Elements of Information Theory

Bilingual course
(Chinese taught course)
Information and Communication Eng. Dept.
Deng Ke

Introduction

- Course Name
  - Elements of Information Thoery
- Period
  - 40 class hours/10 weeks
- Credits
  - 2.5
- Reference Books
  - Elements of Information Thoery
  - Information Theory and Reliable Communication
  - 信息论——基础理论与应用

Introduction

- Homework and Exam
  - 4~5 homework
  - Final exam
- Prerequisite Courses
  - Probability Theory
  - Stochastic Process
- Web Pages
  - http://unit.xjtu.edu.cn/dengke
- Office
  - 605

Introduction

- Telephone number
  - 82668714
- Reason
- Strategy
- Difference with another course
  - Language
  - Makeup exam
  - Concept

Introduction to the content

The History of Communication

- Origins -Practice and Theory
- Morse 1837
  - Telegraph (wired) and Morse code
- Bell 1876
  - Telephone (wired)
- Marconi 1901
  - Radio transmission across the Atlantic.
- Radio telegraph(about 1910)
- Shortwave Television(1927-1929)

The History of Communication

- Radar (1943)
- Modern Digital Communication
  - Cell phone
  - Satellite communication
  - Optic fiber communication
  - Twisted Pair
  - GPS

  ....

Founder, Claude E. Shannon

- Claude E. Shannon, 1916-2001
  - Graduated in 1936 from University of Michigan with two bachelor's degrees, one in electrical engineering and one in mathematics
  - Got his master's degree from M.I.T. in 1937
  - Got his PhD in mathematics from M.I.T. in 1940
  - Joined Bell Labs.
  - Spent the rest of his life in Bell Labs and M.I.T.
  - Found Information Theory in 1948

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Information Theory

- "A Mathematical Theory of Communication" in Bell System Technical Journal, 1948
- Research on the transmission of information over a noisy channel.
- Focus on the quantification of information.
- Find the fundamental quantificationlimits on signal processing operations such as compressing data and on reliably storing and communicating data.

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Information Theory

- More than Communications
  - Mathematics (Probability theory and statistics)
  - Physics (Thermo-dynamics)
  - Computer science (Kolmogorov complexity)
  - Economics (Investment)
- Mainly research on the statistics characteristic of the information quantificationally

Of course, we only focus on the aspect of communications in this course.

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Chapters

- Chapter 1
  - Introduction, Measurement of information
- Chapter 2
  - Entropy and Mutual Information
- Chapter 3
  - Asymptotic EquipartitionProperty (AEP)
- Chapter 4
  - Source Coding(Data Compression)
- Chapter 5
  - Channel Capacity and Channel Coding Theorem
- Chapter 6
  - Differential Entropy and the Gaussian Channel

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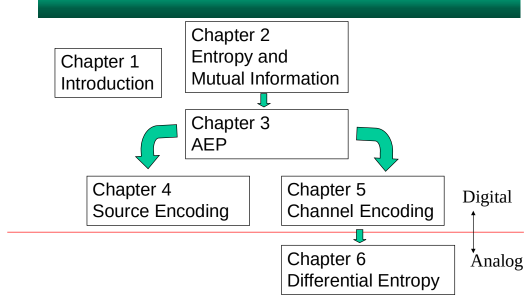
Structures



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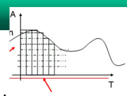
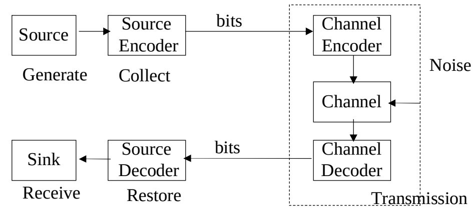
Modern Digital Communication



- Analog signal → Digital signal
  - Sampling -Time discretization
  - Quantizing -Amplitude discretization
- In this Course
  - Time discretization
- Analog: waveforms directly transmitted through channel. →Infinite possibilities
- Digital : Using a finite waveform→ finite possibilities
- Reason: Moore's Law

System Model



- Think→Write→Pack→Post→Unpack→Read→Act

Modern Digital Communication

- Source Encoder
  - Eliminate as much redundancy from source as possible.
- Channel encoder
  - Introduce controlled redundancy to protect form errors in channel.
- The separation between source and channel coding is a essential characteristic in modern digital communications

Source Encoding

- Text
  - ASCII, GB2312, GBK
- Sound
  - MP3(MPEG1 Layer-3)
- Voice
  - PCM
- Image
  - BMP, JPG,
- Video
  - AVI(divx, xvid, H.264), RMVB, FLV

Channel Encoding

- 1950 Hamming block code
- 1960 Reed Solomon code
- 1967 Viterbi decoding
- 1993 Turbo code
- 1963 Low-density parity-check code (LDPC)
- 1996 rediscovered (another efficient decoding algorithm)

The Definition of Information

- Two fundamental questions in communication theory
  - How much a source can be compressed?
  - How much information can be sent through a given channel?

  More power, more faster communications.
- How to define information?
- Message
  - Text, Voice, Image
  - Knowledge with transmission

The Definition of Information

- Knowledge in the Message
  - fixed
  - Huge
  - not able to transmission completely
- The Measurement of the difference of the receiver
- Not able to define the absolute value of the knowledge in the mesage
- Associated with the priori knowledge of the receiver

The Definition of Information

- Example 1
  - 32 teams are in the final of FIFA World Cup 2002
  - Brazil, England, France, Germany, Argentina, ……, China !
  - Which will be the champion ?
  - Brazil is the champion –not so surprise –less information
  - China is the champion !!!! –great surprise –more information
- Analysis
  - not so surprise →big probability→less information
  - great surprise →small probability→more information

The Measurement of Information

- Information is associated with probability
- Example 2
  - dicing
- Probability reflect the prior knowledge
- Therefore, information is defined as a function of probability
- $I_x = f(P_x)$
- f: What function?
- Three requirements

The Measurement of Information

1. $f(1)=0$
2. $f(P_x)$ decreases with P_x
3. If message z contains two independent messages, x, y, $I_z = I_x + I_y$

1. To determine the function, rewrite the last requirement, $f(P_z)= f(P_x)+ f(P_y)$, and we have $P_z= P_xP_y$, then, $f(P_x P_y)= f(P_x)+ f(P_y)$.
2. The logarithm function occurs to us, which satisfy 1 and 3. For requirement 2, we must use

The Measurement of Information

$$I_x \triangleq \log_a \frac{1}{p_x} = -\log_a p_x \qquad (a>1)$$

- Where a is an arbitrary number, for easy to use, a is usually selected as
  1. $a= 2$, the unit of the information is bit
  2. $a= e$, the unit of the information is nat
- The features of I_x
  - $I_x \geq 0$, If and only if $P_x=1$, $I_x=0$
  - 1. $I_x > I_y$, when $P_x < P_y$
  - 2. $I_{x+y}=I_x+I_y$, when x and y are independent