Chapter 2: Introduction to Source and Channel

1.1. Information source

1.2. Information channel

Properties of communication system

- Most of the components are deterministic
  - Knowing the input, the output will surely be determined.
  - Except: Source and channel
    - Cannot to determine in advance the information that these components will generate
    - Uncertainties of the communication system
    - Need to be investigated
      - Based on statistical probability models

2.1. Source

Model

- A collection of primitive information (not through any artificial transformation) such as voice, music, images...
- Primitive information:
  - Mostly continuous functions $f(t)$ of time
  - One or more parameters are time varying parameters
    - Black and white h(x,y,t) where x and y are spatial coordinates of image
    - Meteorological parameters $g(\lambda_i, t)$ with λ_i can be humidity, temperature…
  - Also continuous of level → present as s(t) that has value in range $(s_{\min}, s_{\max})$

2.1. Source

Model (Cont.)

- The primitive information can be sent directly to the channel for transmission
  → Continuous source
- Transformation before transmission
  - Discrete over time
  - Discrete over level
  →Discrete source
- Note:
  - Continuous source: the number of information: cannot be counted
  - Discrete source: the number of information: limited

2.1. Source

Model (Cont.)

- A source message: reflect statical nature of the source
  - The longer the message, the more correct of the reflection
  - The message: instance of source
- At a given time, source generate a random message

→Mathematical point of view: the source is the **statistical structure of a random process**

→ To identify source, it is necessary to know the rule of this random process

2.1. Source

Model (Cont.)

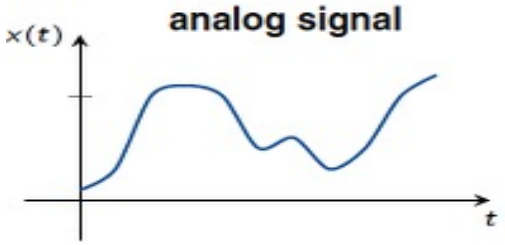
- Discrete source: sequence of n consecutive finite symbol of an alphabet (symbol set):
- Source:
  - X = $(x_1 x_2 \ldots x_n)$
  - S = $(s_1 s_2 \ldots s_n)$
- To identify the statistical properties of the source
  - Set of X or S source symbols
  - Appearing probability of each symbol P(x) or P(s)
- Source can be represented as (X, P(x)) or (S, P(s))

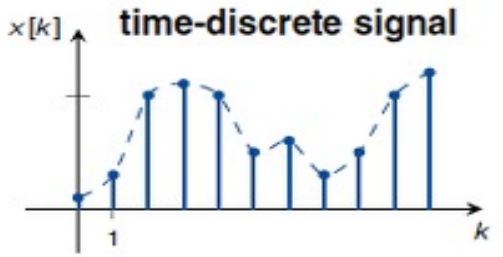
2.1. Source

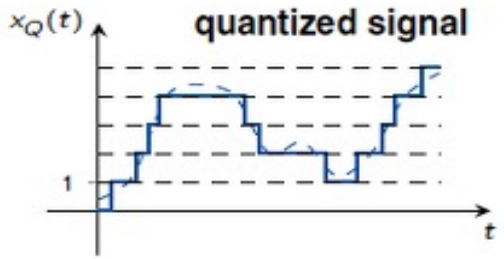
- Continuous source need to be converted to discrete source
  - Sampling
    - Extract samples from a function at certain times: the new function does not lose information compared to original function
    - Shannon sampling theorem (homework)
  - Quantization
    - Mapped value to integer values to store in digital information systems
    - Quantization step (homework)

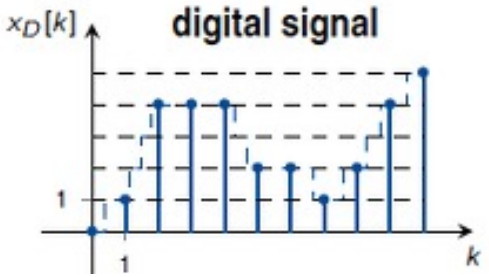
2.1. Source

- Analog signal: x(t)
- Discrete signal:
  - Time discrete signal x(k): Only appear at separate times
  - Discrete value signal (quantized signal) $x_Q(t)$: take separate values from finite set of possible values
- Digital signal $x_D(k)$: discrete time and discrete value signal









2.2.Channel

- In terms of signal transmission: channel is signal conversion system with frequency and pulse characteristics.
  - Evaluate factor: bandwidth, delay, attenuation, distortion…
- In terms of information transmission: model the characteristics of channel when transmit an information from input to output
  - Evaluation factor: error rate, transmission rate, channel capacity…
- Information theory investigates information transmission

2.2. Channel (cont.)

- Common communication environments:
  - Two conductor cable
  - Coaxial cable
  - Optical fiber
  - Wireless communication environment

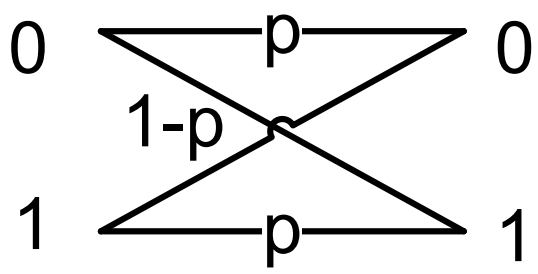
2.2. Channel (cont.)

- Channel
  - Input can be 0 or 1
  - Output can be 0 or 1
  - Without noise:
    - transmit 0 → receive 0
    - Probability for receive 1 when 1 is transmitted is 100%
    - The probability that the channel confuses, receive 0 when send 1 and receive 1 when send 0 is 0%
  - Noisy channel:
    - Probability of obtain 0 at the output when signal 1 is in input or vice versa > 0%
    - The noise of the channel depends on these probabilities
      - Transition probabilities: getting one symbol a at output when symbol b is input

2.2. Channel (cont.)

- Transition probabilities

$$P(Y=0 \mid X=1) = P(Y=1 \mid X=0) = p$$
$$P(Y=1 \mid X=1) = P(Y=0 \mid x=0) = 1-p$$



- Idea case 1: the probability of converting
  - 0 to 0 and 1 to 1 is 1
  - 0 to 1 and 1 to 0 is 0
- Idea case 2:
  - 1 to 0 is 1
  - 0 to 1 is 0
- Worst case: all probabilities are 1/2

2.2. Channel (cont.)

- General case: input and output of channel are both discrete signals
  - Continuous → Discrete

- If the input has m messages and the output has n messages

→ properties of channel represented by a matrix m*n (channel matrix)