

Contents

1. THE SCIENCE OF INFORMATION	1
2. INFORMATION MEASURES	5
2.1 Independence and Markov Chains	5
2.2 Shannon's Information Measures	10
2.3 Continuity of Shannon's Information Measures	16
2.4 Chain Rules	17
2.5 Informational Divergence	19
2.6 The Basic Inequalities	23
2.7 Some Useful Information Inequalities	25
2.8 Fano's Inequality	28
2.9 Entropy Rate of Stationary Source	32
Problems	36
Historical Notes	39
3. ZERO-ERROR DATA COMPRESSION	41
3.1 The Entropy Bound	42
3.2 Prefix Codes	45
3.2.1 Definition and Existence	45
3.2.2 Huffman Codes	48
3.3 Redundancy of Prefix Codes	54
Problems	58
Historical Notes	59
4. WEAK TYPICALITY	61
4.1 The Weak AEP	61

4.2	The Source Coding Theorem	64
4.3	Efficient Source Coding	66
4.4	The Shannon-McMillan-Breiman Theorem	68
	Problems	70
	Historical Notes	71
5.	STRONG TYPICALITY	73
5.1	Strong AEP	73
5.2	Strong Typicality Versus Weak Typicality	81
5.3	Joint Typicality	82
5.4	An Interpretation of the Basic Inequalities	92
	Problems	93
	Historical Notes	94
6.	THE I -MEASURE	95
6.1	Preliminaries	96
6.2	The I -Measure for Two Random Variables	97
6.3	Construction of the I -Measure μ^*	100
6.4	μ^* Can be Negative	103
6.5	Information Diagrams	105
6.6	Examples of Applications	112
	Appendix 6.A: A Variation of the Inclusion-Exclusion Formula	119
	Problems	121
	Historical Notes	124
7.	MARKOV STRUCTURES	125
7.1	Conditional Mutual Independence	126
7.2	Full Conditional Mutual Independence	135
7.3	Markov Random Field	140
7.4	Markov Chain	143
	Problems	146
	Historical Notes	147
8.	CHANNEL CAPACITY	149
8.1	Discrete Memoryless Channels	153
8.2	The Channel Coding Theorem	158
8.3	The Converse	160

<i>Contents</i>	xix
8.4 Achievability of the Channel Capacity	166
8.5 A Discussion	171
8.6 Feedback Capacity	174
8.7 Separation of Source and Channel Coding	180
Problems	183
Historical Notes	186
9. RATE-DISTORTION THEORY	187
9.1 Single-Letter Distortion Measures	188
9.2 The Rate-Distortion Function $R(D)$	191
9.3 The Rate-Distortion Theorem	196
9.4 The Converse	204
9.5 Achievability of $R_I(D)$	206
Problems	212
Historical Notes	214
10. THE BLAHUT-ARIMOTO ALGORITHMS	215
10.1 Alternating Optimization	216
10.2 The Algorithms	218
10.2.1 Channel Capacity	218
10.2.2 The Rate-Distortion Function	223
10.3 Convergence	226
10.3.1 A Sufficient Condition	227
10.3.2 Convergence to the Channel Capacity	230
Problems	231
Historical Notes	231
11. SINGLE-SOURCE NETWORK CODING	233
11.1 A Point-to-Point Network	234
11.2 What is Network Coding?	236
11.3 A Network Code	240
11.4 The Max-Flow Bound	242
11.5 Achievability of the Max-Flow Bound	245
11.5.1 Acyclic Networks	246
11.5.2 Cyclic Networks	251
Problems	259
Historical Notes	262

12. INFORMATION INEQUALITIES	263
12.1 The Region Γ_n^*	265
12.2 Information Expressions in Canonical Form	267
12.3 A Geometrical Framework	269
12.3.1 Unconstrained Inequalities	269
12.3.2 Constrained Inequalities	270
12.3.3 Constrained Identities	272
12.4 Equivalence of Constrained Inequalities	273
12.5 The Implication Problem of Conditional Independence	276
Problems	277
Historical Notes	278
13. SHANNON-TYPE INEQUALITIES	279
13.1 The Elemental Inequalities	279
13.2 A Linear Programming Approach	281
13.2.1 Unconstrained Inequalities	283
13.2.2 Constrained Inequalities and Identities	284
13.3 A Duality	285
13.4 Machine Proving – ITIP	287
13.5 Tackling the Implication Problem	291
13.6 Minimality of the Elemental Inequalities	293
Appendix 13.A: The Basic Inequalities and the Polymatroidal Axioms	297
Problems	298
Historical Notes	300
14. BEYOND SHANNON-TYPE INEQUALITIES	301
14.1 Characterizations of Γ_2^* , Γ_3^* , and $\bar{\Gamma}_n^*$	302
14.2 A Non-Shannon-Type Unconstrained Inequality	310
14.3 A Non-Shannon-Type Constrained Inequality	315
14.4 Applications	321
Problems	324
Historical Notes	325
15. MULTI-SOURCE NETWORK CODING	327
15.1 Two Characteristics	328
15.1.1 The Max-Flow Bounds	328
15.1.2 Superposition Coding	330

15.2	Examples of Application	335
15.2.1	Multilevel Diversity Coding	335
15.2.2	Satellite Communication Network	336
15.3	A Network Code for Acyclic Networks	337
15.4	An Inner Bound	340
15.5	An Outer Bound	342
15.6	The LP Bound and Its Tightness	346
15.7	Achievability of \mathcal{R}_{in}	350
	Appendix 15.A: Approximation of Random Variables with Infinite Alphabets	360
	Problems	361
	Historical Notes	364
16.	ENTROPY AND GROUPS	365
16.1	Group Preliminaries	366
16.2	Group-Characterizable Entropy Functions	372
16.3	A Group Characterization of $\bar{\Gamma}_n^*$	377
16.4	Information Inequalities and Group Inequalities	380
	Problems	384
	Historical Notes	387
	Bibliography	389
	Index	403