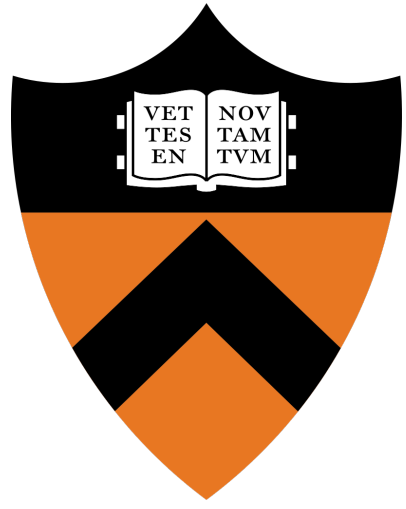
Introduction



Yuxin Chen

Princeton University, Fall 2018

Statistical signal processing

Statistical signal processing

..., and more generally, statistical information and data processing?

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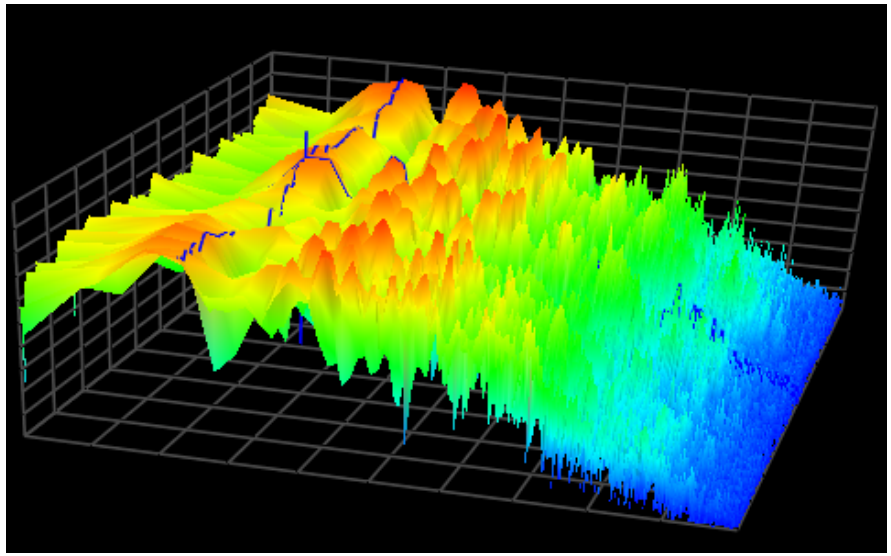
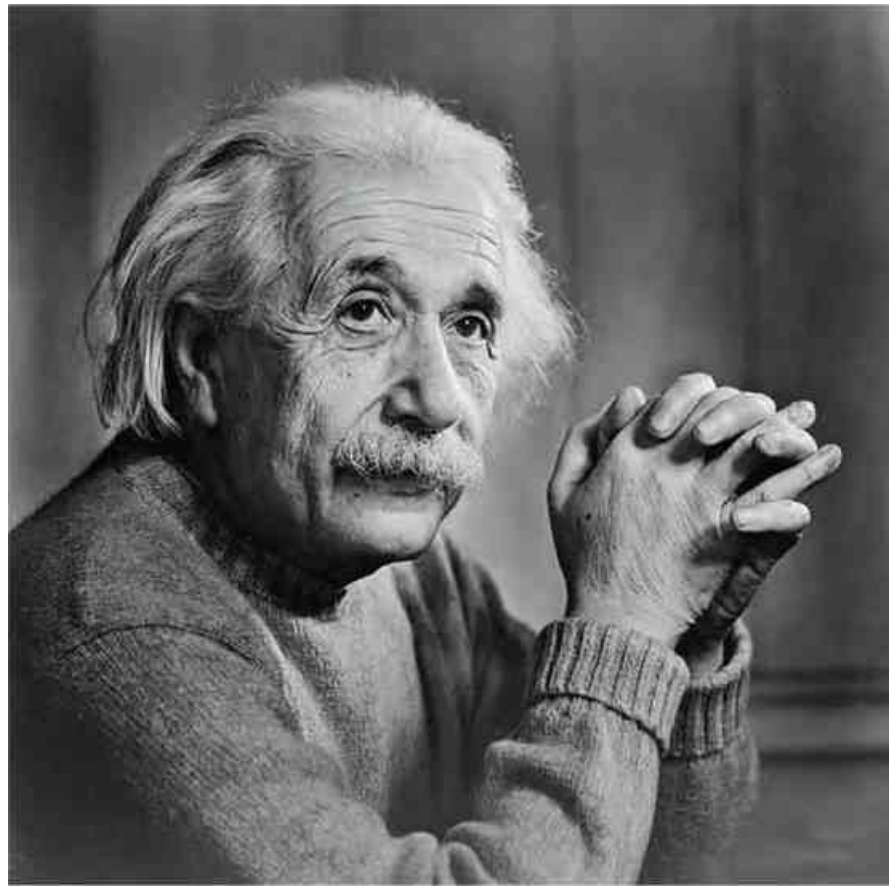


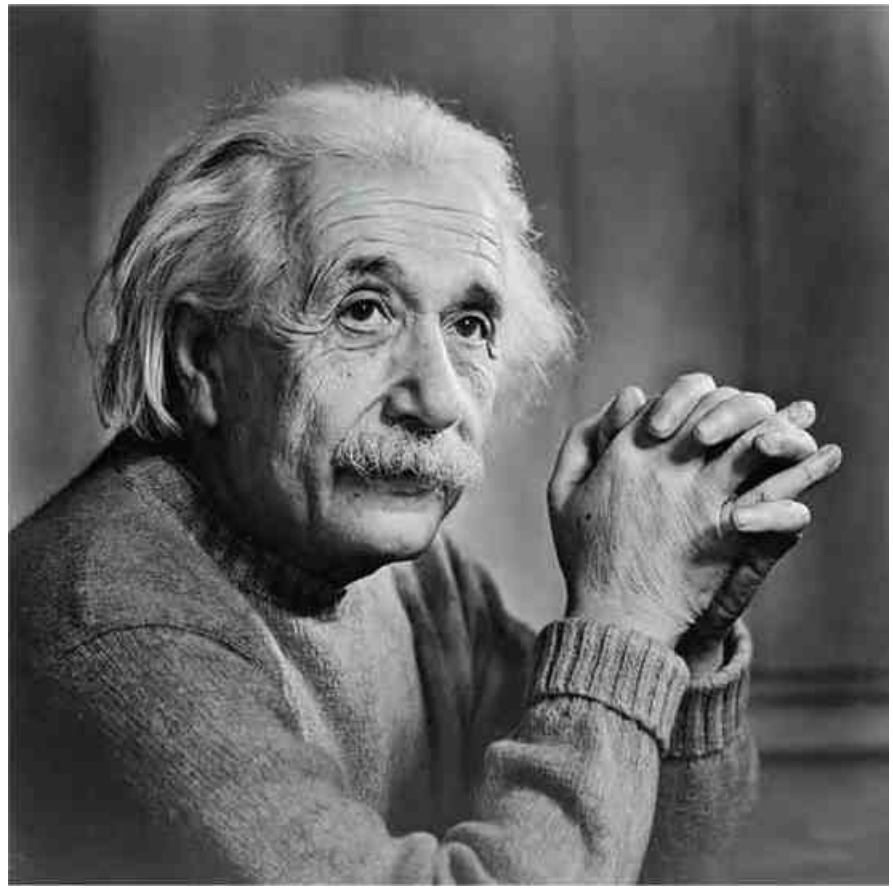
- Essence: extracting information from $\underbrace{\text{noisy data / observations}}_{\text{modeled via randomness}}$

Why study randomness?



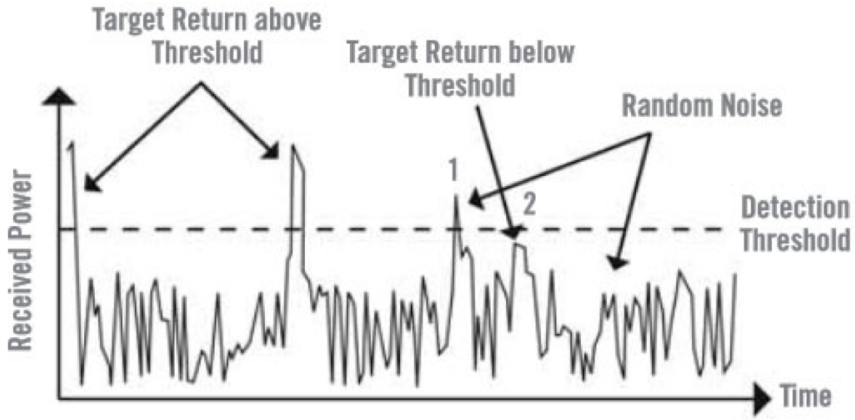
Does God play dice with the universe?

Why study randomness?



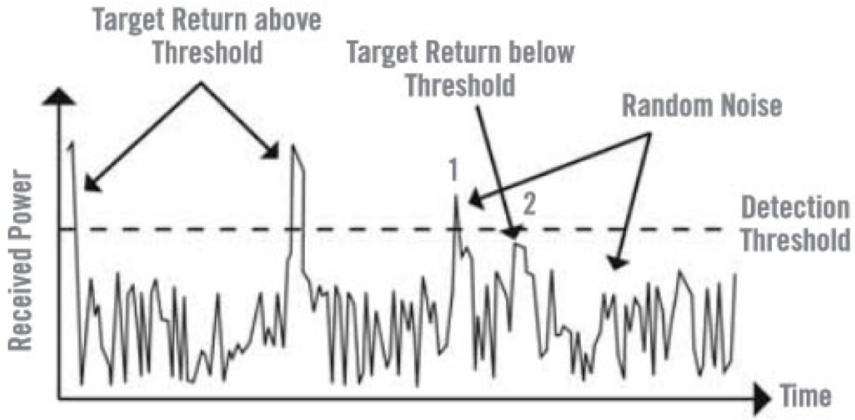
Does God play dice with the universe? Probably yes!

Why study randomness?



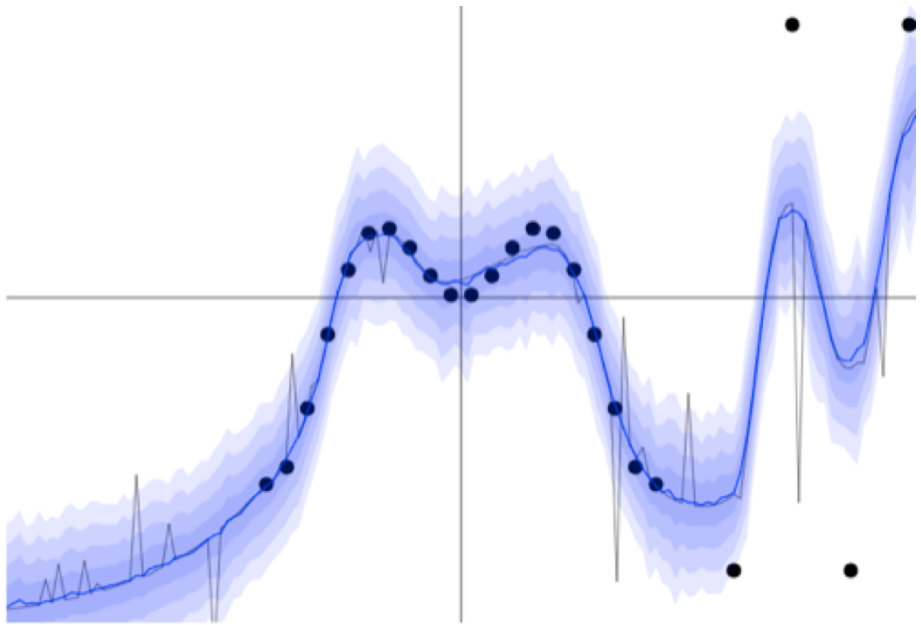
- An essential component in modeling and analyzing nature
  - random signals are all around us (e.g. audio, image, video, geophysical, medical, financial, $\cdots$)

Why study randomness?



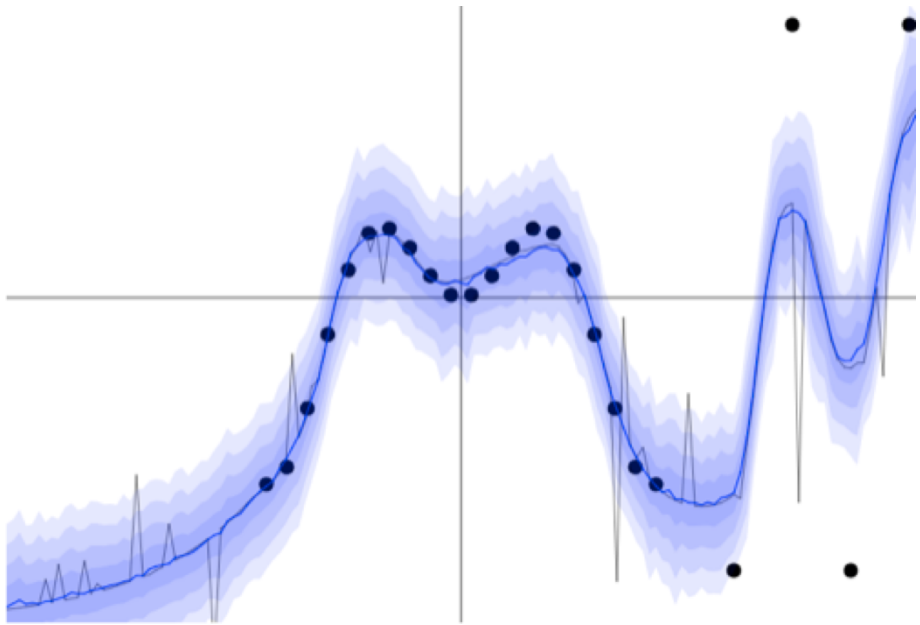
- An essential component in modeling and analyzing nature
  - many scientific experiments are similar to games of chance, since multiple trials of the same procedure lead to results that vary from one trial to another

Why study randomness?



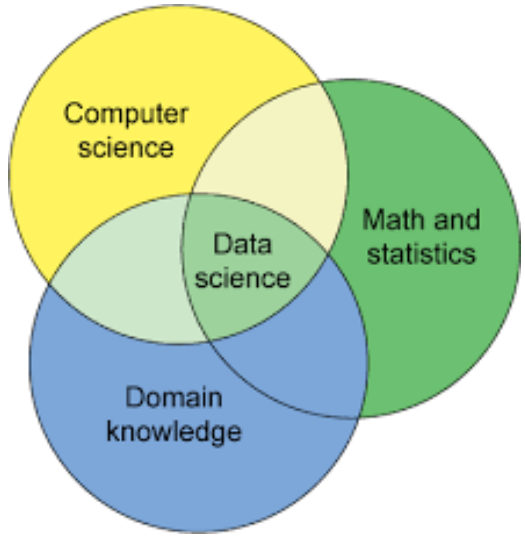
- Plays a key role in almost every field of modern science and engineering (EE, CS, physics, biology, finance, ...)
  - use probabilistic models (for the given area) to characterize randomness of data

Why study randomness?



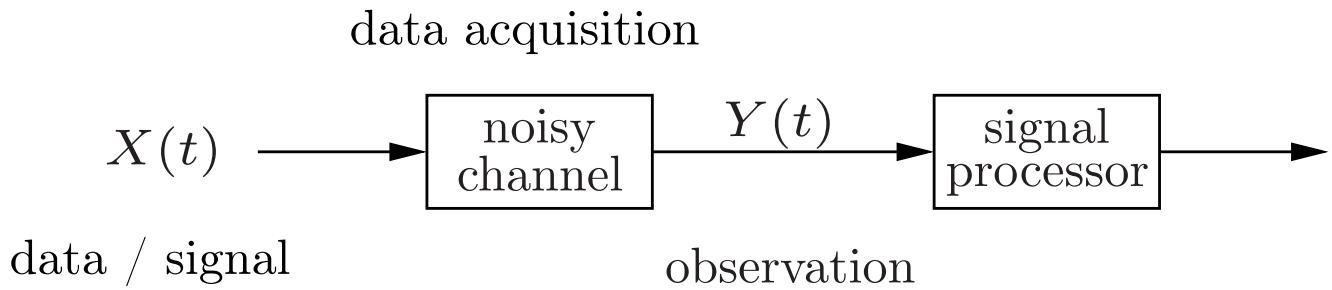
- Plays a key role in almost every field of modern science and engineering (EE, CS, physics, biology, finance, ...)
    - The models might or might not correspond to reality very well, but when they do, the situation might be completely understood while still being random

Why study randomness?



- Backbone of numerous important concepts in ***data science***
  - statistical inference
  - classification
  - statistical machine learning
  - ...

Statistical signal / information processing



Generic statistical information processing problems, which deal with

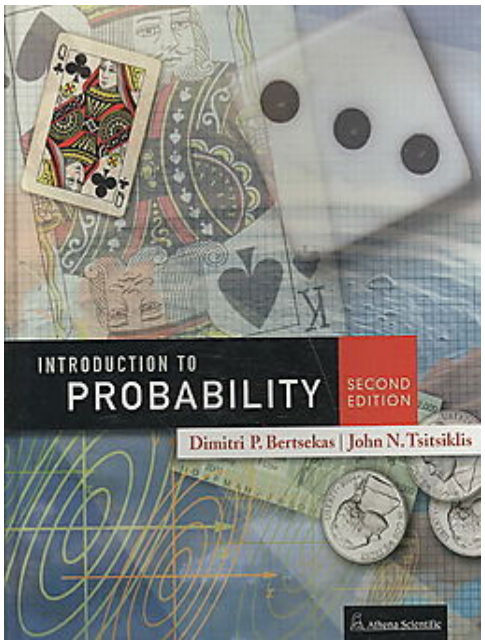
- modeling of data (signal)
- modeling of data acquisition process (channels)
- design of "optimal" information processing algorithms

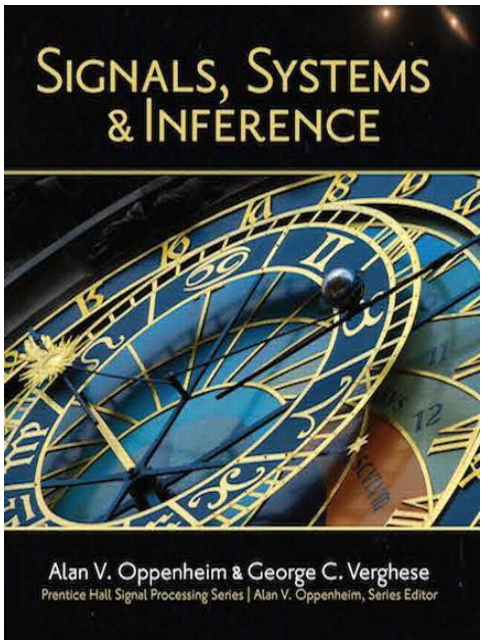
We will *probably* cover these topics ...

- Review of basic probability
- Hypothesis testing / detection / classification
  - decide which hypothesis out of a finite number of possible alternatives corresponds to the truth
- Random processes
  - probabilistic models that evolve in time
- Estimation and regression
  - find an estimate that is close to true signal
- Estimation for random processes
  - Kalman filter

Textbooks

We recommend these two books, and will also provide our own notes





Prerequisites

- basic linear algebra
- calculus
- a little about Fourier transform
- a programming language (e.g. Python, Matlab, ...)
- basic probability (e.g. ORF 245, ORF 309)

Prerequisites

What you need to know about probability

- sample space, events, and probability functions
- cumulative distribution function, probability mass function, probability density function
- expectation, variance, covariance, and moments
- independence, and conditional independence
- Bayes' rule
- Bernoulli, binomial, geometric, uniform, exponential, and Gaussian distributions
- conditional probability, and conditional expectation
- moment generating functions

Prerequisites

What you don't need to know

- measure theory
- convergence of random variables
- random processes (which we will teach from scratch in this class)
- Brownian motion
- random walks
- branching process
- Markov chain
- Markov's inequality, Chebyshev's inequality, Chernoff bound
- law of large numbers
- central limit theorem
- ...

Grading

- Homeworks (40%): *(probably)* 8 problem sets
  - Typically due before Monday lecture
  - Use Piazza as the main mode of electronic communication; please post (and answer) questions there!

- Midterm and final exams (60%)
  - Your score for this part is determined by

$$\max\left\{\frac{\text{midterm} + \text{final}}{2},\ \text{final}\right\}$$

Office hours

- Instructor: Yuxin Chen, B316 Equad, Mon / Wed 11am - 12pm
- TA: Qingcan Wang, 218 Fine hall, Thu 2-3pm