Applied Cryptography

Lecture 0

Manoj Prabhakaran

University of Illinois Urbana-Champaign

What is Cryptography?

What is Cryptography?

- It's all about controlling access to information

What is Cryptography?

- It's all about controlling access to information
  - Access to learning and/or influencing information

What is Cryptography?

- It's all about controlling access to information
  - Access to learning and/or influencing information
  - Do we know what we are talking about?

What is information?

What is information?

- Or rather the lack of it?

What is information?

- Or rather the lack of it?
  - Uncertainty

What is information?

- Or rather the lack of it?
  - Uncertainty
  - The word is Entropy

What is information?

- Or rather the lack of it?
  - Uncertainty
  - The word is Entropy
    - Borrowed from thermodynamics

What is information?

Rudolf Clausius

- Or rather the lack of it?
  - Uncertainty
  - The word is Entropy
    - Borrowed from thermodynamics

What is information?

Rudolf Clausius

Ludwig Boltzmann

- Or rather the lack of it?
  - Uncertainty
  - The word is Entropy
    - Borrowed from thermodynamics

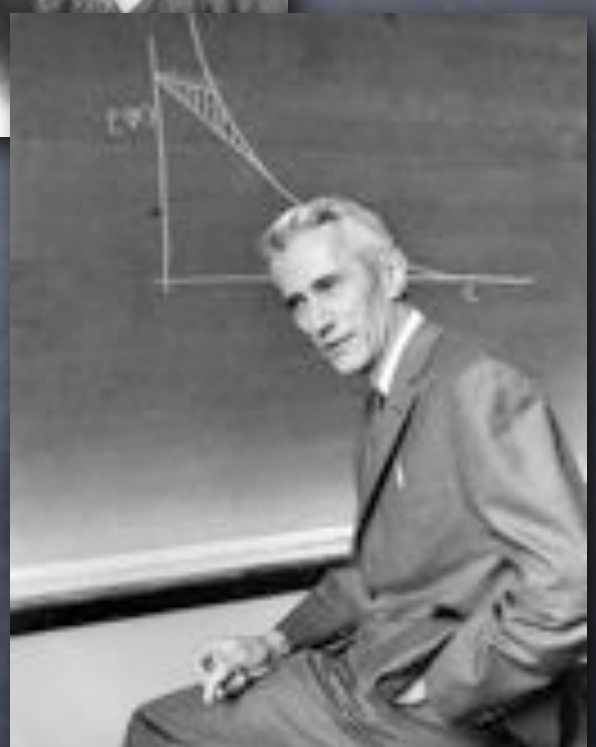
What is information?

- Or rather the lack of it?
  - Uncertainty
  - The word is Entropy
    - Borrowed from thermodynamics

Rudolf Clausius

Ludwig Boltzmann

Claude Shannon



What is information?

Rudolf Clausius

Ludwig Boltzmann

Claude Shannon

- Or rather the lack of it?
  - Uncertainty
  - The word is Entropy
    - Borrowed from thermodynamics
    - An inherently "probabilistic" notion

What is information?

Claude Shannon

What is information?

- Information Theory: ways to quantify information

Claude Shannon

What is information?

- Information Theory: ways to quantify information
  - Application 1: to study efficiency of communication (compression, error-correction)

Claude Shannon

What is information?

- Information Theory: ways to quantify information
  - Application 1: to study efficiency of communication (compression, error-correction)
  - Application 2: to study the possibility of secret communication

Claude Shannon

What is information?

- Information Theory: ways to quantify information
  - Application 1: to study efficiency of communication (compression, error-correction)
  - Application 2: to study the possibility of secret communication
    - The latter turned out to be a relatively easy question! Secret communication possible only if (an equally long) secret key is shared ahead of time

Claude Shannon

Access to Information

Access to Information

- A second look

Access to Information

- A second look
- Information at hand may still not be "accessible" if it is hard to work with it

Access to Information

- A second look
- Information at hand may still not be "accessible" if it is hard to work with it
  - Computation!

Access to Information

- A second look
- Information at hand may still not be "accessible" if it is hard to work with it
  - Computation!
- Shannon's information may reduce uncertainty only for computationally all-powerful parties

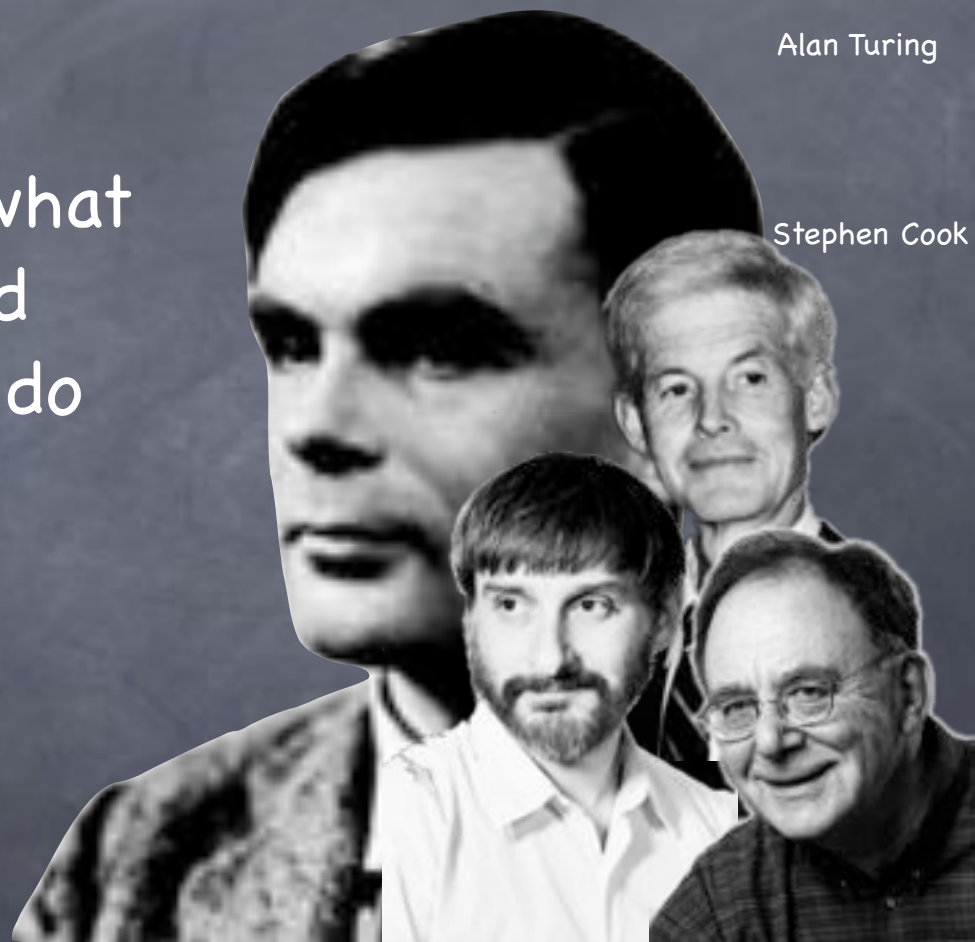
Computational Complexity

Computational Complexity

- A systematic study of what computationally bounded parties can and cannot do

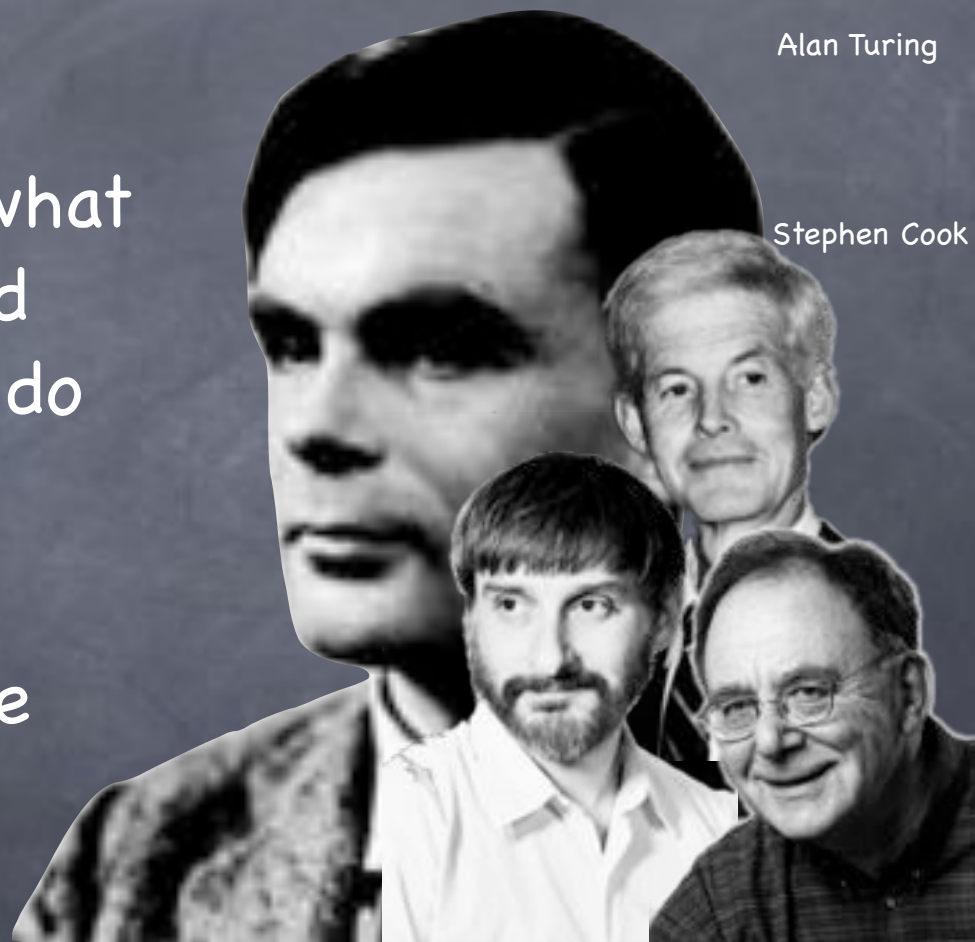
Computational Complexity

- A systematic study of what computationally bounded parties can and cannot do
- A young and rich field



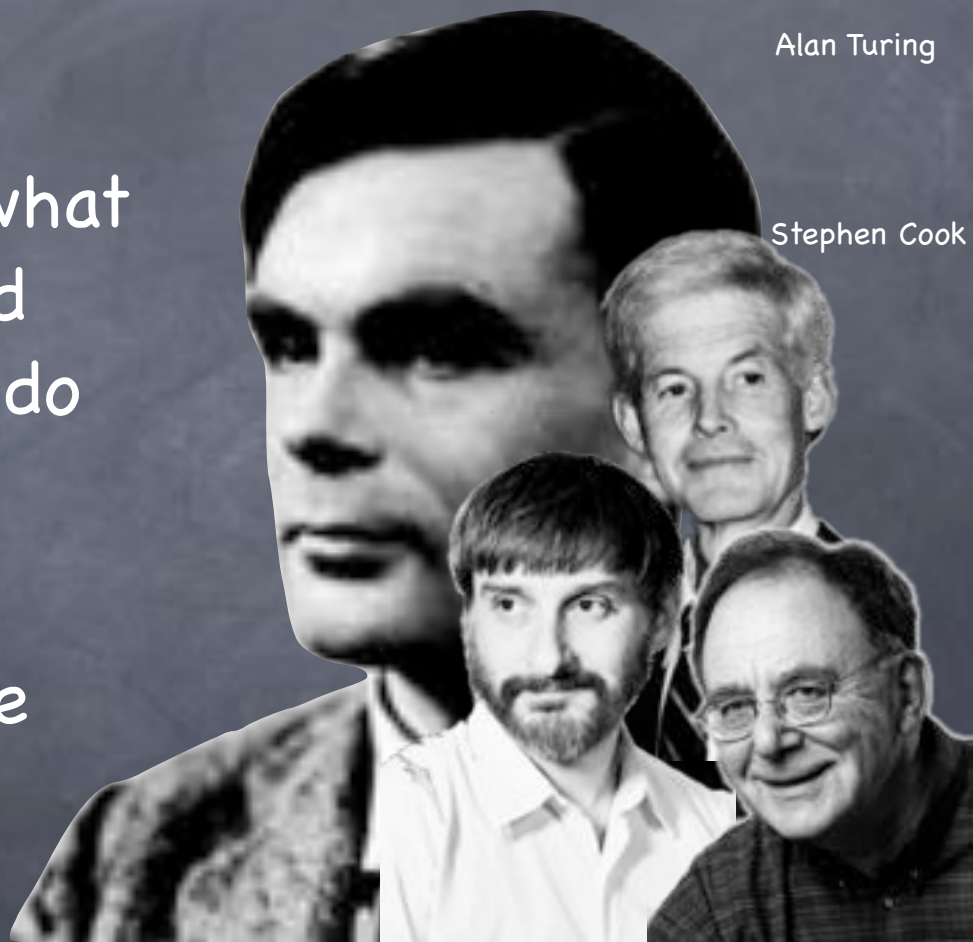
Computational Complexity

- A systematic study of what computationally bounded parties can and cannot do
- A young and rich field
- Much known, much more unknown



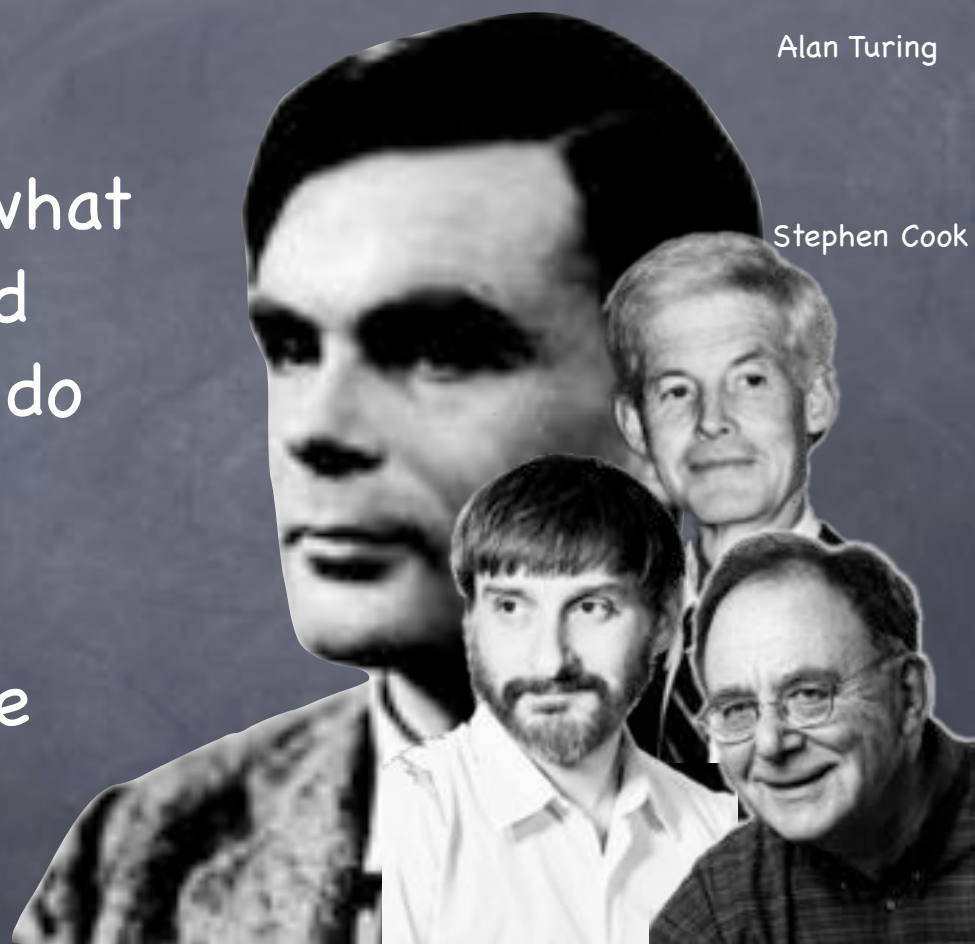
Computational Complexity

- A systematic study of what computationally bounded parties can and cannot do
- A young and rich field
- Much known, much more unknown
  - Much "believed"



Computational Complexity

- A systematic study of what computationally bounded parties can and cannot do
- A young and rich field
- Much known, much more unknown
  - Much "believed"
- Basis of the Modern Theory of Cryptography



Compressed Secret-Keys

Compressed Secret-Keys

- Pseudo-random number generator

Compressed Secret-Keys

- Pseudo-random number generator
  - a.k.a Stream Cipher

Compressed Secret-Keys

- Pseudo-random number generator
  - a.k.a Stream Cipher
  - Generate a long string of random-looking bits from a short random seed

Compressed Secret-Keys

- Pseudo-random number generator
  - a.k.a Stream Cipher
  - Generate a long string of random-looking bits from a short random seed
- Impossible in the information-theoretic sense

Compressed Secret-Keys

Manuel Blum

Andy Yao

- Pseudo-random number generator
  - a.k.a Stream Cipher
  - Generate a long string of random-looking bits from a short random seed
- Impossible in the information-theoretic sense
  - But possible against computationally bounded players!

The Public-Key Revolution

The Public-Key Revolution

- "Non-Secret Encryption"

The Public-Key Revolution

- "Non-Secret Encryption"
  - No a priori shared secrets

The Public-Key Revolution

- "Non-Secret Encryption"
  - No a priori shared secrets
  - Instead, a public key. Anyone can create encryptions, only the creator of the key can decrypt!

The Public-Key Revolution

- "Non-Secret Encryption"
  - No a priori shared secrets
  - Instead, a public key. Anyone can create encryptions, only the creator of the key can decrypt!

The Public-Key Revolution

- "Non-Secret Encryption"
  - No a priori shared secrets
  - Instead, a public key. Anyone can create encryptions, only the creator of the key can decrypt!

James Ellis

The Public-Key Revolution

- "Non-Secret Encryption"
  - No a priori shared secrets
  - Instead, a public key. Anyone can create encryptions, only the creator of the key can decrypt!

The Public-Key Revolution

- "Non-Secret Encryption"
  - No a priori shared secrets
  - Instead, a public key. Anyone can create encryptions, only the creator of the key can decrypt!

The Public-Key Revolution

- "Non-Secret Encryption"
  - No a priori shared secrets
  - Instead, a public key. Anyone can create encryptions, only the creator of the key can decrypt!
- Publicly verifiable digital signatures

The Public-Key Revolution

- "Non-Secret Encryption"
  - No a priori shared secrets
  - Instead, a public key. Anyone can create encryptions, only the creator of the key can decrypt!
- Publicly verifiable digital signatures

Merkle, Hellman, Diffie

The Public-Key Revolution

- "Non-Secret Encryption"
  - No a priori shared secrets
  - Instead, a public key. Anyone can create encryptions, only the creator of the key can decrypt!
- Publicly verifiable digital signatures


Merkle, Hellman, Diffie


Shamir, Rivest, Adleman

The Public-Key Revolution

- "Non-Secret Encryption"
  - No a priori shared secrets
  - Instead, a public key. Anyone can create encryptions, only the creator of the key can decrypt!
- Publicly verifiable digital signatures
- Forms the backbone of today's secure communication


Merkle, Hellman, Diffie


Shamir, Rivest, Adleman

Crypto-Mania

Crypto-Mania

- Public-Key cryptography and beyond!

Crypto-Mania

- Public-Key cryptography and beyond!
- Secret computation: collaboration among mutually distrusting parties

Crypto-Mania

- Public-Key cryptography and beyond!
- Secret computation: collaboration among mutually distrusting parties
  - Compute on distributed data, without revealing their private information to each other

Crypto-Mania

- Public-Key cryptography and beyond!
- Secret computation: collaboration among mutually distrusting parties
  - Compute on distributed data, without revealing their private information to each other
  - Compute on encrypted data

Crypto-Mania

- Public-Key cryptography and beyond!
- Secret computation: collaboration among mutually distrusting parties
  - Compute on distributed data, without revealing their private information to each other
  - Compute on encrypted data
- And other fancy things... with sophisticated control over more complex "access" to information

Crypto-Mania

- Public-Key cryptography and beyond!
- Secret computation: collaboration among mutually distrusting parties
  - Compute on distributed data, without revealing their private information to each other
  - Compute on encrypted data
- And other fancy things... with sophisticated control over more complex "access" to information
- Do it all faster, better, more conveniently and more securely (or find out if one cannot). And also make sure we know what we are trying to do.

Crypto-Mania

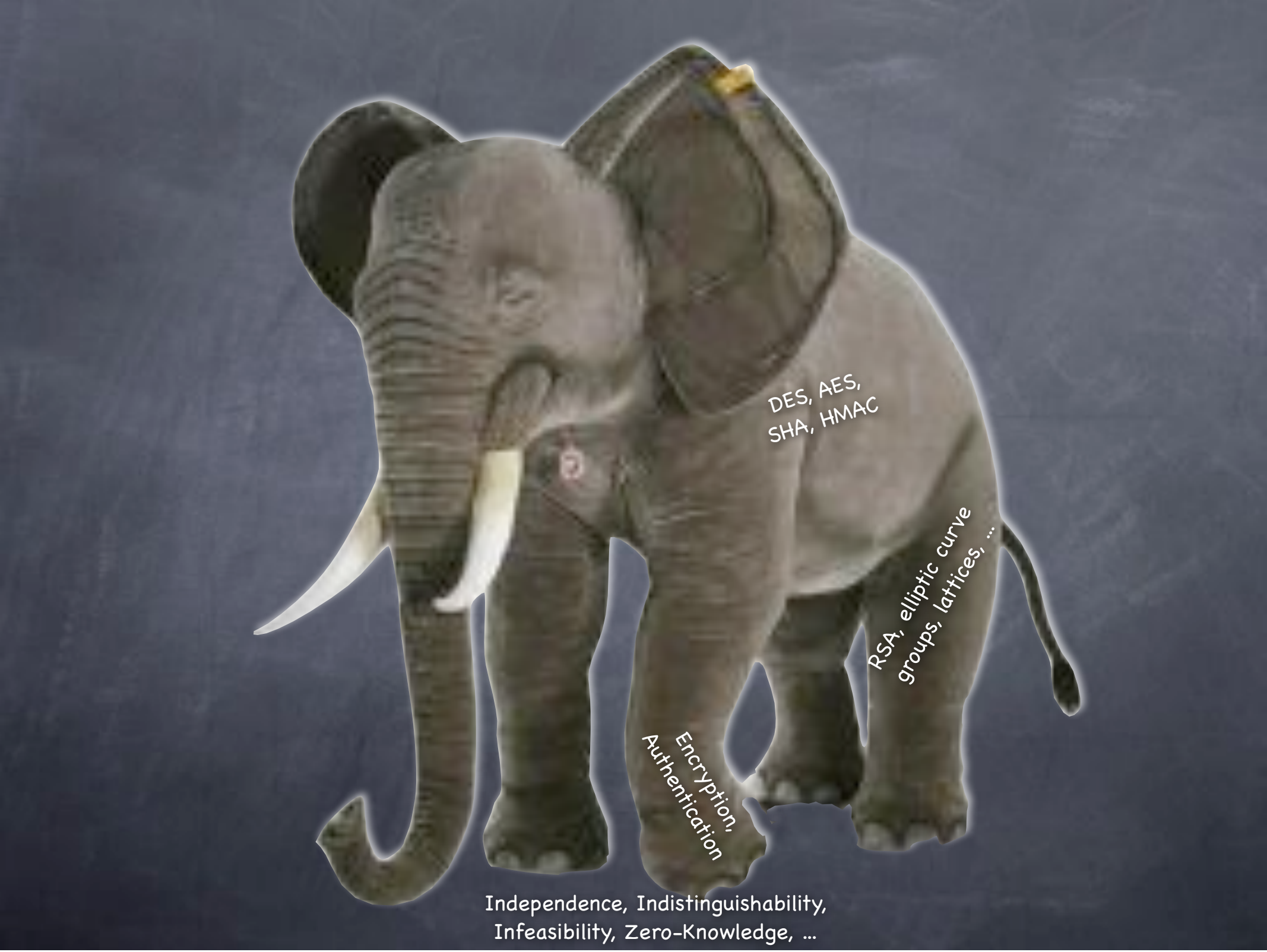
- Public-Key
- S
  m
  -
  -
- And
  over
- Do it
  secur
  sure

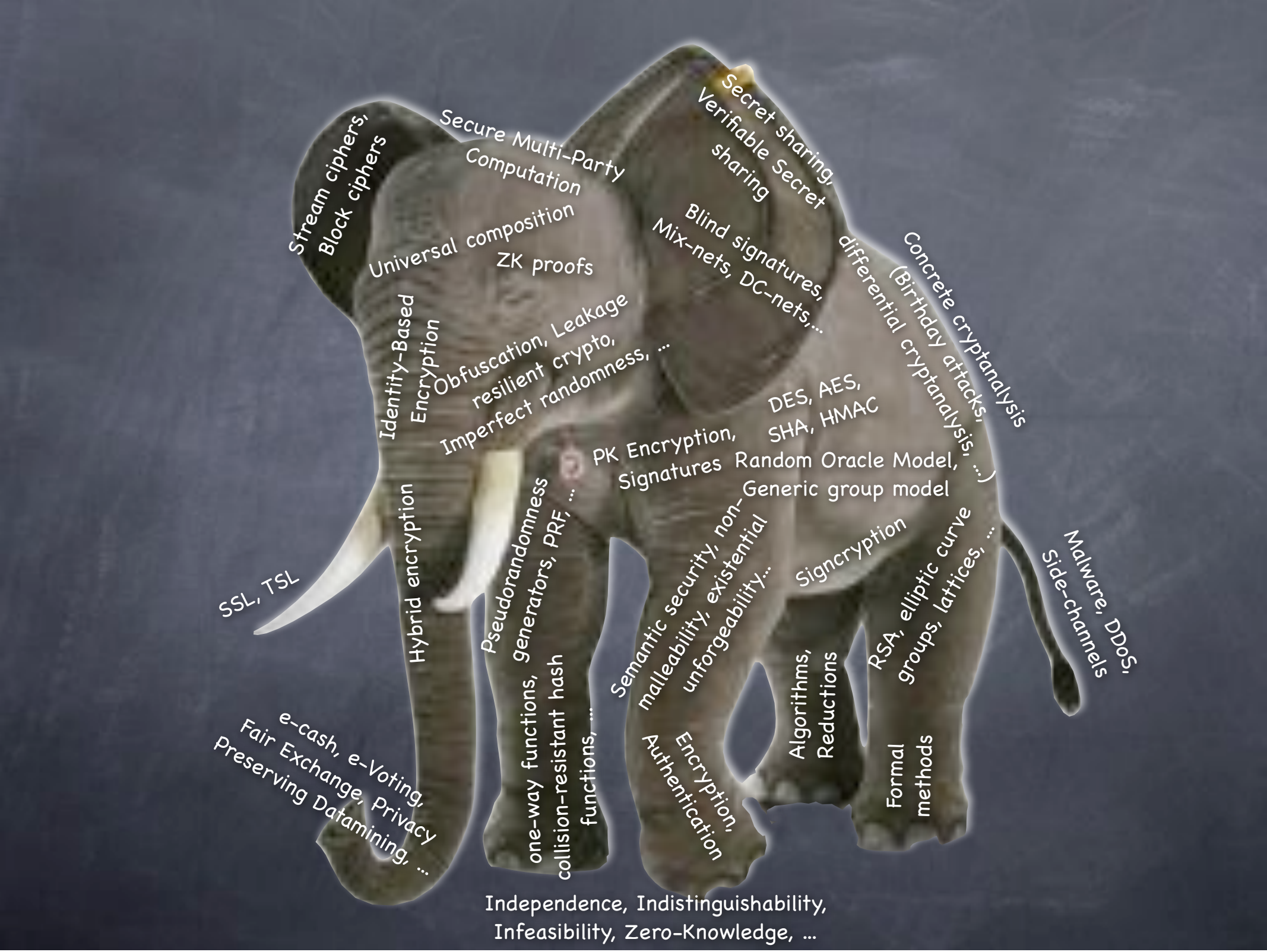
…and also make
…we are trying to do.


Independence, Indistinguishability,
Infeasibility, Zero-Knowledge, ...


Encryption,
Authentication
Independence, Indistinguishability,
Infeasibility, Zero-Knowledge, ...


DES, AES,
SHA, HMAC
Encryption,
Authentication
Independence, Indistinguishability,
Infeasibility, Zero-Knowledge, ...


DES, AES,
SHA, HMAC
RSA, elliptic curve
groups, lattices, ...
Encryption,
Authentication
Independence, Indistinguishability,
Infeasibility, Zero-Knowledge, ...


Stream ciphers,
Block ciphers
Secure Multi-Party Computation
Secret sharing,
Verifiable Secret sharing
Universal composition
ZK proofs
Blind signatures,
Mix-nets, DC-nets,...
Concrete cryptanalysis
(Birthday attacks,
differential cryptanalysis, ...)
Identity-Based Encryption
Obfuscation, Leakage resilient crypto,
Imperfect randomness, ...
DES, AES,
SHA, HMAC
PK Encryption,
Signatures
Random Oracle Model,
Generic group model
SSL, TSL
Hybrid encryption
Pseudorandomness
generators, PRF, ...
Semantic security, non-malleability, existential unforgeability...
Signcryption
Malware, DDoS,
Side-channels
RSA, elliptic curve
groups, lattices, ...
e-cash, e-Voting,
Fair Exchange, Privacy
Preserving Datamining, ...
one-way functions,
collision-resistant hash
functions, ...
Algorithms,
Reductions
Encryption,
Authentication
Formal methods
Independence, Indistinguishability,
Infeasibility, Zero-Knowledge, ...

In This Course

In This Course
(how to tame the elephant...)

In This Course
(how to tame the elephant...)

- Fundamental notions of secrecy and infeasibility

In This Course
(how to tame the elephant...)

- Fundamental notions of secrecy and infeasibility
- Secure communication (encryption, authentication): definitions, building blocks, construction

In This Course
(how to tame the elephant...)

- Fundamental notions of secrecy and infeasibility
- Secure communication (encryption, authentication): definitions, building blocks, construction
- And much more: Secure multi-party computation, computing on encrypted data, bleeding edge crypto, quick and dirty crypto...

In This Course
(how to tame the elephant...)

- Fundamental notions of secrecy and infeasibility
- Secure communication (encryption, authentication): definitions, building blocks, construction
- And much more: Secure multi-party computation, computing on encrypted data, bleeding edge crypto, quick and dirty crypto...
- Project: You can pick a topic for surveying/research, or an implementation project

In This Course
(how to tame the elephant...)

- Fundamental notions of secrecy and infeasibility
- Secure communication (encryption, authentication): definitions, building blocks, construction
- And much more: Secure multi-party computation, computing on encrypted data, bleeding edge crypto, quick and dirty crypto...
- Project: You can pick a topic for surveying/research, or an implementation project
- A few assignments

In This Course
(how to tame the elephant...)

In This Course
(how to tame the elephant...)

- http://www.cs.illinois.edu/class/fa11/cs598man/

In This Course
(how to tame the elephant...)

- http://www.cs.illinois.edu/class/fa11/cs598man/
- Textbook for first part: Katz and Lindell

In This Course
(how to tame the elephant...)

- http://www.cs.illinois.edu/class/fa11/cs598man/
- Textbook for first part: Katz and Lindell
- There's a blog and a wiki.

In This Course
(how to tame the elephant...)

- http://www.cs.illinois.edu/class/fa11/cs598man/
- Textbook for first part: Katz and Lindell
- There's a blog and a wiki.
- Office Hours: TBA