Advanced Communication Coding Theory

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About the course

- Time:
  - 08:00~09:35, Wed,
  - 08:00~09:35, Fri,

- Instructor:
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About the course

- required course
- Textbook:
  - Khalid Sayood, Introduction to data compression, Morgan Kaufman, 5th Edition, 2018.
- Grading:
  - Attendance:20%
  - Assignment: 20%
  - Presentation:30%
  - Report:30%

About the course

- Content:
  - Introduction
  - Lossless Compression
  - Huffman Coding
  - Arithmetic Coding
  - Dictionary Coding

Introduction

- Data compression
  - Data compression is the art or science of representing information in a compact form
  - some examples
    - Long-distance call
    - Digital TV
    - DVD
    - mp3 player

why data compression need

- More and more of the information that we generate and use is in digital form- in the form of numbers represented by bytes of data
- the explosive growth of data that needs to be transmitted and stored
- We need develop better transmission and storage technologies.

How does compression work?

- Exploit statistical redundancy

  -Take advantage of repeated parts (redundancy/patterns) in the source

  -Describe frequently occurring events efficiently

  -Lossless coding: only statistical redundancy

- Introduce acceptable deviations

  -Omit information that the humans cannot perceive

  visible light; infrared ray; ultraviolet rays

  infrasonic frequency； ultrasonic requency;

  -Match the signal resolution (in space, time, amplitude) to the application

  -Lossy coding: exploit both perceptual and statistical redundancy

How does compression work?

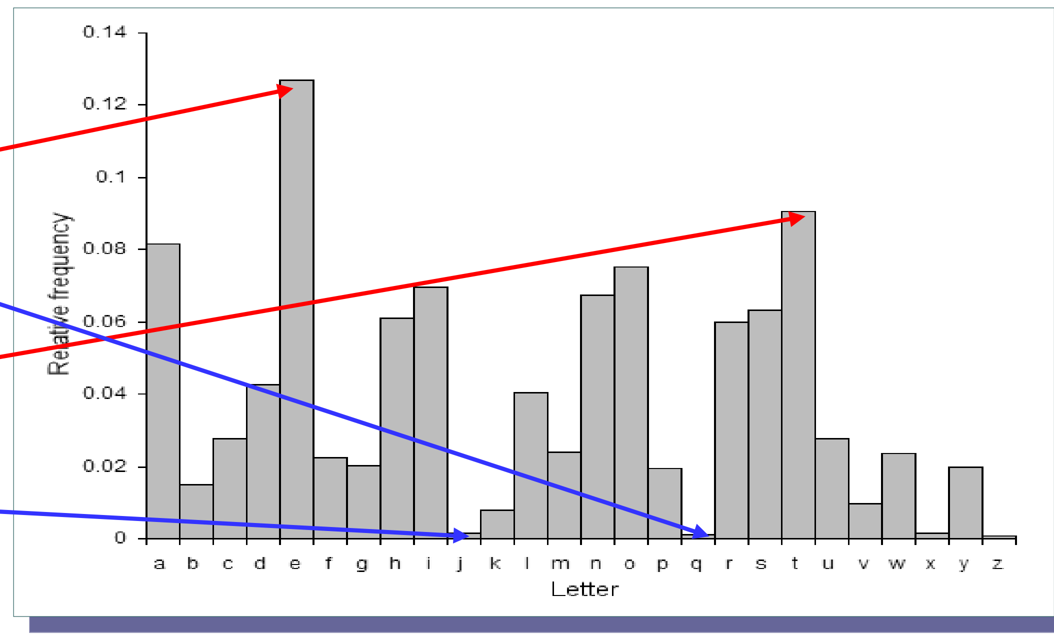
- Statistical structure/redundancy
  - Morse code
  - Braille code
- perceptual limitations of humans
  - By discarding irrelevant information
  - MP3

Morse code

Samuel Morse

Letters sent by telegraph are encoded with dots and dashes

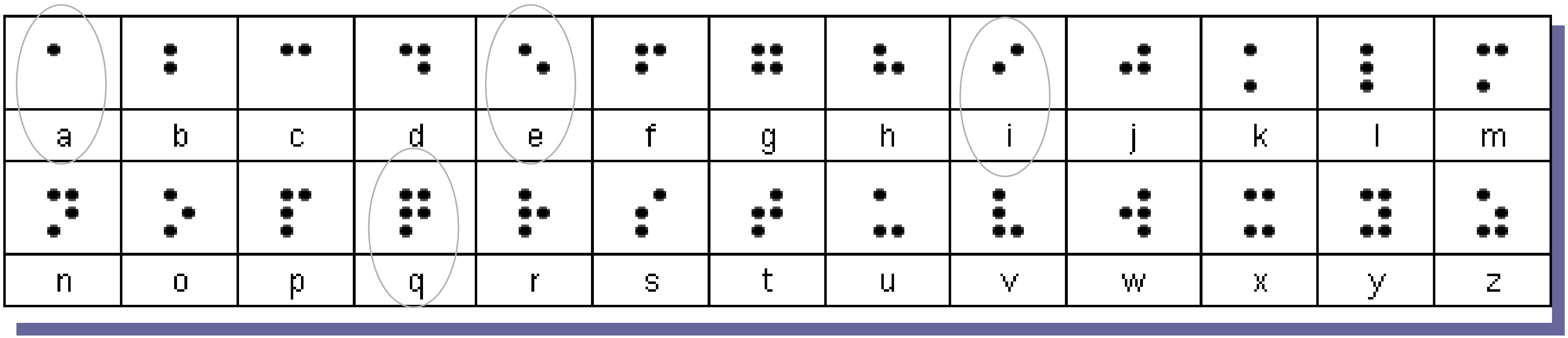
A	.–	M	––
B	–...	N	–.
C	–.–.	O	–––
D	–..	P	.––.
E	.	Q	––.–
F	..–.	R	.–.
G	––.	S	...
H	....	T	–
I	..	U	..–
J	.–––	V	...–
K	–.–	W	.––
L	.–..	X	–..–



More frequently occurring characters, shorter sequence

Braille code

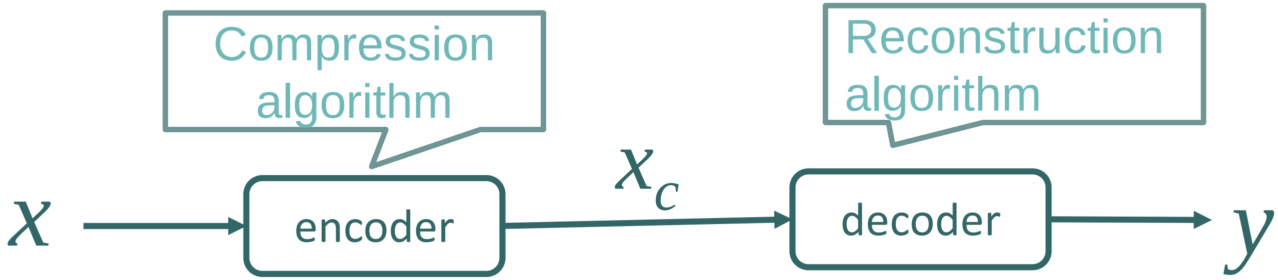
Louis Braille



2×3 arrays of dots are used to represent text

Each character differ from each other by the position and number of dots in the array.

Compression techniques



- Compression algorithm
  - Take an input x and generate a representation x_c
- Reconstruction algorithm
  - Operate on the compressed representation x_c to generate the reconstruction y

Compression techniques

- Based on the requirements of reconstruction

Data compression

- Lossless compression
  $y=x$
- Lossy compression
  $y \neq x$

Measures of performance

Lossless compression

- Compression ratio
- Rate
- Distortion
- Fidelity and quality

Lossy compression

Measure of performance

- Compression ratio

$$= \frac{\text{The number of bits of x}}{\text{The number of bits of xc}}$$

Suppose we store an image.
Before compression, the size is 256×256 pixels, 1byte/pixel
After compression, 16,384bytes

Compression ratio? 4:1

Measure of performance

- Rate
  - The average number of bits required to represent a single sample

Suppose we store an image.
Before compression, the total size is 256×256 pixels(samples)
After compression, 16,384bytes

Assume 8bits per byte, rate?   2

Measure of performance

- Distortion
  - In lossy compression, the reconstruction differs from the original data.
  - The difference between the original and the reconstruction is called the *distortion.*
    - the mean squared error (MSE),
    - signal-to-noise ratio (SNR),
    - decibels (abbreviated to dB),
    - peak-signal-to-noise-ratio (PSNR)

Measure of performance

- Fidelity and quality
  - Often used to measure the difference between the reconstruction and the original
  - Rely more on the human who see or listen
  - perceptual difference

Example

- Suppose we have the following sequence generated by a source

$$a\not{b}barrayaran\not{b}array\not{b}ran\not{b}far\not{b}faar\not{b}faaar\not{b}away$$

Total 8 symbols.
If we use binary code to represent the symbols, what's the rate? 3
Now, if we use the code shown in Table 1.1, sequence length is 106 bits for 41 symbols. What's the new rate? 2.58
And compression ratio? 1.16：1

TABLE 1.1 **A code with codewords of varying length.**

a	1
$\not{b}$	001
b	01100
f	0100
n	0111
r	000
w	01101
y	0101

Modeling and coding

- The development of data compression algorithms can be divided into two phases:
  - Modeling: extract information about any redundancy that exist in the data and describe the redundancy in the form of a model
  - Coding: encode the model and the residual between the data and the model

Modeling and coding

- Ex.1.2.1
  - $S_n = 9,11,11,11,14,13,15,17,16,17,20,21$

Before compression, rate? $2^5=32$

Modeling: $\hat{S}n = n + 8$,

9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

Residual= $Sn - \hat{S}n$,

0, 1, 0, -1, 1, -1, 0, 1, -1, -1, 1, 1

-1	00
0	01
1	10

Rate? $2^2=4$

Modeling and coding

- Ex.1.2.2
  - $S_n = 27,28,29,28,26,27,29,28,30,32,34,36,38$

Before compression, rate? $2^6=64$

Modeling: $\hat{S}1 = 0$; $\hat{S}_n = S_{n-1}$ *for* $n > 1$

0, 27,28, 29, 28, 26, 27, 29, 28, 30, 32,34,36

Residual= $Sn - \hat{S}n$,

27, 1, 1, -1, -2, 1, 2, -1,2, 2, 2, 2,2

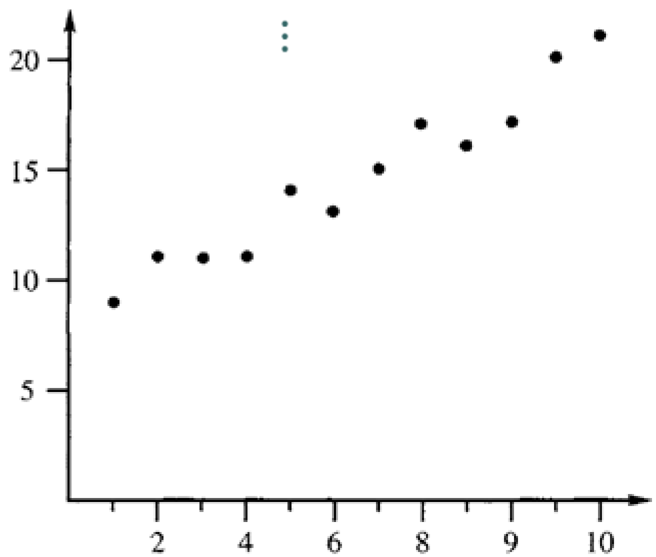
Rate? $2^5=32$

Modeling and coding

- How can we make a good model

$\hat{x}_n = n + 8, n = 1,2, \ldots$

$\vdots$



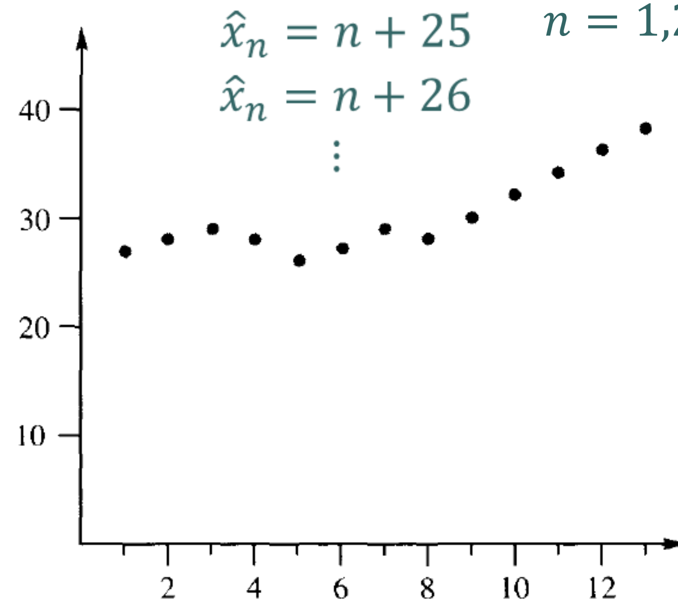
$\hat{x}_n = x_{n-1}$

$\hat{x}_n = n + 25$

$\hat{x}_n = n + 26$

$\vdots$

$n = 1,2, \ldots$



describe the redundancy/pattern/repeated parts as closer as possible