University of Calgary

Schulich School of Engineering

Department of Electrical and Computer Engineering

ENEL 563 Biomedical Signal Analysis

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Final Examination

Saturday, 26 April 2014

8:00 a.m. – 11:00 a.m. (180 minutes)

EEEL 345

Total Marks: 50

Instructions:

1. This is a closed-book, closed-notes exam.
2. Calculators and electronic devices of any kind are NOT permitted in the exam.
3. Answer all (six) questions.
4. For questions requiring mathematical derivation, show all steps clearly.
5. For questions requiring algorithms, provide the reason or logic for each step.
6. Specify units or dimensions when appropriate.
7. When drawing plots of signals, spectra, etc., label the axes clearly.

Question 1:

(a) In the context of skeletal muscles and electromyography (EMG), define a motor unit with a list of its constituent parts.

Explain what is meant by the following terms:

(b) innervation ratio,

(c) a train of single-motor-unit action potentials (with a figure),

(d) firing rate, and

(e) biphasic and triphasic action potentials (with figures).

(6 marks)

Question 2: Write equations that define

(a) the cross-correlation function (CCF) of two signals, and

(b) the Fourier transform of a signal.

(c) Derive an expression for the Fourier transform of the CCF in terms of the Fourier transforms of the two individual signals. Show and explain all steps. You may use continuous-time or discrete-time notation.

(6 marks)

Question 3:

(a) Write a mathematical expression to define the power spectral density (PSD) function of a discrete-time signal.

(b) Describe a step-by-step algorithm to derive the median frequency of a PSD function. Explain the role of each step of your algorithm.

(c) Draw schematic sketches of two PSD functions and indicate their approximate median frequencies. Explain the difference between the two examples. Suggest a potential use of the median frequency in biomedical signal analysis.

(6 marks)

Question 4:

(a) A signal containing three events is specified as $x(n) = 3\,\delta(n) + 2\,\delta(n-1) + \delta(n-2)$ $+1.5\,\delta(n-10) + \delta(n-11) + 0.5\,\delta(n-12)$ $+0.75\,\delta(n-20) + 0.5\,\delta(n-21) + 0.25\,\delta(n-22)$. Plot the signal.

(b) Identify the basic signal pattern that is common between the three events in $x(n)$. Write a mathematical expression for the basic signal. Express $x(n)$ in terms of the basic signal.

(c) Specify the impulse response of a matched filter to detect the basic signal defined in part (b) as well as its repeated occurrences present in $x(n)$.

(d) Compute and plot the output of the matched filter. Explain how the result may be used to detect occurrences of the basic signal.

(10 marks)

Question 5:

(a) Describe the significance of the P wave in the analysis of ECG signals.

(b) Describe a method for the detection of P waves in an ECG signal. Explain the purpose and reasoning behind each step of the method. Give at least one nontrivial equation representing a step in the method.

(c) Draw schematic sketches representing an input signal and the corresponding output at each stage of the method.

(6 marks)

See the next page for the next question.

Question 6: Propose a digital signal processing system for the analysis of a single-channel electroencephalographic (EEG) signal for the purpose of staging of sleep. Your design should include the following parts and steps:

(a) A preliminary explanation of how the EEG changes as a person goes from a wakeful state to deep sleep. Give the names of the four basic EEG rhythms and their typical bandwidths.

(b) A procedure with at least one parameter to detect the eyes-open state prior to sleep. Include at least one mathematical equation or formula.

(c) A procedure with at least one parameter to detect the eyes-closed and resting state before sleep. Include at least one mathematical equation or formula.

(d) A procedure with at least one parameter to detect deep sleep. Include at least one mathematical equation or formula.

(e) A consolidated procedure to analyze the various stages of sleep over a period of eight hours. Explain how you associate parts of the EEG signal with various stages of wakefulness or sleep.

(16 marks)

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