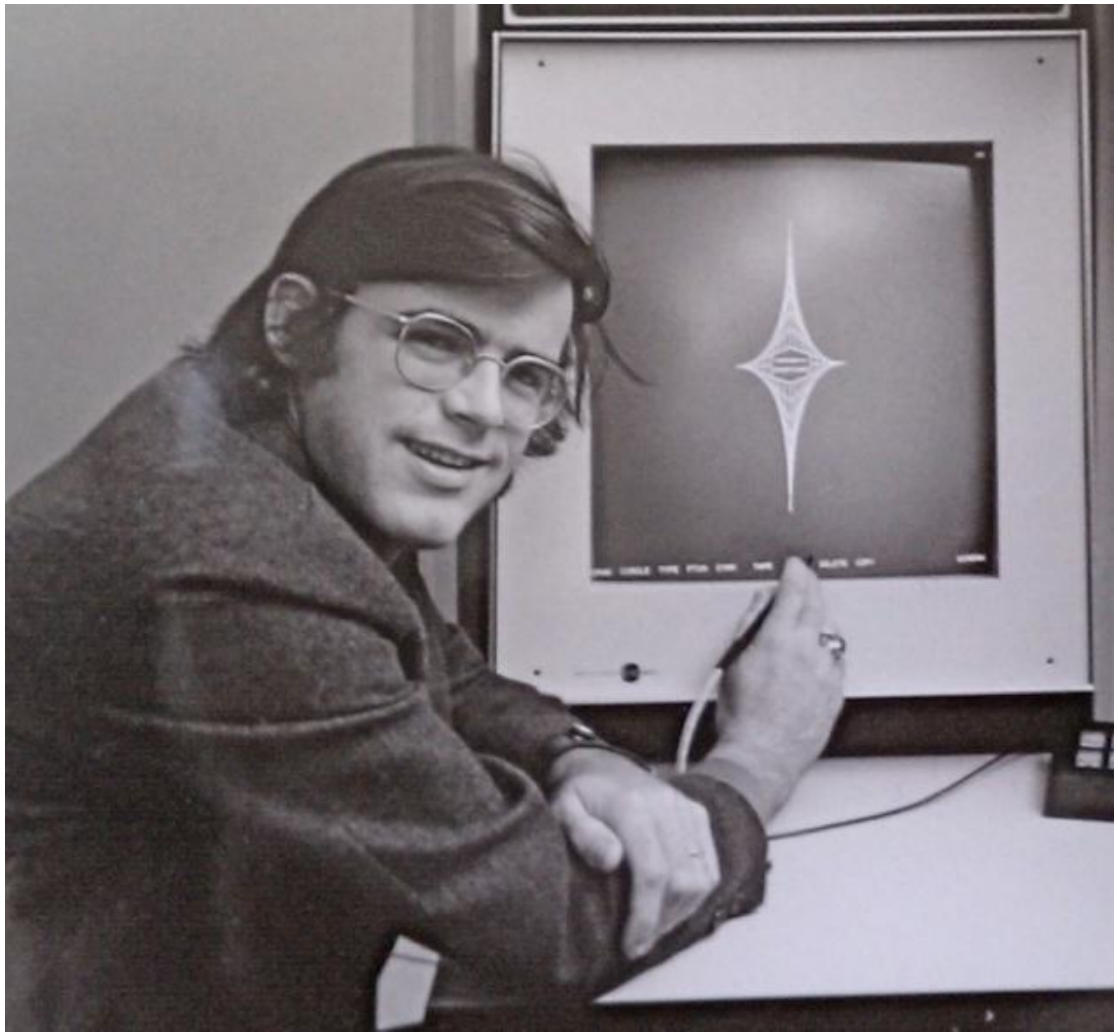
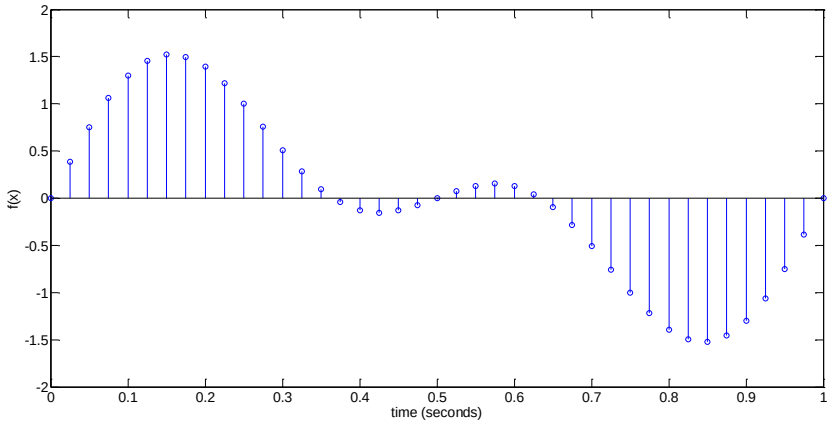
Who is this dashing gent?

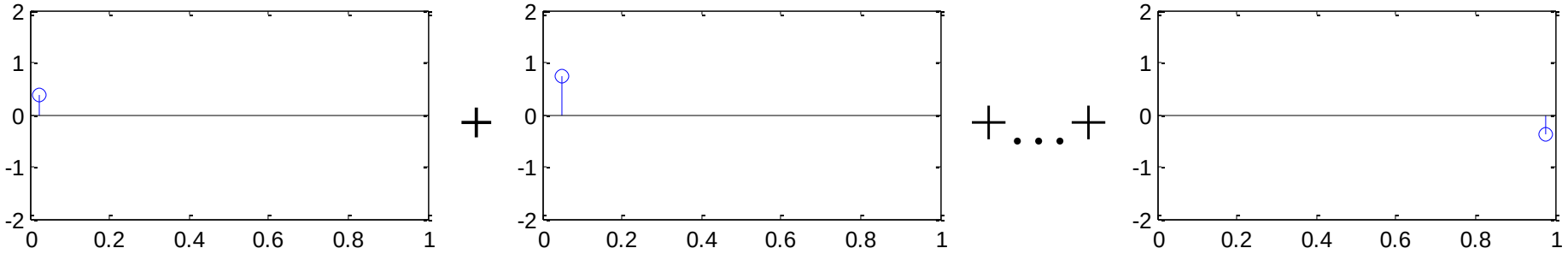


Time vs. Frequency Domain

- Audio signal

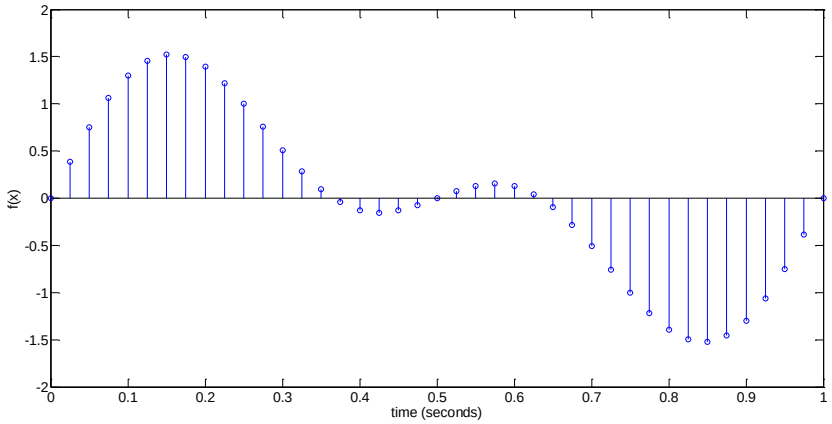


- Representation 1: Sum of **many** delta functions

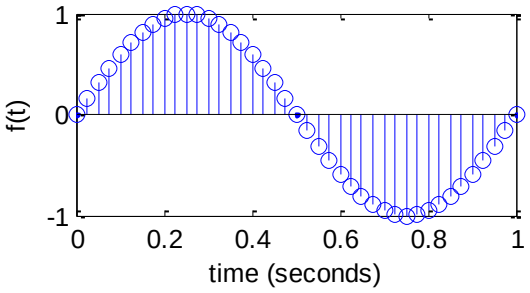


Time vs. Frequency Domain

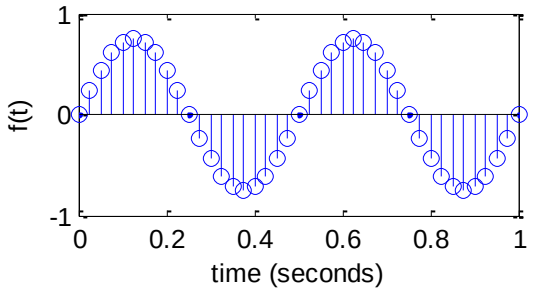
- Audio signal



- Representation 2: Sum of **two** sine functions

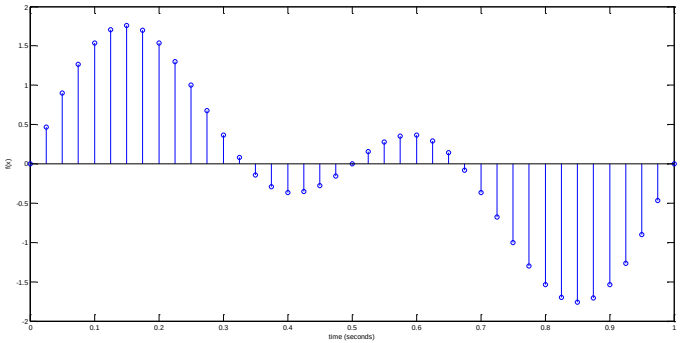


+

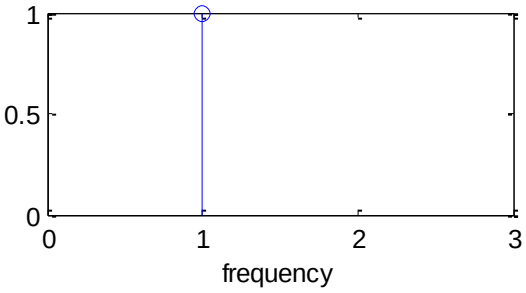


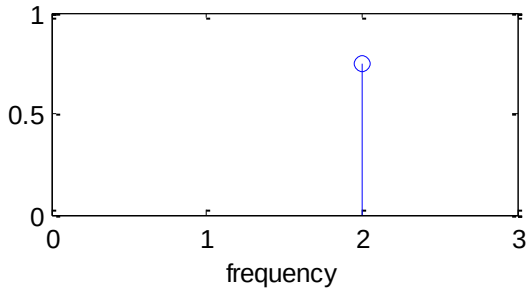
Kolmogorov Complexity

- Simplest way to represent:



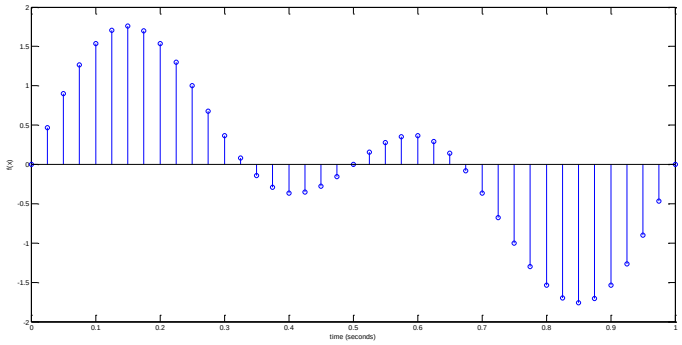
- Equivalent representations:
  - Sum of two sine functions in the time domain.
  - Sum of two deltas in the frequency domain.



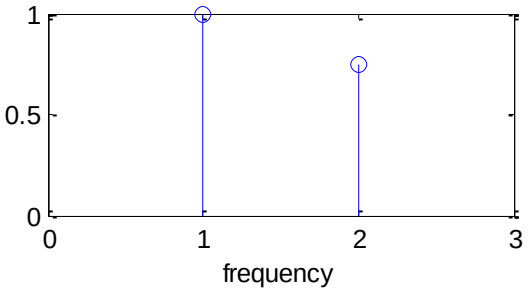


Time Domain to Frequency Domain

Time:



Frequency:



Which sinusoids to use!

DFT and FFT

- DFT: Discrete Fourier Transform, $O(N^2)$

sinusoid amplitudes

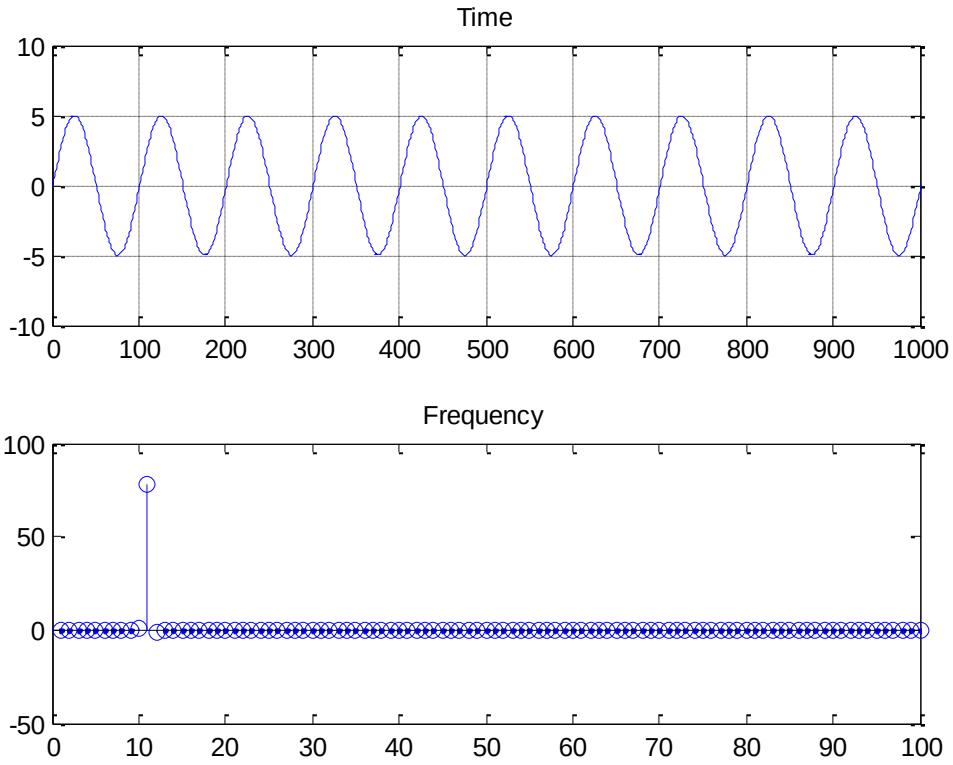
samples

$$X_k = \sum_{n=0}^{N-1} x_n e^{-i2\pi k \frac{n}{N}}$$

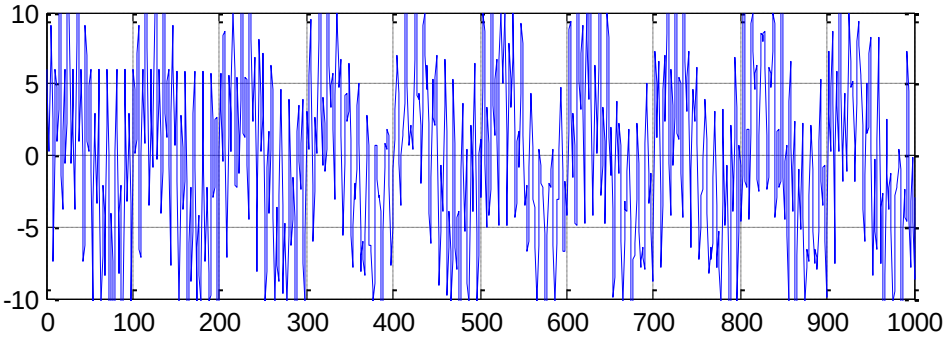
- Non-obvious fact: We compute N sinusoid amplitudes.
  - In previous example, only two were non-zero.
- FFT: Fast Fourier Transform
  - Recursive version of DFT
  - Runs in O(N log N)!

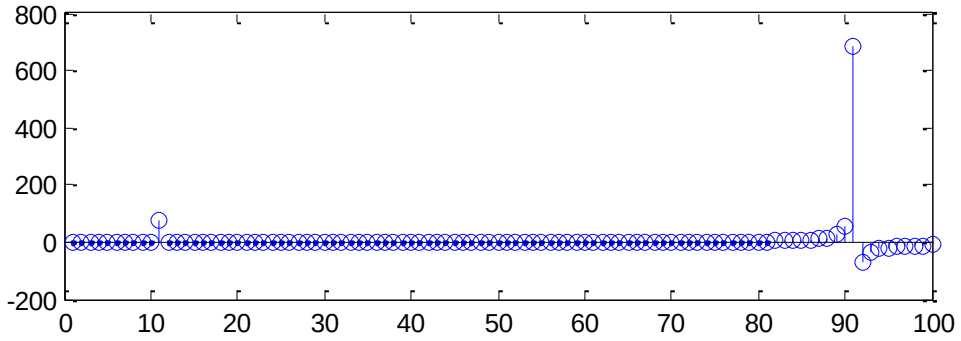
Frequency Filtering

- Nice clean input signal

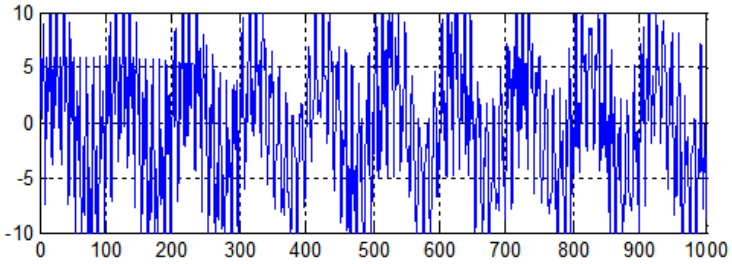


Frequency Filtering

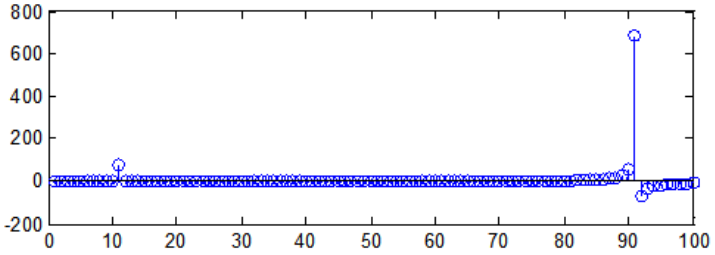




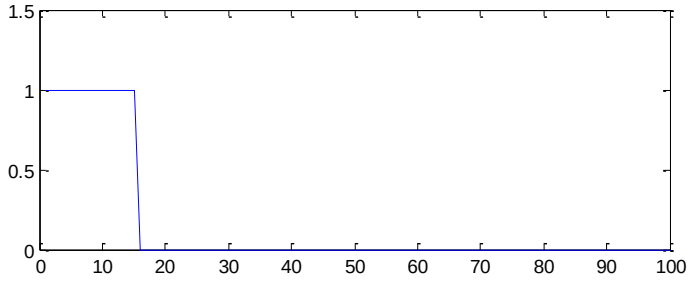
Frequency Filtering



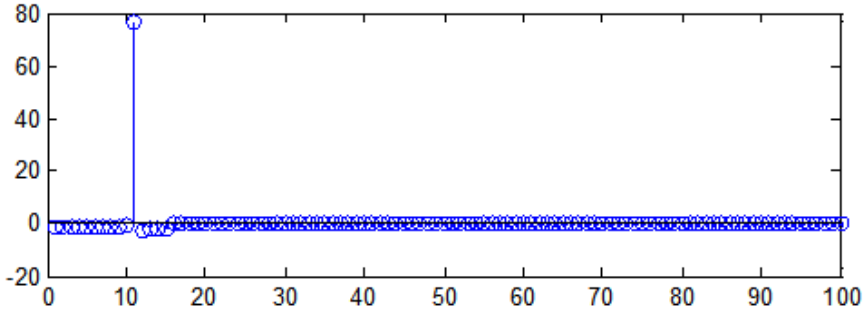
FFT



×

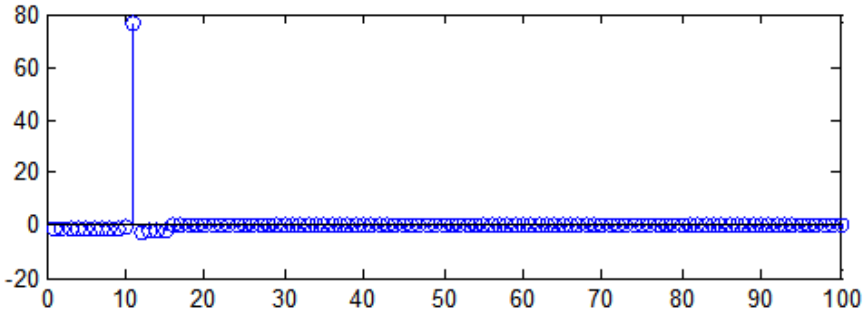


=

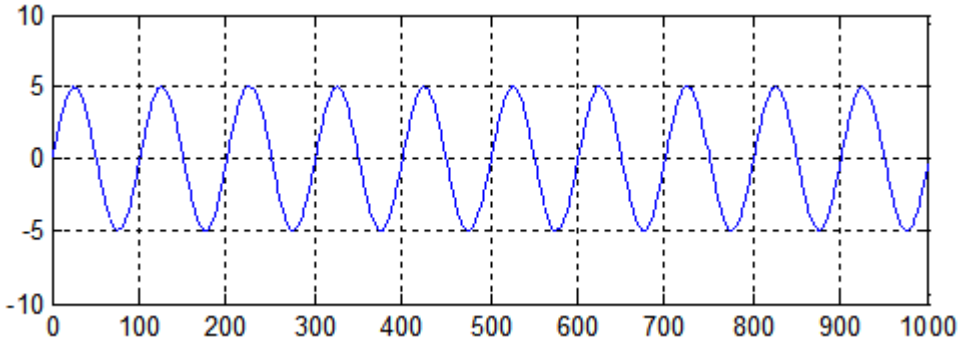


What do I do with this??

Frequency Filtering

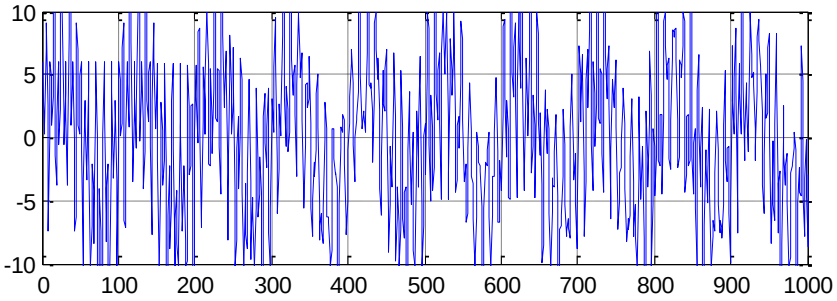


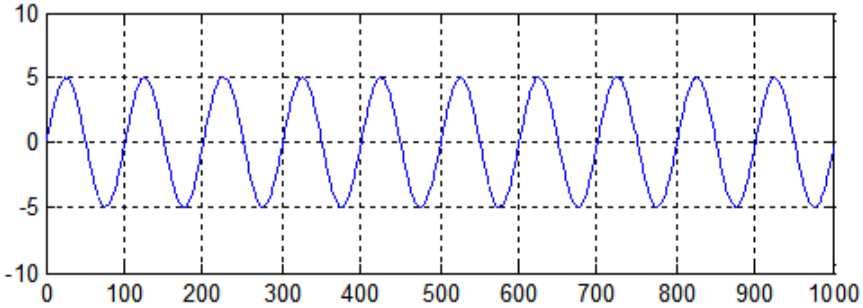
IFFT

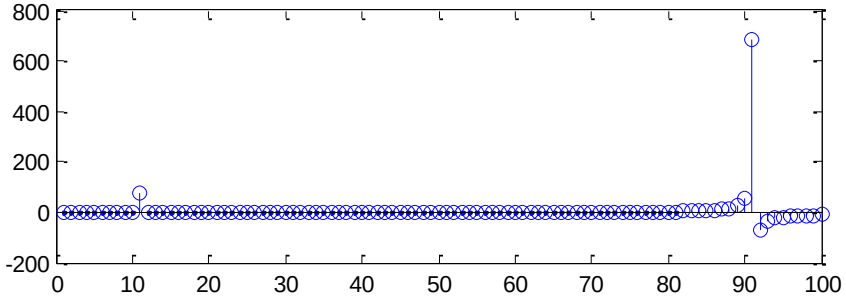


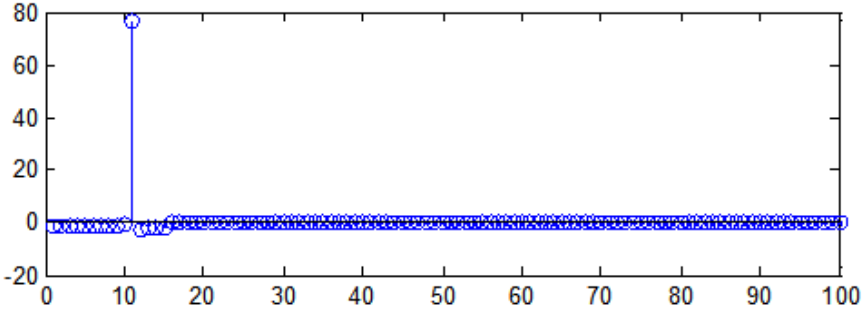
(audible errors are outside the part on the graph)

Frequency Filtering Summary









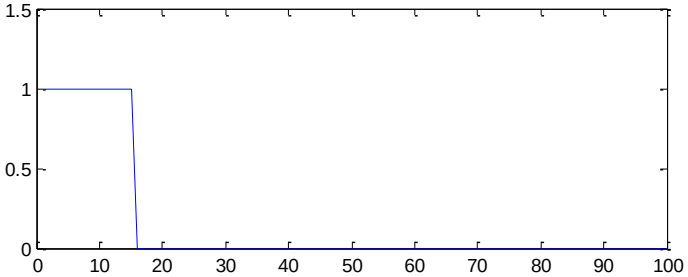
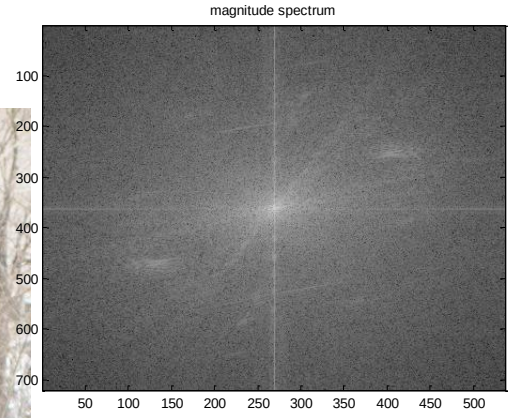
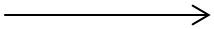
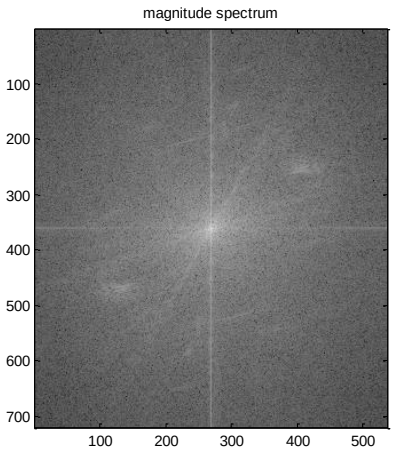


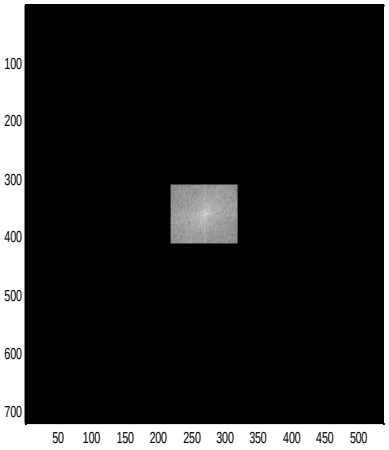
Image FFTs


magnitude spectrum
100
200
300
400
500
600
700
50
100
150
200
250
300
350
400
450
500

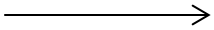
Low Pass Filtering with Image FFTs

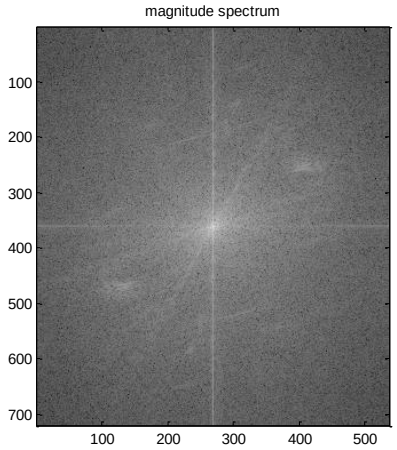


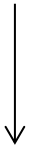


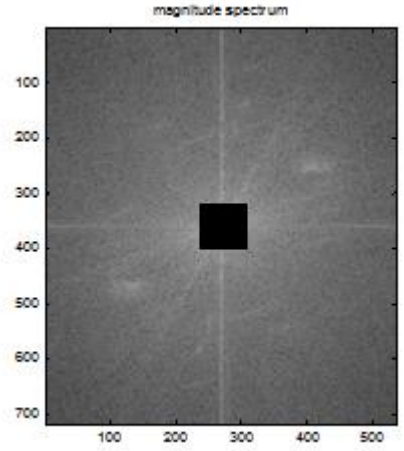


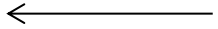
High Pass Filtering with Image FFTs

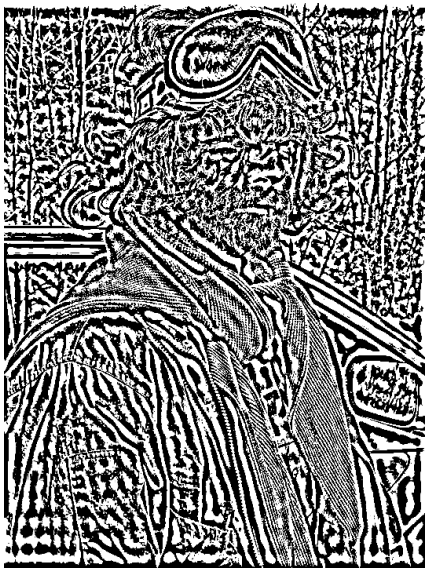












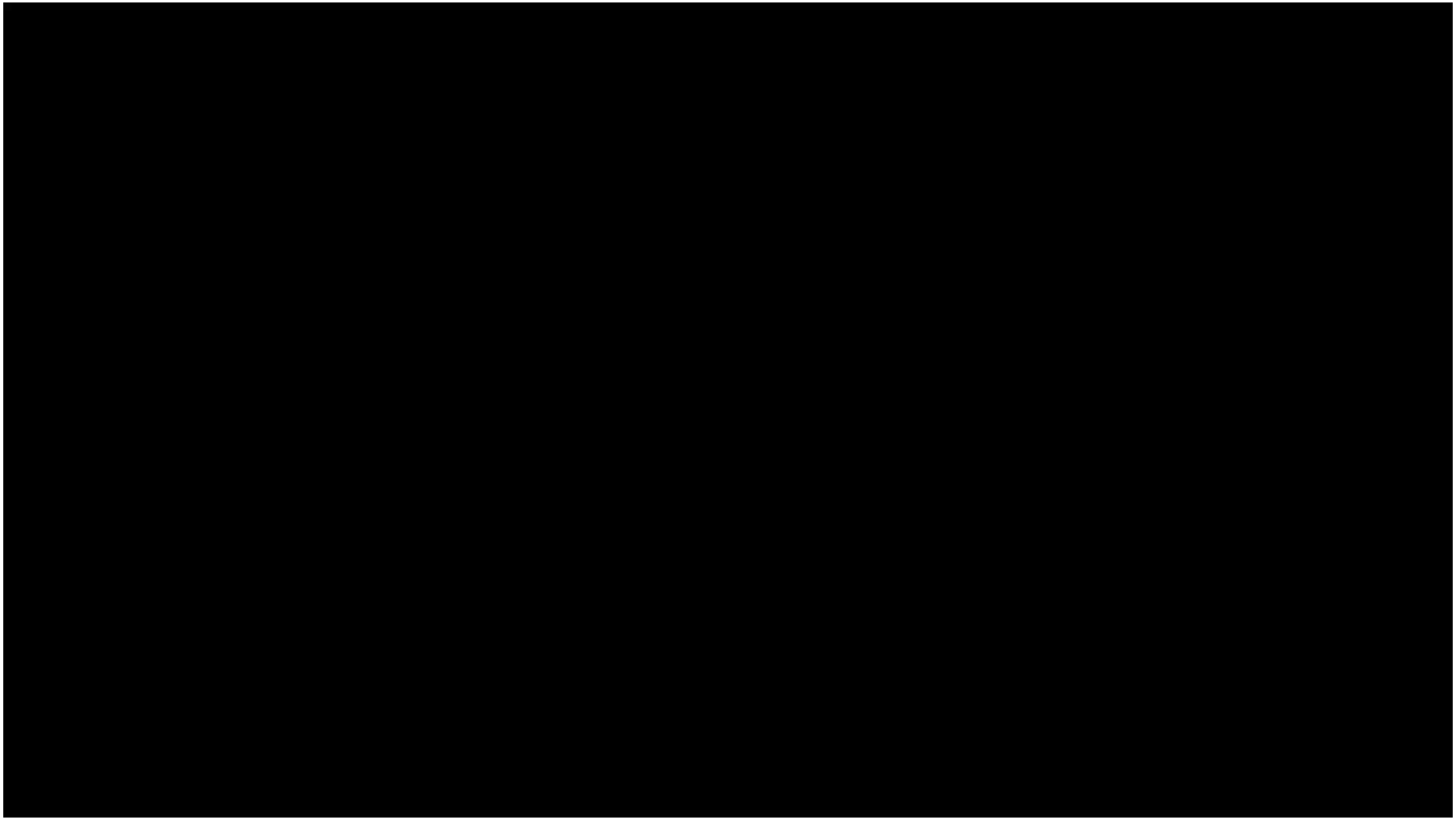
Phase Vocoding

- FFT:
  - Basis for Pitch and Time Shifting

Related Courses

- COS314: Intro to Computer Music
- COS325: Transforming Reality by Computer
- ELE301: Signals and Systems

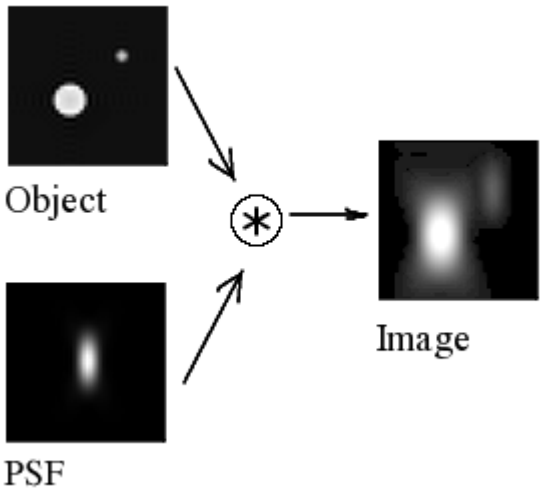
COMPUTER GRAPHICS



De-blurring

De-blurring

General model of blur

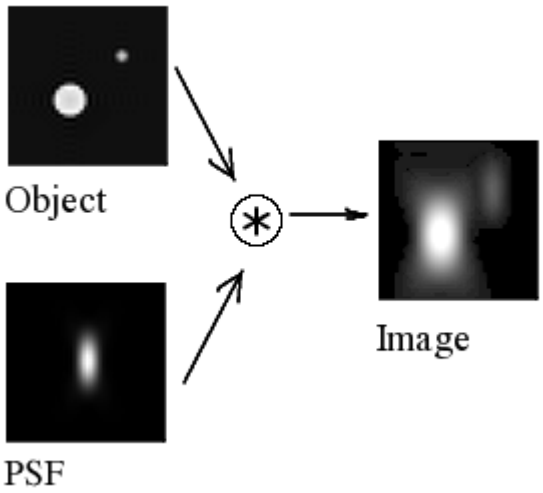


PSF = point-spread function (given by blur kernel)

effect of blur on single point

* = convolution

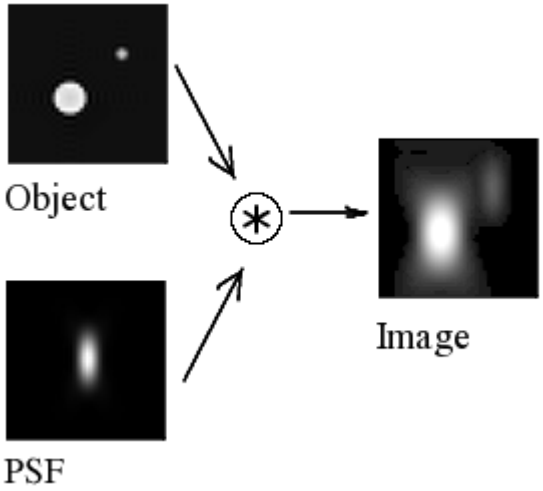
Non-blind deconvolution

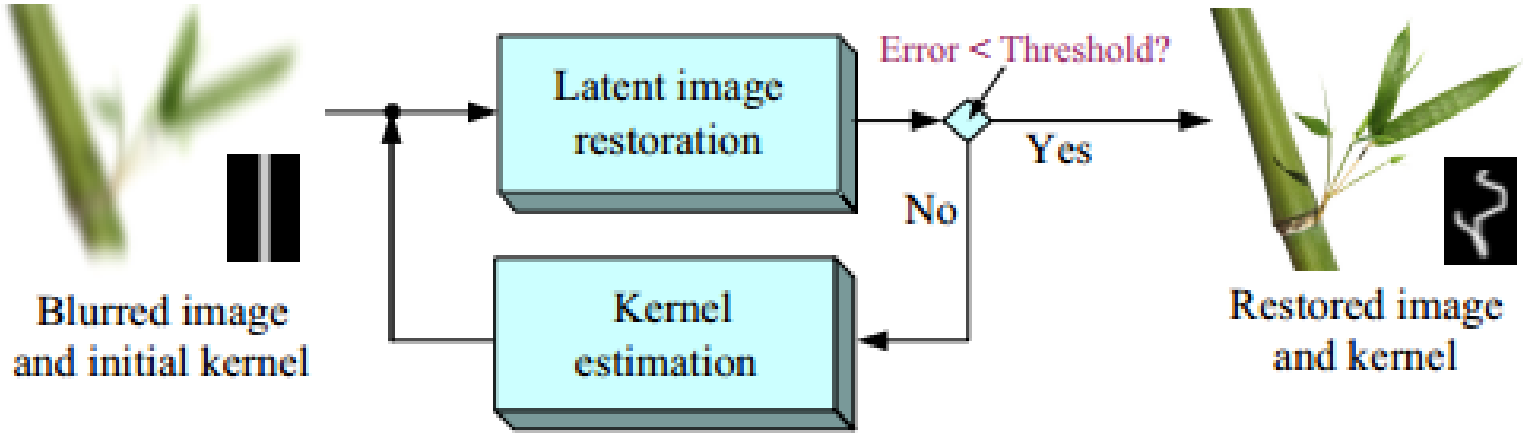


- PSF is known
- Lucy-Richardson algorithm

- Assume Poisson distribution on input pixels
- Iterative approximation

Blind deconvolution





Related Courses

- COS426 – Computer Graphics
- COS496 – Computer Vision

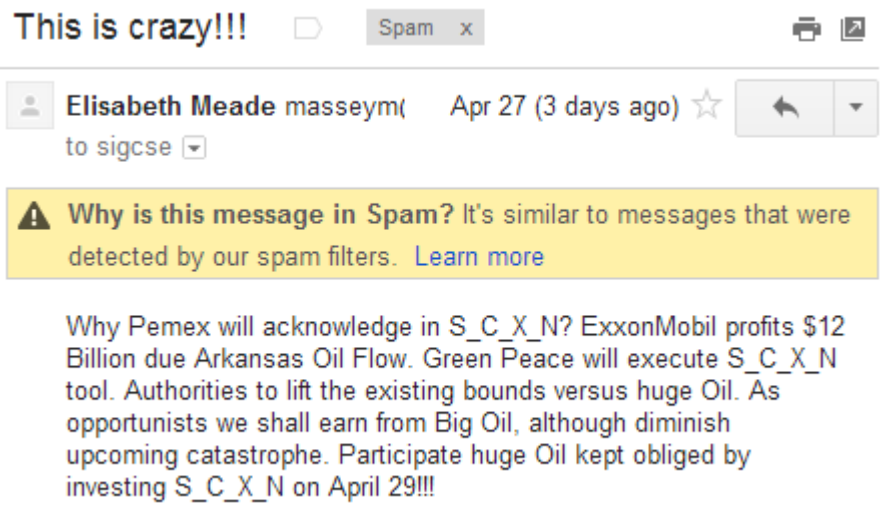
CLASSIFICATION

Classification

- Given an input, assign a label from a list
  - Email text → {spam, ham}
  - Handwritten digit → {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}

Classification

- Given an input, assign a label from a list.



→ **spam**

→ 0

→ 2

Supervised Learning

- Given set of labeled training data.
  - Training set
  - Testing set
- Use training set to train a model.
- Use testing set to test performance of model.

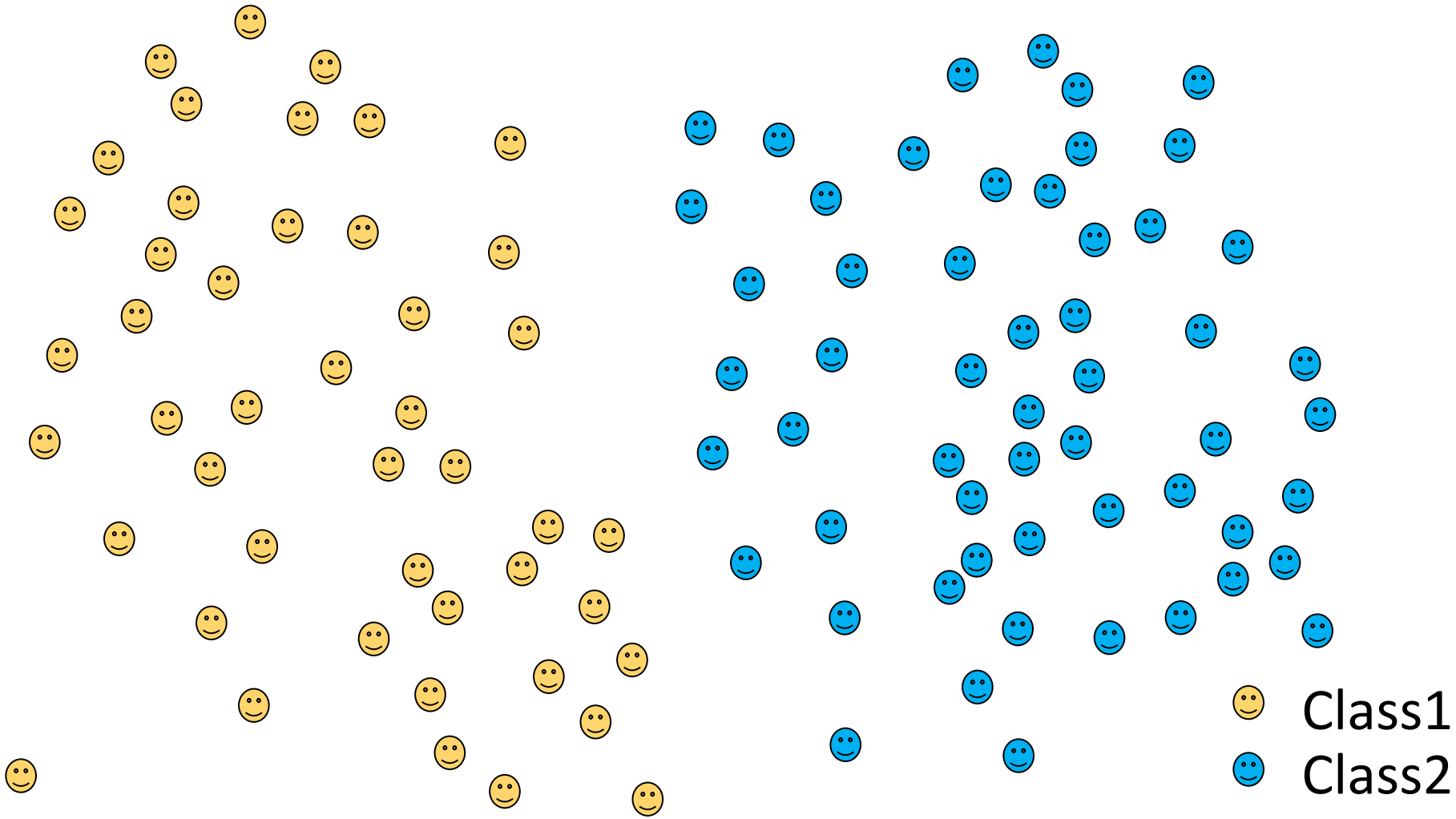
Support Vector Machines

- Vanilla version: Binary classifier (two labels)

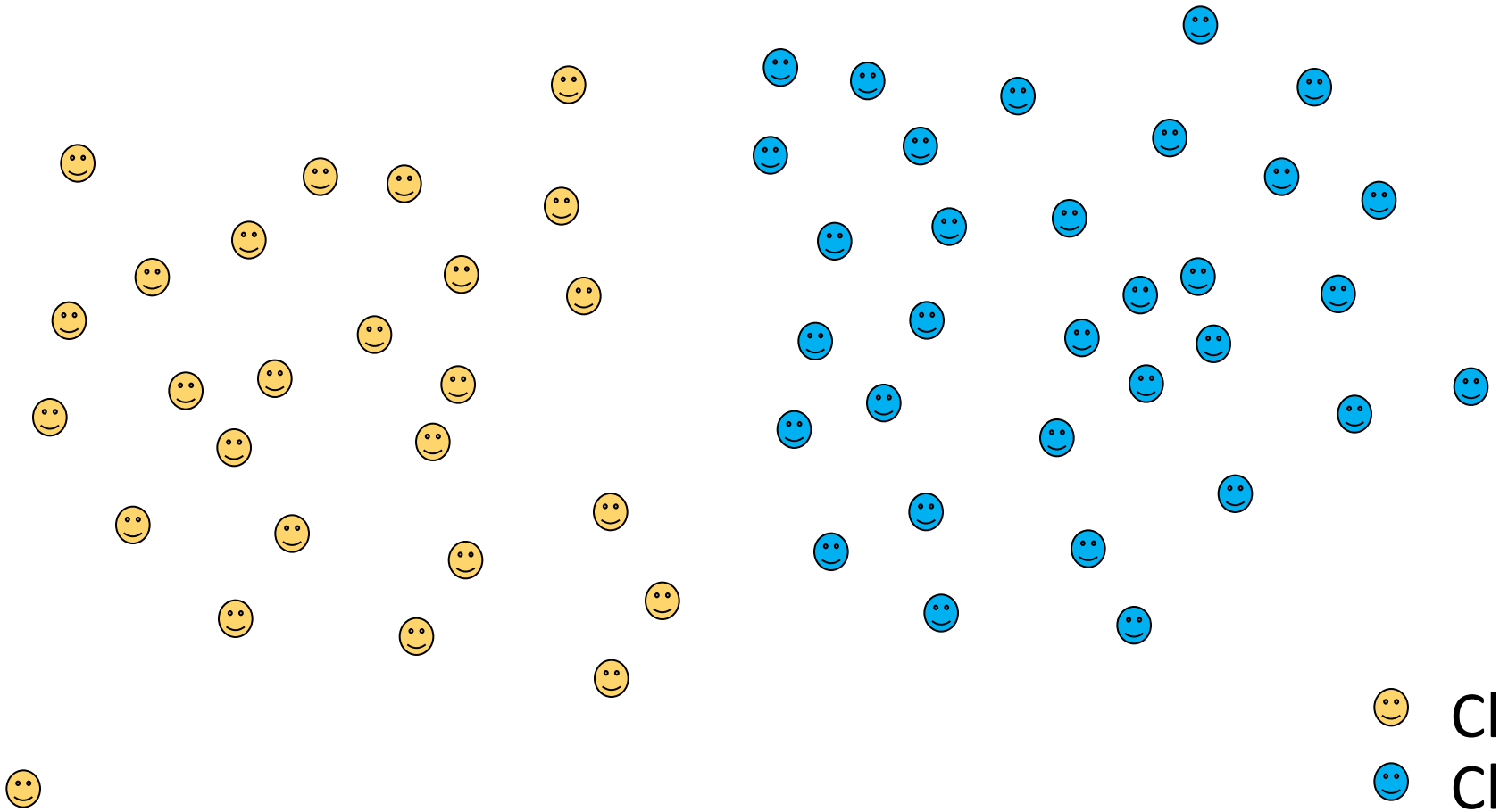
- Basic idea
  - Each input is a point in an N-dimensional space
  - Find best hyper-plane separating the two classes

- Examples
  - {rent, income} → {happy, sad}
  - {age, weight, height, blood sugar, sex} → {has diabetes, no}
  - email → {spam, ham}

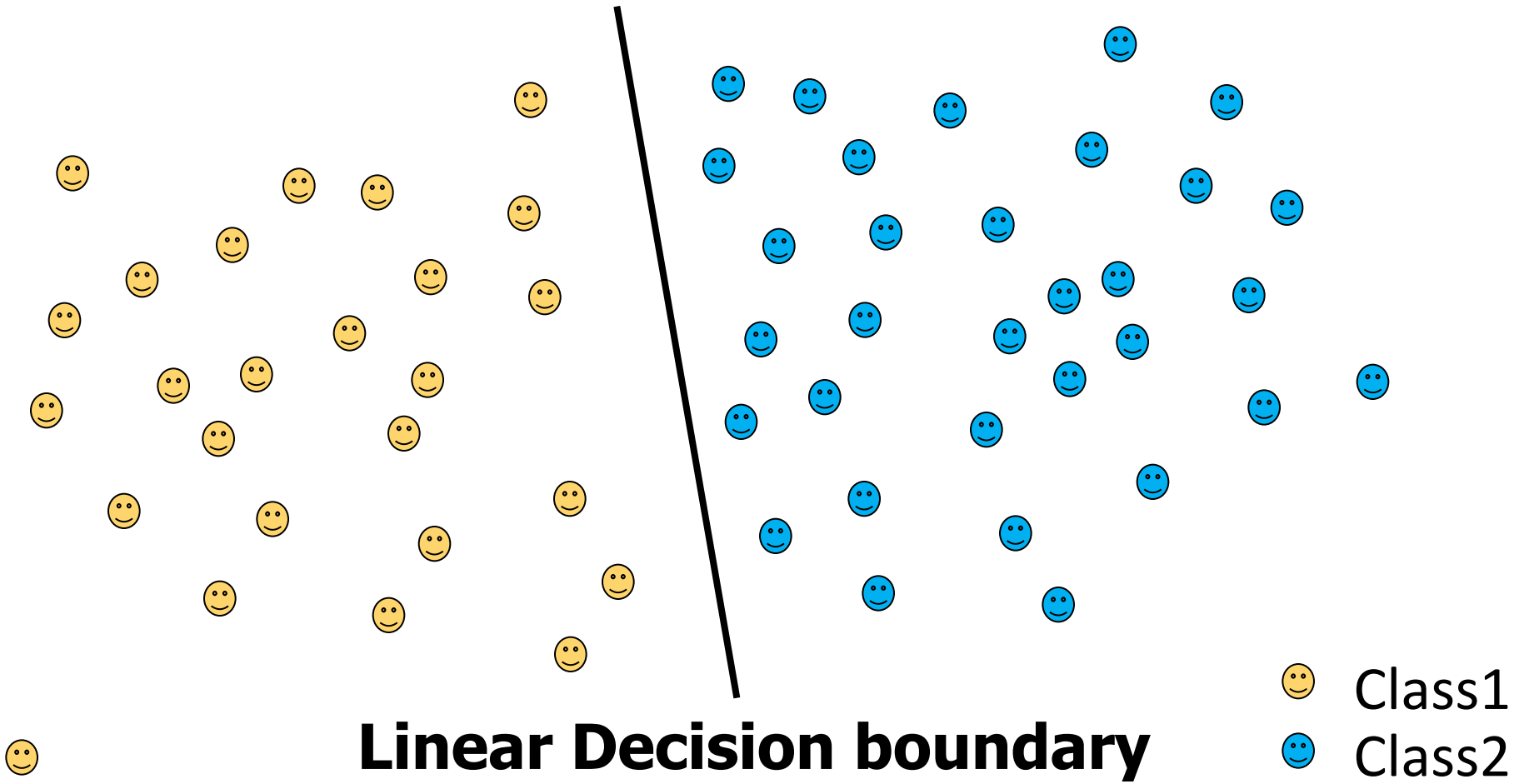
Goal: Build a classifier



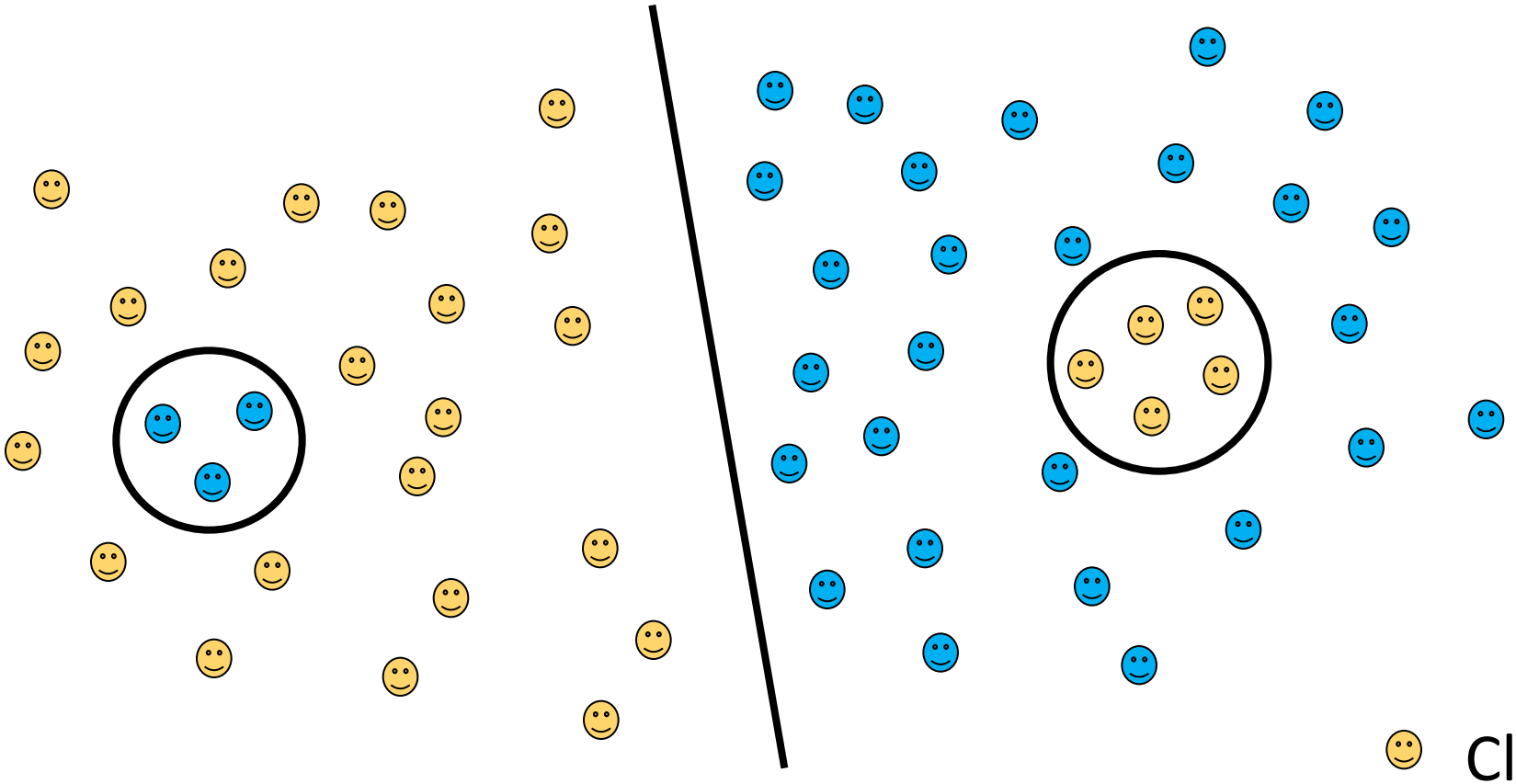
Construct Training Set (randomly)



Linearly Separable Data



Non Linearly Separable Data

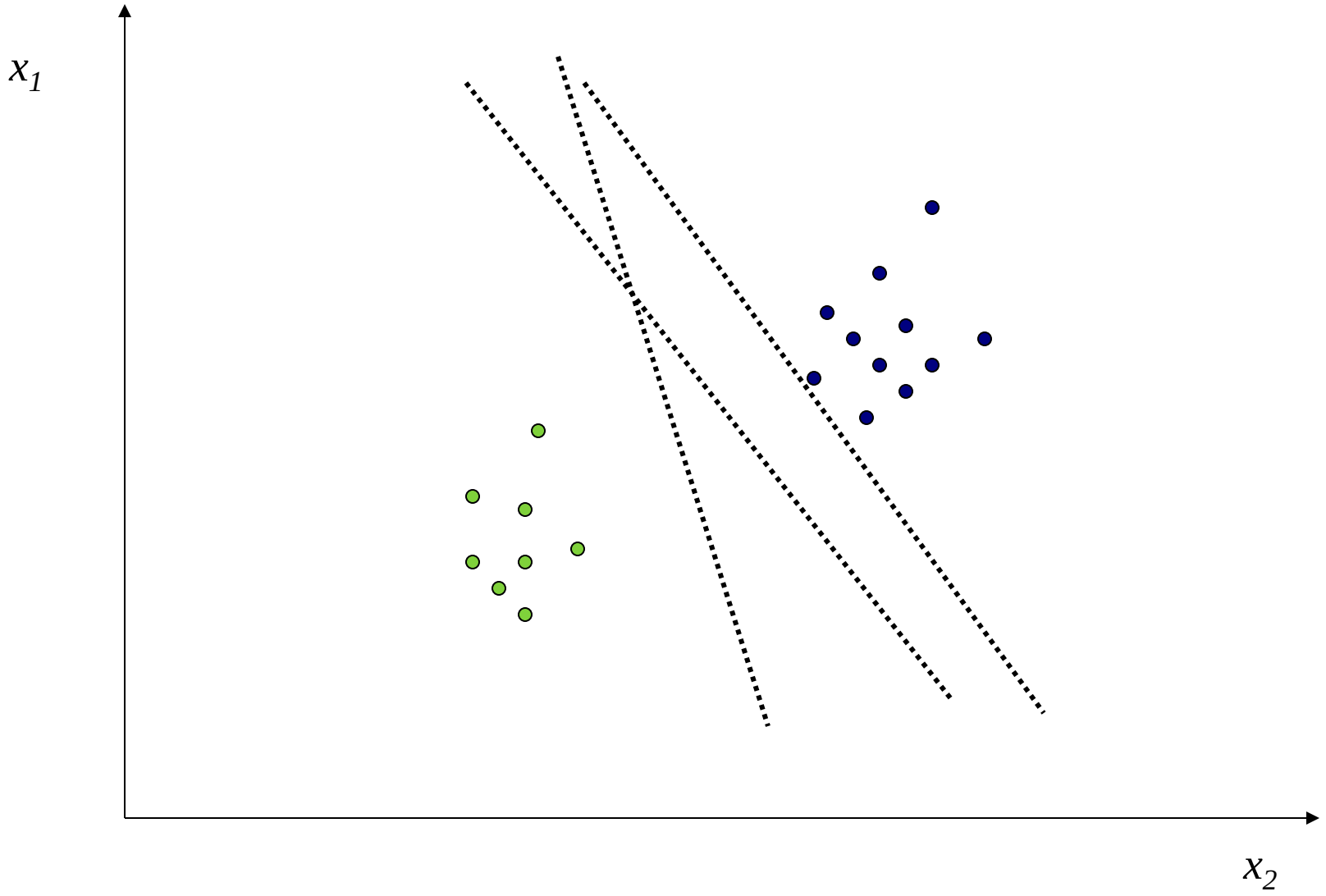


Class1
Class2

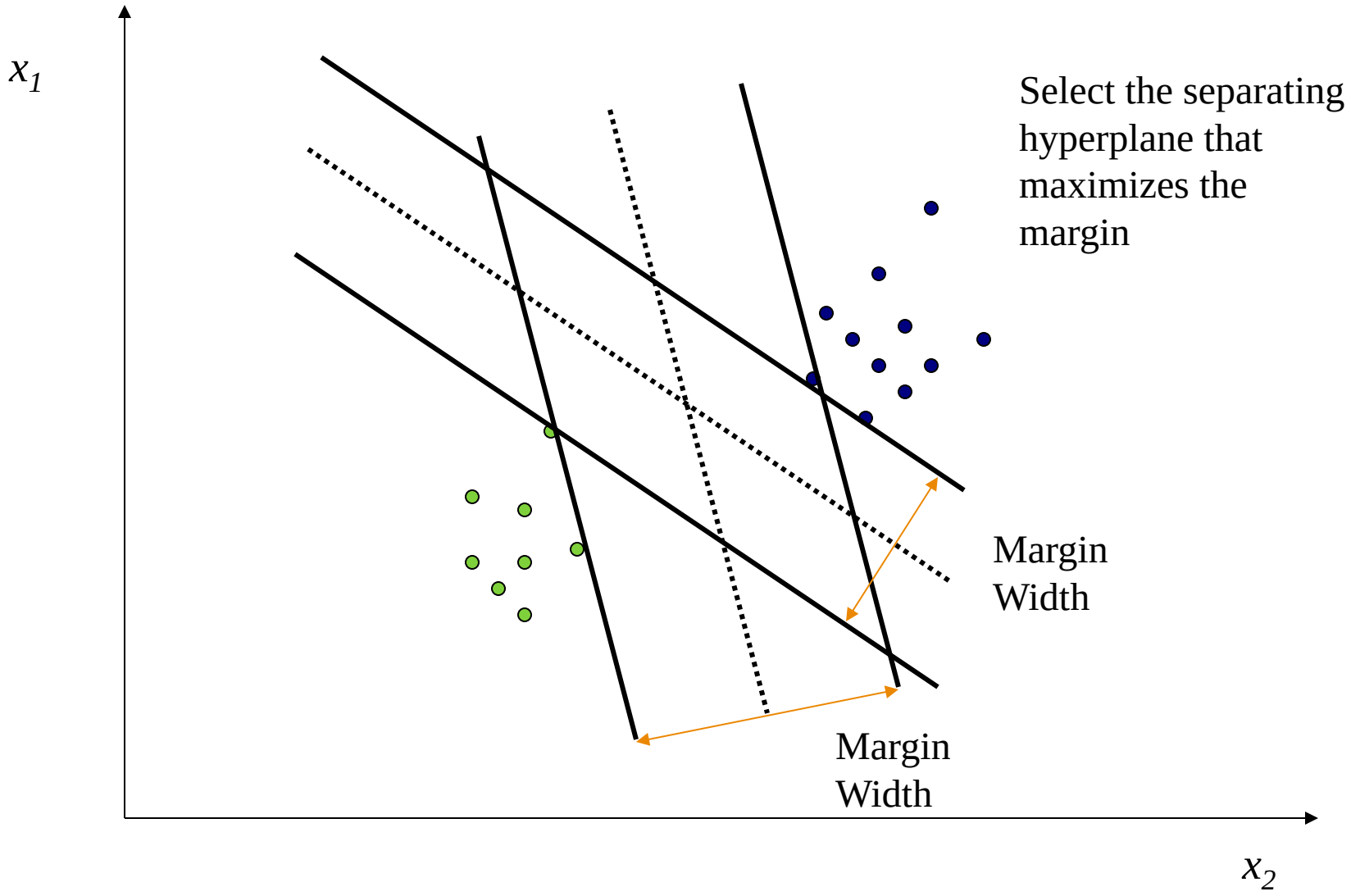
Non Linear Classifier

(so do something fancier…)

Which Separating Hyperplane to Use?

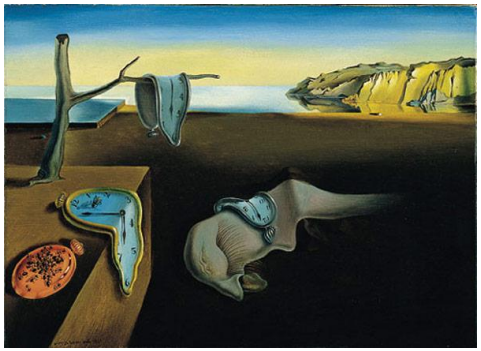


Maximizing the Margin

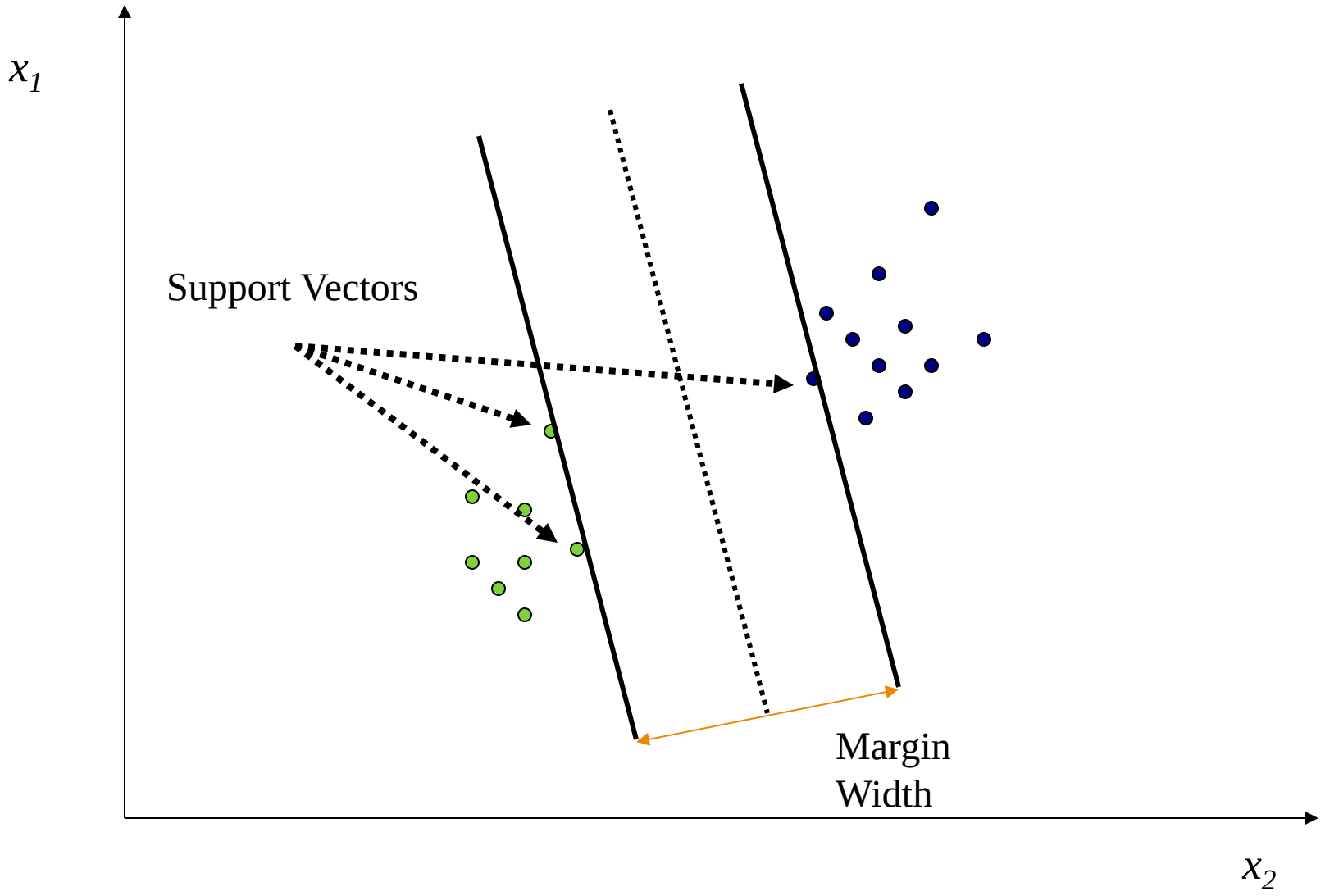


Digression

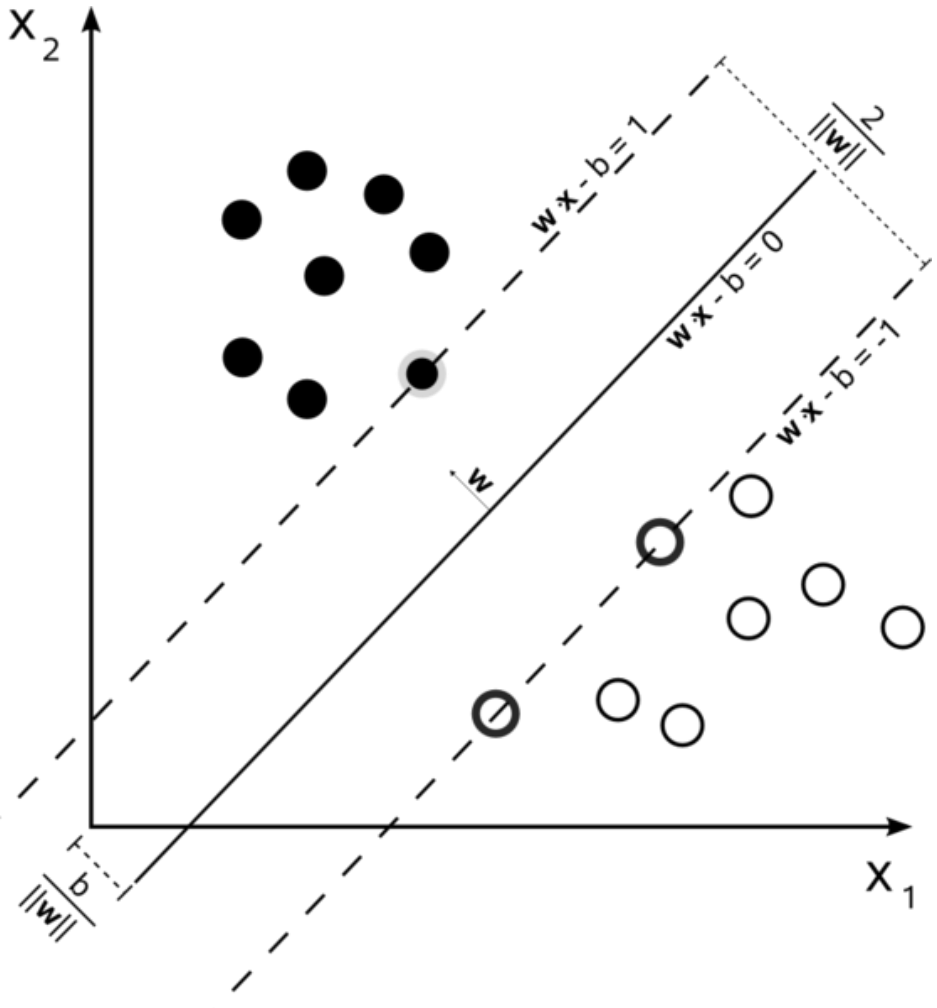
- Why are we drawing straight lines (or planes (or hyperplanes))?
  - Avoids overfitting!



Support Vectors



Finding the Separating Hyperplane



$$\min_{w,b} ||\boldsymbol{w}||$$

With two constraints:

Class 1 data obeys

$$\boldsymbol{wx_i} - b \leq -1$$

And class 2 data obeys

$$\boldsymbol{wx_i} - b \geq 1$$

Don’t be scared of the math!

What does this have to do with email?

- How do we represent our email as a number?

- Approach: First byte is our first dimension. Second byte is our second dimension, etc.
  - Is this a good idea?

What does this have to do with email?

- “C H E A P V1agra www.viagra4man.ru no prescription required”

- Better approach, create a feature vector!

Example of a Feature Vector

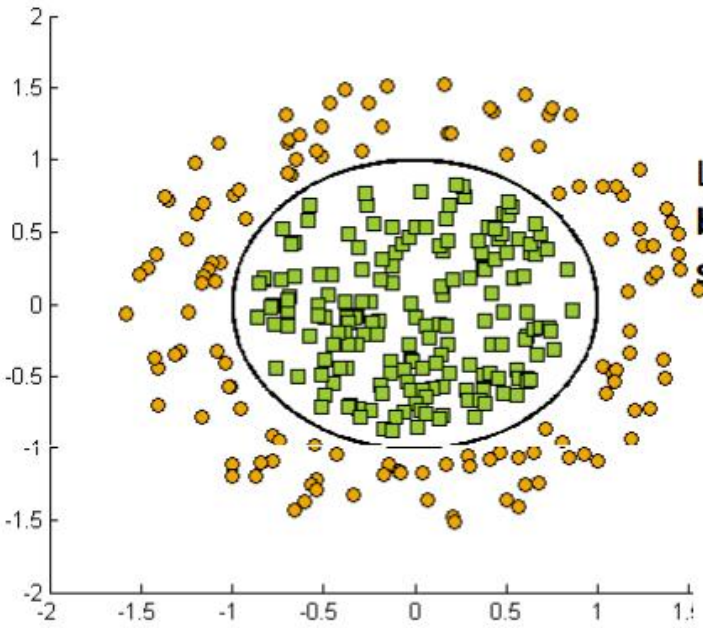
"… the last time I'll trust a monkey. What would a monkey do with a shirt anyway?"

- Example: Feature TF vector:
  - {1, 3, 0, 0, 0, 0, 0, …., 1, 0, 0, …, 2, 0, ….}

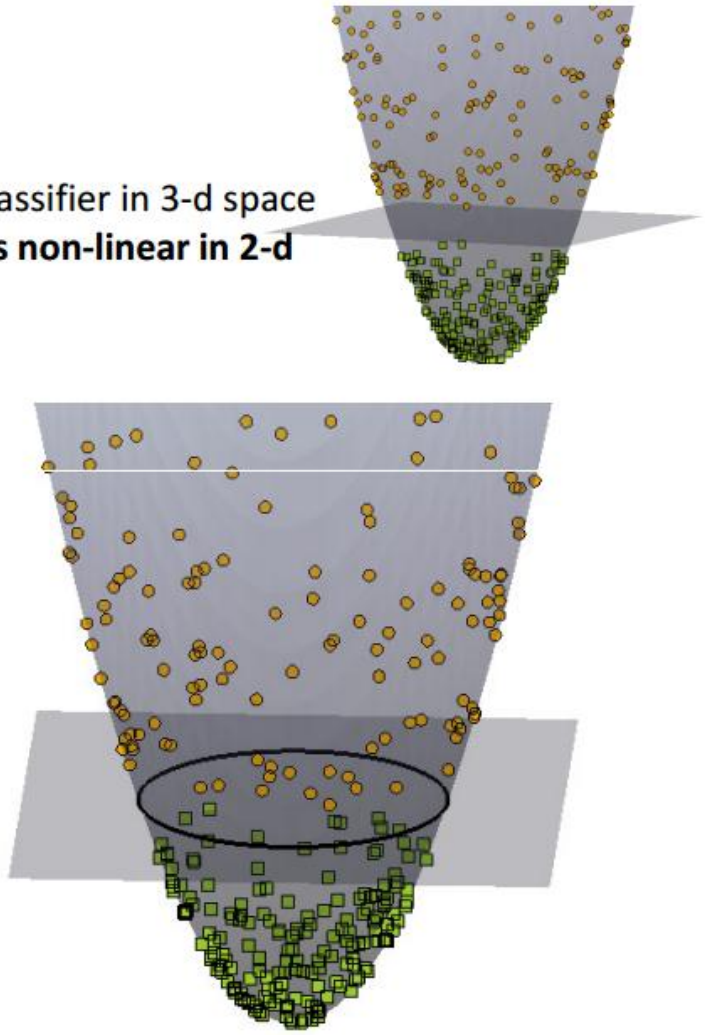
- Feature vector variants:
  - Could weight uncommon words more highly.
  - Could normalize the total size of the vector.

- Question:
  - What data structure might we want to use when building this vector?
  - When using the SVM to see if a particular email is spam?

The Kernel Trick



Linear classifier in 3-d space **becomes non-linear in 2-d space!**

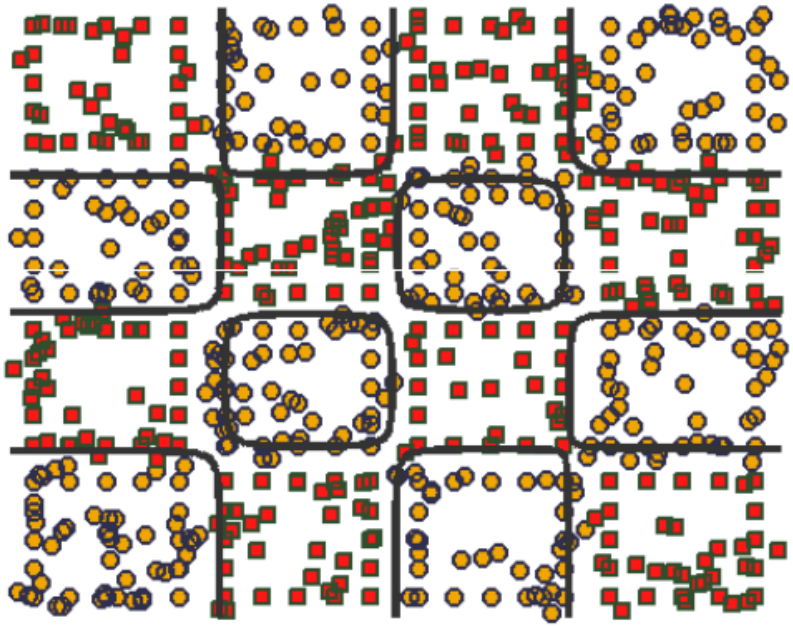


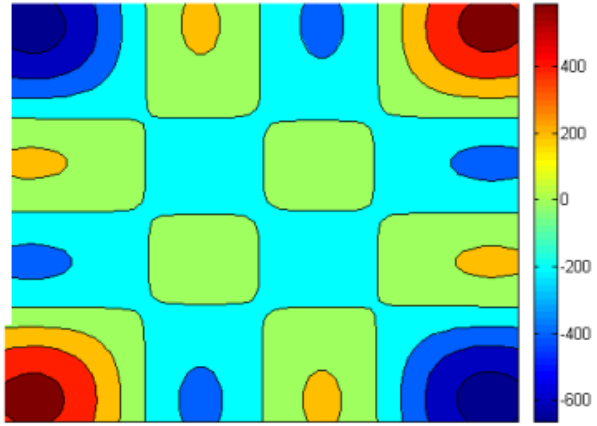
Naïve solution: Transform the input data into a higher dimension using the following nonlinear transformation:

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \rightarrow \begin{bmatrix} x_1^2 \\ \sqrt{2}x_1x_2 \\ x_2^2 \end{bmatrix}$$

Gaussian Kernel

$$\kappa(\mathbf{x}, \mathbf{z}) = \exp - \frac{\|\mathbf{x}-\mathbf{z}\|^2}{\sigma}$$

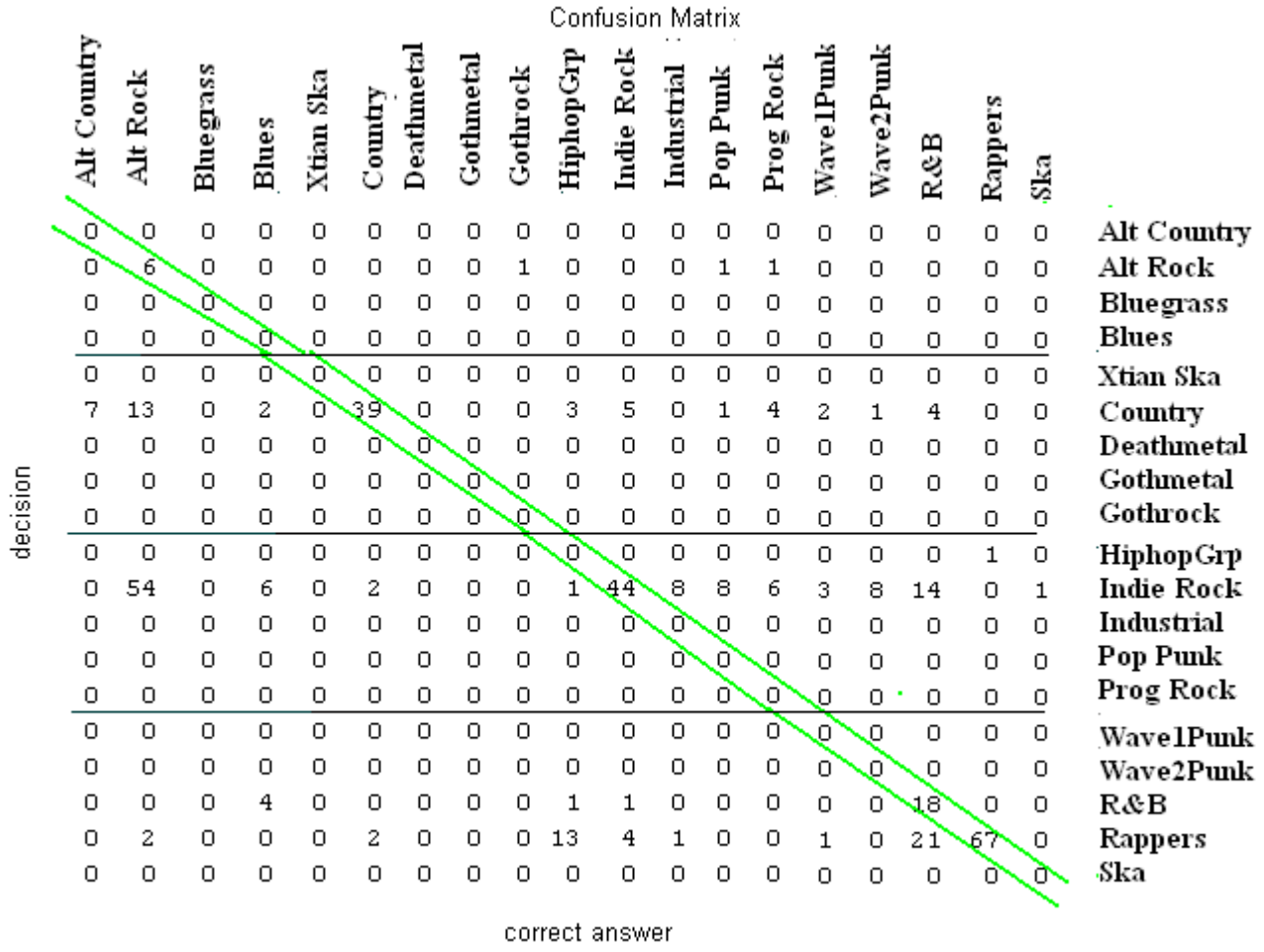




Machine Learning

- SVM: Solves binary classification
- Many other problems
  - Multiway classification
  - Regression
  - Clustering

Music Genre Classification



decision \ correct answer	Alt Country	Alt Rock	Bluegrass	Blues	Xtian Ska	Country	Deathmetal	Gothmetal	Gothrock	HiphopGrp	Indie Rock	Industrial	Pop Punk	Prog Rock	Wave1Punk	Wave2Punk	R&B	Rappers	Ska
Alt Country	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alt Rock	0	6	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0
Bluegrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blues	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xtian Ska	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Country	7	13	0	2	0	39	0	0	0	3	5	0	1	4	2	1	4	0	0
Deathmetal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gothmetal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gothrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HiphopGrp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Indie Rock	0	54	0	6	0	2	0	0	0	1	44	8	8	6	3	8	14	0	1
Industrial	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pop Punk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prog Rock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wave1Punk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wave2Punk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R&B	0	0	0	4	0	0	0	0	0	1	1	0	0	0	0	0	18	0	0
Rappers	0	2	0	0	0	2	0	0	0	13	4	1	0	0	1	0	21	67	0
Ska	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Related Courses

- COS401 – Intro to Machine Translation
- COS402 – Artificial Intelligence
- COS424 – Interacting with Data

INFERENCE

Forensics, security, privacy

Facebook Likes study

Predictors of high intelligence

- Curly Fries, Colbert Report…

Low intelligence

- Sephora, Harley Davidson…

Sexual orientation: 88% accuracy

Religious affiliation: 82% accuracy

Supermarkets: predictive analytics

Forbes


College Vs. Retirement Savings


Best And Worst Cities For Jobs


How America's Wealthiest Get Rich

TECH | 2/16/2012 @ 11:02AM | 1,458,125 views

How Target Figured Out A Teen Girl Was Pregnant Before Her Father Did

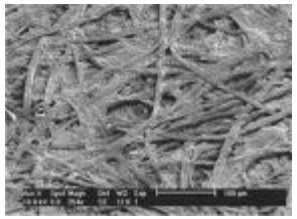
Every time you go shopping, you share intimate details about your consumption patterns with retailers. And many of those retailers are studying those details to figure out what you like, what you need, and which coupons are most likely to make you happy. Target, for example, has figured out how to data-mine its way into your womb, to figure out whether you have a baby on the way long before you need to start buying diapers.

Charles Duhigg outlines in the New York Times

Everything has a Fingerprint





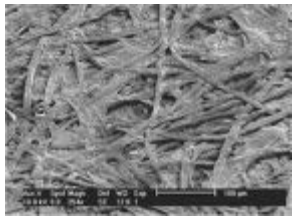


Devices, human behavior and anything in between

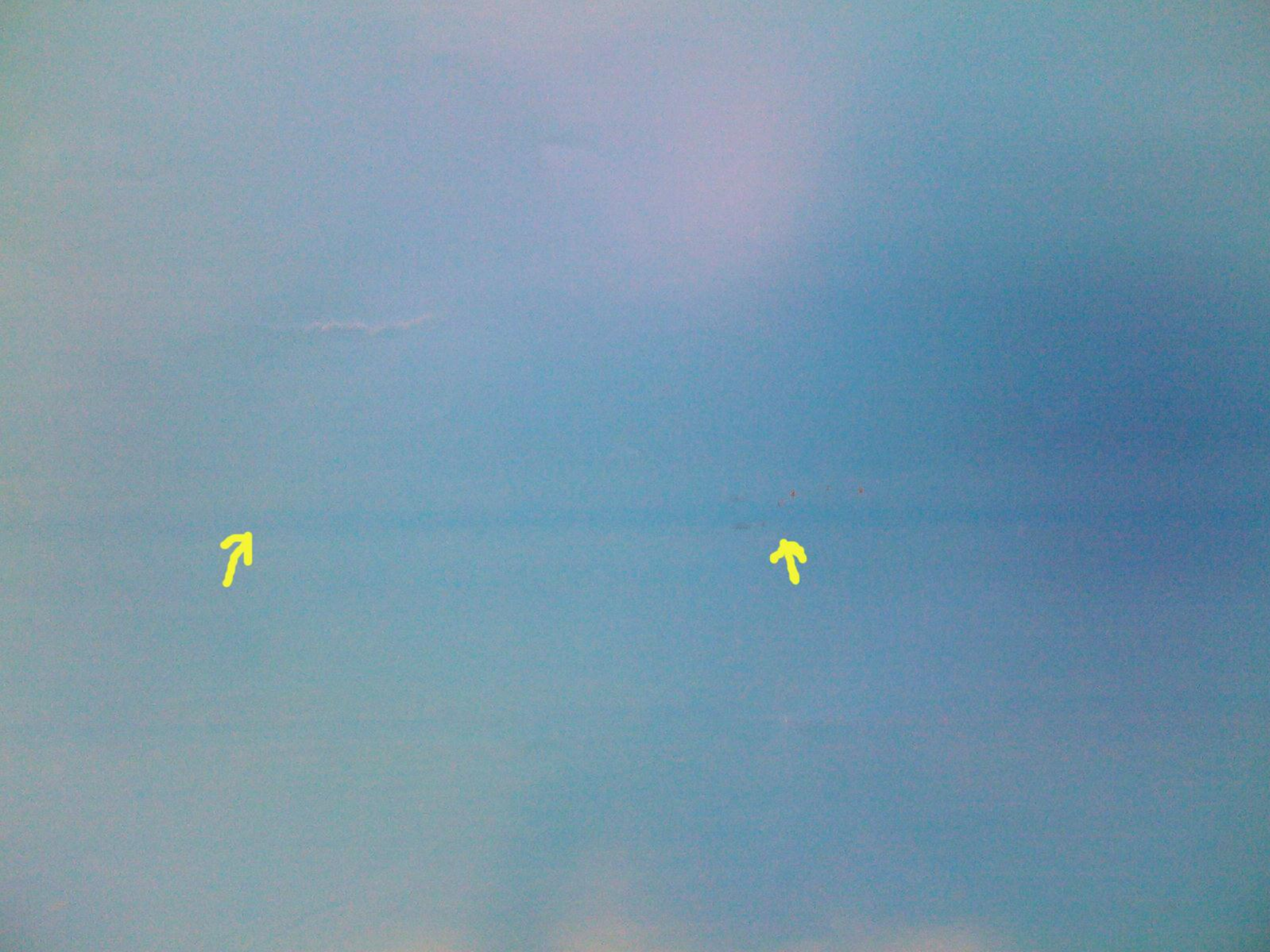
Everything has a Fingerprint



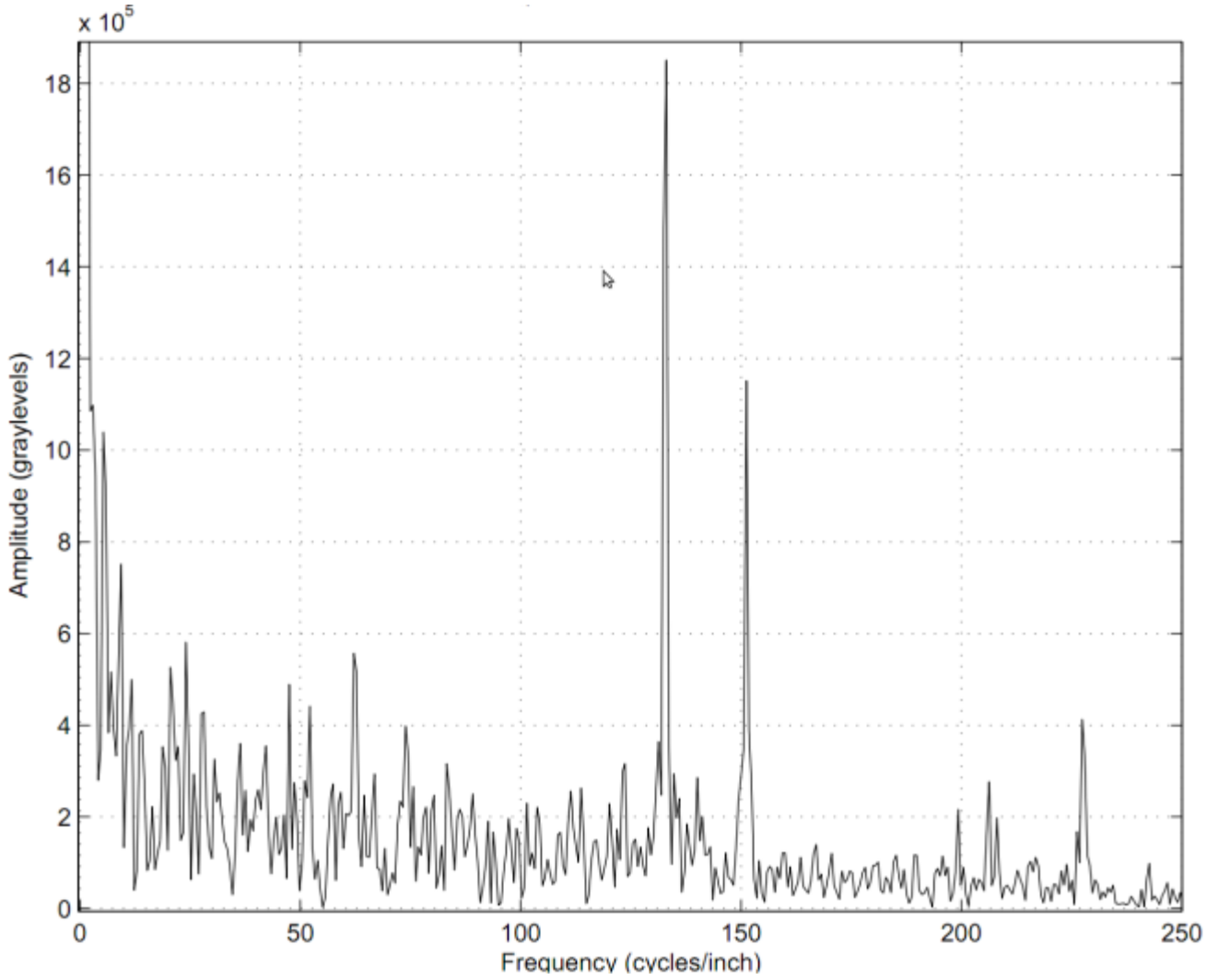




Devices, human behavior and anything in between



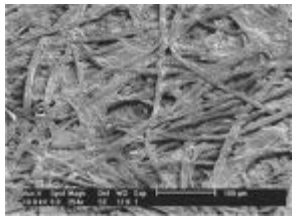
After applying Fourier Transform



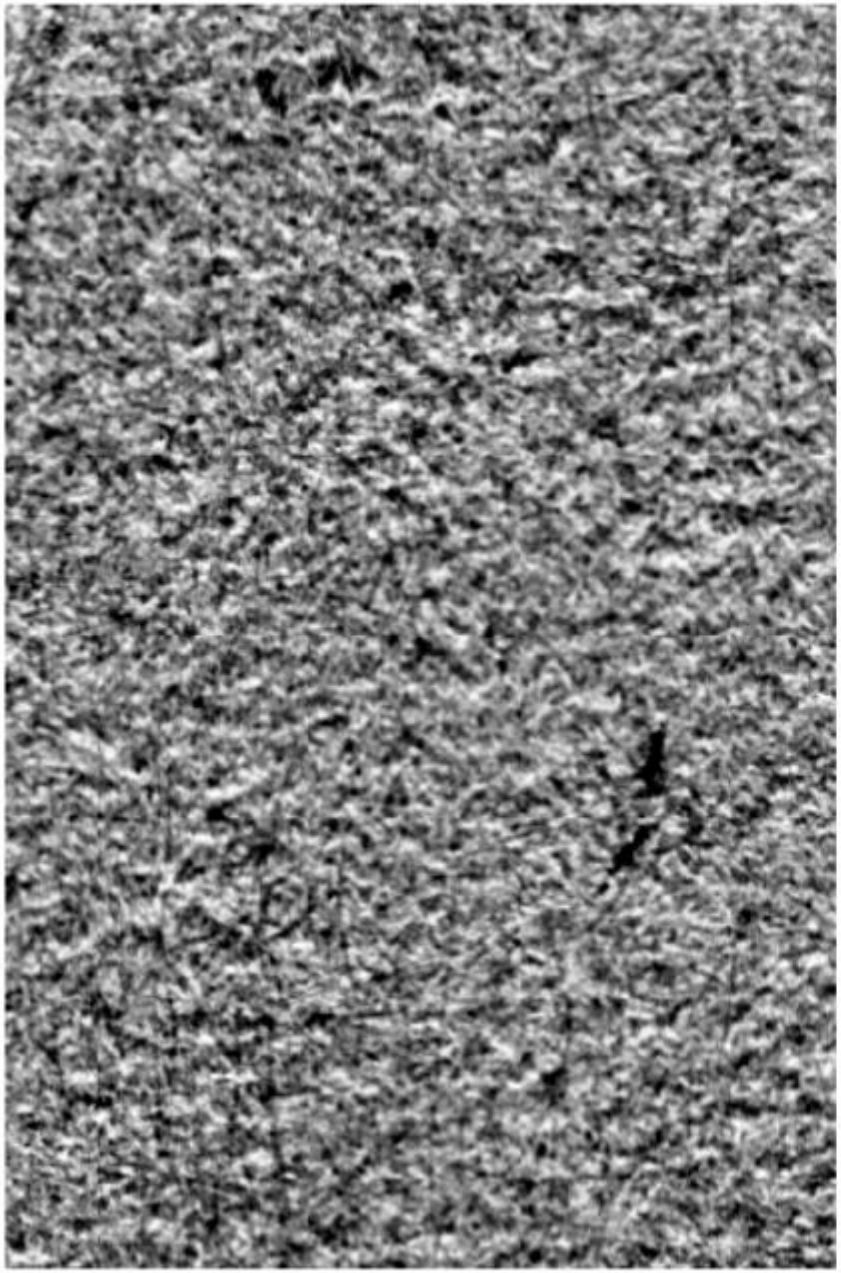
Everything has a Fingerprint

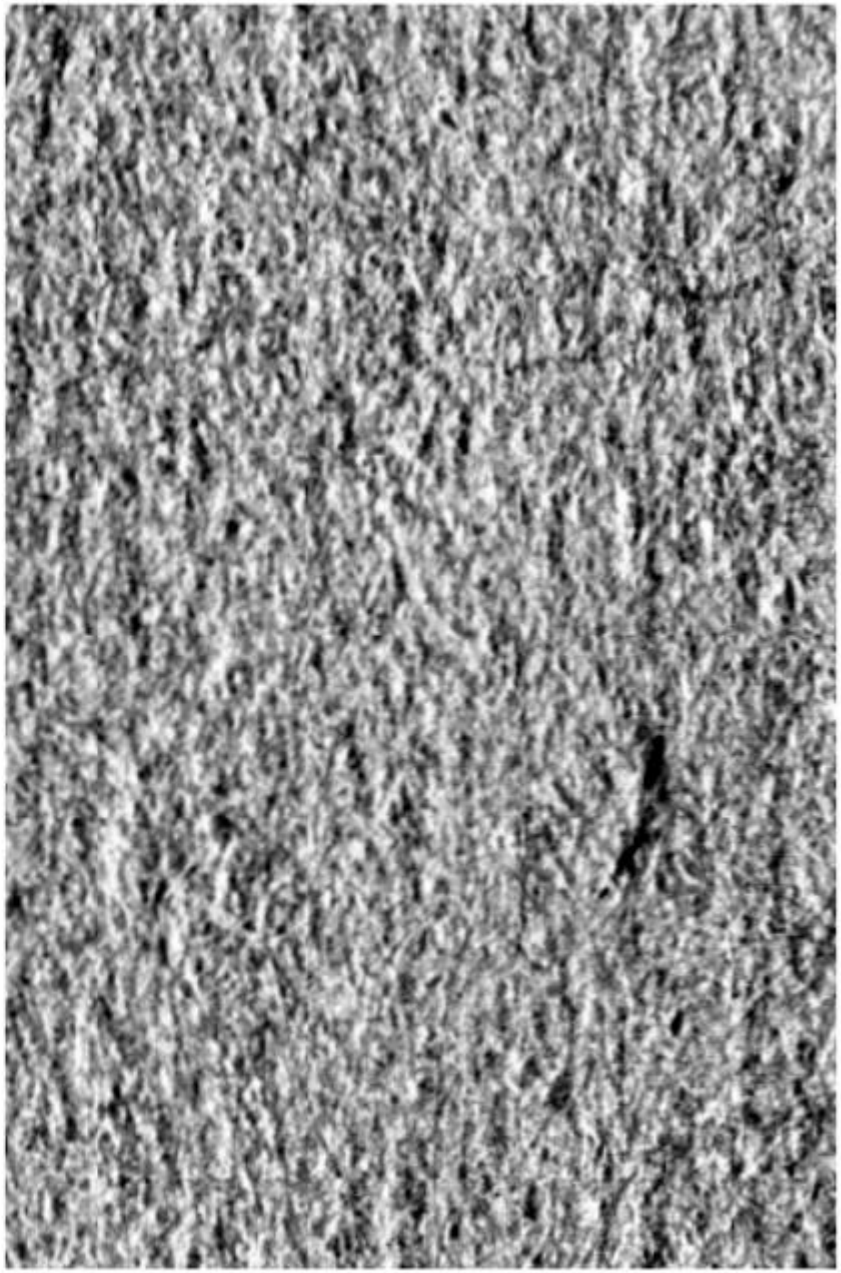






Devices, human behavior and anything in between



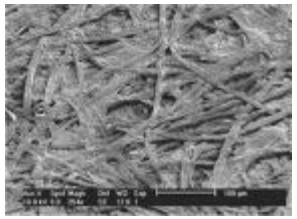


3D structure reconstructed from scans

Everything has a Fingerprint





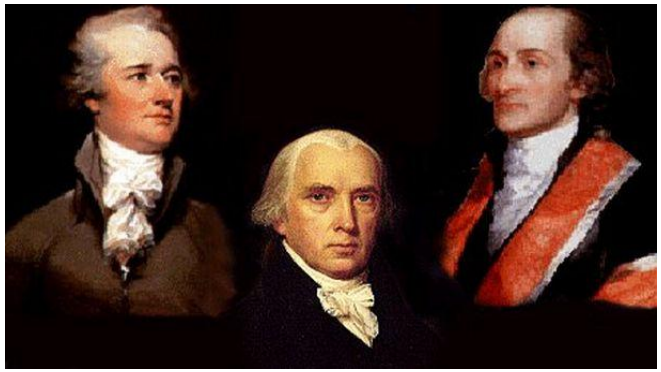


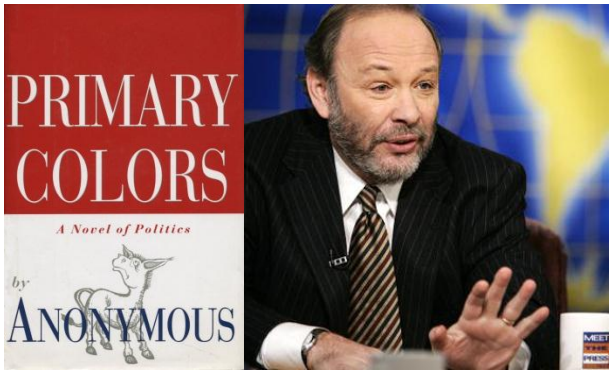
Devices, human behavior and anything in between

What’s being typed?

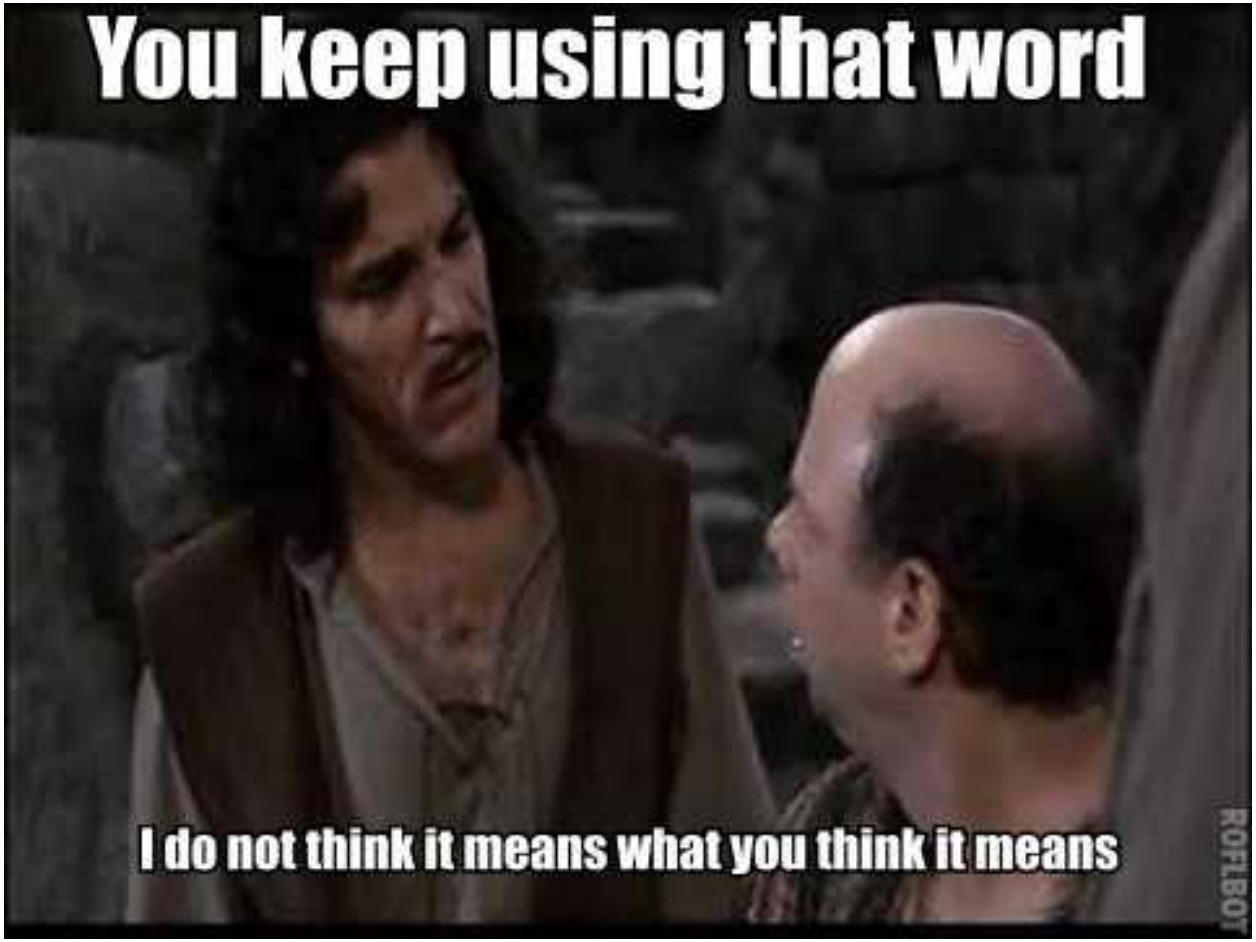
Is writing style sufficient to deanonymize material posted online?

Stylometric author identification: Notable successes

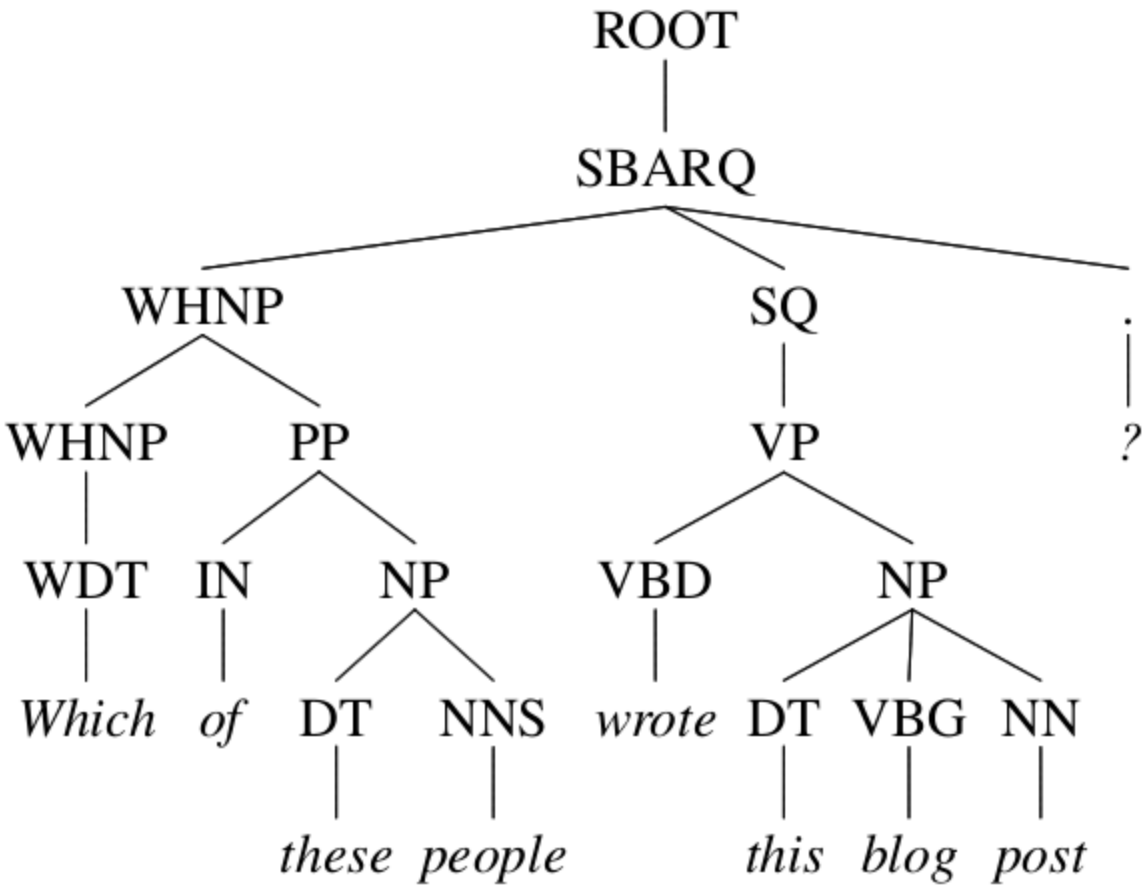




Linguistic Idiosyncracies



A sample parse tree



Say 'Ahhh': A Simpler Way To Detect Parkinson's

by NPR STAFF

July 21, 2012 4:32 PM

Getting a diagnosis for Parkinson's disease might be as easy as placing a phone call.

There's currently no cure for Parkinson's, a debilitating neurological disease. There's also no blood test that can detect it, meaning early intervention is almost impossible.

But soon there might be a shockingly easy way to screen for Parkinson's disease. It would be as simple as picking up the telephone and saying "ahhh."

"There's some evidence, admittedly weak, that voice disturbances may well be one of the first or early indicator of the disease," mathematician Max Little tells weekends on *All Things Considered* host Guy Raz.

Related Courses

- COS432 – Computer Security
- COS402 – Artificial Intelligence
- COS511 – Foundations of Machine learning

DYNAMICAL SYSTEMS

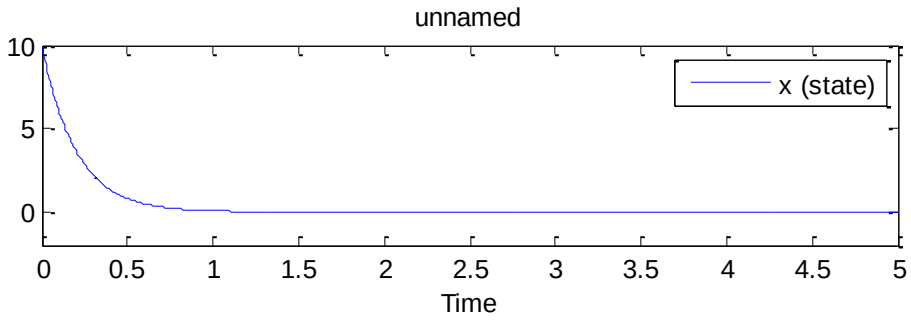
Actual Chaos

http://www.youtube.com/watch?v=pYPRnxS6uAw

Simulated Chaos

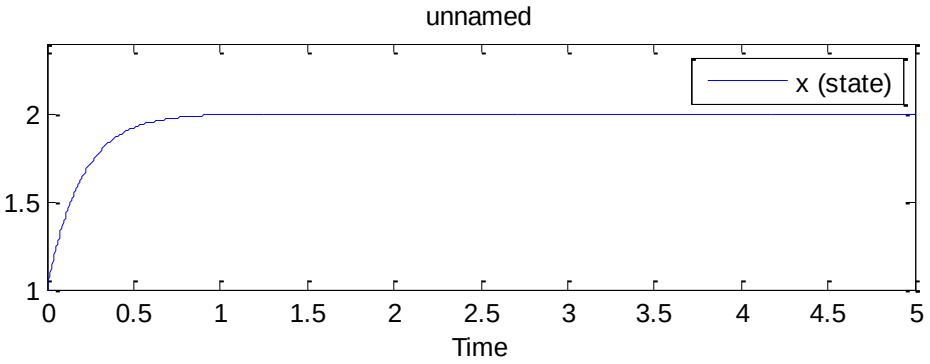
Population Dynamics

$$\frac{dx_1}{dt} = -dx_1$$



$p = 10, \qquad x_1(0) = 10$

$$\frac{dx_1}{dt} = p - dx_1$$



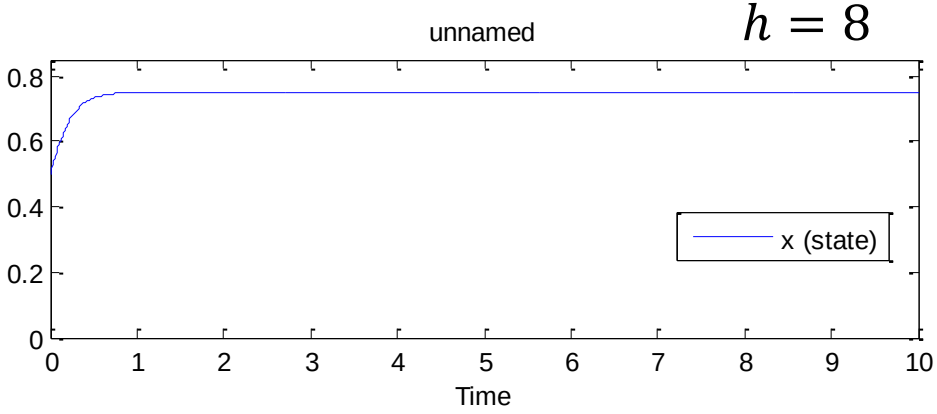
$p = 10, d = 5, x_1(0) = 1$

Population Dynamics

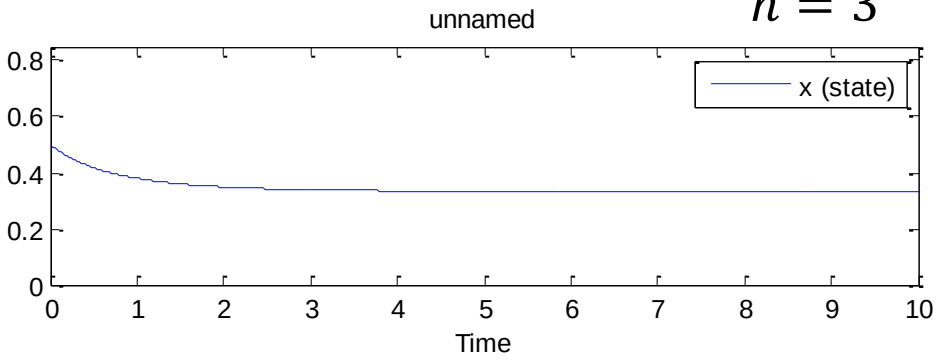
$$\frac{dx_1}{dt} = chx_1(1 - x_1) - dx_1$$

- c: colonization rate
- h: habitat availability
- x_1: population

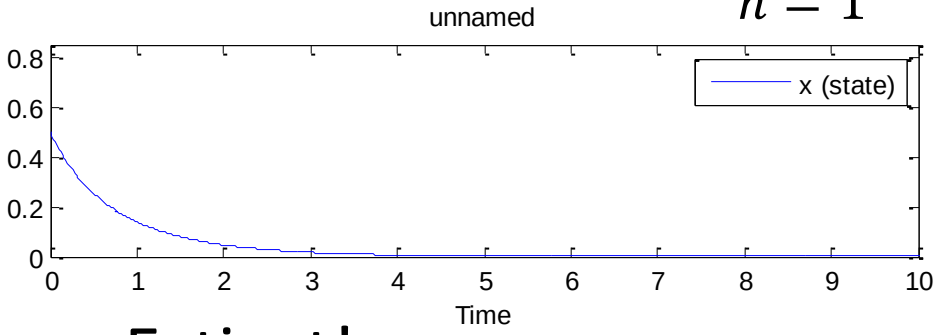
$h = 8$



$h = 3$

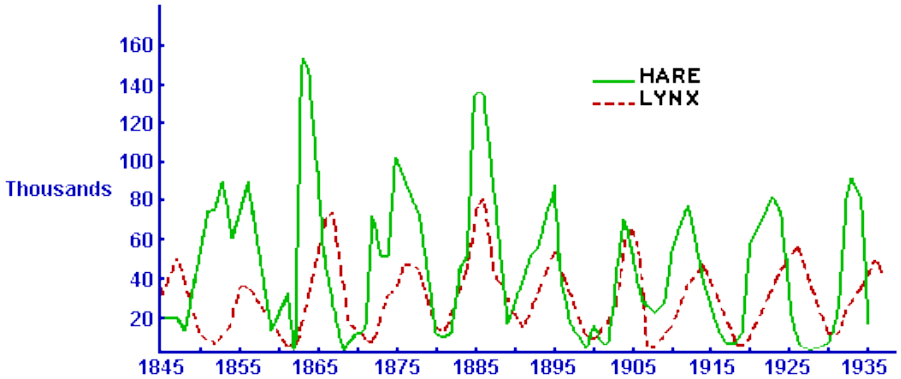


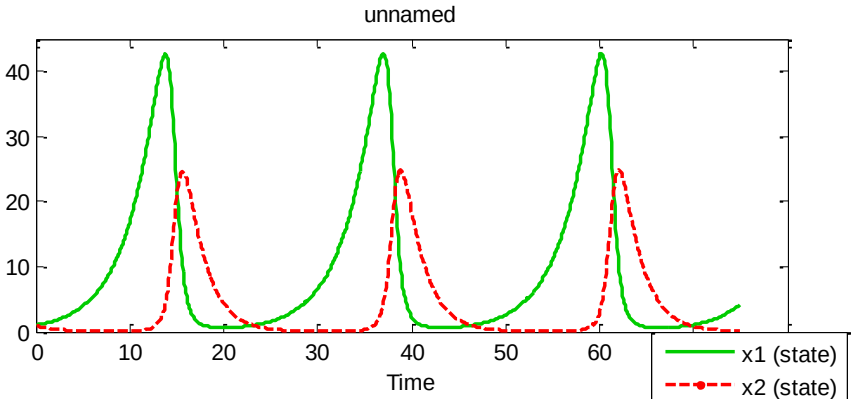
$h = 1$



Extinct!

Predator prey





- $\frac{dx_1}{dt} = b_1 x_1 - d_1 x_1 x_2$
- $\frac{dx_2}{dt} = -d_2 x_2 + b_2 x_1 x_2$
  - d_i: death rates
  - b_i: birth rates

ODEs and PDEs

- Often relatively easy to specify.
- Often very hard to analyze.
  - Symbolic analysis is tough.
  - Simulation is often much easier.

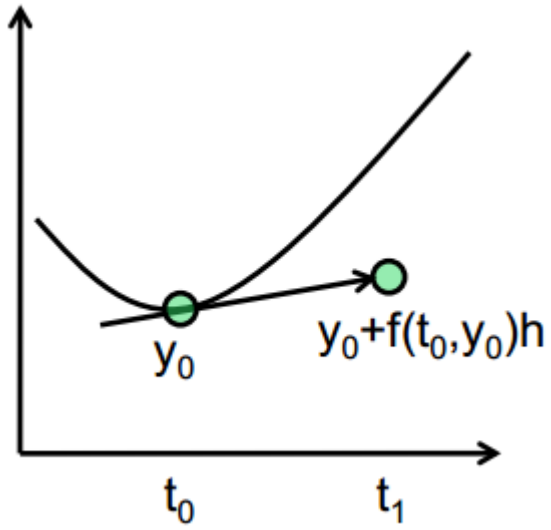
$$\{c1^2\,c2\,d^3\,k^2\,L2\,L3 + c1^3\,c2\,d\,k^3\,L2\,L3 + 2\,c1^2\,c2\,d^2\,k^2\,L1\,L2\,L3 + c1^3\,c2\,k^3\,L1\,L2\,L3 + c1^2\,c2\,d\,k^2\,L1^2\,L2\,L3 + d^7\,L2^2\,L3 + 2\,c1\,d^5\,k\,L2^2\,L3 + c1^2\,d^3\,k^2\,L2^2\,L3 + 4\,d^6\,L1\,L2^2\,L3 + 6\,c1\,d^4\,k\,L1\,L2^2\,L3 + 2\,c1^2\,d^2\,k^2\,L1\,L2^2\,L3 + 6\,d^5\,L1^2\,L2^2\,L3 + 6\,c1\,d^3\,k\,L1^2\,L2^2\,L3 + c1^2\,d\,k^2\,L1^2\,L2^2\,L3 + 4\,d^4\,L1^3\,L2^2\,L3 + 2\,c1\,d^2\,k\,L1^3\,L2^2\,L3 + d^3\,L1^4\,L2^2\,L3 + d^7\,L2^2\,r + 2\,c1\,d^5\,k\,L2^2\,r + c1^2\,d^3\,k^2\,L2^2\,r + 4\,d^6\,L1\,L2^2\,r + 6\,c1\,d^4\,k\,L1\,L2^2\,r + 2\,c1^2\,d^2\,k^2\,L1\,L2^2\,r + 6\,d^5\,L1^2\,L2^2\,r + 6\,c1\,d^3\,k\,L1^2\,L2^2\,r + c1^2\,d\,k^2\,L1^2\,L2^2\,r + 4\,d^4\,L1^3\,L2^2\,r + 2\,c1\,d^2\,k\,L1^3\,L2^2\,r + d^3\,L1^4\,L2^2\,r + c1^2\,c2\,d^3\,k^2\,L3\,r + 2\,c1^2\,c2\,d^2\,k^2\,L1\,L3\,r + c1^2\,c2\,d\,k^2\,L1^2\,L3\,r + 2\,d^7\,L2\,L3\,r + 2\,c1\,d^5\,k\,L2\,L3\,r + 3\,c1^2\,c2\,d^2\,k^2\,L2\,L3\,r + c1^3\,c2\,k^3\,L2\,L3\,r + 8\,d^6\,L1\,L2\,L3\,r + 6\,c1\,d^4\,k\,L1\,L2\,L3\,r + 4\,c1^2\,c2\,d\,k^2\,L1\,L2\,L3\,r + 12\,d^5\,L1^2\,L2\,L3\,r + 6\,c1\,d^3\,k\,L1^2\,L2\,L3\,r + c1^2\,c2\,k^2\,L1^2\,L2\,L3\,r + 8\,d^4\,L1^3\,L2\,L3\,r + 2\,c1\,d^2\,k\,L1^3\,L2\,L3\,r + 2\,d^3\,L1^4\,L2\,L3\,r + 7\,d^6\,L2^2\,L3\,r + 10\,c1\,d^4\,k\,L2^2\,L3\,r + 3\,c1^2\,d^2\,k^2\,L2^2\,L3\,r + 24\,d^5\,L1\,L2^2\,L3\,r + 24\,c1\,d^3\,k\,L1\,L2^2\,L3\,r + 4\,c1^2\,d\,k^2\,L1\,L2^2\,L3\,r + 30\,d^4\,L1^2\,L2^2\,L3\,r + 18\,c1\,d^2\,k\,L1^2\,L2^2\,L3\,r + c1^2\,k^2\,L1^2\,L2^2\,L3\,r + 16\,d^3\,L1^3\,L2^2\,L3\,r + 4\,c1\,d\,k\,L1^3\,L2^2\,L3\,r + 3\,d^2\,L1^4\,L2^2\,L3\,r + 2\,d^7\,L2\,r^2 + 2\,c1\,d^5\,k\,L2\,r^2 + 8\,d^6\,L1\,L2\,r^2 + 6\,c1\,d^4\,k\,L1\,L2\,r^2 + 12\,d^5\,L1^2\,L2\,r^2 + 6\,c1\,d^3\,k\,L1^2\,L2\,r^2 + 8\,d^4\,L1^3\,L2\,r^2 + 2\,c1\,d^2\,k\,L1^3\,L2\,r^2 + 2\,d^3\,L1^4\,L2\,r^2 + 7\,d^6\,L2^2\,r^2 + 10\,c1\,d^4\,k\,L2^2\,r^2 + 3\,c1^2\,d^2\,k^2\,L2^2\,r^2 + 24\,d^5\,L1\,L2^2\,r^2 + 24\,c1\,d^3\,k\,L1\,L2^2\,r^2 + 4\,c1^2\,d\,k^2\,L1\,L2^2\,r^2 + 30\,d^4\,L1^2\,L2^2\,r^2 + 18\,c1\,d^2\,k\,L1^2\,L2^2\,r^2 + c1^2\,k^2\,L1^2\,L2^2\,r^2 + 16\,d^3\,L1^3\,L2^2\,r^2 + 4\,c1\,d\,k\,L1^3\,L2^2\,r^2 + 3\,d^2\,L1^4\,L2^2\,r^2 + d^7\,L3\,r^2 + 3\,c1^2\,c2\,d^2\,k^2\,L3\,r^2 + 4\,d^6\,L1\,L3\,r^2 + 4\,c1^2\,c2\,d\,k^2\,L1\,L3\,r^2 + 6\,d^5\,L1^2\,L3\,r^2 + c1^2\,c2\,k^2\,L1^2\,L3\,r^2 + 4\,d^4\,L1^3\,L3\,r^2 + d^3\,L1^4\,L3\,r^2 + 14\,d^6\,L2\,L3\,r^2 + 10\,c1\,d^4\,k\,L2\,L3\,r^2 + 3\,c1^2\,c2\,d\,k^2\,L2\,L3\,r^2 + 48\,d^5\,L1\,L2\,L3\,r^2 + 24\,c1\,d^3\,k\,L1\,L2\,L3\,r^2 + 2\,c1^2\,c2\,k^2\,L1\,L2\,L3\,r^2 + 60\,d^4\,L1^2\,L2\,L3\,r^2 + 18\,c1\,d^2\,k\,L1^2\,L2\,L3\,r^2 + 32\,d^3\,L1^3\,L2\,L3\,r^2 + 4\,c1\,d\,k\,L1^3\,L2\,L3\,r^2 + 6\,d^2\,L1^4\,L2\,L3\,r^2 + 21\,d^5\,L2^2\,L3\,r^2 + 20\,c1\,d^3\,k\,L2^2\,L3\,r^2 + 3\,c1^2\,d\,k^2\,L2^2\,L3\,r^2 + 60\,d^4\,L1\,L2^2\,L3\,r^2 + 36\,c1\,d^2\,k\,L1\,L2^2\,L3\,r^2 + 2\,c1^2\,k^2\,L1\,L2^2\,L3\,r^2 + 60\,d^3\,L1^2\,L2^2\,L3\,r^2 + 18\,c1\,d\,k\,L1^2\,L2^2\,L3\,r^2 + 24\,d^2\,L1^3\,L2^2\,L3\,r^2 + 2\,c1\,k\,L1^3\,L2^2\,L3\,r^2 + 3\,d\,L1^4\,L2^2\,L3\,r^2 + d^7\,r^3 + 4\,d^6\,L1\,r^3 + 6\,d^5\,L1^2\,r^3 + 4\,d^4\,L1^3\,r^3 + d^3\,L1^4\,r^3 + 14\,d^6\,L2\,r^3 + 10\,c1\,d^4\,k\,L2\,r^3 + 48\,d^5\,L1\,L2\,r^3 + 24\,c1\,d^3\,k\,L1\,L2\,r^3 + 60\,d^4\,L1^2\,L2\,r^3 + 18\,c1\,d^2\,k\,L1^2\,L2\,r^3 + 32\,d^3\,L1^3\,L2\,r^3 + 4\,c1\,d\,k\,L1^3\,L2\,r^3 + 6\,d^2\,L1^4\,L2\,r^3 + 21\,d^5\,L2^2\,r^3 + 20\,c1\,d^3\,k\,L2^2\,r^3 + 3\,c1^2\,d\,k^2\,L2^2\,r^3 + 60\,d^4\,L1\,L2^2\,r^3 + 36\,c1\,d^2\,k\,L1\,L2^2\,r^3 + 2\,c1^2\,k^2\,L1\,L2^2\,r^3 + 60\,d^3\,L1^2\,L2^2\,r^3 + 18\,c1\,d\,k\,L1^2\,L2^2\,r^3 + 24\,d^2\,L1^3\,L2^2\,r^3 + 2\,c1\,k\,L1^3\,L2^2\,r^3 + 3\,d\,L1^4\,L2^2\,r^3 + 7\,d^6\,L3\,r^3 + 3\,c1^2\,c2\,d\,k^2\,L3\,r^3 + 24\,d^5\,L1\,L3\,r^3 + 2\,c1^2\,c2\,k^2\,L1\,L3\,r^3 + 30\,d^4\,L1^2\,L3\,r^3 + 16\,d^3\,L1^3\,L3\,r^3 + 3\,d^2\,L1^4\,L3\,r^3 + 42\,d^5\,L2\,L3\,r^3 + 20\,c1\,d^3\,k\,L2\,L3\,r^3 + c1^2\,c2\,k^2\,L2\,L3\,r^3 + 120\,d^4\,L1\,L2\,L3\,r^3 + 36\,c1\,d^2\,k\,L1\,L2\,L3\,r^3 + 120\,d^3\,L1^2\,L2\,L3\,r^3 + 18\,c1\,d\,k\,L1^2\,L2\,L3\,r^3 + 48\,d^2\,L1^3\,L2\,L3\,r^3 + 2\,c1\,k\,L1^3\,L2\,L3\,r^3 + 6\,d\,L1^4\,L2\,L3\,r^3 + 35\,d^4\,L2^2\,L3\,r^3 + 20\,c1\,d^2\,k\,L2^2\,L3\,r^3 + c1^2\,k^2\,L2^2\,L3\,r^3 + 80\,d^3\,L1\,L2^2\,L3\,r^3 + 24\,c1\,d\,k\,L1\,L2^2\,L3\,r^3 + 60\,d^2\,L1^2\,L2^2\,L3\,r^3 + 6\,c1\,k\,L1^2\,L2^2\,L3\,r^3 + 16\,d\,L1^3\,L2^2\,L3\,r^3 + L1^4\,L2^2\,L3\,r^3 + 7\,d^6\,r^4 + 24\,d^5\,L1\,r^4 + 30\,d^4\,L1^2\,r^4 + 16\,d^3\,L1^3\,r^4 + 3\,d^2\,L1^4\,r^4 + 42\,d^5\,L2\,r^4 + 20\,c1\,d^3\,k\,L2\,r^4 + 120\,d^4\,L1\,L2\,r^4 + 36\,c1\,d^2\,k\,L1\,L2\,r^4 + 120\,d^3\,L1^2\,L2\,r^4 + 18\,c1\,d\,k\,L1^2\,L2\,r^4 + 48\,d^2\,L1^3\,L2\,r^4 + 2\,c1\,k\,L1^3\,L2\,r^4 + 6\,d\,L1^4\,L2\,r^4 + 35\,d^4\,L2^2\,r^4 + 20\,c1\,d^2\,k\,L2^2\,r^4 + c1^2\,k^2\,L2^2\,r^4 + 80\,d^3\,L1\,L2^2\,r^4 + 24\,c1\,d\,k\,L1\,L2^2\,r^4 + 60\,d^2\,L1^2\,L2^2\,r^4 + 6\,c1\,k\,L1^2\,L2^2\,r^4 + 16\,d\,L1^3\,L2^2\,r^4 + L1^4\,L2^2\,r^4 + 21\,d^5\,L3\,r^4 + c1^2\,c2\,k^2\,L3\,r^4 + 60\,d^4\,L1\,L3\,r^4 + 60\,d^3\,L1^2\,L3\,r^4 + 24\,d^2\,L1^3\,L3\,r^4 + 3\,d\,L1^4\,L3\,r^4 + 70\,d^4\,L2\,L3\,r^4 + 20\,c1\,d^2\,k\,L2\,L3\,r^4 + 160\,d^3\,L1\,L2\,L3\,r^4 + 24\,c1\,d\,k\,L1\,L2\,L3\,r^4 + 120\,d^2\,L1^2\,L2\,L3\,r^4 + 6\,c1\,k\,L1^2\,L2\,L3\,r^4 + 32\,d\,L1^3\,L2\,L3\,r^4 + 2\,L1^4\,L2\,L3\,r^4 + 35\,d^3\,L2^2\,L3\,r^4 + 10\,c1\,d\,k\,L2^2\,L3\,r^4 + 60\,d^2\,L1\,L2^2\,L3\,r^4 + 6\,c1\,k\,L1\,L2^2\,L3\,r^4 + 30\,d\,L1^2\,L2^2\,L3\,r^4 + 4\,L1^3\,L2^2\,L3\,r^4 + 21\,d^5\,r^5 + 60\,d^4\,L1\,r^5 + 60\,d^3\,L1^2\,r^5 + 24\,d^2\,L1^3\,r^5 + 3\,d\,L1^4\,r^5 + 70\,d^4\,L2\,r^5 + 20\,c1\,d^2\,k\,L2\,r^5 + 160\,d^3\,L1\,L2\,r^5 + 24\,c1\,d\,k\,L1\,L2\,r^5 + 120\,d^2\,L1^2\,L2\,r^5 + 6\,c1\,k\,L1^2\,L2\,r^5 + 32\,d\,L1^3\,L2\,r^5 + 2\,L1^4\,L2\,r^5 + 35\,d^3\,L2^2\,r^5 + 10\,c1\,d\,k\,L2^2\,r^5 + 60\,d^2\,L1\,L2^2\,r^5 + 6\,c1\,k\,L1\,L2^2\,r^5 + 30\,d\,L1^2\,L2^2\,r^5 + 4\,L1^3\,L2^2\,r^5 + 35\,d^4\,L3\,r^5 + 80\,d^3\,L1\,L3\,r^5 + 60\,d^2\,L1^2\,L3\,r^5 + 16\,d\,L1^3\,L3\,r^5 + L1^4\,L3\,r^5 + 70\,d^3\,L2\,L3\,r^5 + 10\,c1\,d\,k\,L2\,L3\,r^5 + 120\,d^2\,L1\,L2\,L3\,r^5 + 60\,d\,L1^2\,L2\,L3\,r^5 + 8\,L1^3\,L2\,L3\,r^5 + 21\,d^2\,L2^2\,L3\,r^5 + 2\,c1\,k\,L2^2\,L3\,r^5 + 24\,d\,L1\,L2^2\,L3\,r^5 + 6\,L1^2\,L2^2\,L3\,r^5 + 35\,d^4\,r^6 + 80\,d^3\,L1\,r^6 + 60\,d^2\,L1^2\,r^6 + 16\,d\,L1^3\,r^6 + L1^4\,r^6 + 70\,d^3\,L2\,r^6 + 10\,c1\,d\,k\,L2\,r^6 + 120\,d^2\,L1\,L2\,r^6 + 6\,c1\,k\,L1\,L2\,r^6 + 60\,d\,L1^2\,L2\,r^6 + 8\,L1^3\,L2\,r^6 + 21\,d^2\,L2^2\,r^6 + 2\,c1\,k\,L2^2\,r^6 + 24\,d\,L1\,L2^2\,r^6 + 6\,L1^2\,L2^2\,r^6 + 35\,d^3\,L3\,r^6 + 60\,d^2\,L1\,L3\,r^6 + 30\,d\,L1^2\,L3\,r^6 + 4\,L1^3\,L3\,r^6 + 42\,d^2\,L2\,L3\,r^6 + 2\,c1\,k\,L2\,L3\,r^6 + 48\,d\,L1\,L2\,L3\,r^6 + 12\,L1^2\,L2\,L3\,r^6 + 7\,d\,L2^2\,L3\,r^6 + 4\,L1\,L2^2\,L3\,r^6 + 35\,d^3\,r^7 + 60\,d^2\,L1\,r^7 + 30\,d\,L1^2\,r^7 + 4\,L1^3\,r^7 + 42\,d^2\,L2\,r^7 + 2\,c1\,k\,L2\,r^7 + 48\,d\,L1\,L2\,r^7 + 12\,L1^2\,L2\,r^7 + 7\,d\,L2^2\,r^7 + 4\,L1\,L2^2\,r^7 + 21\,d^2\,L3\,r^7 + 24\,d\,L1\,L3\,r^7 + 6\,L1^2\,L3\,r^7 + 14\,d\,L2\,L3\,r^7 + 8\,L1\,L2\,L3\,r^7 + L2^2\,L3\,r^7 + 21\,d^2\,r^8 + 24\,d\,L1\,r^8 + 6\,L1^2\,r^8 + 14\,d\,L2\,r^8 + 8\,L1\,L2\,r^8 + L2^2\,r^8 + 7\,d\,L3\,r^8 + 4\,L1\,L3\,r^8 + 2\,L2\,L3\,r^8 + 7\,d\,r^9 + 4\,L1\,r^9 + 2\,L2\,r^9 + L3\,r^9 + r^{10}\}$$

Steady State output of Kinase Cascade Model that I explored in grad school

Euler's method

$$\frac{dy}{dt} = f(t, y)$$

- Suppose we know $y = y_0$ at $t = t_0$
- What is y_1 at time $t_1 = t_0 + h$?
  - $y_1 = y_0 + f(t_0, y_0)h$



Runge-Kutta

- Key idea:
  - Use multiple values of t

- Example:
  - $y_{i+1} = y_i + (0.5k_1 + 0.5k_2)h$
    - $k_1 = f(t_i, y_i)$
    - $k_2 = f(t_i + h, y_i + k_1 h)$

- Compare to Euler:
  - $y_1 = y_0 + f(t_0, y_0)h$

One big question

- What time step should we use?
  - Fixed time step.
  - Better: Adaptive time steps.

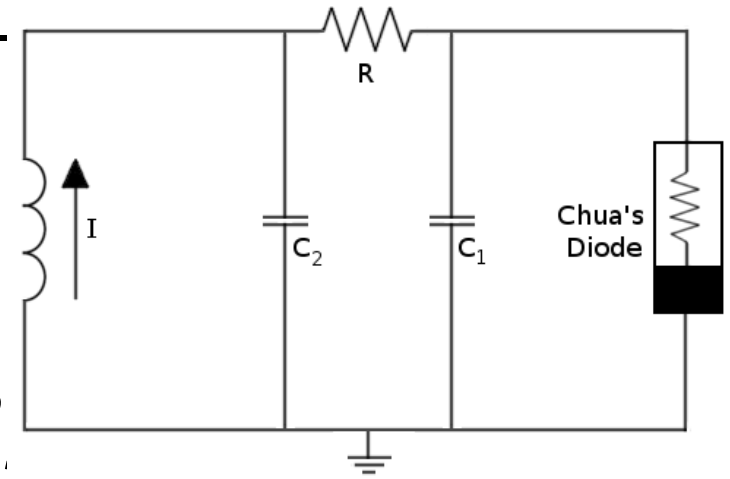
- Vast space of accuracy vs. time tradeoffs!

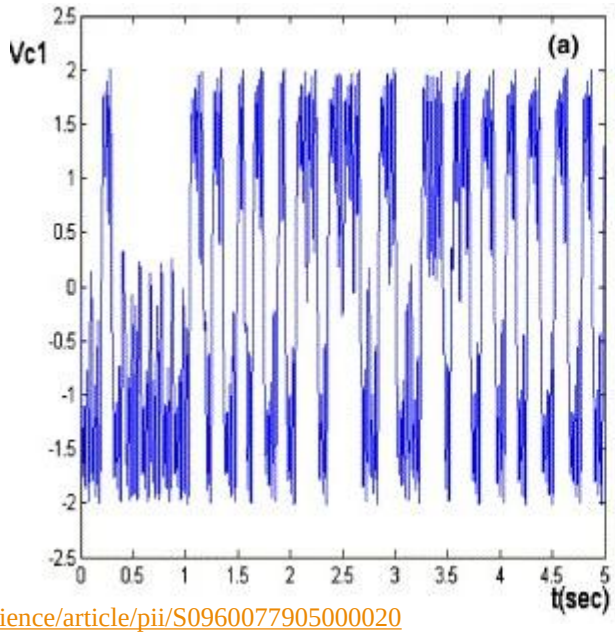
Simulated Circuit Chaos

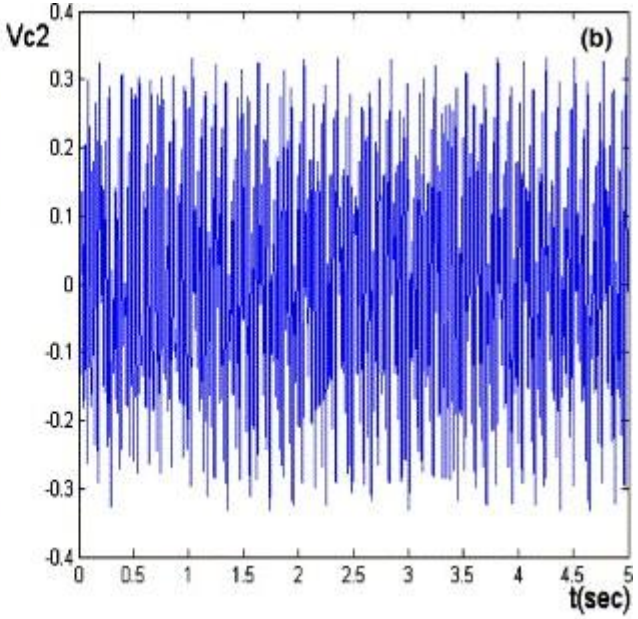
$$\frac{dx}{dt} = \alpha[y - x -$$

$$\frac{dy}{dt} = x - y$$

$$\frac{dz}{dt} = -\beta$$







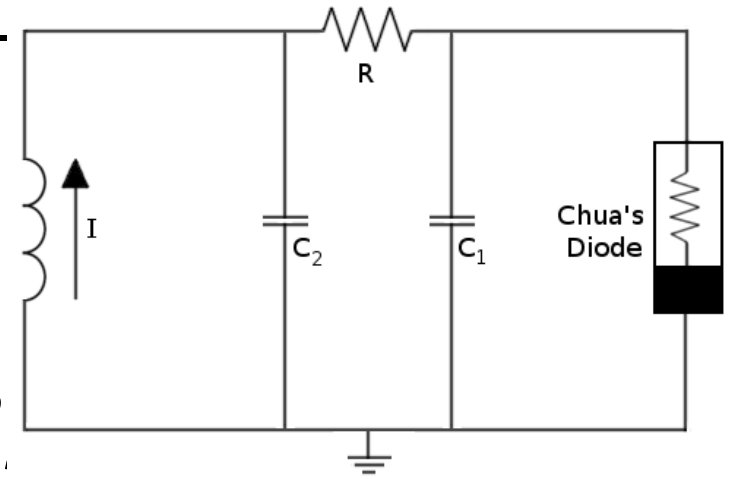
http://www.sciencedirect.com/science/article/pii/S0960077905000020

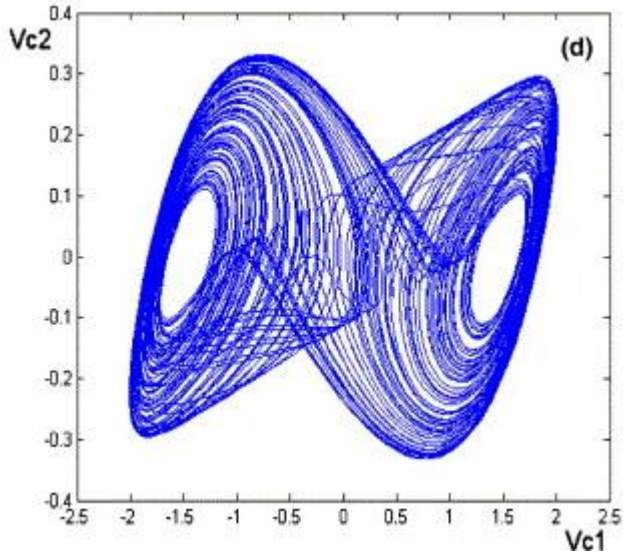
Simulated Circuit Chaos

$$\frac{dx}{dt} = \alpha[y - x -$$

$$\frac{dy}{dt} = x - y$$

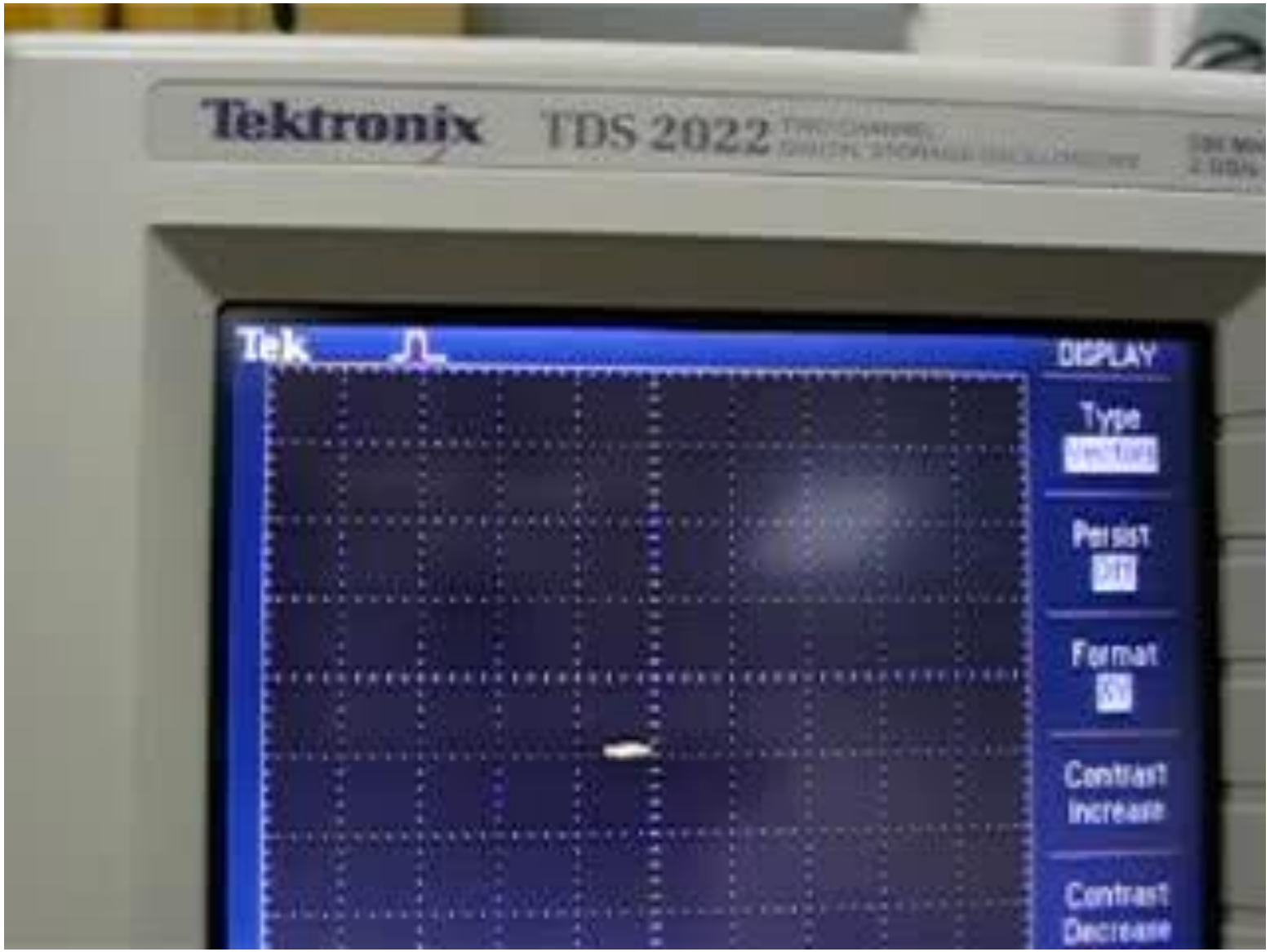
$$\frac{dz}{dt} = -\beta$$



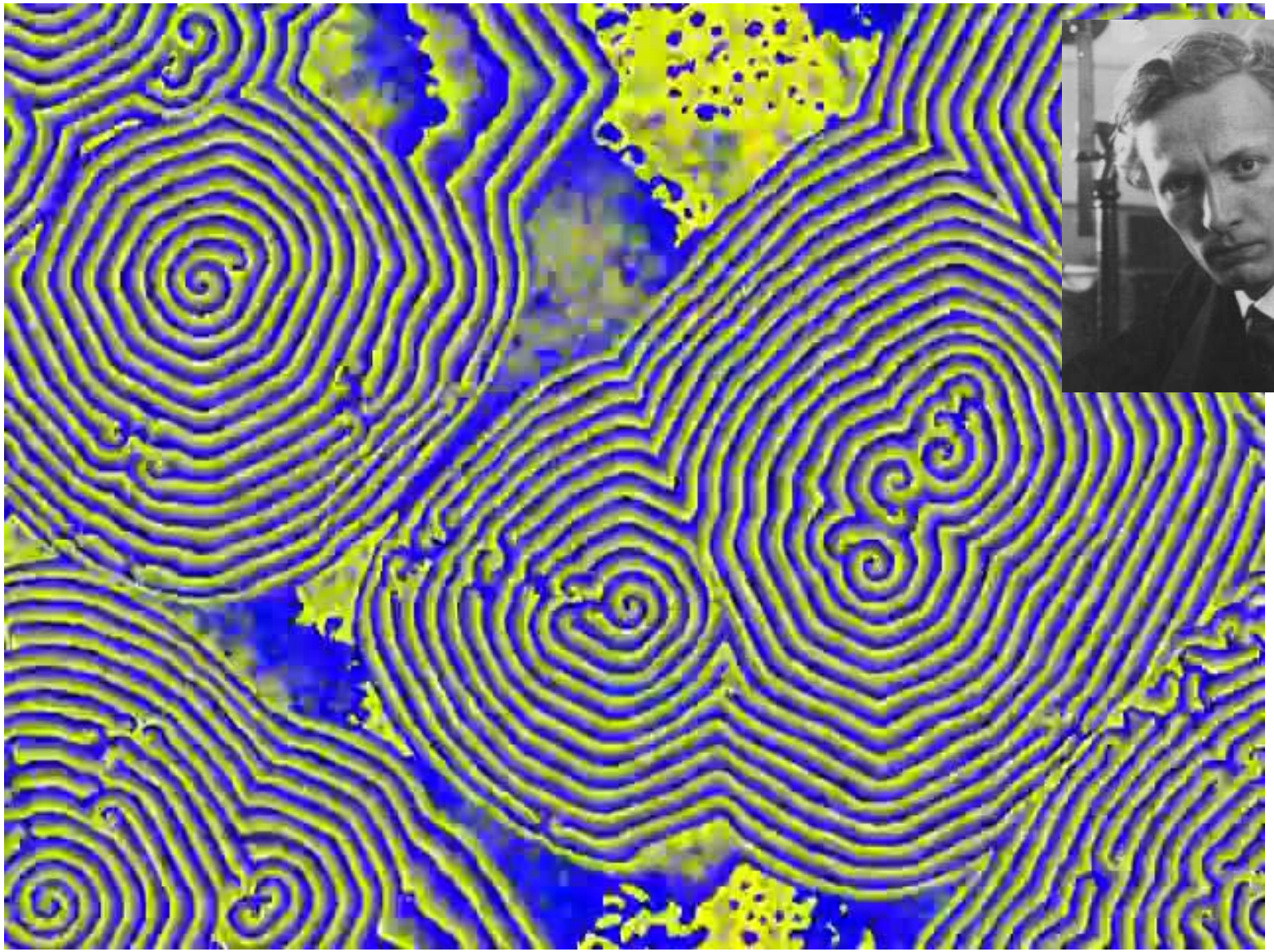


http://www.sciencedirect.com/science/article/pii/S0960077905000020

Chua's Circuit in Action

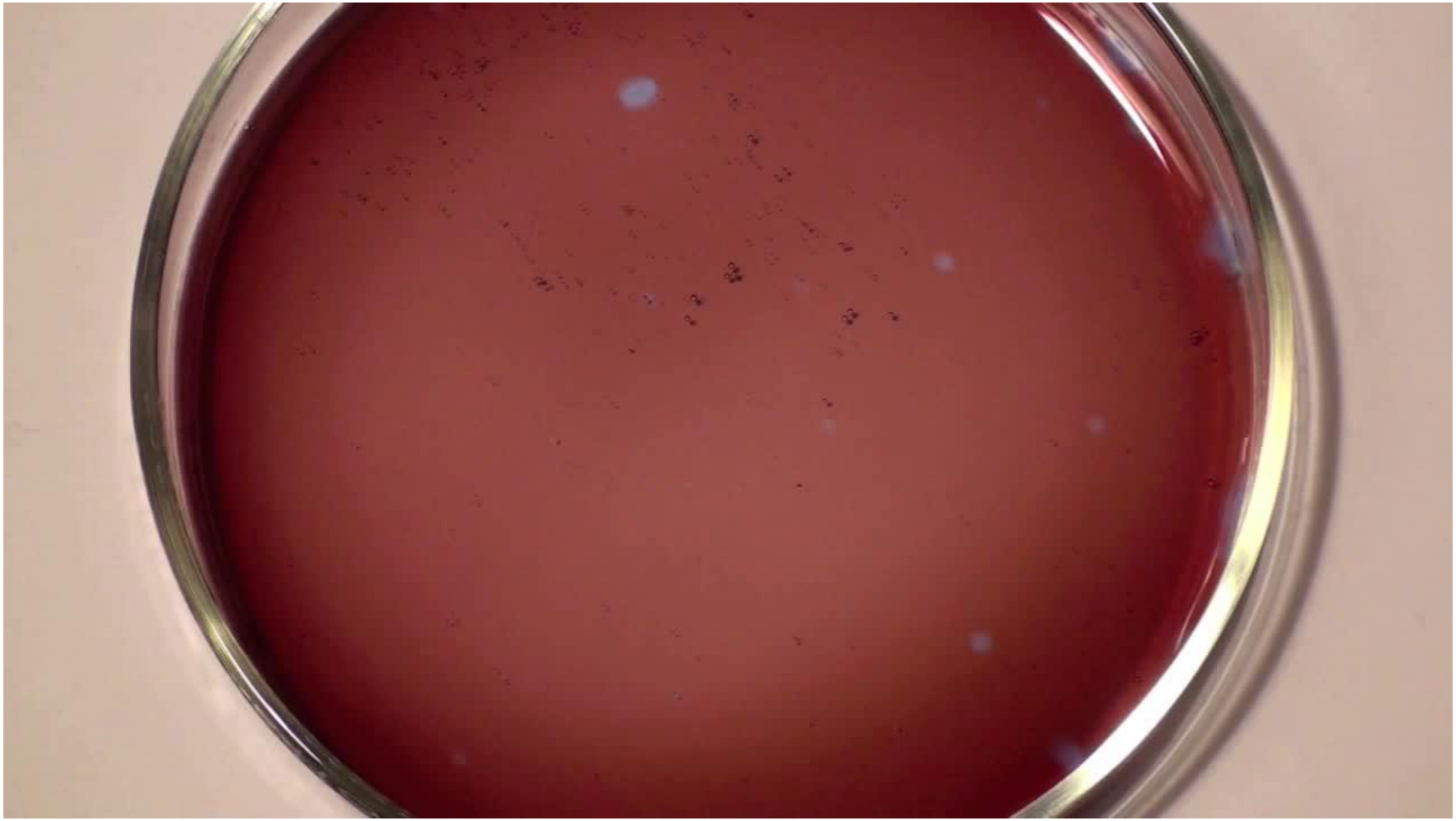


Belousov–Zhabotinsky reaction



http://www.youtube.com/watch?v=D6qIfT7EGv4

Belousov–Zhabotinsky reaction



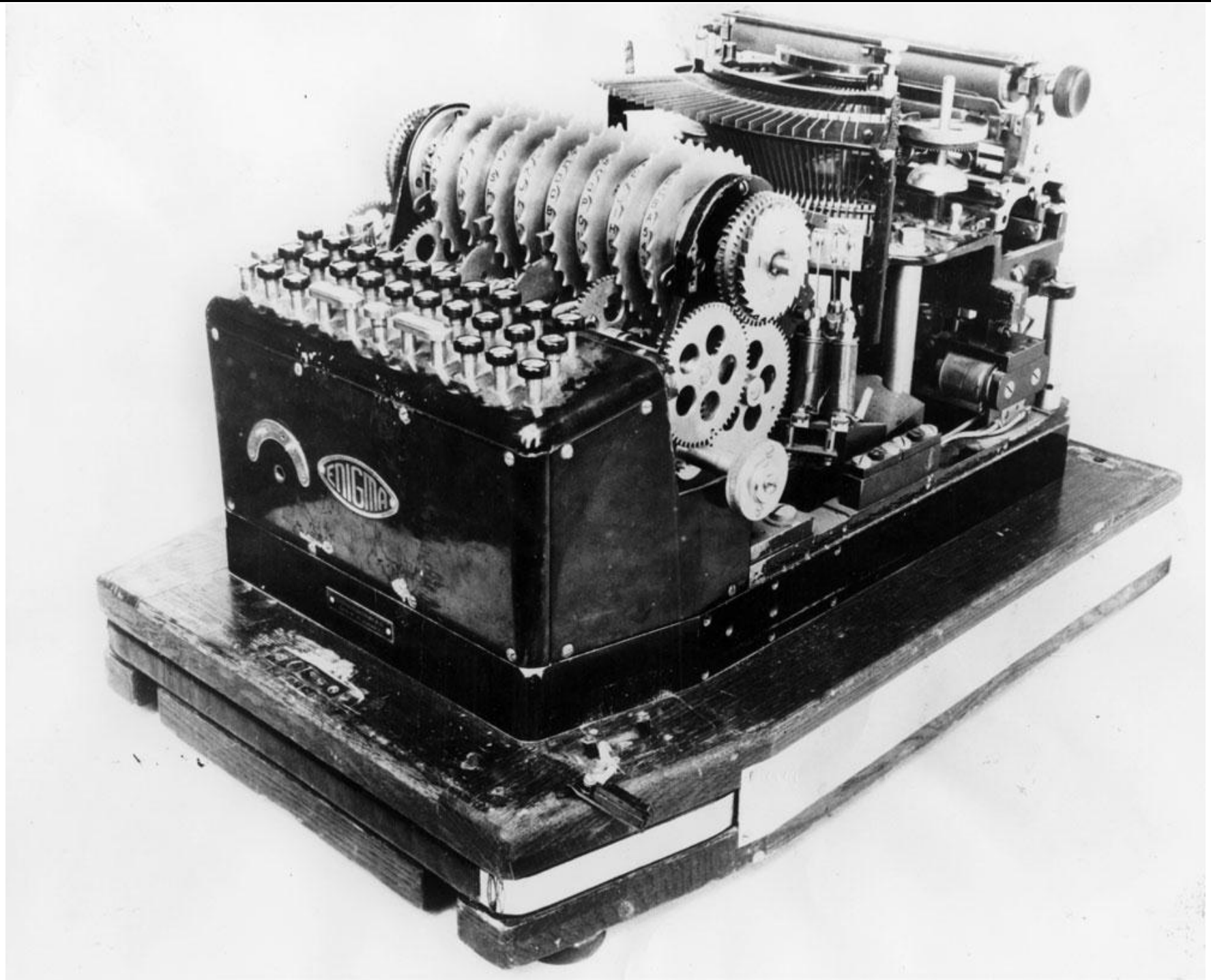
http://www.youtube.com/watch?v=3JAqrRnKFHo

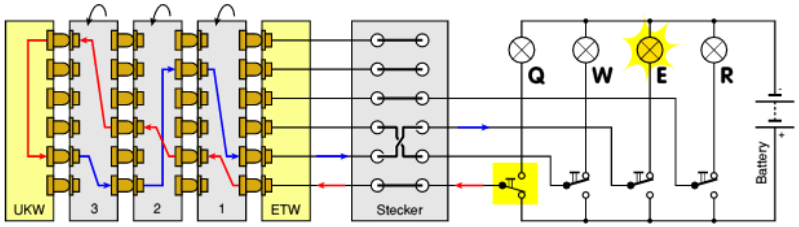
Related Courses

- COS323: Computing for the Physical and Social Sciences

TWO TALES OF CRYPTOGRAPHY

The Enigma machine

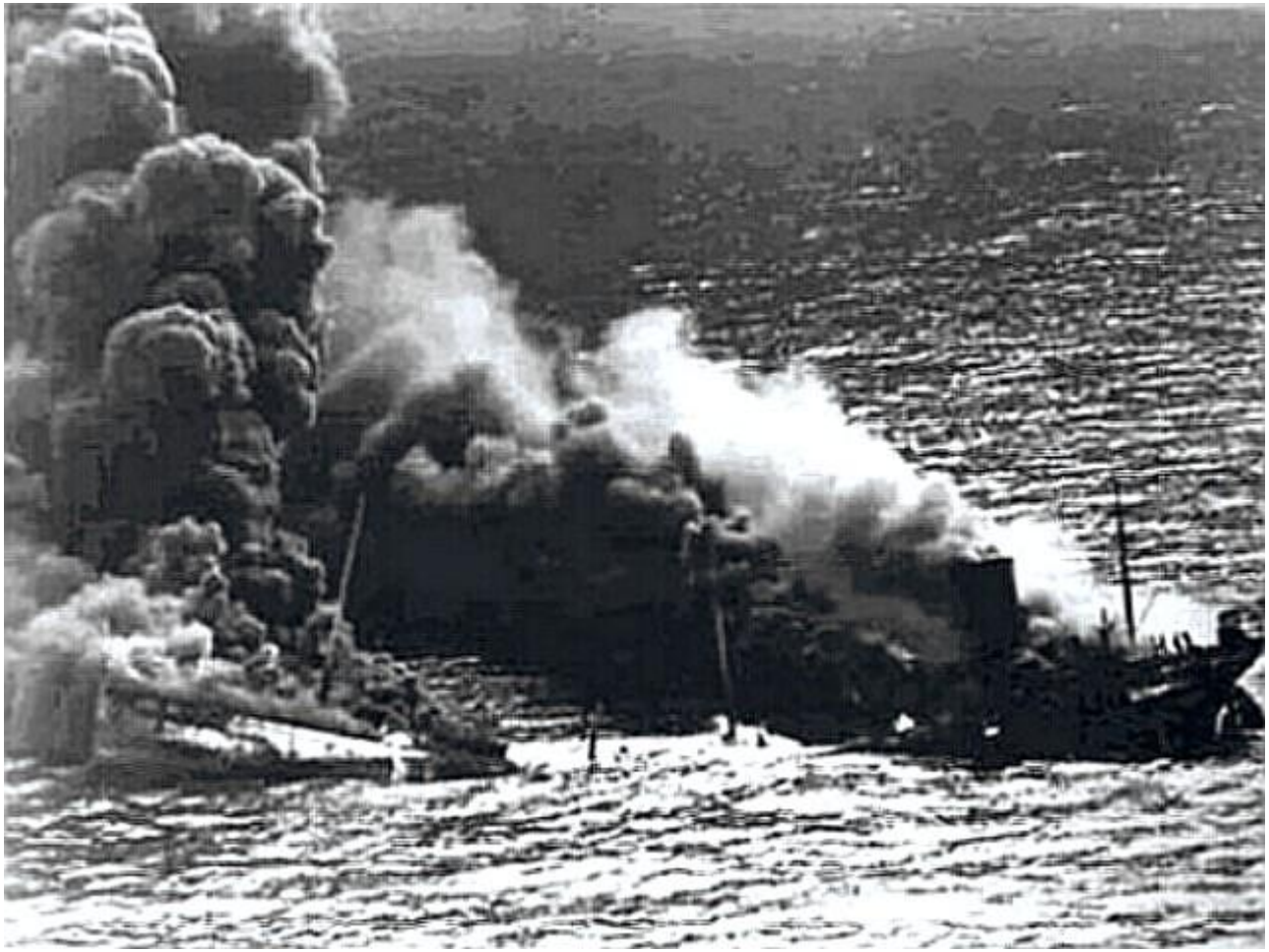

ENIGMA


UKW
3
2
1
ETW
Stecker
Q
W
E
R
Battery


11
12
13
14
15
16
Crypto Museum


Q
W
E
R
T
Z
U
I
C
V
B
G
H
N
M
A
Crypto Museum

Sinking of the *Reuben James*, 1941



Fatal flaw: no letter can encrypt to itself

Ciphertext	O	H	J	Y	P	D	O	M	Q	N	J	C	O	S	G	A	W	H	L	E	I	H	Y	S	O	P	J	S	M	N	U
Position 1			K	E	I	N	E	B	E	S	O	N	D	E	R	E	N	E	R	E	I	G	N	I	S	S	E				
Position 2				K	E	I	N	E	B	E	S	O	N	D	E	R	E	N	E	R	E	I	G	N	I	S	S	E			
Position 3					K	E	I	N	E	B	E	S	O	N	D	E	R	E	N	E	R	E	I	G	N	I	S	S	E		

Crib: *Keine besonderen ereignisse*

Eisenhower: Enigma cryptanalysis was decisive in Allied victory

Group discussion

Alice and Bob each have their own locks/keys

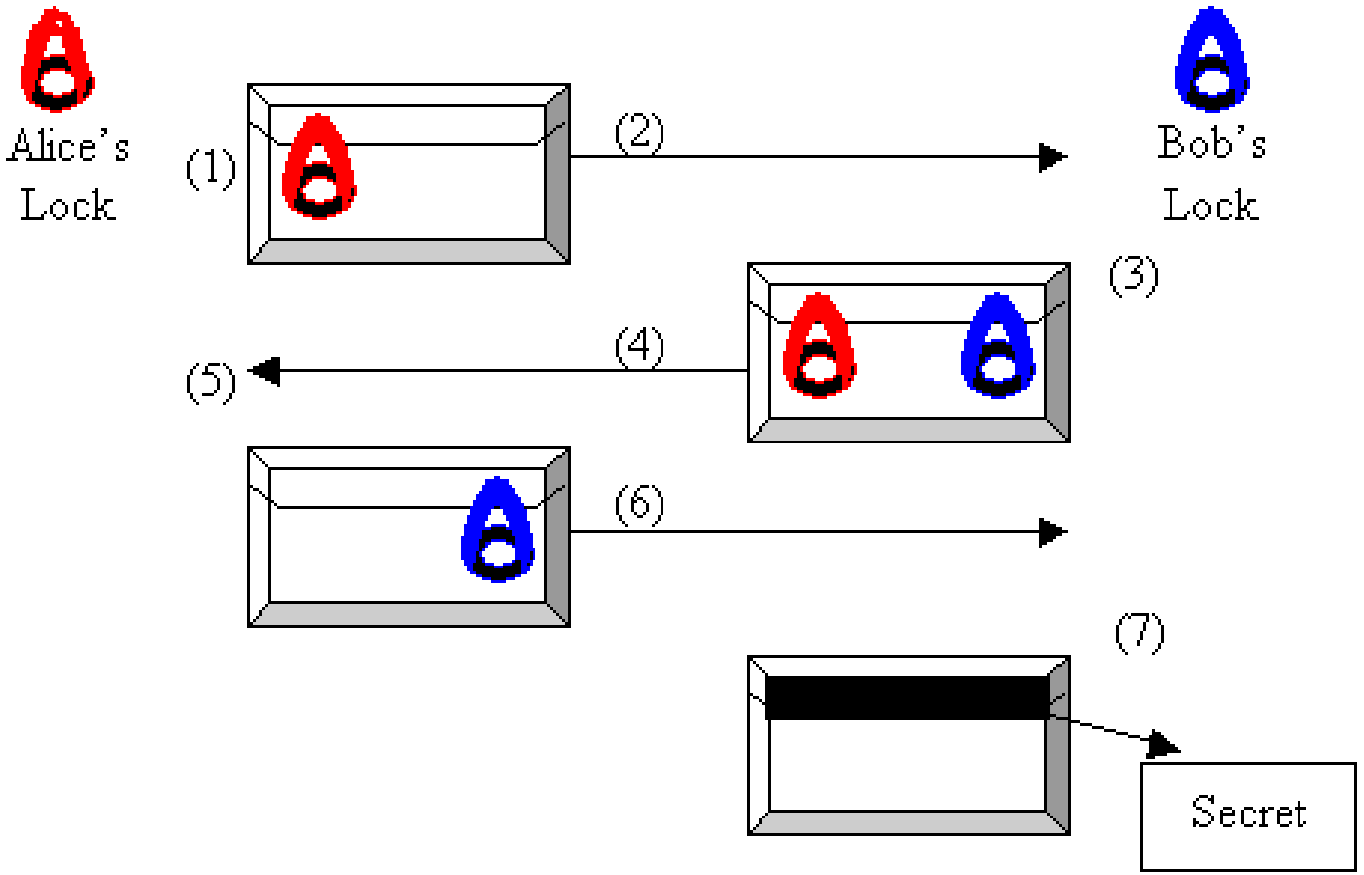
Neither has key to other's lock

Alice has a box (duh)

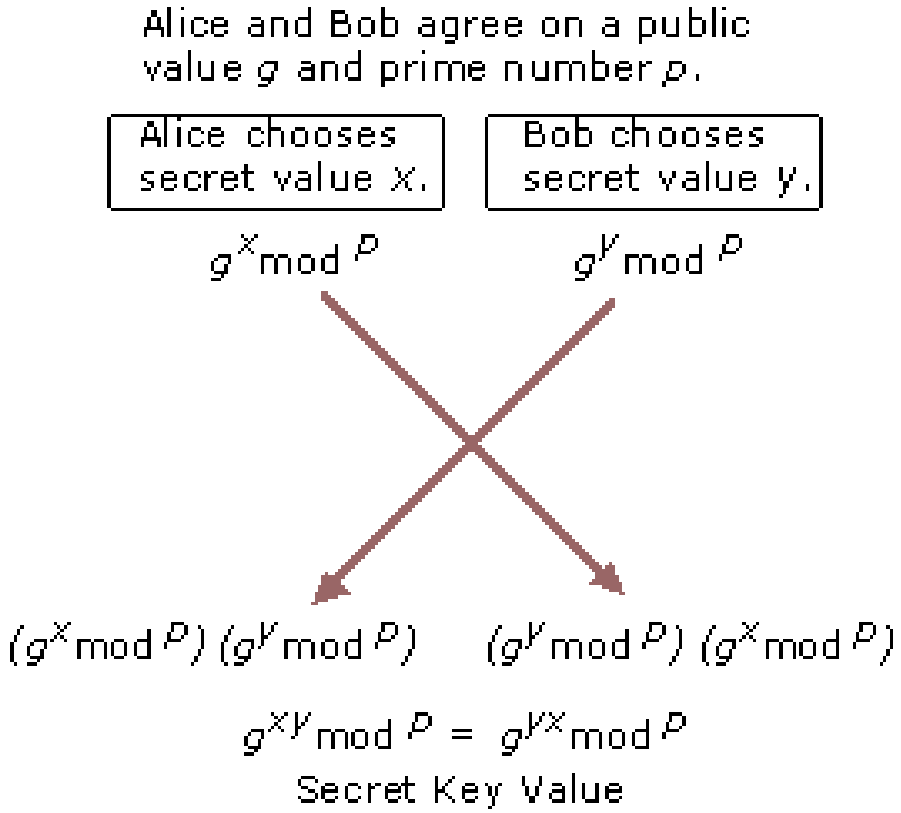
They don't trust the mail carrier

Can Alice send a secret message to Bob?

Solution



This can be achieved mathematically!



Diffie-Hellman key exchange

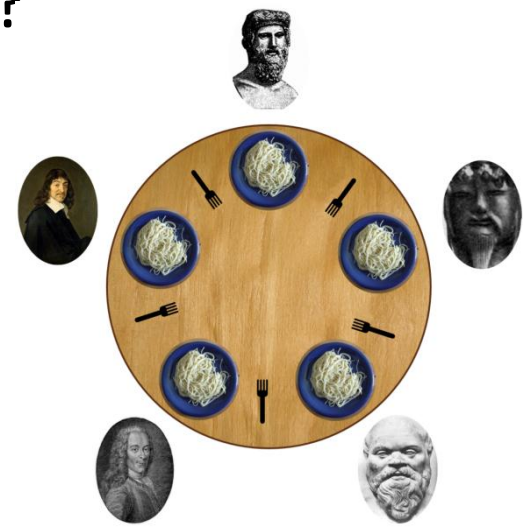
Related Courses

- COS432 – Computer Security
- COS433 – Cryptography

THE DINING PHILOSOPHERS PROBLEM

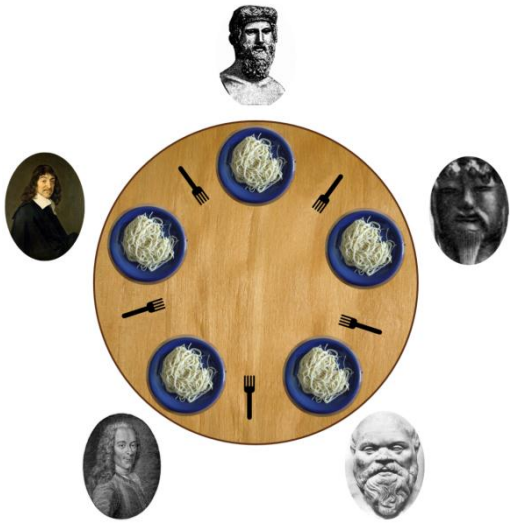
The Dining Philosophers Problem

- Five philosophers alternately eat and think.
- Can only eat if two forks held.
- Cannot pick up two forks simultaneously.
- Philosophers cannot communicate.
  - What strategy should they use to make sure that nobody starves?



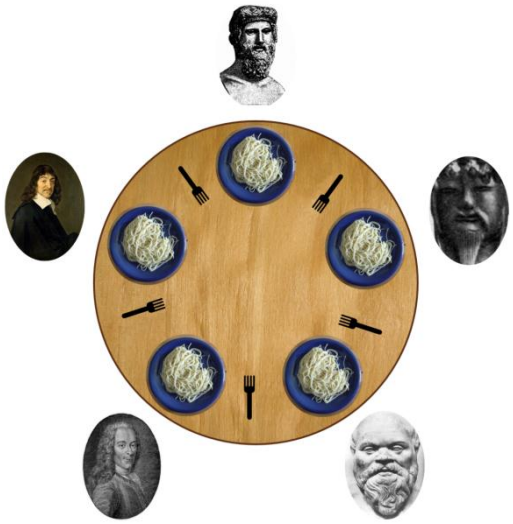
The Dining Philosophers Problem

- Dangerous strategy style:
  - If left fork available, pick it up. Wait until right fork is available.



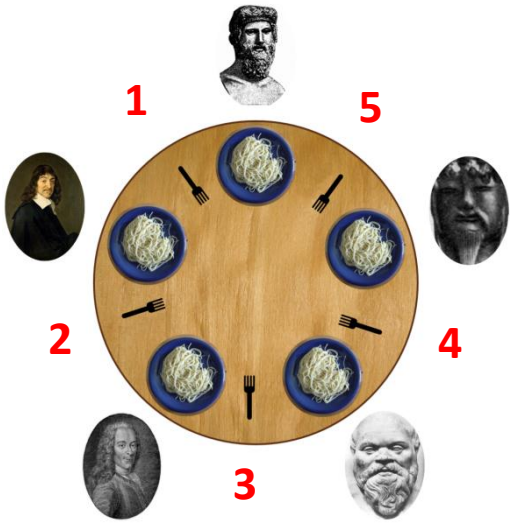
The Dining Philosophers Problem

- Still a dangerous strategy style:
  - If left fork available, pick it up. Wait until right fork is available. If more than 10 seconds pass, put down left fork.



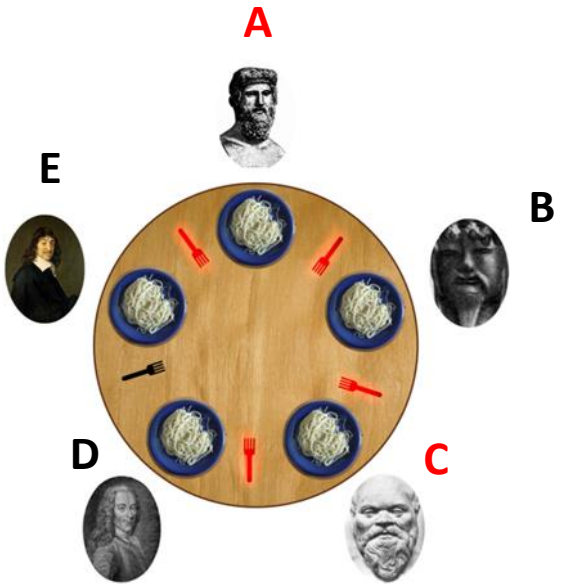
Dijkstra's Solution

- Give number to each fork
  - Philosopher always picks up smaller fork first
- Why is this useful?
  - Prevents deadlock. Fork 5 cannot be picked up unless someone is ready to eat.
- Doesn't scale!



Semaphores (also Dijkstra)

- Have a waiter as an arbitrator. Only allow someone with a fork to pick up the 5th fork.
  - A and C are eating.
  - If D or E want to eat, waiter will tell them they can't pick up their fork (only one on table).
- No deadlock, but someone might still starve.



Related Courses

- COS318 – Operating Systems

- Also: Check out www.cs.utexas.edu/~EWD sometime. Lots of interesting and random thoughts. Some are even funny.

THINKING OUTSIDE THE BOX

Non-Turing machine computers

Solving equations using bike parts

Diophantine equation: find ***integers*** $x_1 \ldots x_n$ s.t.

$$a_1x_1 + a_2x_2 + \ldots a_nx_n = b$$

WHAT IS THE SIMPLEST POSSIBLE COMPUTER?

(Or) Simplest interesting Universe

Discrete, 1-dimensional space and time

Each point in space-time has binary value

Local physics

- Value of a state at time t+1 determined entirely by neighboring values at time t

Discuss in groups: how many such universes?

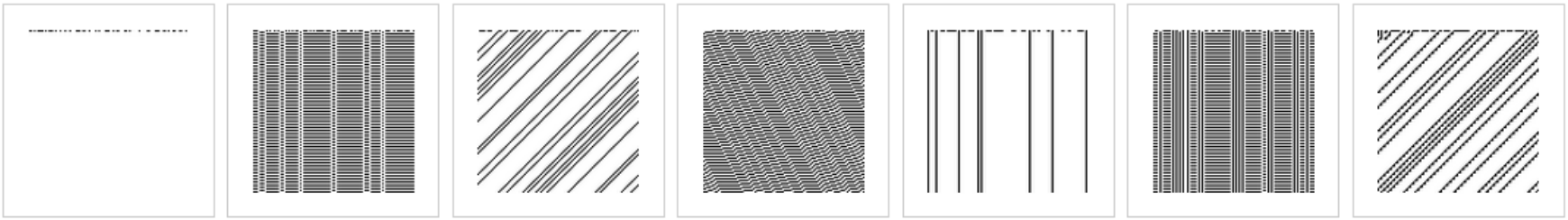
current pattern	111	110	101	100	011	010	001	000
new state	?	?	?	?	?	?	?	?

Each Universe is called “Rule n” n<256

This is the infamous Rule 110

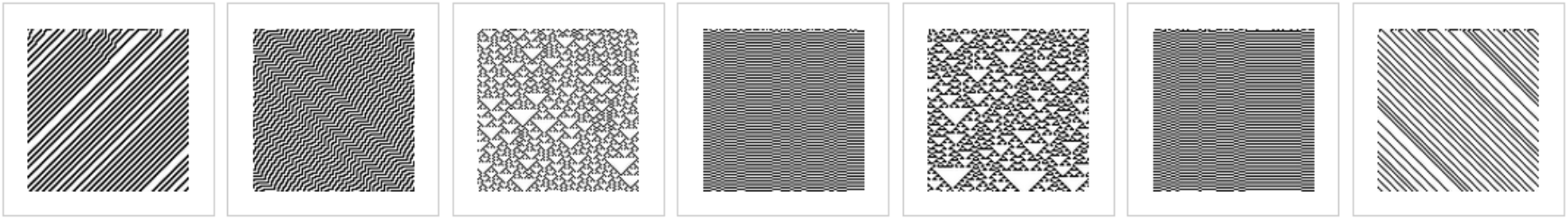
current pattern	111	110	101	100	011	010	001	000
new state	0	1	1	0	1	1	1	0

Most rules aren’t interesting

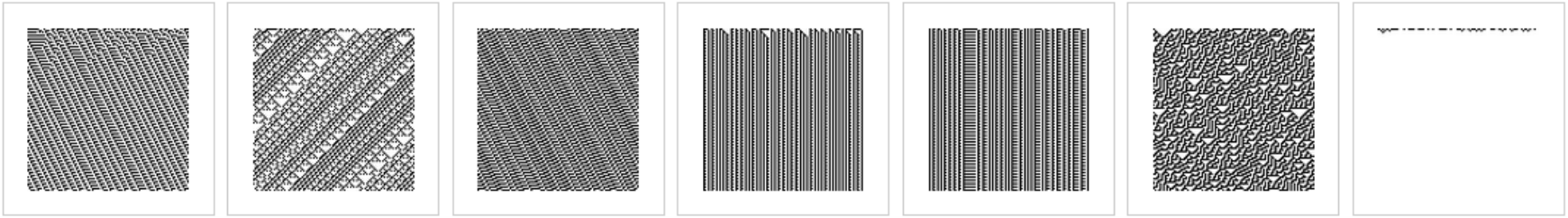


Rule 0 Rule 1 Rule 2 Rule 3 Rule 4 Rule 5 Rule 6

Rule 7 Rule 8 Rule 9 Rule 10 Rule 11 Rule 12 Rule 13

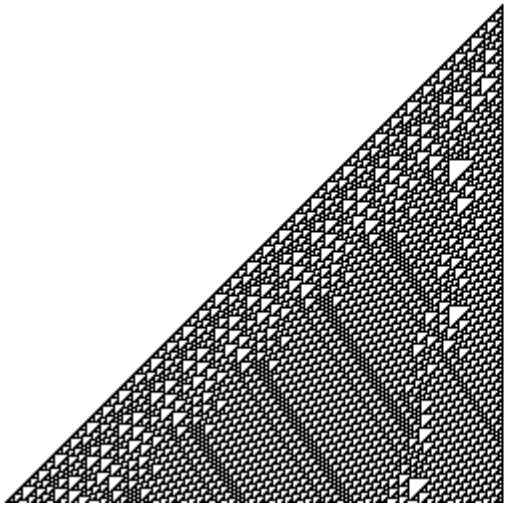


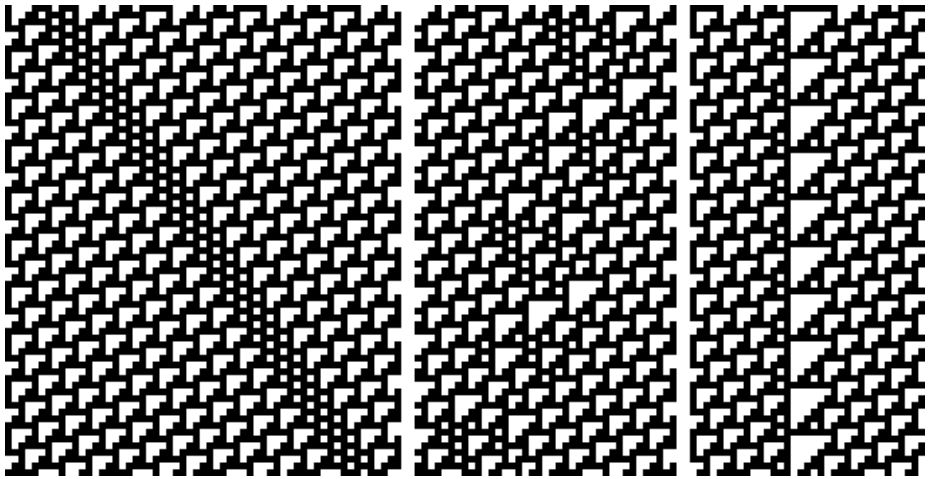
Rule 14 Rule 15 Rule 18 Rule 19 Rule 22 Rule 23 Rule 24



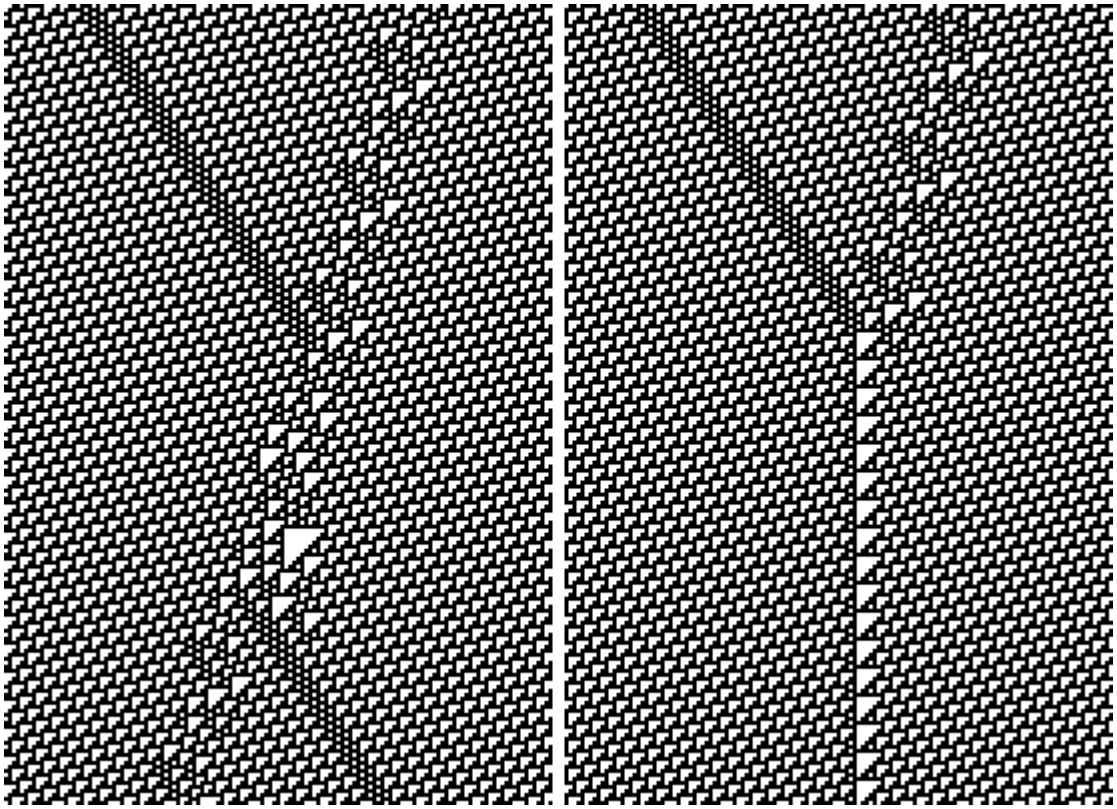
Rule 25 Rule 26 Rule 27 Rule 28 Rule 29 Rule 30 Rule 32

Here's Rule 110

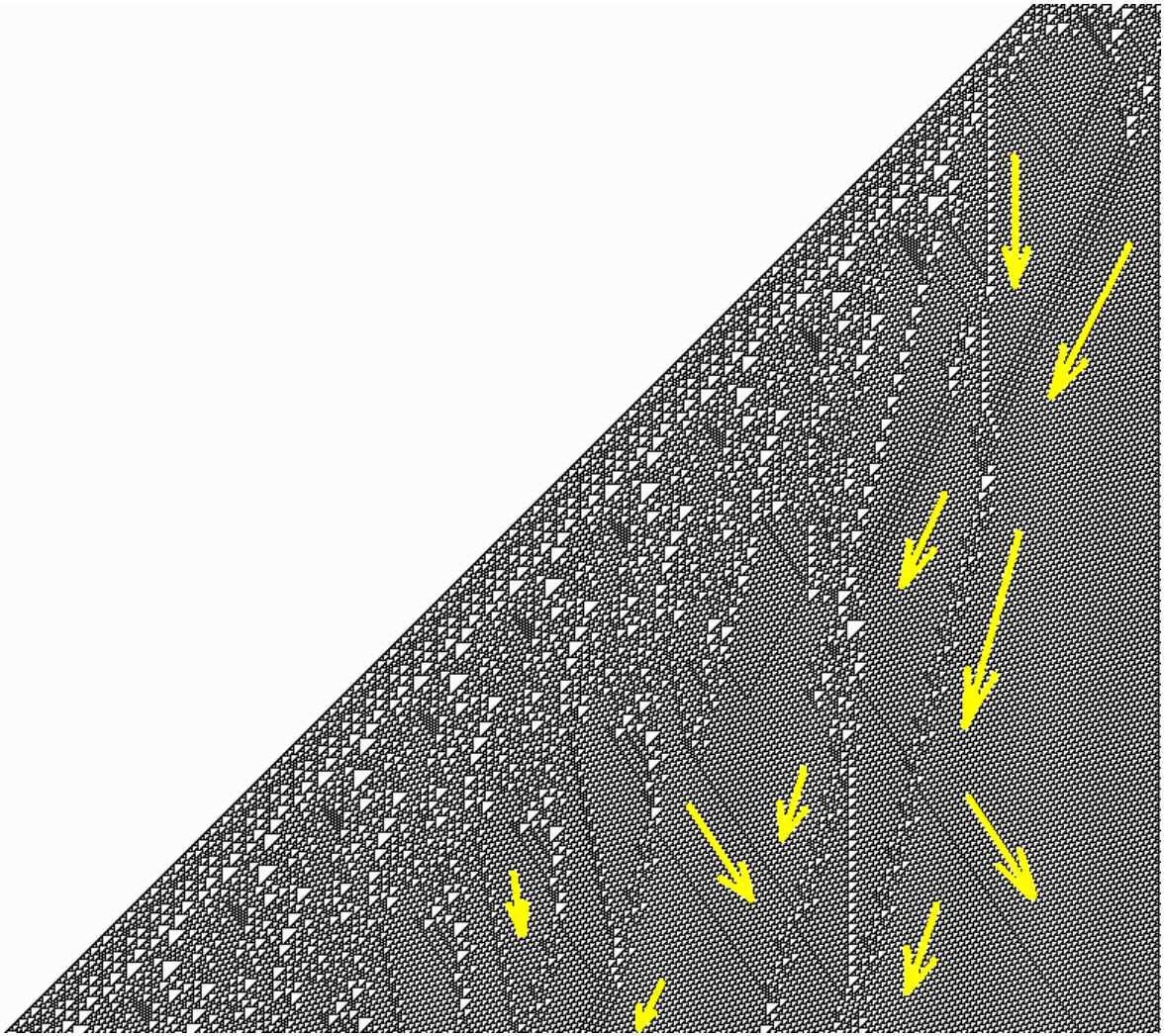




Here's Rule 110



Here's Rule 110



Theorem (Matthew Cook, 2004):

Rule 110 is Turing complete.

Related Courses

- COS487 – Theory of Computation
- COS433 – Cryptography

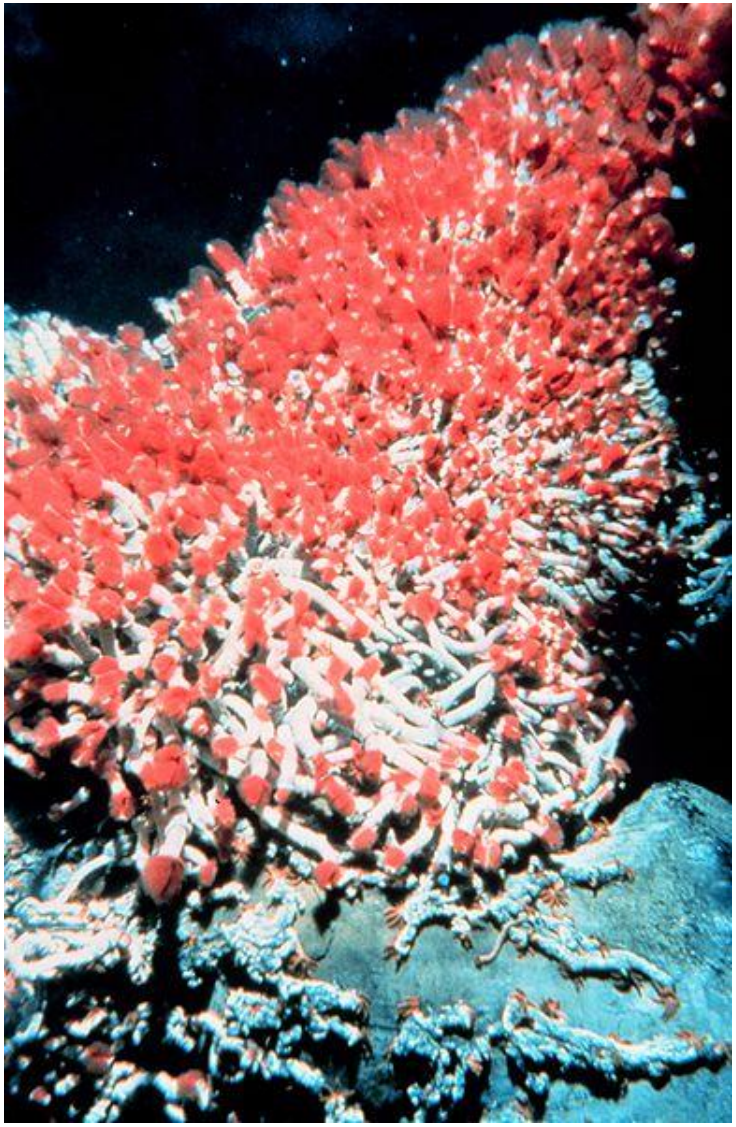
ENVIRONMENTAL GENOMICS
A.K.A. METAGENOMICS

Fermi Paradox (1950)

- "Where is everybody?"
  - The Sun is young compared to its neighbors.
  - At any practical interstellar speed, the entire galaxy could be colonized in tens of millions of years.

- Interesting questions:
  - How common are planets?
  - What conditions can support life?
  - What are the chances life becomes intelligent?

Extremophiles



Environmental Genomics

- Much easier to read short sequences.
- Hard to predictably cut into small sequences.

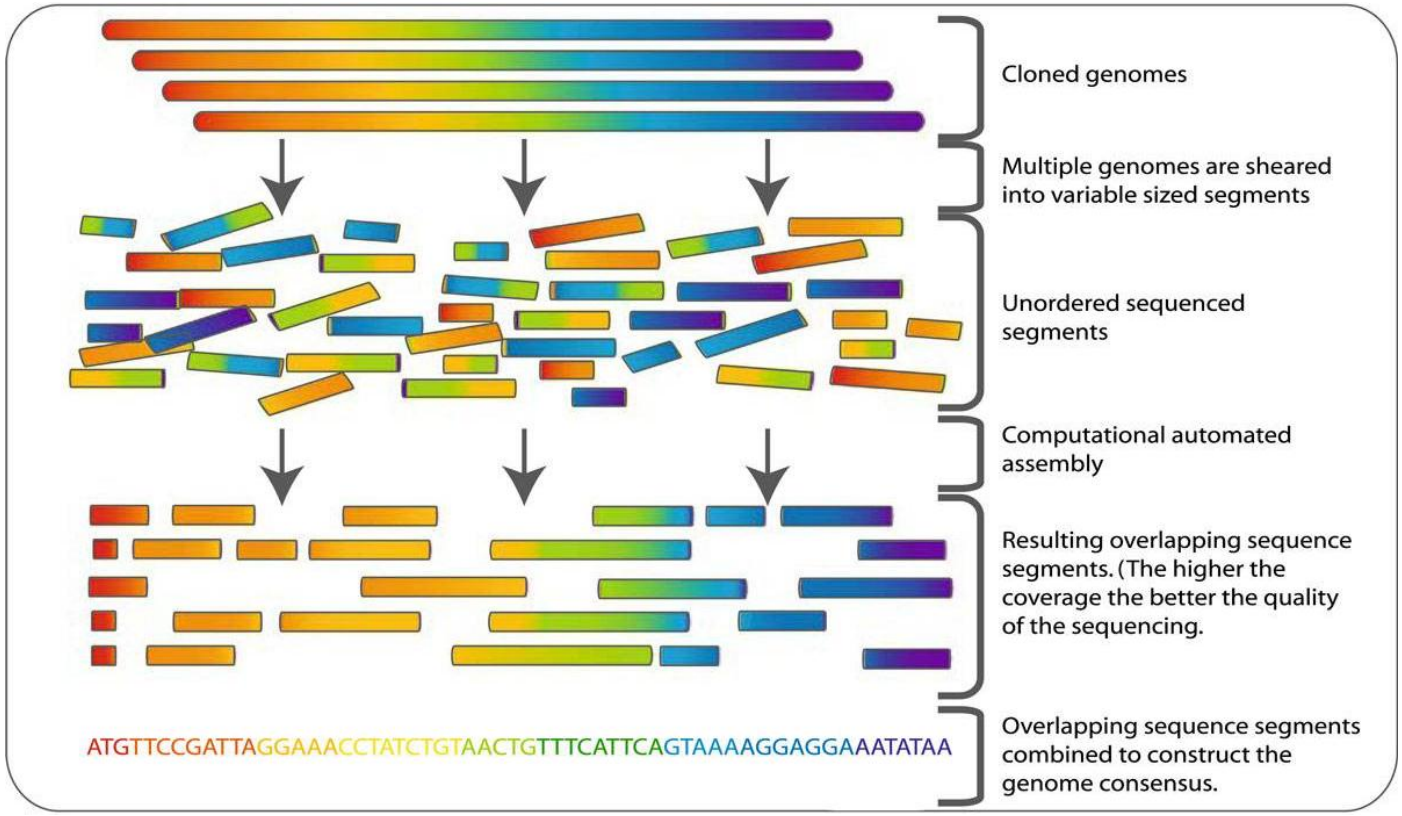


Figure: Computational biology methods and their application to the comparative genomics of endocellular symbiotic bacteria of insects.
http://www.ncbi.nlm.nih.gov/pubmed/19495914

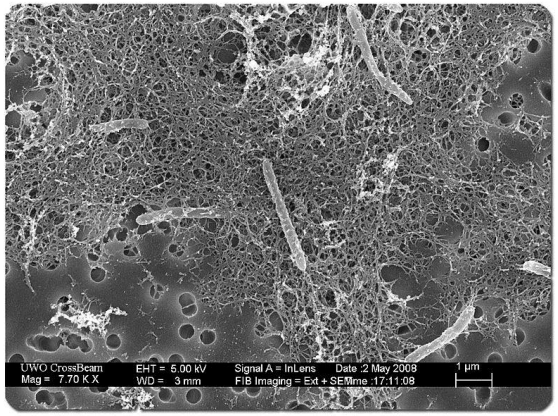
Algorithm

- Greedy algorithm
  - Calculate pairwise alignments.
  - Find the two fragments with the largest overlap.
  - Merge them.
  - Repeat until nothing else can be merged.

- Caveats
  - Fragments may have errors (use edit distance).
  - Fragments may be backwards.

Audax viator

- Lives 1.7 miles below ground.
  - No oxygen. No light. 140 degrees fahrenheit.
- Obtains energy from hydrogen and sulfate produced by decaying uranium.
- Only species in its ecosystem.
  - Completely independent of the sun (unlike deep sea life which uses oxygen).



Audax viator

- Environmental metagenomics
  - 1500 gallons of water filtered
  - Only one distinct genome found using shotgun reassembly
- Reading the source code of a bacterium
  - Noisy substring matching with other life
    - Can probably form endospores
    - Can extract carbon from carbon dioxide
    - Can extract nitrogen from rocks

Related Courses

- COS455 – Intro to Genomics and Computational Molecular Biology

The dark side

My cousins like my statuses re #Syria then unlike them straight away. Thus notifying me they're with the revolt but still cant show it :(

about 5 hours ago via web

Retweeted by you and 20 others

Reply Retweeted (Undo)

tweets4peace

♡ Freedom ~ Syria ♡

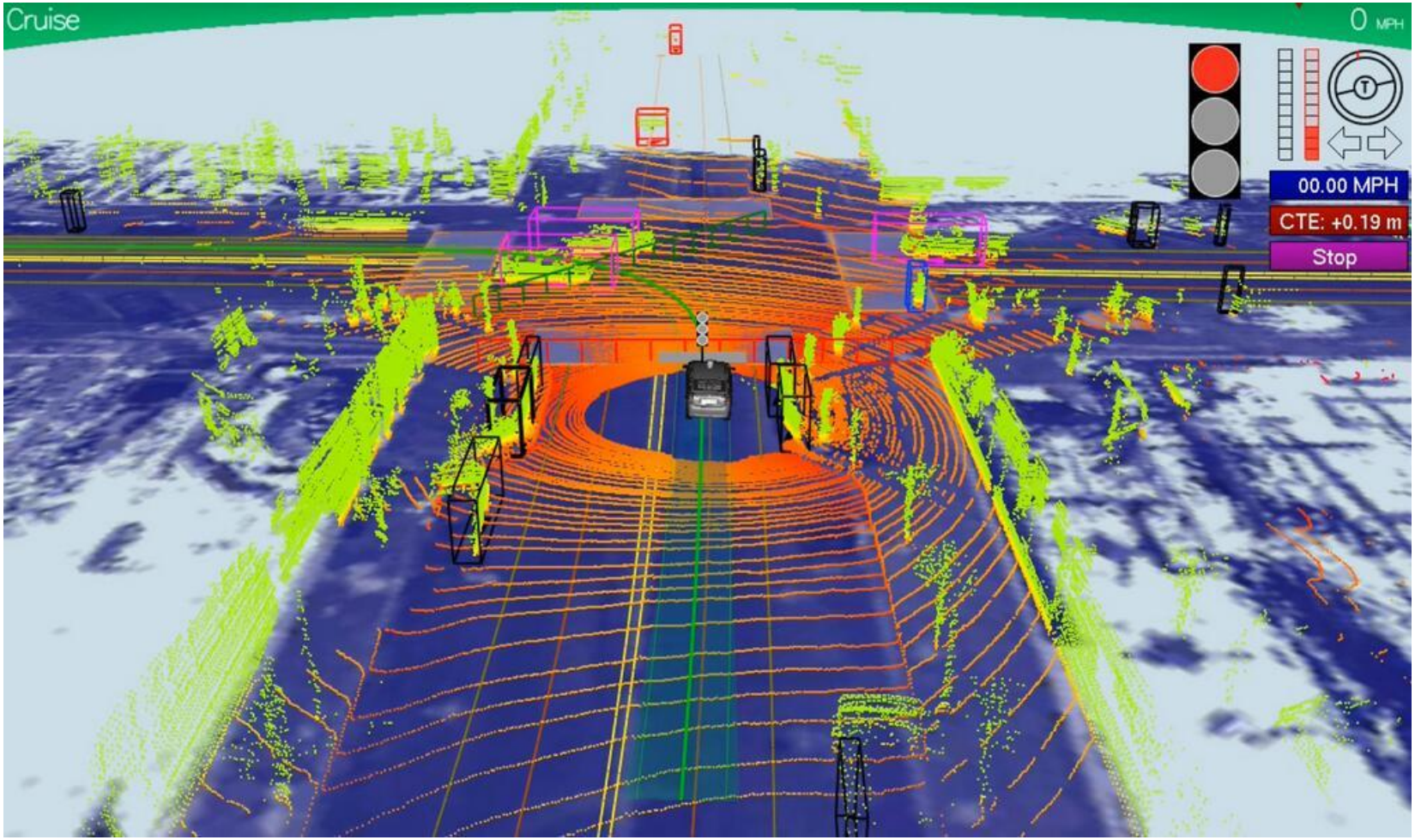
There’s just something about the picture of an engineer in Silicon Valley pushing a feature live at the end of a week, and then heading out for some beer, while people halfway around the world wake up and start using the feature and trusting their lives to it. It gives you pause.

Mat Honan, Wired:
“In the space of one hour, my entire digital life was destroyed”

Yet, the future looks bright

Car accidents:
over 1 million deaths a year

We will save every one of those lives



Google's self-driving car gathers almost 1 GB/**second**
This is what it "sees"

Additional Citations

- High quality motion deblurring from a single image
  - http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.218.6835
- Private traits and attributes are predictable from digital records of human behavior
  - http://www.pnas.org/content/early/2013/03/06/1218772110.full.pdf+html
- Fingerprinting
  - http://33bits.org/tag/fingerprinting/
  - http://33bits.org/2012/02/20/is-writing-style-sufficient-to-deanonymize-material-posted-online/
- Keyboard Acoustic Emanations Revisited
  - http://www.tygar.net/papers/Keyboard_Acoustic_Emanations_Revisited/ccs.pdf

Additional Citations

- Enigma
  - https://en.wikipedia.org/wiki/Cryptanalysis_of_the_Enigma
- Diffie Hellman
  - http://technet.microsoft.com/en-us/library/cc962035.aspx
- Rule 110
  - https://en.wikipedia.org/wiki/Rule_110
- Solving equations using bike parts
  - https://rjlipton.wordpress.com/2009/06/29/solving-diophantine-equations-the-easy-way/