Advances in Digital Signal Processing

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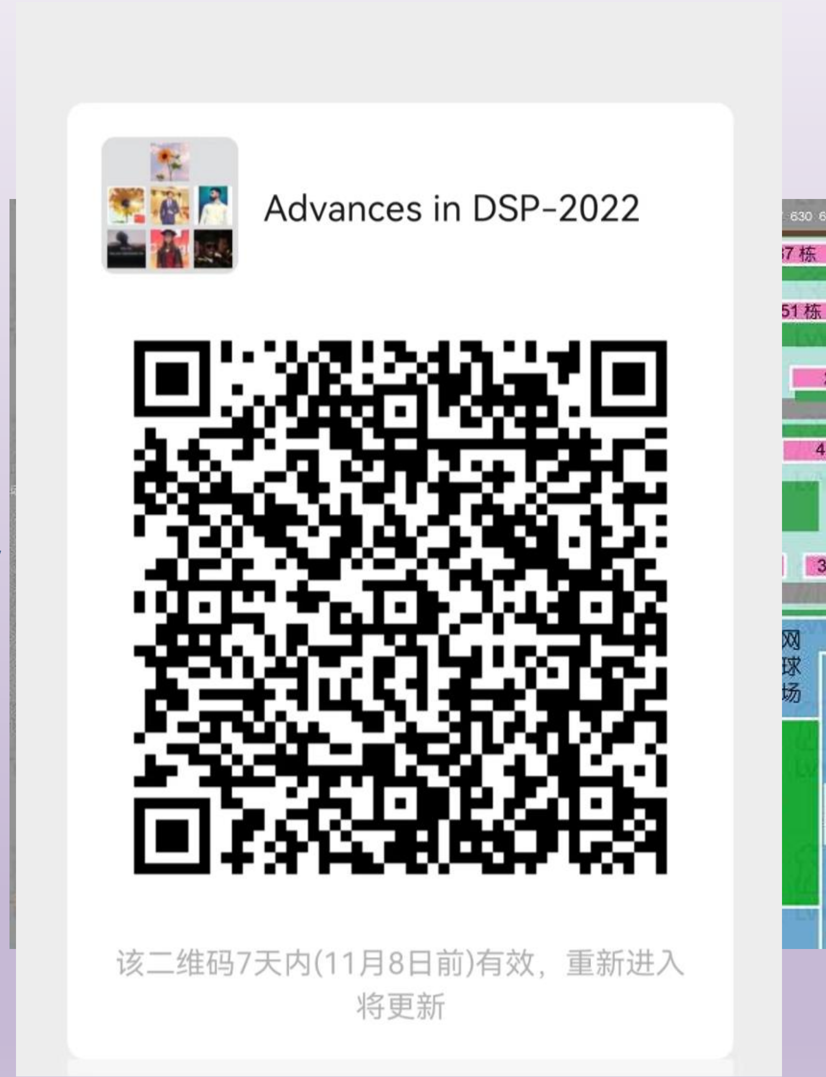


Assessment

Coursework: 40%

- 1 MATLAB Exercises:

Report: 60%

You can write a report in any research topic you are interested in. The requirements are

- Soft copy
- Student ID + Name
- Line Spacing: 1.5
- Font Style: Times new Roman
- Font Size: 12
- Single column
- 8-9 pages

No plagiarism!!!

Book List

Textbook:

1. H.C.So, ***Digital Signal Processing: Foundations, Transforms and Filters, with Hands-on MATLAB Illustrations***, McGraw-Hill, 2010

References:

2. A.V.Oppenheim and R.W.Schafer, ***Discrete-Time Signal Processing***, 3rd Edition, Pearson, 2009
3. J.G.Proakis and D.G.Manolakis, ***Digital Signal Processing: Principles, Algorithms and Applications***, 4th Edition, Pearson Prentice-Hall, 2007
4. S.K.Mitra, ***Digital Signal Processing: A Computer-Based Approach***, 4th Edition, McGraw-Hill, 2011
5. V.K.Ingle and J.G.Proakis, ***Digital Signal Processing Using MATLAB***, 3rd Edition, Cengage Learning, 2012

MATLAB Resources

S. Attaway, ***MATLAB: A Practical Introduction to Programming and Problem Solving***, 4th Edition, Butterworth-Heinemann, 2017

A. Gilat, ***MATLAB: An Introduction with Applications***, 5th Edition, John Wiley & Sons, 2015

http://www-h.eng.cam.ac.uk/help/tpl/programs/matlab.html

http://www.mathworks.com/help/matlab/ref/helpdesk.html

http://www.mathworks.com/matlabcentral/fileexchange/2189-digital-signal-processing-using-matlab

Syllabus Outline

- Foundations of Signal Processing
  Signal Processing Overview, Analog Signal Analysis, Discrete-Time Signals and Systems, Sampling and Reconstruction of Analog Signals
- Discrete-Time Signal Analysis Tools
  z-Transform, Discrete-Time Fourier Transform (DTFT), Discrete Fourier Series (DFS), Discrete Fourier Transform (DFT)
- Digital Filters
  Response, Realization and Design of Finite Impulse Response (FIR) Filters and Infinite Impulse Response (IIR) Filters
- Application Case Studies
  Telephone Touch-tone Generation and Decoding, Interference Cancellation

Intended Learning Outcomes

On completion of this course, you will be able to

- Recognize properties of continuous-time and discrete-time signals and systems such as stability, causality, linearity and time-invariance
- Explain the relationship among different signal processing transforms
- Analyse discrete-time systems and calculate system parameters using appropriate transforms
- Design and realize digital filters according to predefined specifications such as filter shapes and cutoff frequency
- Develop signal processing techniques for engineering problems

Precursors/Prerequisites

Basic knowledge in linear algebra, complex number, differentiation and integration, e.g.,

For a complex number $a+jb$, $j=\sqrt{-1}$, its magnitude and phase are $|a+jb|=\sqrt{a^2+b^2}$ and $\angle(a+jb)=\tan^{-1}(b/a)$

Euler formulas: $\cos(x)=\dfrac{e^{jx}+e^{-jx}}{2}$, $\sin(x)=\dfrac{e^{jx}-e^{-jx}}{2j}$

$$\frac{d(3x^n+2x+1)}{dx}=n\times 3x^{n-1}+2x^{1-1}=3nx^{n-1}+2$$

$=1 = 2T$ $\quad k=0$

$$\int_{-T}^{T}e^{-jkt}dt=-\frac{1}{jk}e^{-jkt}\Big|_{-T}^{T}=-\frac{e^{-jkT}-e^{jkT}}{jk}=\frac{2\sin(kT)}{k}$$

$k\neq 0$

Overview of Signal Processing

Chapter Intended Learning Outcomes:

(i) Understand basic terminology in signal processing

(ii) Differentiate digital signal processing and analog signal processing

(iii) Describe basic signal processing application areas

Signal:

- Anything that conveys information, e.g.,
    - Speech
    - Electrocardiogram (ECG)
    - Radar pulse
    - DNA sequence
    - Stock price
    - Code division multiple access (CDMA) signal
    - Image
    - Video

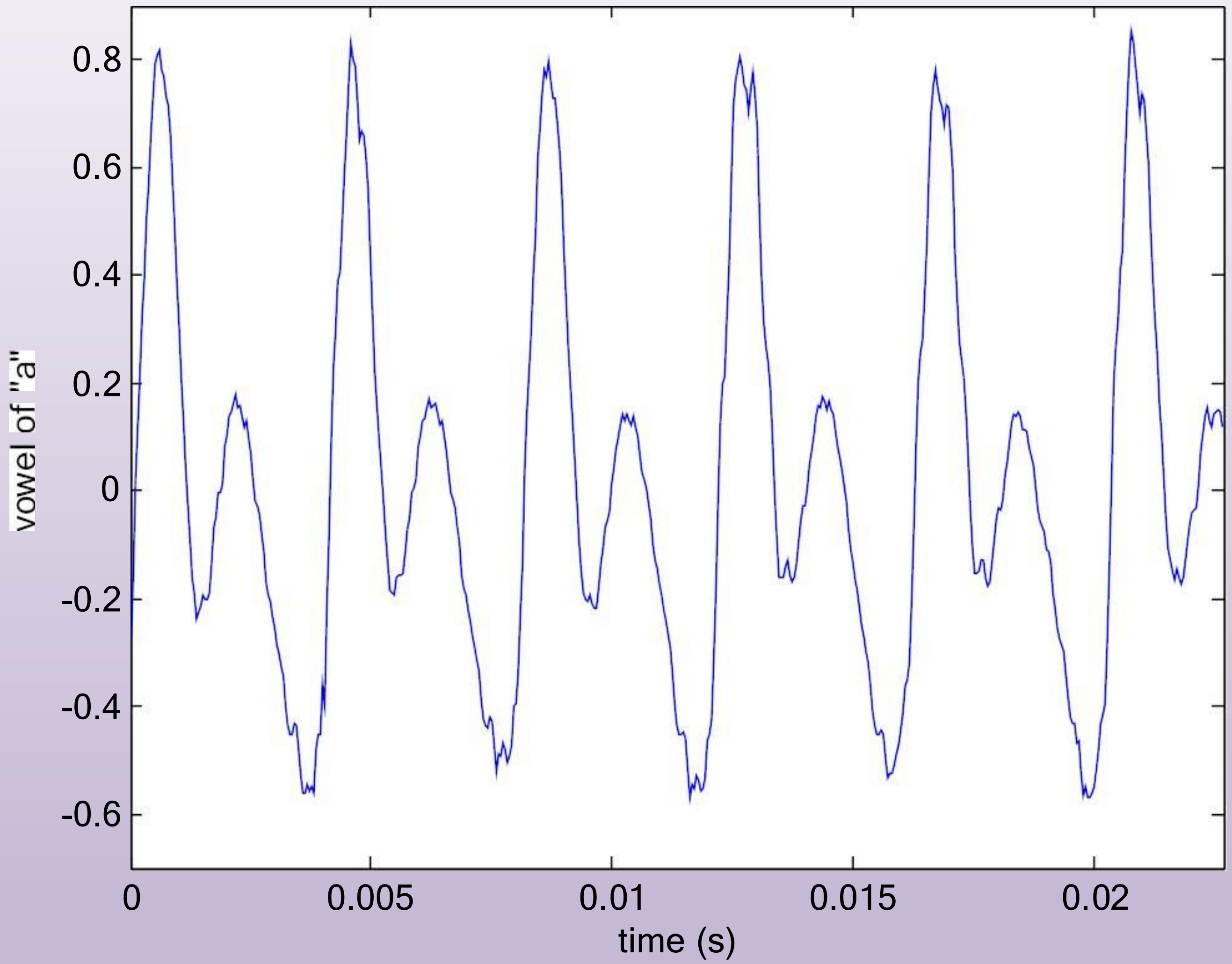


Fig.1.1: Speech

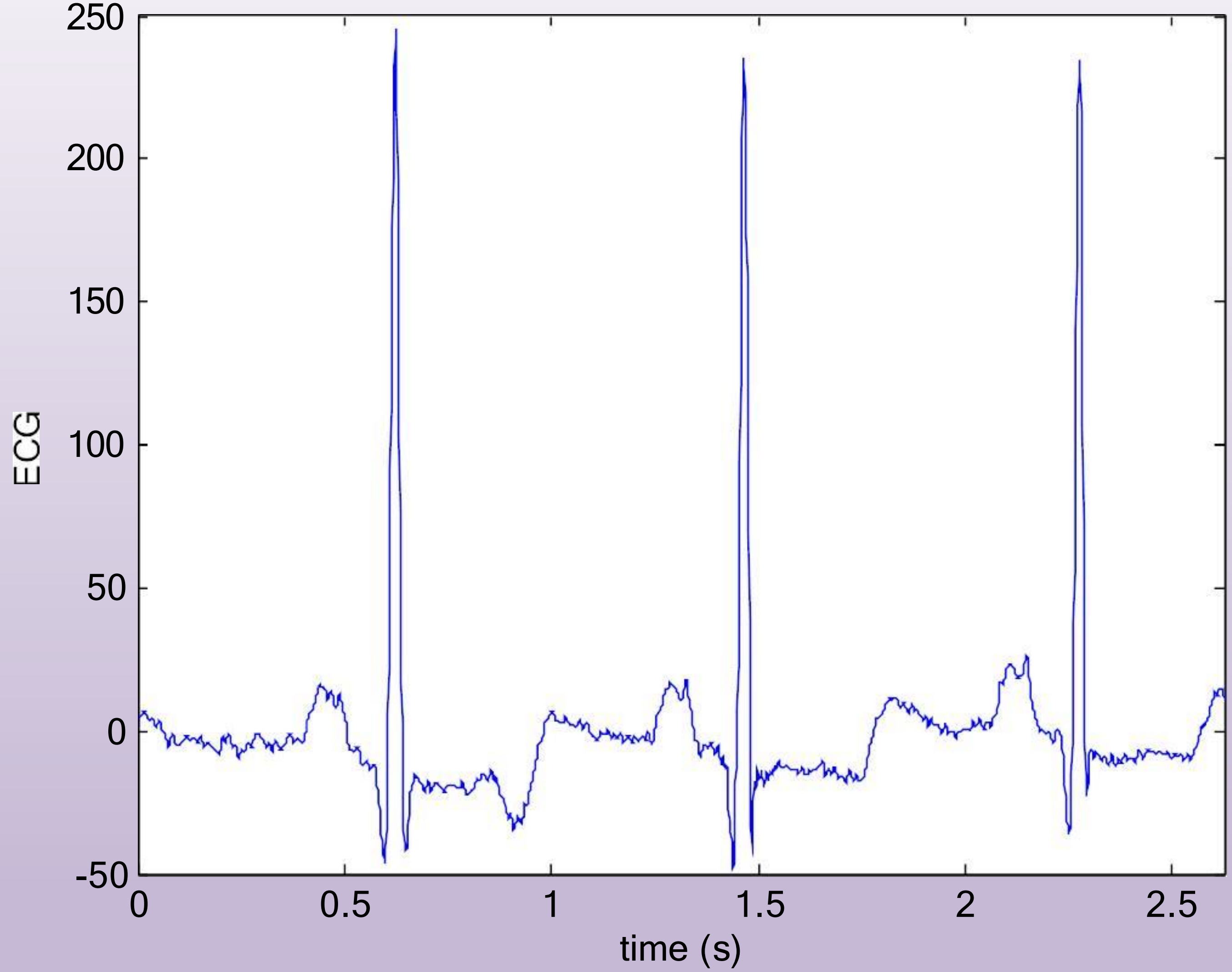


Fig.1.2: ECG

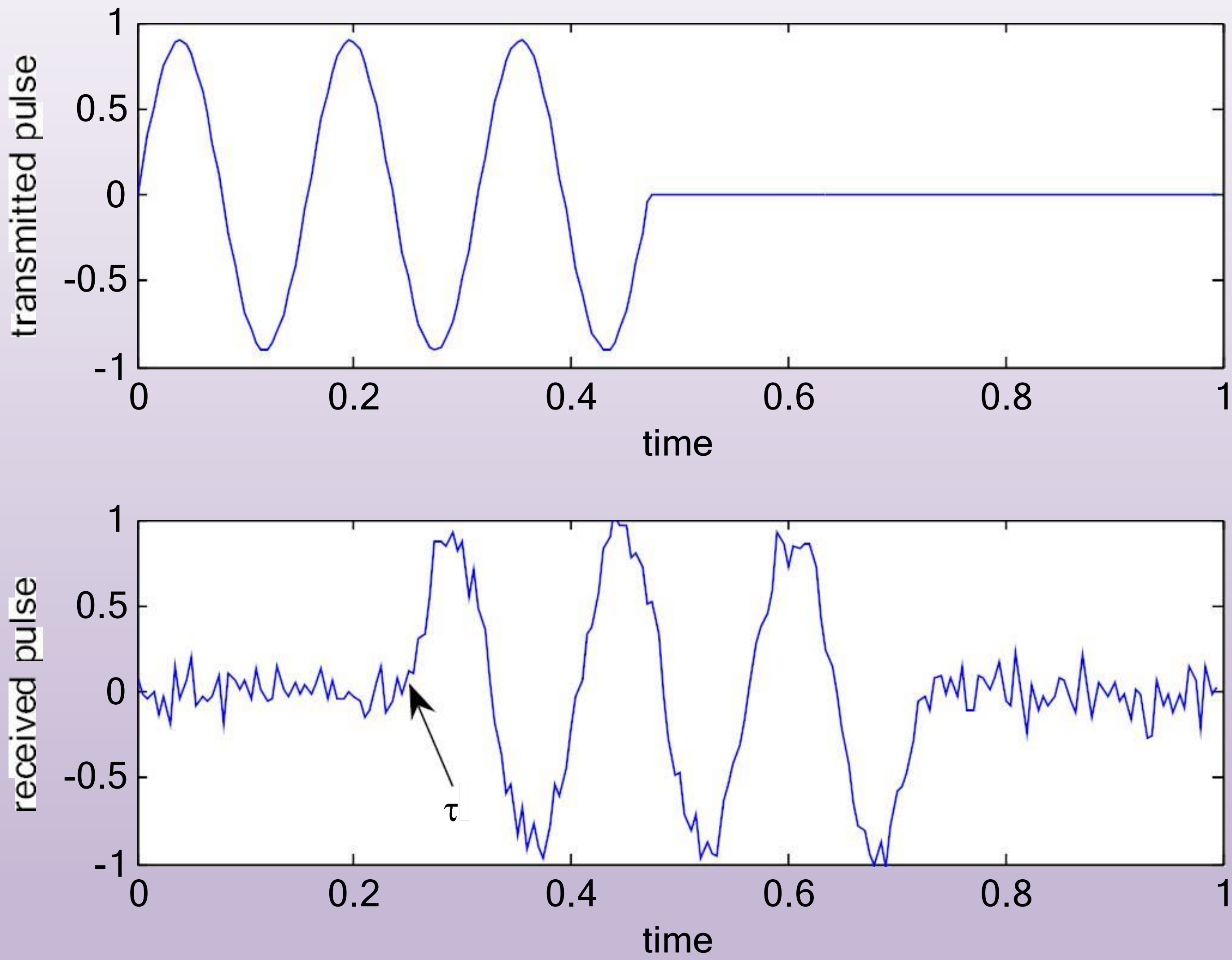
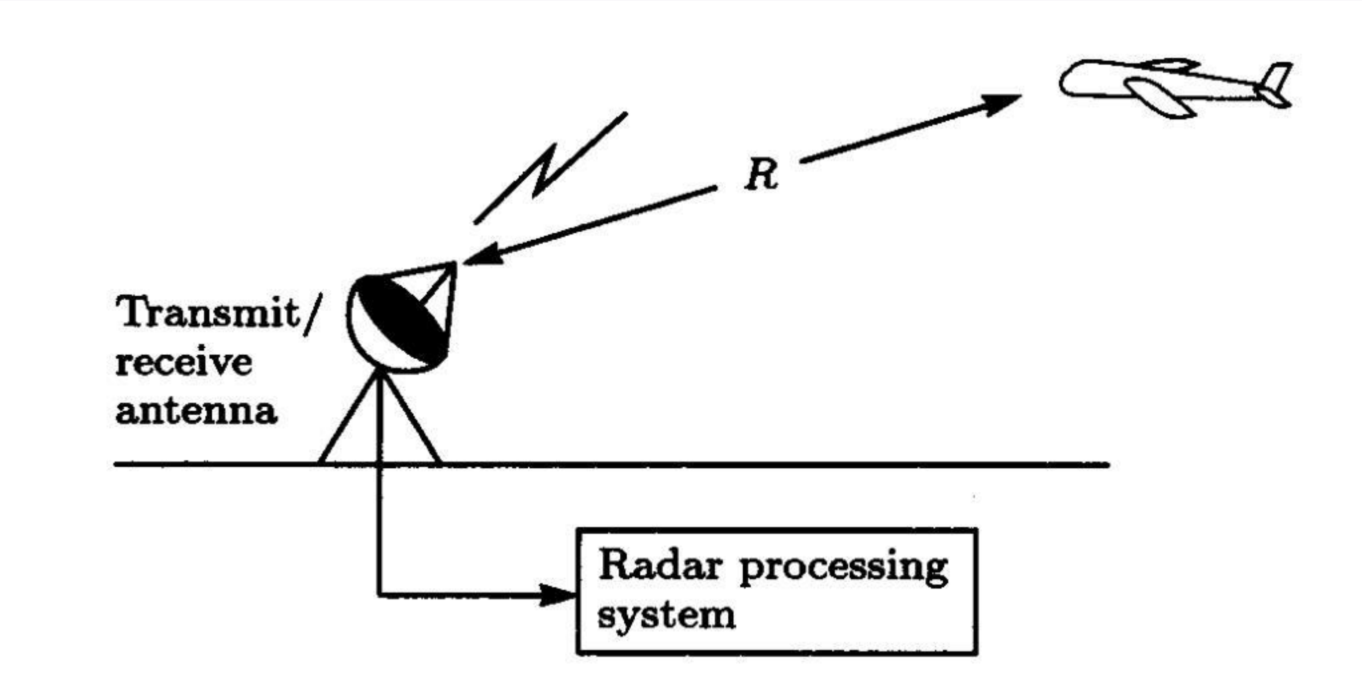


Fig.1.3: Transmitted & received radar waveforms: $s(t)$ & $r(t)$



$$r(t) = s(t-\tau) + w(t)$$

Fig.1.4: Radar ranging

Given the signal propagation speed, denoted by c, the time delay τ is related to R as:

$$\tau = \frac{2R}{c} \qquad (1.1)$$

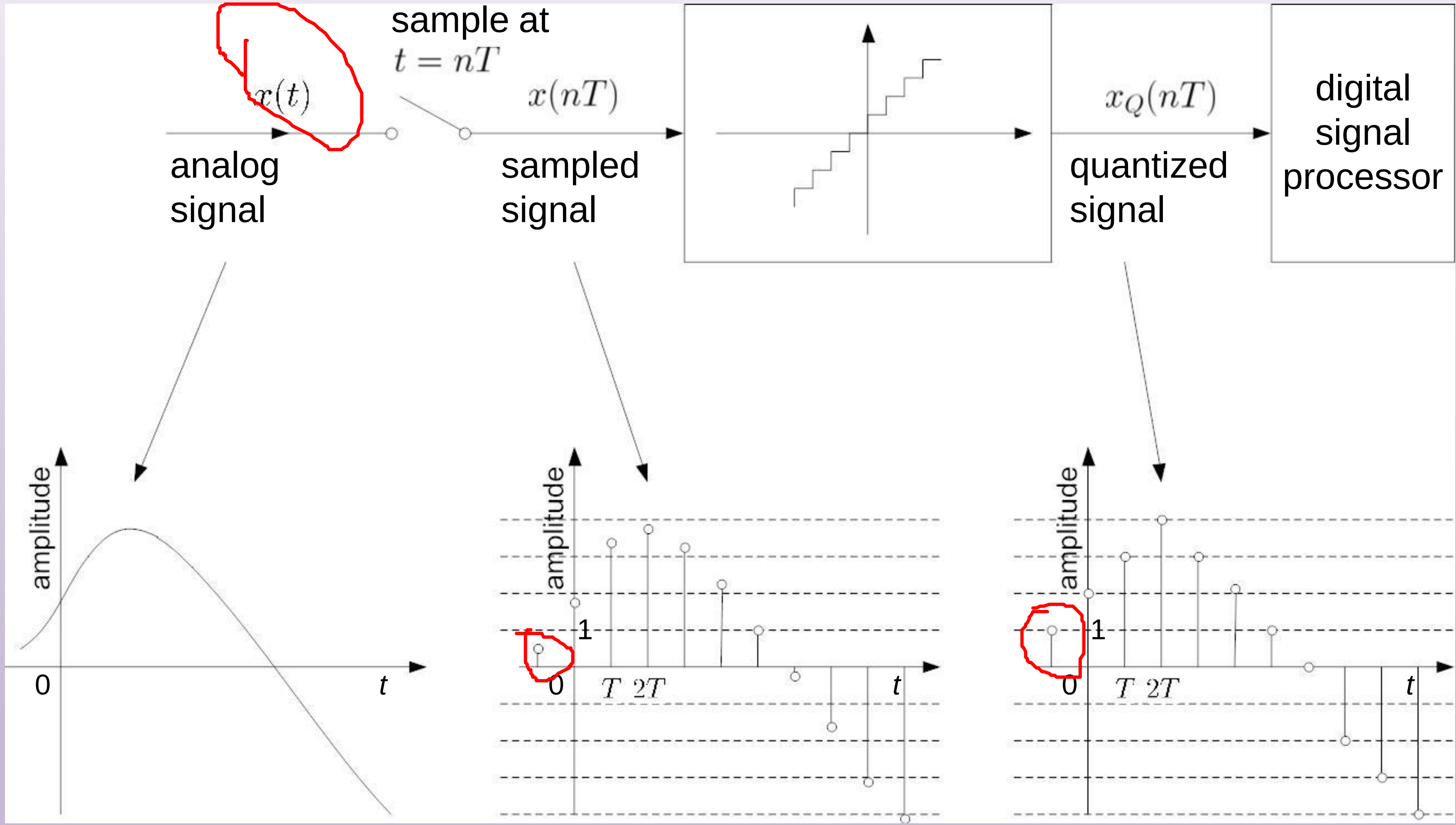
Hence the radar pulse contains the object range information

- Can be a function of one, two or three independent variables, e.g., speech is 1-D signal, function of time; image is 2-D, function of space; wind is 3-D, function of latitude, longitude and elevation

- 3 types of signals that are functions of time:
  - Continuous-time (analog) $x(t)$: defined on a continuous range of time t, amplitude can be any value

sample

  - Discrete-time $x(nT)$: defined only at discrete instants of time $t = \cdots -T, 0, T, 2T, \cdots$, amplitude can be any value
  - Digital (quantized) $x_Q(nT)$: both time and amplitude are discrete, i.e., it is defined only at $t = \cdots -T, 0, T, 2T, \cdots$ and amplitude is confined to a finite set of numbers



time and amplitude
continuous

time discrete
amplitude continuous

time and amplitude
discrete

Fig. 1.5: Relationships between $x(t)$, $x(nT)$ and $x_Q(nT)$

$x(nT)$ at $n=0$ is close to 2 and $x_Q(0)=2$

$x(nT) \in (3,4)$ at $n=1$ and $x_Q(T)=3$

Using 4-bit representation, $x_Q(0)=0010$ and $x_Q(T)=0011$, and in general, the value of $x_Q(nT)$ is restricted to be an integer between -8 and 7 according to the two's complement representation.

In digital signal processing (DSP), we deal with $x_Q(nT)$ as it corresponds to computer-based processing. Throughout the course, it is assumed that discrete-time signal = digital signal, or the quantizer has infinite resolution

System:

- Mathematical model or abstraction of a physical process that relates input to output, e.g.,
  - Grading system: inputs are coursework and examination marks, output is grade
  - Squaring system: input is 5, then the output is 25 5^2
  - Amplifier: input is $\cos(\omega t)$, then output is $10\cos(\omega t)$
  - Communication system: input to mobile phone is voice, output from mobile phone is CDMA signal
  - Noise reduction system: input is a noisy speech, output is a noise-reduced speech
  - Feature extraction system: input is $\cos(\omega t)$, output is ω
- Any system that processes digital signals is called a digital system, digital filter or digital (signal) processor

Processing:

- Perform a particular function by passing a signal through system

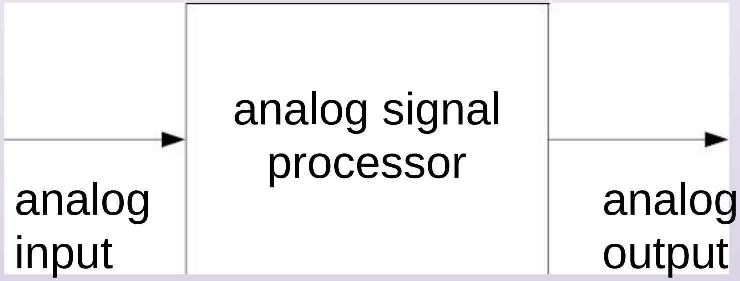


Fig.1.6: Analog processing of analog signal

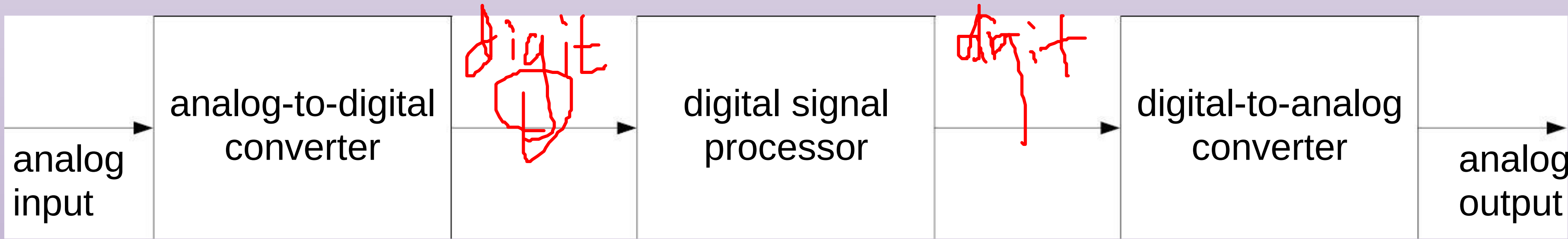


Fig.1.7: Digital processing of analog signal

Advantages of DSP over Analog Signal Processing

- Allow development with the use of PC, e.g., MATLAB
- Allow flexibility in reconfiguring the DSP operations simply by changing the program
- Reliable: processing of 0 and 1 is almost immune to noise and data are easily stored without deterioration
- Lower cost due to advancement of VLSI technology
- Security can be introduced by encrypting/scrambling
- Simple: additions and multiplications are main operations

DSP Application Areas

- Speech
  - Compression (e.g., LPC is a coding standard for compression of speech data)
  - Synthesis (computer production of speech signals, e.g., text-to-speech engine by Microsoft)
  - Recognition (e.g., PCCW’s 1083 telephone number enquiry system)
  - Enhancement (e.g., noise reduction for a noisy speech)

DSP Application Areas

- **Audio**
  - Compression (e.g., MP3 is a coding standard for compression of audio data)
  - Generation of music by different musical instruments such as piano, cello, guitar and flute using computer
  - Song with low-cost electronic piano keyboard quality
  - Automatic music transcription (writing a piece of music down from a recording)

- **Image and Video**
  - Compression (e.g., JPEG and MPEG is are coding standards for image and video compression, respectively)
  - Recognition such as face, palm and fingerprint

DSP Application Areas

- Enhancement

Fig.1.8: Photo enhancement

- Construction of 3-D objects from 2-D images
- Computer animation in film industry

DSP Application Areas

- Communications: encoding and decoding of digital communication signals
- Astronomy: finding the periods of orbits
- Biomedical Engineering: medical care and diagnosis, analysis of ECG, electroencephalogram (EEG), nuclear magnetic resonance (NMR) data
- Bioinformatics: DNA sequence analysis, extracting, processing, and interpreting the information contained in genomic and proteomic data
- Finance: market risk management, trading algorithm design, investment portfolio analysis