Classical Cryptography

Introduction: a puzzling matter?

Karst Koymans

Informatics Institute

University of Amsterdam

(version 22.4, 2023/02/06 10:41:38 UTC)

Tuesday, February 7, 2023

1. Organisation
   - Global Structure
   - Lectures
   - Exercises
   - Homework and support
   - Examination
2. Book(s)
3. Advice
4. Basic concepts in cryptography
5. Some examples
6. Puzzling

Outline

1. Organisation
   - Global Structure
   - Lectures
   - Exercises
   - Homework and support
   - Examination
2. Book(s)
3. Advice
4. Basic concepts in cryptography
5. Some examples
6. Puzzling

Outline

1. Organisation
   - Global Structure
   - Lectures
   - Exercises
   - Homework and support
   - Examination
2. Book(s)
3. Advice
4. Basic concepts in cryptography
5. Some examples
6. Puzzling

Organisation

- Information is available on
  - The OS3 Website/Wiki
    - For the first three weeks
    - `https://www.os3.nl/2022-2023/courses/crypto/start`
  - Canvas
    - For the remainder of the course
    - `https://canvas.uva.nl/courses/36021`
- Lectures
- Practical exercises
- Programming exercises

Outline

1. Organisation
   - Global Structure
   - Lectures
   - Exercises
   - Homework and support
   - Examination
2. Book(s)
3. Advice
4. Basic concepts in cryptography
5. Some examples
6. Puzzling

Lectures 1

- The course will be divided in two parts
- Part I
  - Lecturer Karst Koymans
  - February 7 — February 24
- Part II
  - Lecturer Taco Walstra
  - February 28 — March 20
- Q&A session for both parts on March 24

Lectures 2

- Seven weeks
- February 7 — March 24
  - Tuesday, 11:00-13:00, SP D1.111
    - Tuesday, March 14 and 21, will be moved to

      Monday, March 13 and 20, 11:00-13:00, **SP C0.05**
  - Friday, 11:00-13:00, SP D1.111
    - Friday, March 17 and 24, 11:00-13:00, **SP L1.01**

Guest Lecture

- **Enigma**
  - Jaap van Ginkel
  - Tuesday, February 28

Outline

1. Organisation
   - Global Structure
   - Lectures
   - Exercises
   - Homework and support
   - Examination
2. Book(s)
3. Advice
4. Basic concepts in cryptography
5. Some examples
6. Puzzling

Practical and “programming” exercises

- February 7 — March 24
  - Tuesday, 13:00-15:00, SP D1.111
    - Tuesday, March 14 and 21, will be moved to

      Monday, March 13 and 20, 13:00-15:00, in SP D1.111
  - Friday, 13:00-15:00, SP D1.111
- Teaching assistants
  - **Kyrian Maat**, **Rick Klarenberg**, **Stijn Maatje**, **Taco Walstra**
- Programming language used is **Ruby**
  - You may replace it by something of your **own choice**
  - This is **not** a programming course
  - The programs are only **tools** supporting your cryptanalysis

Outline

1. Organisation
   - Global Structure
   - Lectures
   - Exercises
   - Homework and support
   - Examination
2. Book(s)
3. Advice
4. Basic concepts in cryptography
5. Some examples
6. Puzzling

Homework and support

- Homework
  - Via assignments/quizzes in Canvas
  - Graded by the teaching assistants
- Support
  - Discussions in Canvas
  - We are not available 24/7

Outline

1. Organisation
   - Global Structure
   - Lectures
   - Exercises
   - Homework and support
   - Examination
2. Book(s)
3. Advice
4. Basic concepts in cryptography
5. Some examples
6. Puzzling

Judgment

- The final grading is determined by
  - **Homework assignments** (20 %)
  - **On-site written exam** (80 %)
- Primary learning material
  - (Referenced parts of) **Cryptology, Classical and Modern**
  - **Slides** from the lectures
- Secondary learning material
  - Referenced parts of Hans van der Meer's **syllabus**
  - Material that can reasonably be expected to be known from practical and programming **exercises**

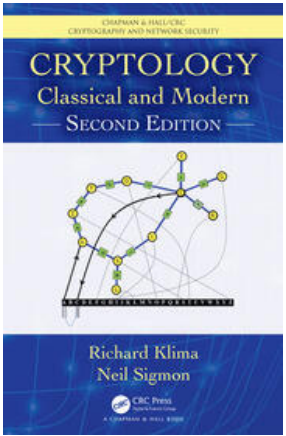
Exam dates

- Classical Cryptography **exam** will be on
  - Wednesday, March 29, 13:00-16:00, REC C1.04
- Classical Cryptography **resit** will be on
  - Friday, June 2, 11:00-14:00, SP D1.116

Outline

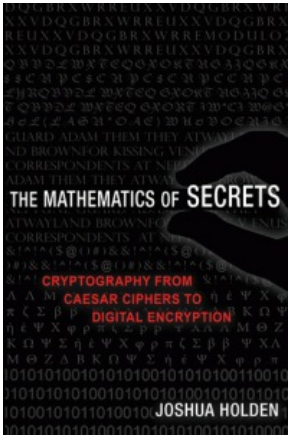
1. Organisation
   - Global Structure
   - Lectures
   - Exercises
   - Homework and support
   - Examination
2. Book(s)
3. Advice
4. Basic concepts in cryptography
5. Some examples
6. Puzzling

Book



- **Cryptology**: Classical and Modern, 2nd edition
- Richard Klima and Neil Sigmon
- ISBN-13: 9781138047624
- `https://www.routledge.com/Cryptology-Classical-and-Modern-Second-Edition/Klima-Sigmon/p/book/9781138047624`

Auxiliary book



- **The Mathematics of Secrets**: Cryptography from Caesar Ciphers to Digital Encryption
- Joshua Holden
- ISBN-13: 9780691141756 (hardcover)
- ISBN-13: 9780691183312 (paperback)
- `http://mathofsecrets.com/` (`https://mathofsecrets.com/`?)

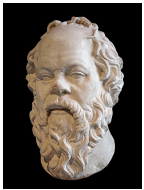
Outline

1. Organisation
   - Global Structure
   - Lectures
   - Exercises
   - Homework and support
   - Examination
2. Book(s)
3. Advice
4. Basic concepts in cryptography
5. Some examples
6. Puzzling

Some advice

- Keep up with theory and practice **right from the start**
- **Read** the book (like in a “flipped classroom”)

The only true wisdom is in knowing you know nothing



—Socrates

Outline

1. Organisation
   - Global Structure
   - Lectures
   - Exercises
   - Homework and support
   - Examination
2. Book(s)
3. Advice
4. Basic concepts in cryptography
5. Some examples
6. Puzzling

Basic terminology

cryptology cryptography plus cryptanalysis

cryptography secret writing

- from ancient Greek κρυπτός: concealed, hidden, secret
- steganography is hidden writing
  - from ancient Greek στεγανός: covered, concealed

cryptanalysis (unauthorised) reading of a cryptogram

- or even discovering secret key(s), possibly only partially

Basic symmetric/secret scheme

$$C = \mathcal{E}(M, K)$$

$$M = \mathcal{D}(C, K)$$

$$M = \mathcal{D}(\mathcal{E}(M, K), K)$$

- $\mathcal{E}$ is encryption; $\mathcal{D}$ is decryption
- M is the message; C is the cryptogram; K is the secret key
- $\mathcal{E}(-, K)$ is injective for each K
- K has to be kept a secret, exclusively between any two communicating parties

Basic asymmetric/public scheme

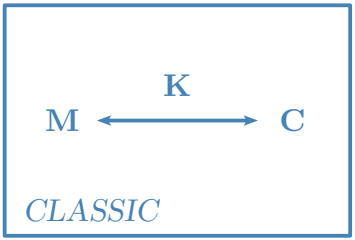
$$C = \mathcal{E}(M, K_p)$$

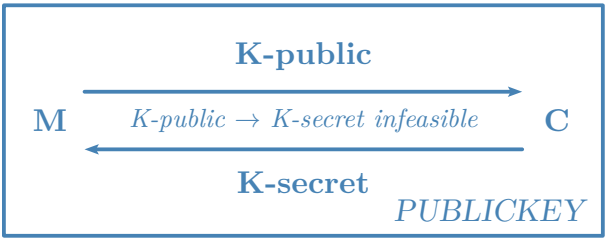
$$M = \mathcal{D}(C, K_s)$$

$$M = \mathcal{D}(\mathcal{E}(M, K_p), K_s)$$

- $\mathcal{E}$ is encryption; $\mathcal{D}$ is decryption
- M is the message; C is the cryptogram; K's are two keys, one public, one secret
- $\mathcal{E}(-, K_p)$ is injective for each K_p
- K_s has to be kept a secret for each participant separately
- K_p must be known to all parties (in a **verifiable** way, for instance through a PKI)
  - PKI stands for Public Key Infrastructure

Symmetric versus asymmetric encryption





Kerckhoffs' rules (some of them are dated)

- The system must be practically, if not mathematically, indecipherable.
- **It should not require secrecy, and it should not be a problem if it falls into enemy hands.**
- It must be possible to communicate and remember the key without using written notes, and correspondents must be able to change or modify it at will.
- It must be applicable to telegraph communications.
- It must be portable, and should not require several persons to handle or operate.
- Lastly, given the circumstances in which it is to be used, the system must be easy to use and should not be stressful to use or require its users to know and comply with a long list of rules.

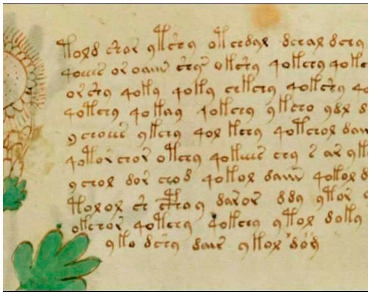
Types of attack

- Increasing in usefulness of available information
  - Ciphertext-only (“Known-ciphertext”)
  - Known-plaintext
  - Chosen-plaintext
  - Chosen-ciphertext
- Increasing in possible interaction
  - Passive (observation only)
  - Active (adaptation of messages)

Outline

1. Organisation
   - Global Structure
   - Lectures
   - Exercises
   - Homework and support
   - Examination
2. Book(s)
3. Advice
4. Basic concepts in cryptography
5. Some examples
6. Puzzling

The Voynich manuscript



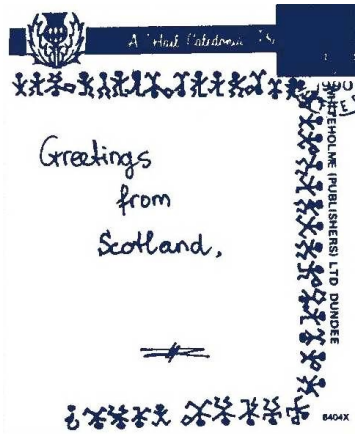
Real or fake? Decoded or not? Latest claims (not convincing[1])

Nicholas Gibbs (September 2017), Greg Kondrak (January 2018, using AI),

Ahmet Ardiç (2018), Gerard Cheshire (2019)

[1]This shows recent activity, but the results are much disputed. Some people have too much fantasy.

A personal message



Source: Hans van der Meer

—

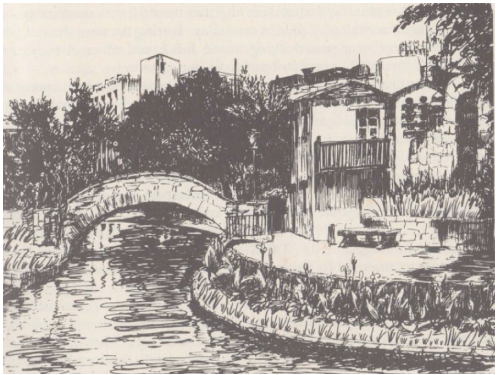
personal message

A personal message

https://en.wikipedia.org/wiki/The_Adventure_of_the_Dancing_Men

https://www.arthur-conan-doyle.com/index.php?title=Dancing_Men_Alphabet

Just a picture?

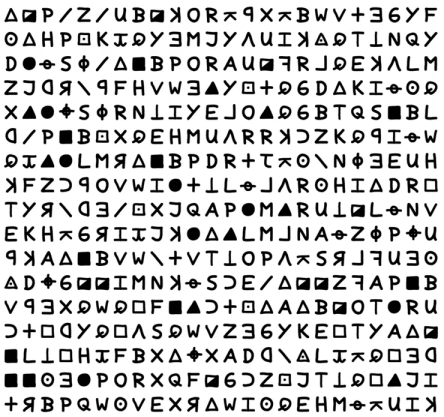


Source: https://scienceblogs.de/klausis-krypto-kolumne/2015/05/21/versteckte-nachrichten-in-modezeichnungen-grashalmen-und-apfelbaeumen/

The Zodiac Killer Z408 cryptogram (July 31, 1969)

Source: https://zodiackiller.fandom.com/wiki/408-cipher

The Z408 cryptogram solution (August 8, 1969)



6SJA a	V b	
3 c	7✦ d	
Z9W+ONE e		
JQ f	R g	M⊷ h
APUK i	/ k	
◪B■ l	◎ m	
OADϕ n	XITD o	
⊀ p	⊥R\ r	
F⊡KA s	HI●L t	
Y u	ↄ v	A w
⊤ x	□ y	

Source: https://www.youtube.com/watch?v=57o8g3d61Sw

The Z408 cryptogram text (with spelling errors retained)

I like killing people because it is so much fun it is more fun than killing wild game in the forrest because man is the most dangeroue anamal of all to kill something gives me the most thrilling experence it is even better than getting your rocks off with a girl the best part of it is thae when I die I will be reborn in paradice and all the I have killed will become my slaves I will not give you my name because you will try to sloi down or atop my collectiog of slaves for my afterlife **ebeorietemethhpiti**

The Z340 cryptogram

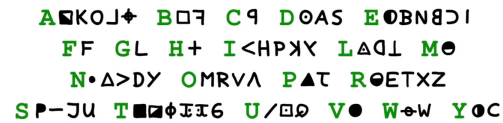
The Z340 cryptogram from November 8, 1969

David Oranchak cracked Z340 with two colleagues on December 5, 2020

https://zodiacrevisited.com/reporting-on-the-zodiac-killer-ciphers/

https://www.youtube.com/watch?v=57o8g3d6lSw

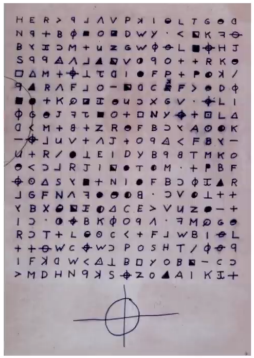
The Z340 cryptogram solution (substitution part)



This is the homophonic substitution part

Source: https://www.youtube.com/watch?v=-1oQLPRE21o

The Z340 cryptogram solution (transposition part)



0	9	18	27	36	45	54	63	72	81	90	99	108	117	126	135	144
136	145	1	10	19	28	37	46	55	64	73	82	91	100	109	118	127
119	128	137	146	2	11	20	29	38	47	56	65	74	83	92	101	110
102	111	120	129	138	147	3	12	21	30	39	48	57	66	75	84	93
85	94	103	112	121	130	139	148	4	13	22	31	40	49	58	67	76
68	77	86	95	104	113	122	131	140	149	5	14	23	32	41	50	59
51	60	69	78	87	96	105	114	123	132	141	150	6	15	24	33	42
34	43	52	61	70	79	88	97	106	115	124	133	142	151	7	16	25
17	26	35	44	53	62	71	80	89	98	107	116	125	134	143	152	8

153	162	171	180	189	198	207	216	225	234	243	300	301	302	303	304	305
284	292	154	163	172	181	190	199	208	217	226	235	244	252	260	268	276
269	277	285	293	155	164	173	182	191	200	209	218	227	236	245	253	261
254	262	270	278	286	294	156	165	174	183	192	201	210	219	228	237	246
238	247	255	263	271	279	287	295	157	166	175	184	193	202	211	220	229
221	230	239	256	264	272	280	288	296	158	167	176	185	194	203	212	248
204	213	222	231	240	249	257	265	273	281	289	297	159	168	177	186	195
187	196	205	214	223	232	241	250	258	266	274	282	290	298	160	169	178
170	179	188	197	206	215	224	233	242	251	259	267	275	283	291	299	161

309	308	307	306	310	311	312	313	315	314	317	316	318	319	320	321	324
323	322	326	325	334	333	332	331	330	329	328	327	335	336	337	338	339

This is the transposition part

Source: `https://www.youtube.com/watch?v=-1oQLPRE21o`

The Z340 cryptogram text (after spelling correction)

I hope you are having lots of fun in trying to catch me. That wasn't me on the TV show, which brings up a point about me. I am not afraid of the gas chamber because it will send me to paradise all the sooner, because I now have enough slaves to work for me where everyone else has nothing when they reach paradise, so they are afraid of death. I am not afraid because I know that my new life is life will be an easy one in paradise death.

Outline

1. Organisation
   - Global Structure
   - Lectures
   - Exercises
   - Homework and support
   - Examination
2. Book(s)
3. Advice
4. Basic concepts in cryptography
5. Some examples
6. Puzzling

Why puzzling?

- Improves accuracy
- Sharpens your brain
- Forces thinking out of the box
- Uses your creativity
- Never a dull moment
- ...

This (and more) is important for cryptanalysts

Why puzzling?

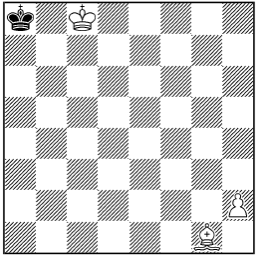
- **I**mproves accuracy
- **S**harpens your brain
- **F**orces thinking out of the box
- **U**ses your creativity
- **N**ever a dull moment
- ...

This (and more) is important for cryptanalysts

Notice the **acrostic** (ἄκρος στίχος — topmost verse)

Puzzle 1: Chess retrograde analysis

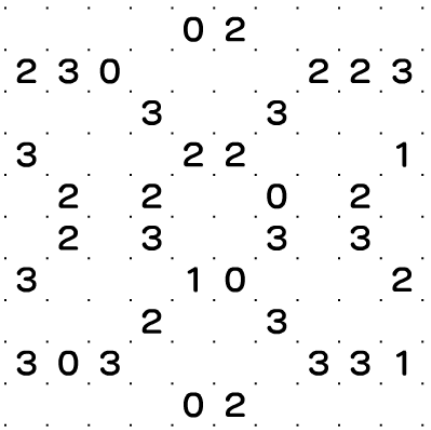
Smullyan



White to move. What was black's last move?

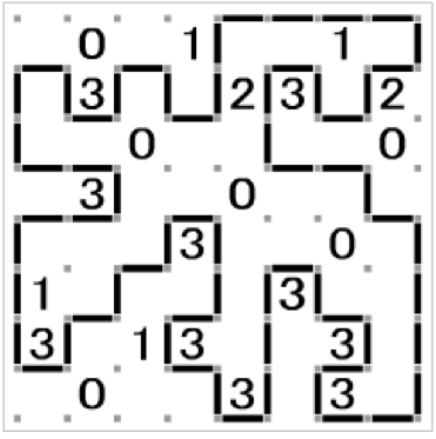
https://www.mathpuzzle.com/retrograde.html

Puzzle 2: Slitherlink



What are the rules of this game?

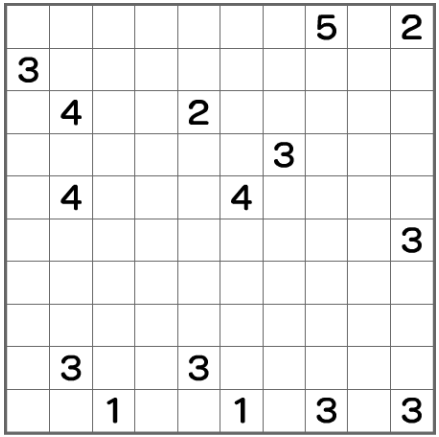
Puzzle 2: Slitherlink continued



Try it yourself

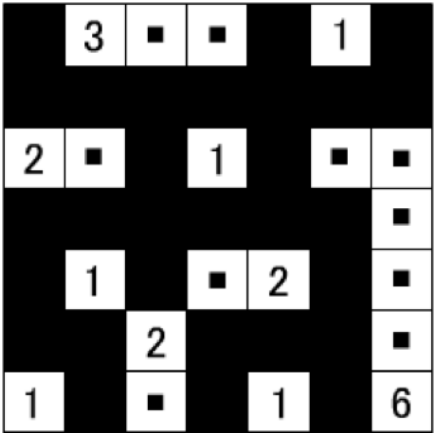
https://www.brainbashers.com/slitherlink.asp

Puzzle 3: Nurikabe



What are the rules of this game?

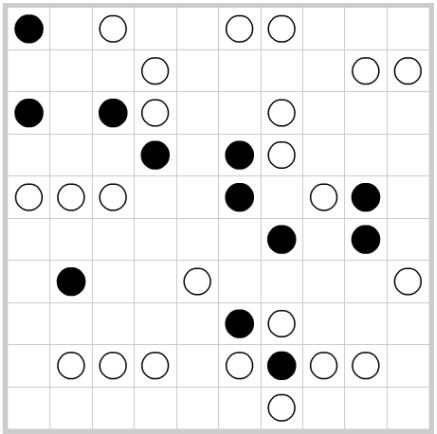
Puzzle 3: Nurikabe continued



Try it yourself

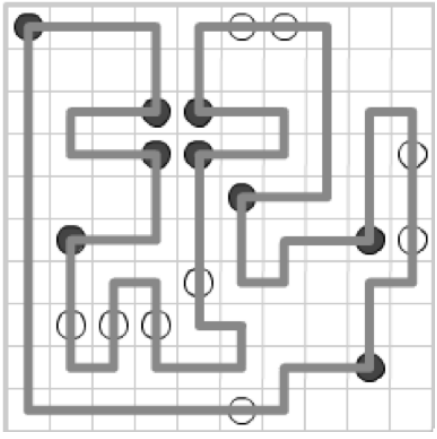
https://www.puzzle-nurikabe.com/

Puzzle 4: Masyu



What are the rules of this game?

Puzzle 4: Masyu continued



Try it yourself

https://www.interactive.onlinemathlearning.com/fun_pearl.php