Chapter 1

Overview

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What is information theory ?

- Fundamental questions in communication theory:
  - How much can we compression data? entropy H.
  - How fast can we transmit data ? channel capacity C.
- Information theory has fundamental contributions to
  - electrical engineering
  - statistical physics
  - computer science
  - statistical inference
  - probability and statistics.

EE: Communication theory

- Is it impossible to send information without error ?
  - Shannon proved that the probability of error could be made nearly zero for all communication rates below channel capacity. (and created a new field of applied mathematics: *information theory*).
  - Compression of a random processes has a limit (the entropy).
  - If the entropy of the source is less than the capacity of the channel, asymptotically error-free communication can be achieved.
- Recent work on the communication aspects of information theory focus on network information theory.
  - The theory of simultaneous communication from many senders to many receivers.

CS: Kolmogorov complexity

- The complexity of a string of data is the length of the shortest binary computer program for computing the string.
  - The Kolmogorov complexity $K \approx$ Shannon entropy H
    - ➜ if the sequence is drawn at random from a distribution that has entropy H.
- Computational complexity (time complexity) $\Rightarrow$ program running time Kolmogorov complexity $\Rightarrow$ program length.
  - Can we simultaneous minimize these two ?

What we will learn in this course

- Basic definition: entropy, mutual information, channel capacity, . . .
- *Data compression*: What is the shortest description of a random variable ?
- *Rate distortion theory*: If distortion D is allowable, what channel capacities are sufficient for transmission and reconstruction with distortion less than or equal to D ?
- *Data transmission*: How do we transmit so that the receiver can decode the message with a small probability of error?
- *Network information theorem*: How do we compress many sources and then jointly reconstruct these compressed message?