Introduction to Modern Cryptography

Master of Logic 2014

1st Quarter Sep / Oct

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- me
- pure mathematics at ETH Zurich
- PhD from Aarhus, Denmark
- research: quantum cryptography
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- plays ultimate frisbee

Malvin Gattinger

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- switched sides of the table

Practicalities

- final grade consists of 50-50:
  - weekly homework, to be graded
  - final exam in week of 20/10/14 - 24/10/14
- details on course homepage: http://homepages.cwi.nl/~schaffne/courses/crypto/2014/

Expectations

We expect from you

- be on time
- code of honor (do not cheat)
- ask questions!

Expectations

We expect from you

- be on time
- code of honor (do not cheat)
- ask questions!

You can expect from us

- be on time
- make clear what goals are
- listen to you and respond to email requests
- keep website up to date

Questions ?

Outline of the Course

- Historical cryptography & principles of modern cryptography
- perfectly-secret encryption

Outline of the Course II

	secret key	public key
confidentiality	private-key encryption	public-key encryption
authentication	message authentication codes (MAC)	digital signatures

Outline of the Course II

- reduction proofs
- pseudorandomness
- block ciphers: DES, AES

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Outline of the Course II

- reduction proofs
- pseudorandomness
- block ciphers: DES, AES

- algorithmic number theory
- key distribution, Diffie-Hellmann
- RSA

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Fun Stuff

- bitcoin (guest lecture by Marc Stevens, CWI)
- zero-knowledge proofs
- multi-party computation (secret sharing, bit commitment, oblivious transfer)
- electronic voting and auctions
- quantum cryptography
- position-based cryptography
- ...

Questions ?

Introduction

- for centuries, cryptography has been an "art of writing codes and solving codes"
- goal: secret communication
- mainly used by military and intelligence
- "modern cryptography"

Claude Elwood Shannon

1916 - 2001

- Father of Information Theory
- Graduate of MIT
- Bell Labs

- juggling, unicycling, chess
- ultimate machine

Silvio Micali

- MIT
- Foundations of Modern Cryptography

Shafi Goldwasser

Oded Goldreich

- Weizmann Institute

Modern Cryptography

- "scientific study of techniques for securing digital information, transactions and distributed computations"
- crypto is everywhere!

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Auguste Kerckhoffs

1835 - 1903

- Dutch linguist and cryptographer
- Kerckhoffs' principle:

"A cryptosystem should be secure even if everything about the system, except the key, is public knowledge"

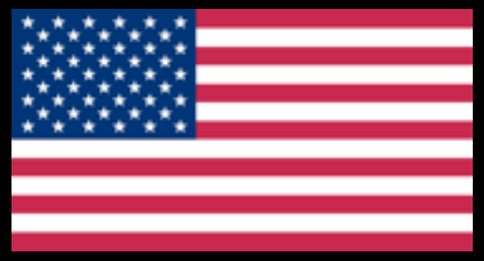
- leader of Volapük movement

AES and SHA competitions

- AES: advanced encryption standard
- SHA: secure hash algorithm
  - both determined by a public procedure led by the National Institute for Standards and Technology (NIST)
  - SHA-3 zoo

Edward Joseph Snowden

1983 -

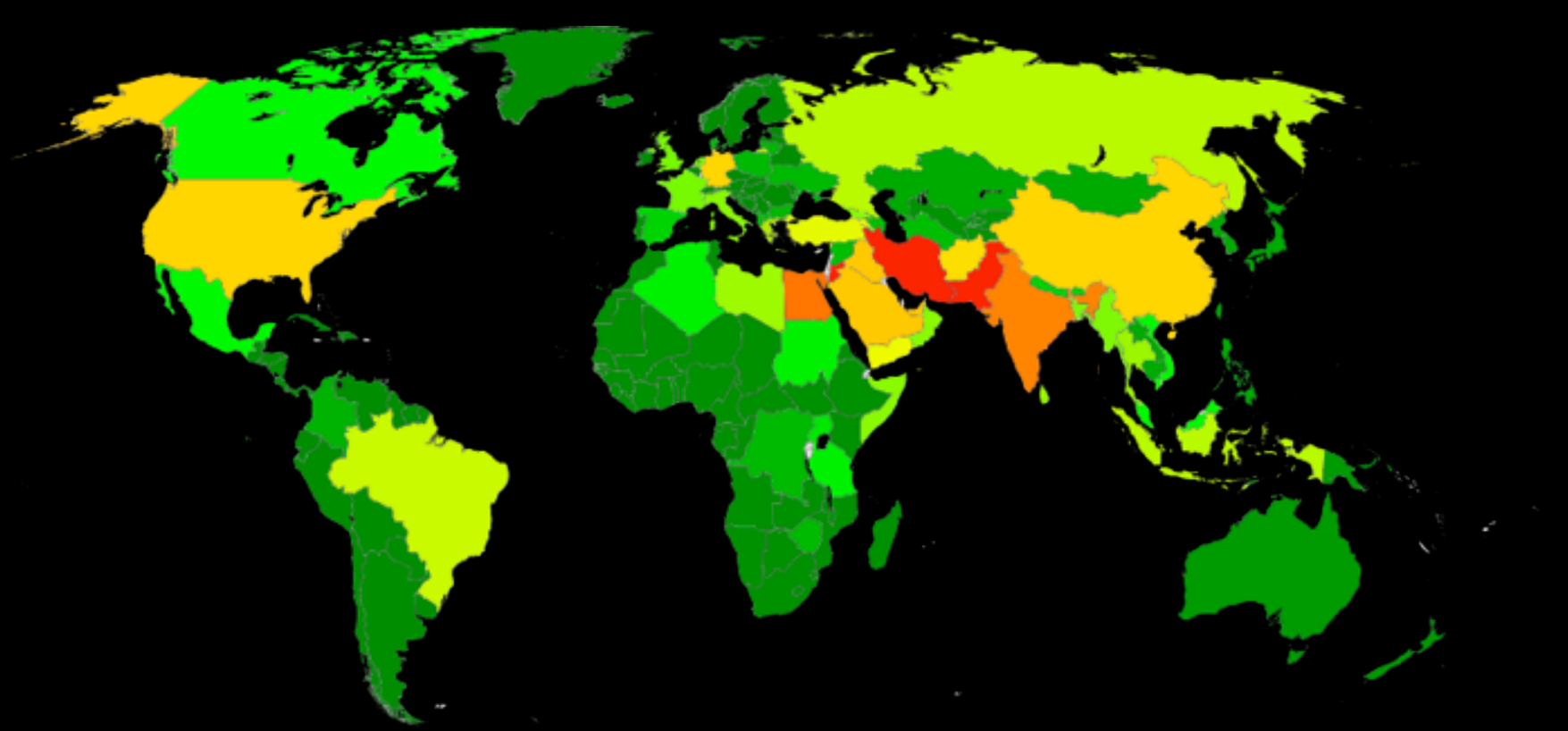


- former CIA employee and NSA contractor
- whistleblower
- on (temporary) asylum in Russia

- Traitor or Hero?

Politics of Cyberwar

- Snowden leaked many thousand top secret documents to various media, documenting a
- mass surveillance programs by secret services from all over the world



Politics of Cyberwar

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- Methods: (in decreasing order of difficulty)
  - Break cryptography
  - Influence industrial standards
  - Pressure manufacturers to make insecure devices
  - Infiltrate hardware and software (communication infrastructure, computers, smartphones etc.)

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- Why mass surveillance?
  - Other than to combat terrorism, these surveillance programs have been employed to assess the foreign policy and economic stability of other countries, and to gather "commercial secrets“.

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TECHNOLOGY

Facebook to Pay $19 Billion for WhatsApp

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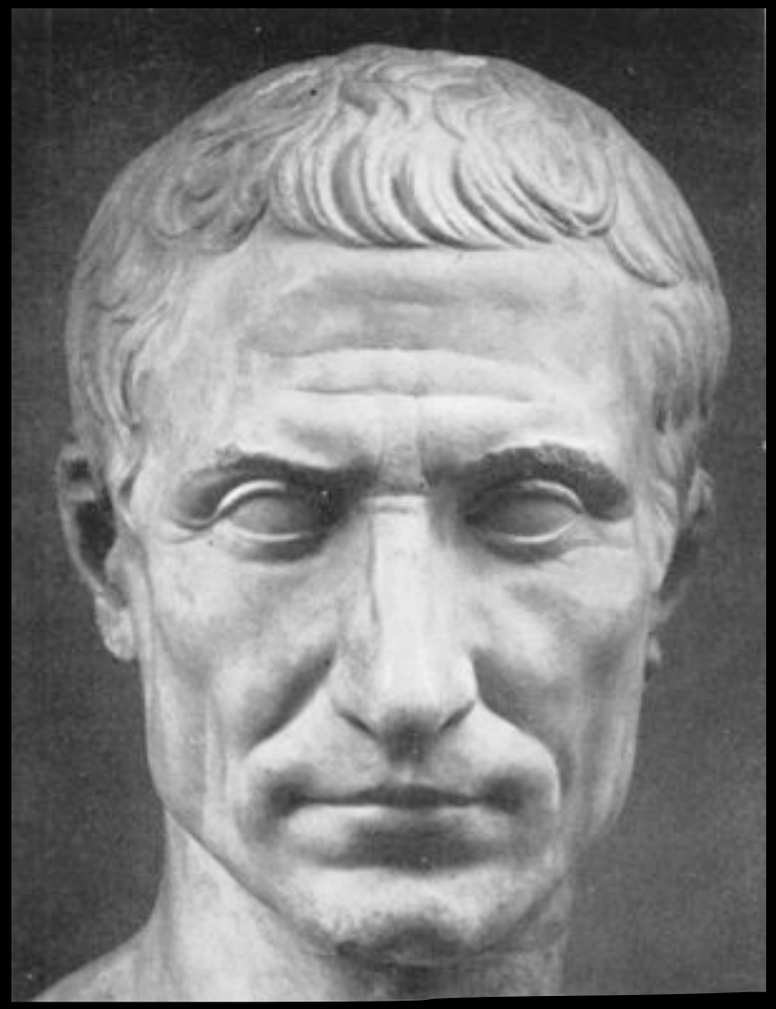
1984

- *"They (the NSA) can use the system to go back in time and scrutinize every decision you've ever made, every friend you've ever discussed something with, and attack you on that basis to sort of derive suspicion from an innocent life and paint anyone in the context of a wrongdoer."* – Edward Snowden

Gaius Julius Caesar

100 BC – 44 BC



- not best known for his cryptographic skills
- Roman general

- suffered from epilepsy, or migraine headache

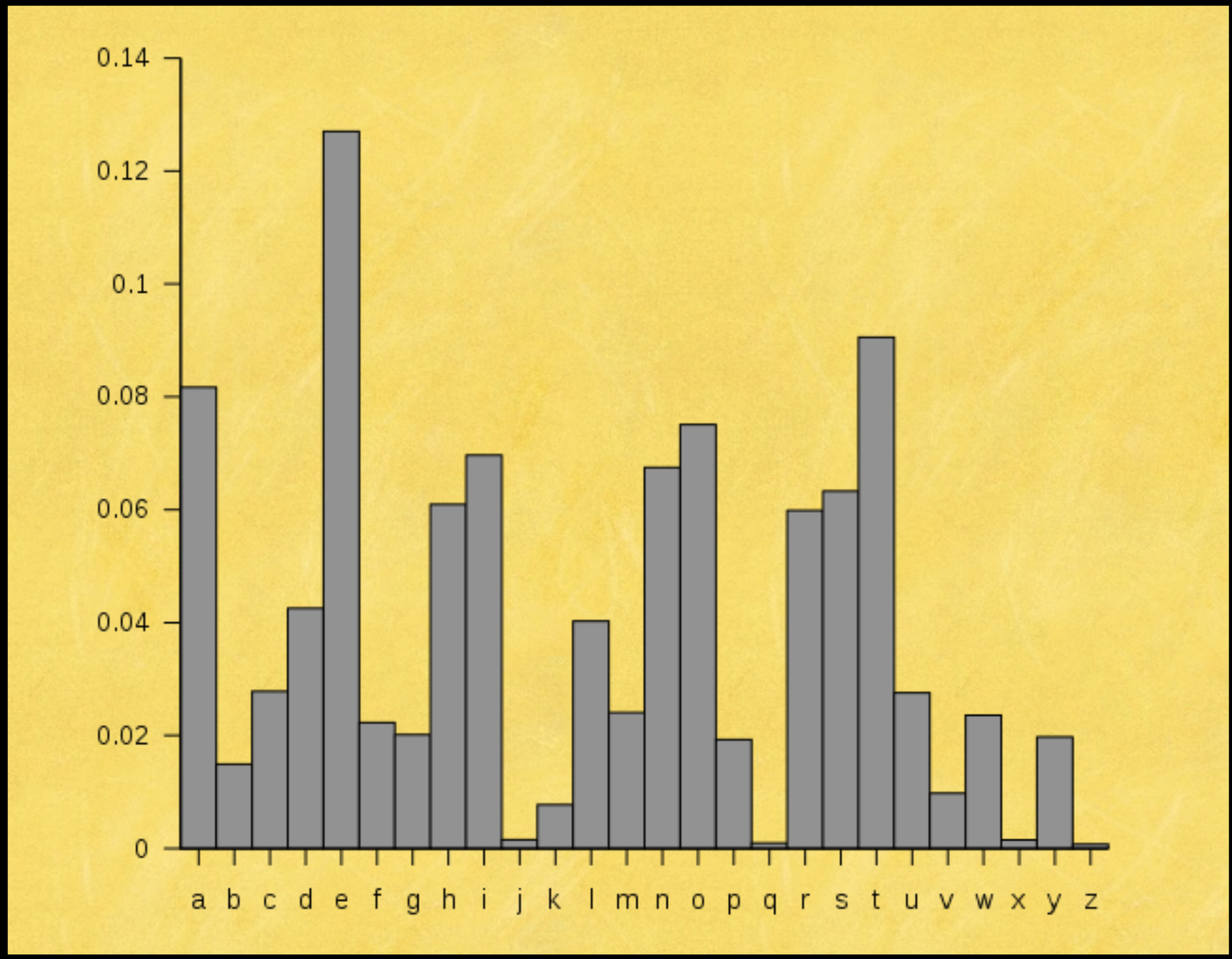
Modular Arithmetic

- Given integers a and $N>1$ we write

$$[a \bmod N] \in \{0,1,2, ..., N\text{-}1\}$$

as the remainder of a upon division by N

Frequency analysis



Wikipedia source

Blaise de Vigenère

1523–1596

- diplomat and cryptographer
- Vigenère's cipher

- interested in alchemy

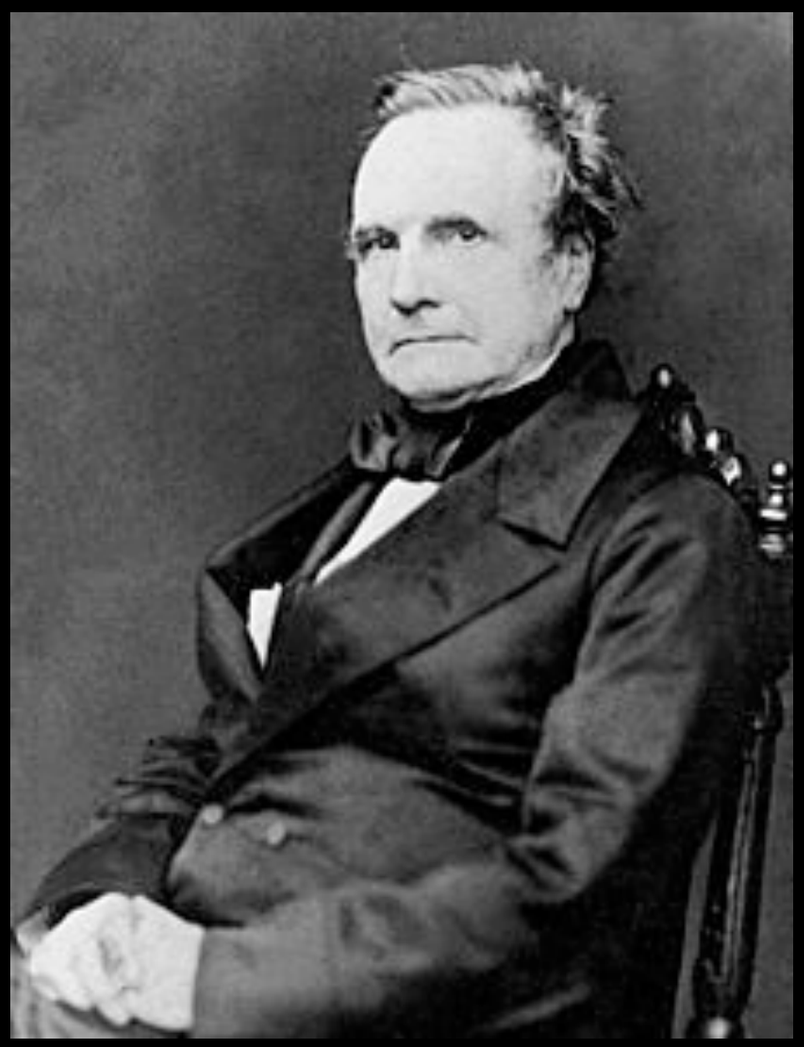
Friedrich Kasiski

1805 – 1881

- Preussian infantry officer
- cryptographer and archeologist

Charles Babbage

1791 – 1871



- mathematician, philosopher, inventor and mechanical engineer
- father of the computer
- designed the "difference machine" and "Analytical Engine"

- counted broken window panes
- hated organ grinders

Jonathan Katz

Yehuda Lindell

- 3 Basic Principles of Modern Cryptography

1. Formulation of Exact Definitions

- "a cryptographic scheme is secure if no adversary of a specified power can achieve a specified break"
  example: encryption
- mathematical definitions vs the real world
  example: power-usage attacks
- cryptographers face a similar problem as Turing: "Am I modeling the right thing?"

2. Reliance on Precise Assumptions

- unconditional security is often impractical
  (unfortunate state of computational complexity)
- validation of assumptions (independent of cryptography)
  example: factoring
- allows to compare crypto schemes

3. Rigorous Proofs of Security

- Intuition is not good enough. History knows countless examples of broken schemes
- bugs vs security holes
  software users vs adversaries
- reduction proofs: Given that Assumption X is true, Construction Y is secure.
  Any adversary breaking Construction Y can be used as subroutine to violate Assumption X.