

Contents

Preface	vii
1 Channels and Constraints	1
1.1 Magnetic Recording	1
1.2 Classical runlength constraints	3
1.3 Coding for Channels	5
1.4 Encoding and decoding for constrained systems	6
1.5 Examples of constraints	11
1.5.1 Anti-whistle constraints	11
1.5.2 Synchronization constraints	12
1.5.3 Multiple-spaced runlength constraints	13
1.5.4 Spectral-null constraints	15
1.5.5 Combined charge–runlength constraints	17
1.5.6 Constraints for PRML	18
1.6 Background on magnetic recording	20
1.6.1 Peak detection	20
1.6.2 PRML detection	22
1.7 Coding in optical recording	25
1.7.1 The compact disk	25
1.7.2 EFM code at rate 8 : 16	26
1.7.3 Dc control	28

1.8	Two-dimensional constraints	31
	Problems	33
2	Constrained Systems	37
2.1	Labeled graphs and constraints	37
2.2	Properties of labelings	40
2.2.1	Deterministic presentation	40
2.2.2	Finite anticipation	41
2.2.3	Finite memory	42
2.2.4	Definite graphs	42
2.2.5	Lossless graphs	43
2.2.6	Summary of terms	43
2.2.7	State labeling	44
2.3	Finite-type constraints	45
2.4	Some operations on graphs	48
2.4.1	Power of a graph	48
2.4.2	Higher edge graph	49
2.4.3	Fiber product of graphs	50
2.5	Irreducibility	50
2.5.1	Irreducible graphs	50
2.5.2	Irreducible constrained systems	52
2.6	Minimal presentations	53
2.6.1	Follower sets and reduced labeled graphs	54
2.6.2	The Moore algorithm	54
2.6.3	Homing words	56
2.6.4	Shannon cover of irreducible constrained systems	57
2.6.5	Shannon cover of finite-type constrained systems	58
2.7	Testing algorithms	60

<i>CONTENTS</i>	iii
2.7.1 Testing for losslessness	60
2.7.2 Testing for finite anticipation	61
2.7.3 Testing for finite memory	61
2.7.4 Testing for definiteness	62
Problems	62
3 Capacity	69
3.1 Combinatorial characterization of capacity	69
3.2 Algebraic characterization of capacity	72
3.3 Perron-Frobenius theory	76
3.3.1 Irreducible matrices	76
3.3.2 Primitivity and periodicity	77
3.3.3 Perron-Frobenius Theorem	81
3.3.4 Stronger properties in the primitive case	85
3.4 Markov chains	88
3.5 Probabilistic characterization of capacity	91
3.6 Approaching capacity by finite-type constraints	94
Problems	95
4 Finite-State Encoders	108
4.1 Definition of finite-state encoders	108
4.2 Block encoders	112
4.3 Sliding-block decodable encoders	116
4.4 Block decodable encoders	121
4.5 Non-catastrophic encoders	123
4.6 Relationships among decodability properties	125
4.7 Markov chains on encoders	125
4.8 Spectral analysis of encoders	126

Problems	129
5 The State-Splitting Algorithm	134
5.1 State splitting	135
5.2 Approximate eigenvectors and consistent splitting	138
5.2.1 Approximate eigenvectors	139
5.2.2 Computing approximate eigenvectors	141
5.2.3 \mathbf{x} -consistent splitting	143
5.3 Constructing the encoder	146
5.4 Strong decoders	151
5.5 Simplifications	155
5.5.1 State merging	155
5.5.2 Sliding-block decoder window	161
5.6 Universality of the state-splitting algorithm	164
5.6.1 Universality for sliding-block decodable encoders	164
5.6.2 Universality for encoders with finite anticipation	165
Problems	166
6 Other Code Construction Methods	173
6.1 IP encoders	173
6.2 Stethering encoders	174
6.3 Generalized tagged (S, n) -encoders	176
6.4 Encoders through variable-length graphs	177
6.4.1 Variable-length graphs and n -codability	177
6.4.2 Variable-length state splitting	178
6.4.3 Method of poles	179
6.5 Look-ahead encoders	180
6.6 Bounded-delay encoders	182

6.7	Transforming a generalized encoder to an ordinary encoder	183
	Problems	184
7	Complexity of Encoders	186
7.1	Complexity criteria	186
7.2	Number of states in the encoder	187
7.3	Values of p and q	191
7.4	Encoder anticipation	193
7.4.1	Deciding upon existence of encoders with a given anticipation	193
7.4.2	Upper bounds on the anticipation	195
7.4.3	Lower bounds on the anticipation	198
7.5	Sliding-block decodability	201
7.6	Gate complexity and time–space complexity	203
	Problems	205
8	Error Correction and Concatenation	207
8.1	Error-Correction Coding	208
8.2	Linear Codes	209
8.2.1	Definition	209
8.2.2	Generator Matrix	210
8.2.3	Parity-check matrix	212
8.3	Introduction to Finite Fields	213
8.4	The Singleton bound and Reed-Solomon codes	216
8.5	Concatenation of ECC and constrained codes	217
8.6	Block and sliding-block compressible codes	220
8.7	Application to burst correction	223
8.8	Constructing sliding-block compressible encoders	226
8.8.1	Super-vectors	226

8.8.2	Consistent splittings	229
8.8.3	Reduction of edge effect in error propagation	234
	Problems	235
9	Error-Correcting Constrained Coding	239
9.1	Error-mechanisms in recording channels	239
9.2	Gilbert-Varshamov-type lower bounds	240
9.2.1	Classical bound for the Hamming metric	240
9.2.2	Hamming-metric bound for constrained systems	241
9.2.3	Improved Hamming-metric bounds	243
9.3	Towards sphere-packing upper bounds	247
9.4	Distance properties of spectral-null codes	250
9.5	Synchronization/bitshift error correction	250
9.6	Soft-decision decoding through Euclidean metric	256
9.7	Forbidden list codes for targeted error events	260
	Problems	260
	Bibliography	263