

Table of Contents

About the Authors.....	xiii
About the Technical Reviewer	XV
Acknowledgments	xvii
Part I: Foundations	1
Chapter 1: Getting Started in Cryptography and Cryptanalysis.....	3
Cryptography and Cryptanalysis	4
Book Structure	5
Internet Resources.....	9
Forums and Newsgroups	10
Standards.....	11
Conclusion	12
References	13
Chapter 2: Cryptography Fundamentals.....	15
Information Security and Cryptography	16
Cryptography Goals	19
Cryptographic Primitives	20
Background of Mathematical Functions	22
Functions: One-to-One, One-Way, Trapdoor One-Way.....	22
Permutations	28
Involutions	28
Concepts and Basic Terminology	29
Domains and Codomains Used for Encryption	29
Encryption and Decryption Transformations	30
The Participants in the Communication Process.....	31

TABLE OF CONTENTS

Digital Signatures.....	32
Signing Process.....	33
Verification Process.....	33
Public-Key Cryptography	33
Hash Functions	36
Case Studies	53
Caesar Cipher Implementation in C++20	53
Vigenère Cipher Implementation in C++20	55
Conclusions.....	58
References.....	58
Chapter 3: Mathematical Background and Its Applicability	65
Preliminaries	66
Conditional Probability	67
Random Variables	68
Birthday Problem	69
Information Theory.....	70
Entropy	70
Number Theory	71
Integers	71
Algorithms in \mathbb{Z}	72
The Integer Modulo n	74
Algorithms \mathbb{Z}_m	75
The Legendre and Jacobi Symbols.....	76
Finite Fields.....	78
Basic Notions.....	78
Polynomials and the Euclidean Algorithm	79
Case Study 1: Computing the Probability of an Event Taking Place	80
Case Study 2: Computing the Probability Distribution	82
Case Study 3: Computing the Mean of the Probability Distribution	84
Case Study 4: Computing the Variance	85
Case Study 5: Computing the Standard Deviation	87

TABLE OF CONTENTS

Case Study 6: Birthday Paradox	89
Case Study 7: (Extended) Euclidean Algorithm	91
Case Study 8: Computing the Multiplicative Inverse Under Modulo q	93
Case Study 9: Chinese Remainder Theorem	96
Case Study 10: The Legendre Symbol	98
Conclusion	101
References	102
Chapter 4: Large Integer Arithmetic	105
Big Integers	106
Big Integer Libraries	112
Conclusion	114
References	114
Chapter 5: Floating-Point Arithmetic	117
Why Floating-Point Arithmetic?	117
Displaying Floating Point Numbers	118
The Range of Floating Point Numbers	119
Floating Point Precision	119
Next Level for Floating-Point Arithmetic	122
Conclusions	123
References	123
Chapter 6: New Features in C++20	125
Feature Testing	125
carries_dependency	125
no_unique_address	127
New Headers in C++20	128
<concepts> Header	128
<compare> Header	131
<format> Header	132
Conclusion	133
References	133

TABLE OF CONTENTS

Chapter 7: Secure Coding Guidelines	135
Secure Coding Checklist	136
CERT Coding Standards	140
Identifiers	141
Noncompliant Code Examples and Compliant Solutions	141
Exceptions	141
Risk Assessment	142
Automated Detection	143
Related Guidelines	143
Rules	144
Rule 1 - Declarations and Initializations (DCL)	144
Rule 2 - Expressions (EXP)	145
Rule 3 - Integers (INT)	146
Rule 5 - Characters and Strings (STR)	146
Rule 6 - Memory Management (MEM)	147
Rule 7 - Input/Output (FIO)	148
Conclusion	148
References	149
Chapter 8: Cryptography Libraries in C/C++20	151
Overview of Cryptography Libraries	151
Hash Functions	152
Public Key Cryptography	153
Elliptic-Curve Cryptography (ECC)	155
OpenSSL	158
Configuration and Installing OpenSSL	158
Botan	177
CrypTool	177
Conclusion	185
References	186

TABLE OF CONTENTS

Part II: Pro Cryptography	187
Chapter 9: Elliptic-Curve Cryptography	189
Theoretical Fundamentals	190
Weierstrass Equation.....	192
Group Law	194
Practical Implementation	195
Conclusion	222
References.....	223
Chapter 10: Lattice-Based Cryptography	225
Mathematical Background.....	225
Example	227
Conclusion	237
References.....	237
Chapter 11: Searchable Encryption	239
Components.....	240
Entities.....	240
Types	241
Security Characteristics	243
An Example	244
Conclusion	255
References.....	256
Chapter 12: Homomorphic Encryption.....	259
Fully Homomorphic Encryption.....	261
Practical Example of Using FHE	263
Conclusion	283
References.....	283

TABLE OF CONTENTS

Chapter 13: Ring Learning with Errors Cryptography	287
Mathematical Background.....	288
Learning with Errors.....	288
Ring Learning With Errors.....	290
Practical Implementation.....	291
Conclusion	299
References.....	299
Chapter 14: Chaos-Based Cryptography.....	303
Security Analysis.....	306
Chaotic Maps for Plaintexts and Images Encryption.....	307
Rössler Attractor	308
Complex Numbers – Short Overview	309
Practical Implementation.....	310
Secure Random Number Generator Using a Chaos Rössler Attractor	312
Cipher Using Chaos and Fractals.....	319
Conclusion	334
References.....	334
Chapter 15: Big Data Cryptography	337
Verifiable Computation.....	341
Conclusion	348
References.....	349
Chapter 16: Cloud Computing Cryptography	353
A Practical Example	354
Conclusion	360
References.....	361
Part III: Pro Cryptanalysis.....	363
Chapter 17: Getting Started with Cryptanalysis	365
Third Part Structure	367
Cryptanalysis Terms.....	367

TABLE OF CONTENTS

A Little Bit of Cryptanalysis History.....	369
Penetration Tools and Frameworks.....	371
Conclusion	373
References	374
Chapter 18: Cryptanalysis Attacks and Techniques	377
Standards.....	377
FIPS 140-2, FIPS 140-3, and ISO 15408	378
Validation of Cryptographic Systems	378
Cryptanalysis Operations	380
Classification of Cryptanalytic Attacks	381
Attacks on Cipher Algorithms	381
Attacks on Cryptographic Keys	383
Attacks on Authentication Protocols.....	384
Conclusion	385
References	385
Chapter 19: Linear and Differential Cryptanalysis.....	387
Differential Cryptanalysis.....	388
Linear Cryptanalysis	396
Performing Linear Cryptanalysis	396
S-Boxes	397
Linear Approximation of S-Box.....	399
Concatenation of Linear Approximations.....	399
Assembling Two Variables	399
Conclusion	408
References	408
Chapter 20: Integral Cryptanalysis.....	411
Basic Notions	411
Practical Approach	413
Conclusion	422
References	422

TABLE OF CONTENTS

Chapter 21: Brute Force and Buffer Overflow Attacks	423
Brute Force Attack	424
Buffer Overflow Attack	432
Conclusion	434
References	434
Chapter 22: Text Characterization	435
The Chi-Squared Statistic	435
Cryptanalysis Using Monogram, Bigram, and Trigram Frequency Counts	439
Counting Monograms	439
Counting Bigrams	440
Counting Trigrams	443
Conclusion	446
References	446
Chapter 23: Implementation and Practical Approach of Cryptanalysis Methods	447
Ciphertext-Only Attack	450
Known-Plaintext Attack.....	450
Chosen-Plaintext Attack.....	451
Chosen-Ciphertext Attack	459
Conclusion	460
References	461
Correction to: Pro Cryptography and Cryptanalysis with C++20	C1
Index.....	463