Tutorial

Series 1

Advanced Biomedical Signal and Image Processing

Master: Plasturgy & Biomedical Engineering

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Exercise 1: Multiple Choice Questions

1. What are biomedical signals?
    - A) Signals used for wireless communication
    - B) Signals generated by the human body
    - C) Signals used in mechanical systems
    - D) Signals used for satellite communication
2. Which of the following is an example of a biomedical signal?
    - A) Radio waves
    - B) Ultrasound waves
    - C) ECG (Electrocardiogram)
    - D) Seismic waves
3. Who is the pioneer of electrocardiography?
    - A) Thomas Edison
    - B) Willem Einthoven
    - C) Albert Einstein
    - D) Nikola Tesla
4. Digital Signal Processing (DSP) is mainly used in biomedical signals for:
    - A) Cooking food
    - B) Enhancing signal quality and analysis
    - C) Creating computer viruses
    - D) Programming mobile applications
5. The process of converting an analog biomedical signal to digital is called:
    - A) Modulation
    - B) Demodulation
    - C) Sampling and Quantization
    - D) Encryption

Exercise 2: True/False Questions

1. Biomedical signals are only electrical in nature.
2. Willem Einthoven won the Nobel Prize for his work on the electrocardiogram.
3. DSP cannot remove noise from biomedical signals.
4. The purpose of sampling is to convert continuous signals into discrete signals.
5. EEG monitors heart activity.

Exercise 3: Short Answer Questions

1. What is the significance of biomedical signals in healthcare?
2. Explain the role of DSP in biomedical signal processing.
3. Briefly describe the historical development of ECG.

Exercise 4:

A biomedical engineer is analyzing an ECG signal that he sampled at a frequency of 500 Hz. The recorded signal contains noise. Using DSP, describe the steps to filter out the noise.

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Exercise 5:

Consider the discrete time signal: $x[n] = \{1,2,3,4\}$. Compute the discrete Fourier transform of this signal. Use this formula:

$$X[k] = \sum_{n=0}^{N-1} x[n] \cdot e^{-j\frac{2\pi}{N}kn}$$

Exercise 6:

A biomedical signal is sampled (Sampling is the process of converting a continuous-time signal into a discrete time signal) at 200 Hz. What is the maximum frequency component that can be accurately represented without aliasing? Think about Nyquist frequency.

Note: aliasing is a common problem in digital signal processing (DSP) that occurs when a continuous signal is sampled at a rate lower than twice its highest frequency component. This causes the high-frequency components to appear as lower-frequency ones, distorting the original signal and creating unwanted artifacts.

Exercise 7:

An ECG signal contains a frequency component at 120 Hz. If the sampling rate is 150 Hz, what alias frequency will appear in the sampled signal?

Exercise 8:

A 10-bit ADC (Analog to digital conversion) is used to digitize an EEG signal ranging from $-1\ mV\ to\ 1\ mV$. What is the quantization step size? The step size is the division range by the number of quantization levels.

Exercise 9:

A noisy biomedical signal contains interference at 60 Hz. Suggest an appropriate digital filter to remove this noise.

Exercise 10: Discrete Fourier transform (DFT)

Compute the DFT of the following sequence: $x[n] = \{1,1,0,0\}$.

Exercise 11: Convolution in DSP

1. Compute the convolution of the following two sequences: $x[n] = \{1,2\}$ and $h[n] = \{1,-1\}$ then $x[n] = \{1,2,3\}$ and $h[n] = \{1,-1\}$. Use the formula:

$$y[n] = x[n] * h[n] = \sum_{k=-\infty}^{\infty} x[k] \cdot h[n-k]$$

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2. Check that the convolution is commutative: for both sequences demonstrate that:

$$h[n] * x[n] = x[n] * h[n]$$

Exercise 12: FIR Filter Design

Design a 3-tap FIR filter with impulse response: $h[n] = \{0.2, 0.5, 0.2\}$ using the input signal: $x[n] = \{1, 2, 1, 0\}$

The number of FIR taps, (often designated as "N") is an indication of

- the amount of memory required to implement the filter,
- the number of calculations required
- the amount of "filtering" the filter can do

In effect, more taps means more stopband attenuation, less ripple, narrower filters, etc.

Exercise 13: FIR filter stability

Determine if the following FIR filter is stable: $h[n] = \{0.3, 0.3, 0.4\}$. A discrete-time system is stable if its impulse response is absolutely summable:

$$\sum_{n=-\infty}^{\infty} |h[n]| < \infty$$

Exercise 14: Frequency Response of FIR Filter

Determine the frequency response of the FIR filter with impulse response: $h[n] = \{1, 1, 1\}$. The Discrete-Time Fourier Transform (DTFT):

$$H(e^{j\omega}) = \sum_{n=0}^{2} h[n] e^{-j\omega n}$$

You can use the Euler's formula:

$$H(e^{j\omega}) = 1 + cos(\omega) - jsin(\omega) + cos(2\omega) - jsin(2\omega)$$

$$H(e^{j\omega}) = 1 + 2cos(\omega) + cos(2\omega) - j[sin(\omega) + sin(2\omega)]$$

Calculate then the magnitude response

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