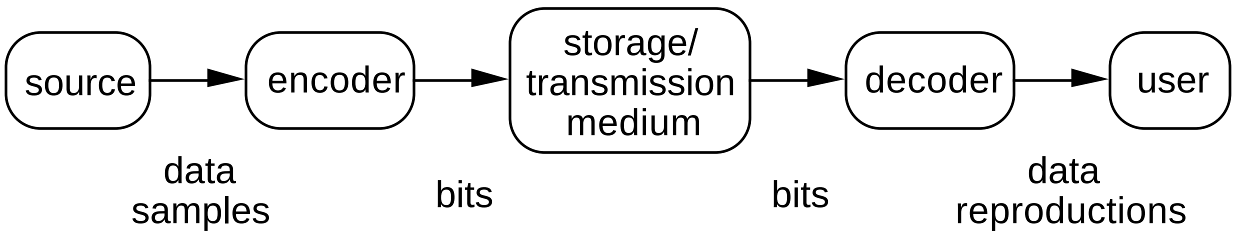
# Introduction to Source Coding/Data Compression

Course is about the **Theory** and **Practice** of **Source Coding,** a.k.a. **Data Compression**

**Data compression** is process of **encoding** data from some **source** into **bits** in such a way that it can be **decoded** back into a **reproduction** of the original data.

**Source code =** data compressor = data compression system = **encoder + decoder**




**encoder creates bits, decoder creates reproduction from bits**

**Goals:**

efficiency: as few bits as possible

accuracy, fidelity: reproduction as much like original as possible

**Source** is assumed to produce **discrete-time samples or symbols**

e.g. text or samples of speech

we won't spend significant time on sampling issues; just assume the source is already sampled

source will be modelled as a **random process**, usually **stationary** and **ergodic**

why assume random?? because if not, why encode it? because can exploit statistical characteristics (what occurs more frequently. what values, what combinations of values (correlation))

autoregressive Gauss-Markov (AR) processes make nice tractable models of speech and image sources.

**Rate** is our measure of efficiency

rate = number of bits/sample

**AVOID** "compression ratio"

why encode into bits?? no big deal, just the most useful convention

**Average Distortion wrt some distortion measure** is our measure of fidelity

satisfactory human perception is usually the "ultimate" criteria

most commonly **MSE**

$$\text{empirical distortion} = D = \frac{1}{n}\sum_{i=1}^{n}(X_i - Y_i)^2$$

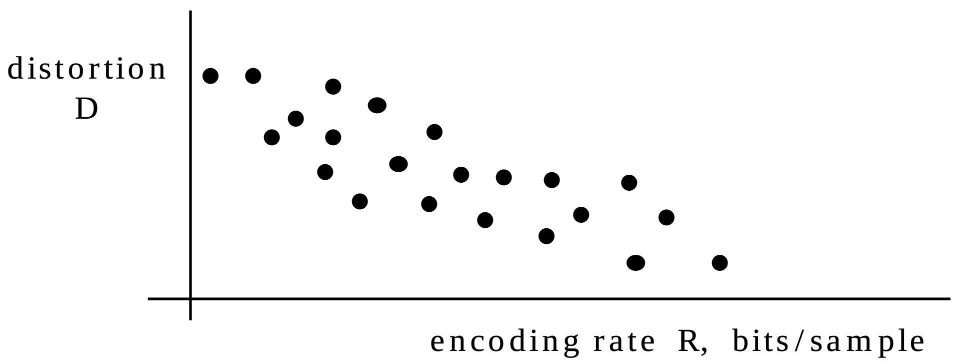
$$\text{statistical distortion} = D = E\left[\frac{1}{n}\sum_{i=1}^{n}(X_i - Y_i)^2\right] \text{ or } E(X-Y)^2$$

why MSE? pro's and cons

other distortion measures

usually emprical = statistical or else we're wasting our time with statistical

**Summary:** code performance on a given source is characterized by **rate and distortion**



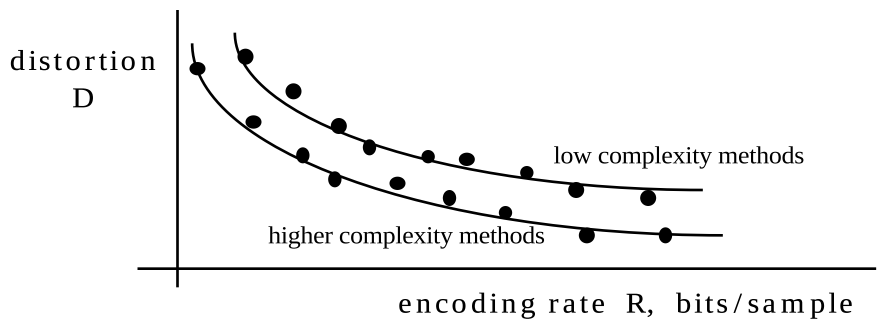

**Lossless coding** is when $\hat{X}$ must equal X; i.e. D = 0

**Lossy coding** is the other case

course is 3/4's lossy, 1/4 lossless, projects are mostly lossy, so we begin with lossy

**Complexity** is other big issue

- implementation complexity
  - number of arithmetic operations per sample
  - bytes of auxiliary storage, e.g. for tables
  - these influence: building cost and operating cost
- design complexity is a lesser issue
- performance vs. complexity



We're not concerned with **channel errors**

Though it's possible to build source codes that are terribly sensitive to channel errors, it is also possible to build them that are not. Any source code can be "fixed" so it is not too sensitive to errors, with only small loss. Typically, $p = 10^{-4}$ is small enough for speech and images, and even $10^{-3}$.

Shannon says that an optimum communication system can have a separation of source code and channel code.

But there are many situations where we're just storing data and the storage medium is so reliable that it doesn't make sense to model it as a noisy channel.

Working through lossy coding (quantization) with channel errors makes interesting excercises.

**Source Coding Issues**

1. **Sources** (skip or skim)

   **discrete valued** -- English text, binary images (e.g. FAX) -- produce **symbols**

   **continuous valued** -- speech, images, audio, video, etc. -- produce **samples or pixels**

   **source models** -- for design and analysis

   some methods don't require source models

   we find Gaussian autoregressive, ARMA and Markov especially easy to deal with

   also IID, stationary memoryless

2. Performance Measures (skip or skim)

   Rate (not much question)

   Distortion -- MSE

   lossless vs. lossy

   lossless for discrete-valued only

3. **Code Structure:** we will consider a variety of such

   **independently code each sample/symbol**

   **dependent coding** -- block, sliding-window, finite-state, predictive, feedback, adaptive, linear transform, waveform or spectral domain

   **fixed-rate** -- constant number of bits produced per symbol/sample

   **variable-rate** -- variable number of bits produced per symbol/sample

4. **Code design to optimize performance** of certain type of code.

   Generic Question 1: How to optimize a given type of code?

5. **Complexity/Cost** of implementation. (skip or skim)

   performance does not mean speed of implementation in this course

   **arithmetic --** number of ops/sample

   **storage --** number of bits of auxiliary storage required

   **building cost --** cost of building or buying hardware for computing and storing

   **running cost --** cost of operating (depreciation, power, heat, rental, or sharing of resources)

   **Tradeoffs: rate, distortion, and complexity.**

6. **Analysis**

   to **predict performance** of specific types of codes and to **predict how to optimize** them and to **identify key characteristics** of good codes.

   to **predict best possible performance of any type of code** and to understand basic properties of optimal codes

   Generic Question 2: What is the best possible performance attainable with a given type of code.

   In this class we use mostly **asymptotic quantization theory** for lossy coding and **entropy theory** for lossless coding. There will be a brief overview of **rate-distortion theory**, a branch of information theory

   **difficult question:** how does complexity reducing structure limit performance??

   **theory is lacking**

## Typical Examples of Lossy Compression

| Source | Uncompressed | Compressed |
|---|---|---|
| Speech | 64 Kbps | 9.6K bps (CELP) |
| B/W Images | 8 bpp | 1 bpp (JPEG) |
| Color Images | 24 bpp | 1.25 bits/pixel |
| Video | 100M bps | .01-20M bps |
| Audio | 1.4M bps | 256K bps (MPEG) |

## Typical Example of Lossless Compression

| | | |
|---|---|---|
| English Text | 7 bits/symbol | 3 bits/symbol |

## Our Syllabus

Review it

Course is theory and practice

3/4's lossy, 1/4 explicitly lossless, but more lossless embedded in discussion of lossy

## Theory and practice

Quite separate in source coding for a long while

theorists knew little of practice and vice versa

now there's some merging

there's some practical theory

and techniques that are theoretically analyzable (or were theoretically proposed) are being used in practice

there's nothing so practical as a good theory

we'll cover both

But we won't entirely avoid theory that has no practice and vice versa