Contents

Part I Finding One's Way in a World of Algorithms

| 1 | Algor | rithms, An Historical Perspective | 3 | |
|---|----------------------|--|----|--|
| | Giorgio Ausiello | | | |
| | 1.1 | Introduction | 3 | |
| | 1.2 | Teaching Algorithms in Ancient Babylonia and Egypt | 4 | |
| | 1.3 | Euclid's Algorithm | 8 | |
| | 1.4 | Al-Khwarizmi and the Origin of the Word Algorithm | 10 | |
| | 1.5 | Leonardo Fibonacci and Commercial Computing | 13 | |
| | 1.6 | Recreational Algorithms: Between Magic and Games | 17 | |
| | 1.7 | Algorithms, Reasoning and Computers | 21 | |
| | 1.8 | Conclusion | 25 | |
| | 1.9 | Bibliographic Notes | 26 | |
| 2 | How | to Design an Algorithm | 27 | |
| | Rosse | ella Petreschi | | |
| | 2.1 | Introduction | 27 | |
| | 2.2 | Graphs | 28 | |
| | | 2.2.1 The Pervasiveness of Graphs | 28 | |
| | | 2.2.2 The Origin of Graph Theory | 32 | |
| | | 2.2.3 The Topological Ordering Problem | 35 | |
| | 2.3 | Algorithmic Techniques | 36 | |
| | | 2.3.1 The Backtrack Technique | 37 | |
| | | 2.3.2 The Greedy Technique | 42 | |
| | 2.4 | How to Measure the Goodness of an Algorithm | 49 | |
| | 2.5 | The Design | 52 | |
| | 2.6 | Bibliographic Notes | 57 | |
| 3 | The (| One Million Dollars Problem | 59 | |
| | Alessandro Panconesi | | | |
| | 3.1 | Paris, August 8, 1900 | 61 | |
| | 3.2 | "Calculemus!" | 65 | |

ix

x Contents

| | 3.3 | Finding Is Hard: Checking Is Easy | 67 |
|-----|--------|---|-----|
| | 3.4 | The Class NP | 70 |
| | 3.5 | Universality | 74 |
| | 3.6 | The Class P | 74 |
| | 3.7 | A Surprising Letter | 76 |
| | 3.8 | The Driving Force of Scientific Discovery | 80 |
| | 3.9 | Bibliographic Notes | 80 |
| Par | t II T | The Difficult Simplicity of Daily Life | |
| 4 | The (| Quest for the Shortest Route | 85 |
| | | 1 Demetrescu and Giuseppe F. Italiano | |
| | 4.1 | Introduction | 85 |
| | 4.2 | The Mathematisch Centrum | 88 |
| | 4.3 | Shortest Paths in Graphs | 89 |
| | 4.4 | Nature and Its Algorithms | 90 |
| | 4.5 | A Simple Idea | 91 |
| | 4.6 | Time Is a Tyrant | 94 |
| | 4.7 | How to Set Your Priorities | 96 |
| | | 4.7.1 The Heap Data Structure | 98 |
| | 4.8 | The Humble Programmer | 100 |
| | 4.9 | Still an Open Challenge | 101 |
| | | 4.9.1 The ALT Algorithm by Goldberg and Harrelson | 103 |
| | 4.10 | Bibliographic Notes | 105 |
| 5 | Web | Search | 107 |
| | Paolo | Ferragina and Rossano Venturini | |
| | 5.1 | The Prologue | 107 |
| | 5.2 | Internet and Web Graphs | 108 |
| | 5.3 | Browsers and a Difficult Problem | 114 |
| | 5.4 | Search Engines | 118 |
| | | 5.4.1 Crawling | 120 |
| | | 5.4.2 The Web Graph in More Detail | 122 |
| | | 5.4.3 Indexing and Searching | 124 |
| | | 5.4.4 Evaluating the Relevance of a Page | 127 |
| | | 5.4.5 Two Ranking Algorithms: PageRank and HITS | 129 |
| | | 5.4.6 On Other Search Engine Functionalities | 133 |
| | 5.5 | Towards Semantic Searches | 134 |
| | 5.6 | Bibliographic Notes | 137 |
| 6 | | rithms for Secure Communication | 139 |
| | | rto Marchetti-Spaccamela | |
| | 6.1 | Introduction | 139 |
| | 6.2 | A Brief History of Cryptography | 141 |
| | | 6.2.1 Monoalphabetic Substitution Codes | 141 |

Contents xi

| | | ****** * * * * * * * * * * * * * * * * | 143 |
|---|-------|---|-----|
| | | 6.2.3 The Enigma Machine | 144 |
| | 6.3 | Cryptographic Codes and Secret Keys | 145 |
| | | 6.3.1 How to Encode a Long Message Using | |
| | | an Integer Function | 146 |
| | | 6.3.2 Cryptanalysis and Robustness | |
| | | of a Cryptographic Protocol | 147 |
| | 6.4 | | 151 |
| | | J = J1 & 1 J | 151 |
| | | J J1 | 152 |
| | 6.5 | • | 153 |
| | | 6.5.1 Modular Arithmetic | 154 |
| | | 6.5.2 Diffie and Hellman's Algorithm | |
| | | for Establishing a Secret Key | 155 |
| | 6.6 | Public-Key Cryptography | 157 |
| | | 6.6.1 The RSA Algorithm | 158 |
| | 6.7 | Digital Signatures and Other Useful Applications | |
| | | , | 161 |
| | | 6.7.1 How Public-Key Cryptography Allows | |
| | | | 162 |
| | 6.8 | Bibliographic Notes | 165 |
| 7 | Algo | rithmics for the Life Sciences | 167 |
| • | | nele Giancarlo | |
| | 7.1 | | 167 |
| | 7.2 | | 170 |
| | 7.3 | Algorithmic Paradigms: Methodological Contributions | |
| | | · · · · · · · · · · · · · · · · · · · | 174 |
| | | 7.3.1 String Algorithmics: Identification | |
| | | | 175 |
| | | 7.3.2 Kolmogorov Algorithmic Complexity: | |
| | | | 178 |
| | | 7.3.3 Graph Algorithmics I: Microarrays and Gene | |
| | | | 179 |
| | | 7.3.4 Graph Algorithmics II: From Single | |
| | | | 182 |
| | 7.4 | Future Challenges: The Fundamental Laws of Biology | |
| | | <u> </u> | 184 |
| | 7.5 | | 185 |
| 8 | The S | Shortest Walk to Watch TV | 187 |
| | | zio Rossi, Antonio Sassano, and Stefano Smriglio | |
| | 8.1 | · · · · · · · · · · · · · · · · · · · | 187 |
| | 8.2 | | 189 |
| | | | 189 |
| | | | 190 |
| | | | |

xii Contents

| | | 8.2.3 Model for the Digital Coverage Assessment | 191 |
|-----|--------|--|-----|
| | | | 194 |
| | 8.3 | The Role of Transmission Delays | 194 |
| | 8.4 | An Algorithm for Optimizing Transmission Delays | 199 |
| | | 8.4.1 From Inconsistent TP Sets to Inconsistent | |
| | | Systems of Inequalities | 200 |
| | | 8.4.2 The Difference Constraints Graph | 202 |
| | | | 203 |
| | 8.5 | | 205 |
| | 8.6 | Bibliographic Notes | 205 |
| 9 | Algoi | rithms for Auctions and Games | 207 |
| | Vince | enzo Bonifaci and Stefano Leonardi | |
| | 9.1 | | 207 |
| | 9.2 | Games and Solution Concepts | 209 |
| | | 9.2.1 Prisoner's Dilemma | 209 |
| | | 9.2.2 Coordination Games | 211 |
| | | 9.2.3 Randomized Strategies | 212 |
| | | 9.2.4 Hawks and Doves | 214 |
| | 9.3 | Computational Aspects of Game Theory | 216 |
| | | 9.3.1 Zero-Sum Games and Linear Optimization | 216 |
| | | 9.3.2 Fixed-Points: Nash's Theorem and Sperner's Lemma | 218 |
| | | 9.3.3 Mixed Nash Equilibria in Non-zero-Sum Games | 221 |
| | 9.4 | Inefficiencies | 222 |
| | | 9.4.1 The Tragedy of the Commons | 222 |
| | | 9.4.2 Routing Games | 224 |
| | 9.5 | Mechanism Design and Online Auctions | 226 |
| | | 9.5.1 The Vickrey Auction | 226 |
| | | 9.5.2 Vickrey–Clarke–Groves Mechanisms | 228 |
| | | 9.5.3 Computational Aspects of Mechanism Design | 230 |
| | 9.6 | Price-Setting Mechanisms and Competitive Equilibria | 233 |
| | 9.7 | Bibliographic Notes | 234 |
| 10 | | 1 0 | 235 |
| | Ricca | ardo Silvestri | |
| | 10.1 | | 235 |
| | 10.2 | Bibliographic Notes | 250 |
| Ref | erence | es | 251 |
| | | | |