Radio. See CCIR Jayant, Nuggehally S., 247 International Electrotechnical Commission Jayant quantizer, 247, 249-253 (IEC), 112, 590 JBIG, 183-188 International Standards Organization (ISO), JBIG2, 189-190 112, 410, 590 Jelinek, F., 83 International Telecommunications Union Jensen's inequality, 50 (ITU-T), 112 Johnston, J. D., 432 differential encoding standards, 345, 347-349 quadrature mirror filters, 432, 433, 434, 448 facsimile encoding, 178–190 Joint cumulative distribution function, 627 G.722 standard, 461–462 G.722.2 standard, 558-559 Joint probability density function, 627 G.726 standard, 347–349 Joint Video Team (JVT), 603 G.728 standard, 551-552 Journal of Educational Psychology, 395 H.261 standard, 582-588 JPEG (Joint Photographic Experts Group) H.263 standard, 598-603 coding, 413-416 H.264 standard, 603–608 differential encoding versus, 349-351 T.4 and T.6 standards, 180–183 discrete cosine transform, 410, 411 T.44, 190-193 image compression and, 410-416 V.42 bis standard, 136-138 JPEG 2000 standard, 494, 512 Video Coding Experts Group lossless standard, 1, 164–166 (VCEG), 603 quantization, 411–413 Interpolation filters, 443 transform, 410-411 Intra mode, 586 JPEG-LS, 170-172 H.263 standard, 600-601 JPEG 2000 standard, 494, 512 H.264 standard, 605-606 Just noticeable difference (ind), 200 Inverse, matrix, 635 Inverse Fourier transform, 366 Karhunen, H., 395 Inverse transform, 396–397 Karhunen-Loéve transform, 401-402 Inverse Z-transform Karlsson, G., 612 defined, 381 Katz, Phil, 133 long division, 386–387 partial fraction expansion, 382-386 Knuth, D. E., 58 tabular method, 381-382 Kolmogorov, A. N., 35 ISO. See International Standards Kolmogorov complexity, 35 Kraft-McMillan inequality, 32–35, 49–51 Organization

Kramer, H. P., 395	Lie algebras, 310
Kroon, P., 550	Linde, Y., 284, 302
	Linde-Buzo-Gray (LBG) algorithm
Lagrange multipliers, 407	empty cell problem, 294
Lane, Thomas G., 416	Hilbert approach, 284, 291
Langdon, G. G., 84	image compression and, 294-299
Laplacian distribution, 216–217	initializing, 287–294
contours of constant probability, 306	known distribution, 283
discrete processes, 231	Lloyd algorithm, 283–284
Gaussian distribution model versus,	pairwise nearest neighbor (PNN)
242–243	algorithm, 292-294
mismatch effects, 244	splitting technique, 288–291
pdf-optimized quantization, 257	training set, 283
output entropies, 265	two-dimensional codebook design,
Lapped orthogonal transform (LOT), 424	284–287
Lattices	Linearly independent vectors, 360
A and D, 309	Linear prediction
defined, 308	code excited, 539, 549–552
root, 310, 637–638	mixed excitation, 555-557
spherical, 309–310	multipulse, 550
Lattice vector quantization, 307–311	Linear predictive coder, 539
LBG. See Linde-Buzo-Gray (LBG)	multipulse, 550
algorithm	pitch period estimation, 543–545
Least mean squared (LMS), 342	synthesis, 549
Least significant bit (LSB)	transmitting parameters, 549
integer implementation, 103–104,	vocal tract filter, 545–548
105, 107	voiced/unvoiced decision, 542–543
predictive coding, 146–147	Linear system models, 218–223
Leaves, 31	Linear systems
Lempel, Abraham, 121	filter, 371–372
Length of Huffman codes, 49–51	impulse response, 369–371
Less Probable Symbol (LPS), 185–186	properties, 368
Letters	time invariance, 368
defined, 16, 27	transfer function, 368–369
digram coding, 119–121	List of insignificant pixels (LIP), 507
optimality of Huffman codes and, 48–49	List of insignificant sets (LIS), 507
probabilities of occurrence in English	List of significant pixels (LSP), 507
alphabet, 75	Lloyd, Stuart O., 254, 283
Levels	Lloyd algorithm, 283–284
MPEG-2 video standard (H.262),	Lloyd-Max algorithm, 254–257
594–599	Lloyd-Max quantizer, 254–257
vector quantization, 276	entropy coding of, 265
Levinson-Durbin algorithm, 530, 547	LMS. See Least mean squared
Lexicographic ordering, 87	Loading factors, 241
LHare, 125	Local motion, 590

LOCO-I, 170	Low-pass coefficients of transforms, 399
Loéve, M., 395	Low-pass filters
Karhunen-Loéve transform, 401-402	Choiflet, 491, 493
Logarithms	Daubechies, 491, 492
overview of, 14–15	defined, 371, 428
self-information, 14	finite impulse response, 430, 449–451
Long division, Z-transform, 386–387	magnitude transfer function, 428-429
Long term prediction (LTP), 532	quadrature mirror, 432, 433, 434, 448
Lookabaugh, T., 303	Smith-Barnwell, 432, 434–435
Look-ahead buffer, 121–122	LPC. See Linear predictive coder
Loop filter, H.261 standard, 584-586	LPC-10 algorithm, 544-545
Lossless compression	LPS (Less Probable Symbol), 185–186
See also Image compression, lossless	Lukaszewicz, J., 254
arithmetic coding and, 112–113	Luminance components, 578
coding, 27–35	LZ77 approach, 121–125
Consultative Committee on Space Data	LZ78 approach, 125-127
Standards recommendations for,	LZSS, 125
67–69	LZW algorithm, 127-133
defined, 4-5, 13	M. 11 1 WACL 1 1 504
derivation of average information, 18–22	Macroblocks, H.261 standard, 584
information theory, 13–22, 35–36	Magnitude transfer function, 428–429
JBIG, 183–188	Main profile, 594
JBIG2, 189–190	Make-up codes, 180
JPEG-LS, 170-172	Markov, Andre Andrevich, 24
minimum description length principle,	Markov models
36–37	binary images and, 24–25
models, 23–27	composite source, 27
Lossy compression	discrete cosine transform and, 403
defined, 5, 13	discrete time Markov chain, 24
differential encoding, 325–351	first-order, 24 overview of, 24–27
distortion, 197–201	text compression and, 25–27
information theory, 201–208	two-state, 179
JBIG2, 189–190	Masking, 201
mathematical preliminaries, 195-224	spectral, 517
models, 215–223	temporal, 517–518
performance measures, 6	Massic transformation, 562
rate distortion theory, 196, 208–215	Mathews, M. V., 395
scalar quantization, 228-264	Matrices
subband coding, 405–470	adjoint, 635–636
transform coding, 392–419	column, 632
vector quantization, 273–321	defined, 631
video compression, 571–614	determinant, 635
wavelet-based compression, 455–513	eigenvalues, 636
LOT. See Lapped orthogonal transform	identity, 631, 634
Lovag, Kempelen Farkas, 538	minor, 635

Matrices (Continued)	Minimum description length (MDL)
operations, 632–636	principle, 36–37
row, 632	Minimum variance Huffman codes, 46-48
square, 631	Minor, matrix, 635
Toeplitz, 547	Mintzer, F., 449
transpose, 632	Mismatch effects
Matrices, transform	pdf-optimized, 257
basis, 400	uniform quantization and, 242–244
discrete cosine, 404	Mixed excitation linear prediction (MELP)
discrete sine, 404	555–557
discrete Walsh-Hadamard, 4044, 406	Mixed Raster Content (MRC)-T.44,
forward, 397	190–193
inverse, 397	MMR. See Modified modified READ
Karhunen-Loéve, 402	Model-based coding, 588-590
orthonormal, 397	Modeling,
separable, 397	defined, 6
Max, Joel, 254	Models
Maximally decimated filter bank, 454	See also Context-based compression and
Maximum value of the error	models
magnitude, 199	adaptive, 17
M-band QMF filter banks, 451–454	-based coding, 588–590
MBE. See Multiband excitation coder	composite source, 27
MDCT. See Modified discrete cosine	finite context, 25–26
transform	ignorance, 23
Mean, 624-625	linear system, 218–223
Mean-removed vector quantization, 312	lossy coding, 215–223
Mean squared error (mse), 198, 275	Markov, 24–27
Mean squared quantization error	physical, 23, 223
companded scalar quantization, 263-264	probability, 23-24, 216-218
defined, 231	sequence and entropy, 17
pdf-optimized quantization, 257	speech production, 223
quantizer design, 231–233	static, 17
uniform quantization, 234	Modified discrete cosine transform
variance mismatch, 242-243	(MDCT), 416–419, 523
Measure of belief, 616–618	MPEG-2 AAC, 528-529
Mechanical filters, 428	Modified Huffman (MH), 180, 187-188
Median Adaptive Prediction, 171	Modified modified READ (MMR) code,
MELP. See Mixed excitation linear	187–188
prediction	Modified READ (MR) code, 181, 187-188
Method of principal components, 395	Modulation property, 366–367
MH. See Modified Huffman	Moffat, A., 150
Midrange blocks, 563	More Probable Symbol (MPS), 185-186
Midrise quantizers, 233-234, 253, 254	Morse, Samuel, 2
Midtread quantizer, 233–234	Morse code, 2
Miller, Warner, 67	Most significant bit (MSB)

integer implementation, 103-104,	MPEG-7 video standard, 591, 610
105, 107	MPEG-SIF, 580
predictive coding, 146–147	MPS. See More Probable Symbol
Mother wavelet, 476, 478	MR. See Modified READ
Motion compensation, 573–576	MRA. See Multiresolution analysis
block-based, 574	MRC (Mixed Raster Content)-T.44,
global, 590	190–193
H.261 standard, 583-584	mse. See Mean squared error
H.264 standard, 604	Multiband excitation coder (MBE),
local, 590	554, 555
Motion vectors, 574–575	Multiplication, scalar, 358–359
unrestricted and H.263 standard, 600	Multipulse linear predictive coding
Move-to-front (mtf) coding, 153, 156-157	(MP-LPC), 550
Moving Picture Experts Group. See MPEG	Multiresolution analysis (MRA), 480–486
MPEG (Moving Picture Experts Group), 1	Multiresolution models, 172–178
advanced audio coding, 527-533	Multistage vector quantization, 313–315
bit reservoir, 526	Munson, W. A., 516
bit sliced arithmetic coding, 533	Fletcher-Munson curves, 201
bitstream order, 593	Mutual information
bitstreams, 519–521	average, 204–205
block switching, 528–529	defined, 204
constrained parameter bitstream, 594	National Aeronautics and Space Agency
display order, 593	(NASA), 2
frames, 591–594	National Television Systems Committee
groups of pictures, 592	(NTSC), 578–579
H.261 compared to, 591–592	Nats, 14
Layer 1, 520–521	Nelson, D. J., 612
Layer II, 521–522	Network video. See Packet video
Layer III (mp3), 522–527	Never Twice the Same Color, 578
layers, overview of, 519	
long term prediction, 532	Node number, adaptive Huffman coding
perceptual noise substitution, 532	and, 58
profiles, 531–532, 594–597	Noise
quantization and coding, 531	See also Distortion; Signal-to-noise ratio
spectral processing, 529–531	(SNR)
stereo coding, 531	boundary gain, 304, 307
subband coding 462–463	comfort, 559
TwinVQ, 532–533	differential encoding and accumulation
MPEG-1 algorithm, 580	of, 329–330
MPEG-1 video standard, 591–594	feedback coding (NFC), 346
MPEG-2 AAC, 527–532	granular, 240, 307
MPEG-2 video standard (H.262), 594-598	overload, 240, 307
MPEG-3 video standard, 590	pdf-optimized, 253–257
MPEG-4 AAC, 532–533	peak-signal-to-noise-ratio (PSNR), 198
MPEG-4 video standard, 603-610	quantization, 231

N 1 1 11 CC 1 55 57	
Nonbinary Huffman codes, 55–57	Parkinson's First Law, 2
Nonuniform scalar quantization	Parseval's theorem, 366, 479
companded, 257–264	Partial fraction expansion, Z-transform,
defined, 253	382–386
midrise, 253, 254	Pasco, R., 83
mismatch effects, 257	Passband, 371
pdf-optimized, 253–257	Pass mode, 181
Nonuniform sources,	pdf. See Probability density function
uniform quantization and, 238-242	pdf-optimized, 253–257
NTSC. See National Television Systems	Peakiness, 557
Committee	Peak-signal-to-noise-ratio (PSNR), 198
Nyquist, Harry, 372, 429	Pearlman, William, 505
Nyquist theorem/rule, 429, 436, 483	Perceptual noise substitution (PNS), 532
NYT (not yet transmitted) node, 59-65	Perfect reconstruction
OBMC. See Overlapped Block Motion	power symmetric FIR filters, 449-451
Compensation	two-channel filter banks, 444–451
Off-line adaptive scalar quantization,	two-channel PR quadrature mirror filters,
244–246	447–449
Offset, 122	Performance
Olshen, R. A., 303	differential encoding, 336
On-line adaptive scalar quantization,	measures of, 5–6
246–248	Periodic extension, Fourier transform
Operational rate distortion, 460	and, 365
Optimality	Periodic signals, Fourier series and, 364
of Huffman codes, 48–49	P frames (predictive coded), 592, 593
of prefix codes, 41–42	Phase Alternating Lines (PAL), 578, 579
Orthogonal random variables, 628	Physical models
Orthogonal sets, 361–362	applications, 23
Orthogonal transform, lapped, 424	speech production, 223
Orthonormal sets, 361–362	Picture resampling, H.263 standard, 601
Orthonormal transforms, 397–398	Picture selection mode, H.263
Outer product, matrix, 634	standard, 601
Overdecimated filter bank, 454	enhanced, 603
Overlapped Block Motion Compensation	Pierce, J. N., 266
(OBMC), 600	
	Pierce, J. R., 588–589 Pitch period
Overload error/noise, 240, 307	differential encoding, 345
Overload probability, 240	
Packet video, 610, 612–613	estimating, 543–545
Pairwise nearest neighbor (PNN)	fractional pitch refinement, 556
algorithm, 292–294	FS 1016 standard, 551
PAL (Phase Alternating Lines), 578, 579	PKZip, 125
Parcor coefficients	PNG (Portable Network Graphics), 125,
DPCM -APF, 339–340	134–136
linear predictive coder and, 547	PNN. See Pairwise nearest neighbor
MPEG-2 AAC, 531	Polar vector quantization, 306–307

Polyphase decomposition, 454–459	Probability density function (pdf), 205,
Portable Network Graphics. See PNG	622–23
ppm. See Prediction with partial match	Probability models
ppma algorithm, 144, 149-150	Gamma distribution, 216, 217, 244
ppmz algorithm, 151	Gaussian distribution, 216, 217
Pratt, W. K., 409, 410, 413, 414	Laplacian distribution, 216–217
Prediction in DPCM, 332–337	lossless compression, 23–24
Prediction with partial match (ppm)	lossy, 216–218
algorithm, 26, 143-149	Product code vector quantizers, 306
escape symbol, 149–150	Profiles
exclusion principle, 151–152	MPEG-2 AAC, 531–532
length of context, 150-151	MPEG-2 video standard (H.262),
Predictive coded (P) frames, 592, 593	594–597
Predictive coding	Progressive image transmission, 173-178
Burrows-Wheeler Transform (BWT),	Pruned tree-structured vector
152–157	quantization, 303
CALIC (Context Adaptive Lossless	Psychoacoustic model, 518-519
Image Compression), 166–170	Pyramid schemes, 177
code excited linear prediction, 539,	Pyramid vector quantization, 305-306
549–552	
dynamic Markov compression (DMC),	QCIF (Quarter Common Interchange
158–160	Format), 580
example of, 7–9	Q coder, 184
facsimile encoding, 178–190	QM coder, 184–186
HINT (Hierarchical INTerpolation), 173	Quadrature mirror filters (QMF), 432, 433,
JPEG-LS, 170–172	434, 447–449
linear predictive coder, 539, 542-549	Quadtree partitioning, 566–568
mixed excitation linear prediction,	Quality, defined, 6
555–557	Quantization
multipulse linear, 550	See also Scalar quantization; Vector
multiresolution models, 172–178	quantization coefficients, transform,
regular pulse excitation with long-term	399, 407–410
prediction (RPE-LTP), 550	H.261 standard, 586–587
typical, 189	H.263 standard, 602
Prefix codes, 31–32	H.264 standard, 606–608
optimality of, 41–42	JPEG, 411–413
Probabilities	MPEG-2 AAC, 531
axiomatic approach, 618–620	noise, 231
Bayes' rule, 616–617	subband coding, 437
conditional, 204	table, 411
contours of constant, 304	Quantization error
frequency of occurrence, 615–616	accumulation in differential encoding,
measure of belief, 616–618	329–330
overload, 240	companded scalar quantization, 260
01011044, 270	companded scalar quantization, 200

Quantization error (Continued)	Reconstruction levels (values)
granular, 240	defined, 231
overload, 240	Linde-Buzo-Gray (LBG) algorithm,
Quantizer distortion, 231	283–284
Quantizers. See Scalar quantization; Vector	Lloyd algorithm, 283-284
quantization	pdf-optimized, 255-257
Quarter Common Interchange Format. See	trellis-coded quantization, 316-321
QCIF	Rectangular vector quantization, 293
_	Recursive indexing
D 1 '11	CALIC (Context Adaptive Lossless
Random variables	Image Compression), 170
defined, 620	entropy-coded quantization, 268
distribution functions, 621–623	Recursively indexed vector quantizers
expectation, 623–624	(RIVQ), 314–315
independent, identically distributed, 627	Redundancy, Huffman coding and, 45
mean, 624–625	Reference picture resampling, 601
orthogonal, 628	Reference picture selection mode, 601
realization, 620	enhanced, 603
second moment, 625	Reflection coefficients, 547
variance, 625	Region of convergence, Z-transform, 379,
Range blocks, 561	380
Rate	Regular pulse excitation (RPE), 550
code, 27–28	Regular pulse excitation with long-term
control, 588	prediction (RPE-LTP), 550
control loop, 526	Relative Element Address Designate
defined, 6	(READ) code, 181
dimension product, 298	Remde, J. R., 550
H.261 standard, 588	Rescaling
sequence coding, 273	QM coder, 186
vector quantization, 275	tags, 97–102
video data, 571	Residual
Rate distortion function	defined, 6, 313
binary sources and, 212–214	sequence and entropy, 17
defined, 208	Residual vector quantization, 313
Gaussian source and, 214–215	Resolution update mode, reduced, 602
operational, 460	Rice, Robert F., 67
Shannon lower bound, 215	Rice codes, 67–69
Rate distortion theory, 196, 208-215	Ripple, 429
READ (Relative Element Address	Rissanen, J. J., 36, 83, 84
Designate) code, 181	RIVQ. See Recursively indexed vector
Reconstruction, perfect. See Perfect	quantizers
reconstruction	Robinson, D. W., 516
Reconstruction	Root lattices, 310, 637–638
algorithm, 3–4	Row matrix, 632
Reconstruction alphabet, 202–203	RPE. See Regular pulse excitation

RPE-LTP. See Regular pulse excitation	Self-information
with long-term prediction	conditional entropy, 202-203
Run-length coding, 179–180	defined, 13–14
	differential entropy, 205–206
Said, Amir, 505	Separable transforms, 397
Sakrison, D. J., 306	Sequences, 83–92
Samet, H., 566	Séquential Coleur avec Mémoire
Sample, use of term, 276	(SECAM), 578
Sample average, 624	Set partitioning in hierarchical trees
Sampling	(SPIHT), 505-512
aliasing, 376	Shade blocks, 563
development of, 372–373	Shannon, Claude Elwood, 13, 16, 19, 25
frequency domain view, 373–374	26, 83, 141–142, 273, 305
theorem, 429	Shannon-Fano code, 83
time domain view, 375–376	Shannon lower bound, 215
zonal, 408–409	Shapiro, J. M., 497
Sayood, K., 612	Shifting property, delta function and, 37
Scalable Sampling Rate, 532	Shifting theorem, 388–389
Scalar multiplication, 358–359	Shoham, Y., 459
Scalar quantization	Short-term Fourier transform (STFT),
adaptive, 244–253	474–476
companded, 257–259	Sibling property, 58
defined, 228	Side information, 244
design of quantizers, 228–233	SIF, MPEG-, 580
entropy-coded, 264–269	Signal representation, video. See Video
high-rate optimum, 266–269	signal representation
Jayant, 249–251	Signals, Systems, and Noise-The nature
mean squared quantization error,	and Process of Communications
231–233	(Pierce), 588–589
nonuniform, 253-264	Signal-to-noise ratio (SNR)
pdf-optimized, 253–257	companded quantization, 258
uniform, 233–244	defined, 198
vector quantization versus, 276–282	differential encoding, 336
Scalefactor, 520	pdf-optimized, 256–257
Scaling	peak-signal-to-noise-ratio (PSNR), 198
Haar, 481–485	profile, 594
linear systems and, 368	Pyramid vector quantization, 306
wavelets, 476-478, 480-486, 488-491	scalar versus vector quantization,
Schroeder, M. R., 550	280–282
Schultheiss, P. M., 395	uniformquantization, 236
Search buffer, 121	Signal-to-prediction-error ratio (SPER),
SECAM (Séquential Coleur avec	336
Mémoire), 578	Significance map encoding, 498, 500
Second extension option, 68	Simple profile, 594
Second moment, 625	Sinusoidal coders, 552–555

Simuracidal ayammla 226 220 221	Culitting tachnique 200 201
Sinusoidal example, 326, 330–331	Splitting technique, 288–291
Sinusoidal transform coder (STC), 554–555	Squared error measure, 198
Sloan, Alan, 561	Square matrix, 631
Slope overload regions, 343	STA. See Japanese Space Agency
Sluyter, R. J., 550	Standard deviation, 625
Smith, M. J. T., 449	Standards
Smith-Barnwell filters, 432, 434–435	CCIR (International Consultative
SNR. See Signal-to-noise ratio (SNR)	Committee on Radio), 601-2
Snr-scalable profile, 594, 596, 601	standard, 579–582
Society of Motion Picture and television	Common Interchange Format (CIF), 580
Engineers, 579	FBI fingerprint image compression, 512
Solomonoff, Ray, 35, 36	FS 1016, 550–551
Sony Dynamic Digital Sound (SDDS), 535	G.722, 461–462
Sound Pressure Level (SPL), 518	G.722.2, 558–559
Source coder, 196–197	G.726, 347–349
Span, 481	G.728, 551–552
Spatially scalable profile, 594, 596, 601	HDTV, 597–598
Spatial orientation trees, 505	ITU-R recommendation BT.601–2,
Spectral masking, 517	
Spectral processing, MPEG-2 AAC,	569–582
529–531	ITU-T H.261, 582–588
Speech compression	ITU-T H.263, 598–603
channel vocoder, 538, 539-542	ITU-T H.264, 603–608
code excited linear prediction, 539,	JBIG, 183–188
549–552	JBIG2, 189–190
differential encoding, 334-337, 345-349	JPEG, 410–416
FS 1016, 550–551	JPEG 2000, 494, 512
G.722 standard, 461-462	linear predictive coder (LPC-10), 539,
G.722.2 standard, 558-559	542–549
G.726 standard, 347-349	MPEG-1 video, 591–594
G.728 standard, 551-552	MPEG-2 video (H.262), 594–598
linear predictive coder, 539, 542-549	MPEG-3 video, 590
mixed excitation linear prediction,	MPEG-4 video, 603-610
555–557	MPEG-7 video, 591, 610
sinusoidal coders, 552–555	MPEG-SIF, 580
subband coding, 461-462	Quarter Common Interchange Format
voiced/unvoiced decision, 542-543	(QCIF), 580
wideband, 558-559	T.4 and T.6, 180-183
Speech production, 223	T.44, 190–193
SPER. See Signal-to-prediction-error ratio	V.42 bis, 136–138
Spherical lattices, 309–310	video signal representation, 579–580
Spherical vector quantization, 306–307	Static dictionary techniques, 118–121
SPIHT. See Set partitioning in hierarchical	Static model, 17
trees	Stationarity, weak and wide sense, 628
Split sample options, 68	Statistical average, 624
	-

Statistically independent, 617 STC. See Sinusoidal transform coder Steinhaus, H., 254 Stero coding, MPEG-2 AAC, 531 STFT. See Short-term Fourier transform Stochastic codebook, FS 1016 standard, 551 Stochastic process, 626–628 Stone, C. J., 303	Tabular method, Z-transform, 381–382 Tags algorithm for deciphering, 92 binary code, generating, 92–109 deciphering, 91–93 defined, 83 dictionary ordering, 87 generating, 84–91, 97–99 lexicographic ordering, 87
Stopband, 371	- -
Structured vector quantization, 303–311 contours of constant probability, 304 lattice, 307–311	partitioning, using cumulative distribution function, 83–86 rescaling, 97–102 Taps, in filters, 430
polar and spherical, 306–307	Taubman, D., 512
pyramid, 305–306 Subband coding algorithm, 436–438	TCM. See Trellis-coded modulation TCQ. See Trellis-coded quantization Television
analysis, 436, 438 analysis filter bank, 436–437 audio coding and, 462–463	black-and-white, 576–578 color, 578
basic description, 423-428	high definition, 533, 597–598
bit allocation, 437, 438, 459-461	Temporally scalable profile, 596, 601 Temporal masking, 517–518
decimation, 436, 438	Temporal Noise Shaping (TNS), 530
downsampling, 436, 438, 440–442	Terminating codes, 180
encoding, 438	Text compression
filter banks, design of, 438–444	Huffman coding and, 74–75
filter banks, <i>M</i> -band QMF, 451–454 filter banks, reconstruction using	Markov models and, 25–27
two-channel, 444–451	LZ77 approach, 121-125
filters, types of, 428–435	LZ78 approach, 125–127
image compression and, 463–470	LZW algorithm, 127-133
polyphase decomposition,	prediction with partial match (ppm),
454–459	143–152
quantization, 437	UNIX compress command, 133
speech coding and, 461–462	T.4 and T.6 standards, 180-183
synthesis, 437–438	T.44 standard, 190-193
upsampling, 439, 443-444	Threshold coding, 409–410
Subspace, 359	Time
Superposition, 368	domain aliasing, 417
Symbol region decoding, 190	domain view, sampling, 375–376
Synthesis filters, 443, 540	invariant linear systems, 368
Synthesis schemes. See Analysis/synthesis	short-term Fourier transform
schemes	and, 474
Systéme Essentiallement Contre les	Toeplitz matrix, 547
Américains, 578	Training set, 283–287

Transfer function	TSVQ. See Tree-structured vector
linear systems and, 368-369	quantization
speech production and, 223	Tunstall codes, 69–71
Transform-Domain Weighted Interleave	TwinVQ, 532-533
Vector Quantization (TwinVQ),	Typical prediction, 189
532–533	
Transforms and transform coding	Unary code, 65–66
audio compression and use of, 416–419	Uncertainty principle, 475
basis matrices, 400	Uncorrelated random variables, 628
bit allocation, 399, 407–410	Underdecimated filter bank, 454
coding gain, 398	Uniform distribution, 216, 625–626
coefficients, 399, 407–410	Uniformly distributed sources, uniform
discrete cosine, 402–404, 410–411	quantization and, 234-236
discrete Fourier, 376–378, 402–403	Uniform scalar quantization, 233–244
discrete sine, 404	image compression and, 236-237
discrete time wavelet transform, 480	midrise versus midtread, 233-234
discrete Walsh-Hadamard, 404, 406	mismatch effects, 242-244
discrete waysi-fradamatu, 404, 406 discrete wavelet transform, 480	nonuniform sources and, 238-242
efficacy of, 398	scalar versus vector quantization,
•	276–282
examples and description of, 392–400 forward, 396	uniformly distributed sources and,
	234–236
Gabor, 474	Uniquely decodable codes, 28–31
H.261 standard, 586	Unisys, 134
H.264 standard, 605	U.S. government standards. See Standards
image compression and use of, 410–416	Units of information, 14
inverse, 396–397	UNIX compress command, 133
JPEG, 410–416	Unvoiced decision, 542–543
Karhunen-Loéve, 401–402	Update procedure, adaptive Huffman
lapped orthogonal, 424	coding and, 59–61
orthonormal, 397–398	Upsampling, 439, 443–444
separable, 397	
short-term Fourier, 474–476	Vaidyanathan, P. P., 438
Transpose matrix, 632	Variable-length coding
Tree-structured vector quantization (TSVQ)	arithmetic, 54, 81–113
decision tree, 302	Golomb, 65–67
design of, 302–303	H.263 standard and inter, 602
pruned, 303	Huffman, 41–77
quadrant, 299–301	LZ77 approach, 121–125
splitting output points, 301	of quantizer outputs, 264–265
Trellis-coded modulation (TCM), 316	Rice, 67–69
Trellis-coded quantization (TCQ), 316–321	Tunstall, 69–71
Trellis diagrams, 318–321	unary, 65–66
Trigonometric Fourier series	Variables, random. See Random variables
representation, 363	Variance, 625

Vector quantization	CCIR (International Consultative
adaptive, 315–316	Committee on Radio), 601-2
bits per sample, 275	standard, 579–582
classified, 313	data rates, 571
decoding, 274–275	discrete cosine transform, 580
defined, 228, 273–276	ITU-T H.261 standard, 582-588
encoding, 274–275	ITU-T H.263 standard, 598-603
gain-shape, 306, 311	ITU-T H.264, 603-608
lattice, 307–311	motion compensation, 573-576
Linde-Buzo-Gray (LBG) algorithm,	MPEG-1 algorithm, 580
282–299	MPEG-1 video standard, 591-594
mean removed, 312	MPEG-2 video standard (H.262),
	594–598
mean squared error, 275	MPEG-3 video standard, 590
multistage, 313–315	MPEG-4 video standard, 603-610
polar, 306–307	MPEG-7 video standard, 591, 610
product code, 306	MPEG-SIF, 580
pyramid, 305–306	packet video, 610, 612-613
rate, 275	still images versus, 571–572
scalar quantization versus, 276–282	YUV data, 580
spherical, 305–307	Videoconferencing and videophones
structured, 303–311	ITU-T H.261 standard, 582–588
tree structured, 299–303	model-based coding, 588–590
trellis coded, 316–321	Video signal representation
Vectors	black-and-white television, 576–578
addition, 358	chrominance components, 578–579
basis, 356–357	color television, 578
linearly independent, 360	Common Interchange Format (CIF), 580
motion, 374–375	frames and fields, 577–578
scalar multiplication, 358–359	luminance component, 578
Vector spaces	MPEG-1 algorithm, 580 MPEG-SIF, 580
basis, 360–361	National Television Systems Committee
dot or inner product, 357, 361	(NTSC), 578–579
defined, 357–359	Quarter Common Interchange Format
orthogonal and orthonormal sets,	(QCIF), 580
361–362	standards, 579–582
subspace, 359	Virtual Reality Modeling Language
Vertical mode, 192	(VRML), 609
Vetterli, M., 612	Viterbi algorithm, 317
V.42 bis standard, 136–138	Vitter, J. S., 58
Video compression	Vocal tract filter, 545–548
asymmetric applications, 590-591	Vocoders (voice coder)
ATM networks, 610–612	channel, 539–542
background information, 573-572	development of, 3

Vocoders (voice coder) (Continued) format, 541 linear predictive coder, 539, 542–549 Voice compression/synthesis. See Speech compression Vorbis, 535 Wavelet-based compression admissibility condition, 479 affine wavelets, 480 coefficients, 480, 488-491 continuous wavelet transform, 479–480 discrete time wavelet transform, 480 discrete wavelet transform, 480 embedded zerotree coder, 497–505 families of wavelets, 491–493 functions, 476–480 Haar scaling function, 481–485 image compression, 494–496 implementation using filters, 486–493 JPEG 2000 standard, 494, 512 mother wavelets, 476, 478 multiresolution analysis, 480–486 scaling, 476-478, 480-486, 488-491 set partitioning in hierarchical trees, 505-512 Weak sense stationarity, 628 Weber fraction/ratio, 200 Weight (leaf), adaptive Huffman coding

and, 58

Welch, Terry, 127–128, 133 Wheeler, D. J., 153 Wide sense stationarity, 628 Wiener-Hopf equations, 334 Witten, I. H., 143, 144, 149 Yeh, Pen-Shu, 67 YUV data, 580

Zahkor, A., 493 Zero block option, 68, 69 Zero frequency problem, 26 Zeros of F(z), 381 Zerotree toot, 497 ZIP, 125 Ziv, Jacob, 121 zlib library, 133 Zonal sampling, 408–409 ZRL code, 414 Z-transform, 378 discrete convolution, 387–389 downsampling, 440–442 inverse, 381 long division, 386–387 partial fraction expansion, 382–386 properties, 387 region of convergence, 379, 380 tabular method, 381–382