University of Calgary

Schulich School of Engineering

Department of Electrical and Computer Engineering

ENEL 563 Biomedical Signal Analysis

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Final Examination

Monday, 22 April 2013

8:00 − 11:00 a.m. (180 minutes)

Room EEEL 151

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: Draw a schematic sketch of a speech signal including segments of voiced and unvoiced speech. Explain their characteristics.

Explain the test for randomness.

Indicate the result you would expect if you were to apply the test for randomness to your speech signal example.

(6 marks)

Question 2: A biomedical signal sampled at 240 Hz contains power-line interference at 60 Hz. Design a notch filter to remove the artifact.

Draw the unit circle in the complex z domain. Indicate the values of z and the frequency in Hz at the intersections of the circle with the axes. Mark the locations of the poles and/or zeros in your filter design.

Derive the transfer function and the impulse response of the filter. Show all steps.

(6 marks)

Question 3: A researcher is interested in recording vibration signals from the knee joint during swinging movement of the leg. However, muscle vibration signals from the thigh muscle were observed to contaminate the knee-joint vibration signal.

Provide recommendations to the researcher on how a filter for adaptive noise cancellation (ANC) may be designed to reduce the muscle artifact. Give a schematic block diagram of the ANC filter. You do not need to derive the mathematical procedures for the filter.

Indicate where and which signals need to be provided as input to the ANC filter, and where the filtered output is to be obtained.

Which part of the ANC filter has time-varying characteristics? Write an equation to describe the input–output relationship of this part.

(8 marks)

Question 4: Describe a procedure for the detection of QRS complexes in an ECG signal.

Give a schematic block diagram of the important steps in the procedure. Include at least four steps.

Give one suitable equation for each step of your algorithm either in the discrete-time domain as a difference equation or in the z domain as a transfer function.

Sketch an ECG signal with at least two beats and show the corresponding output at the various steps of your procedure. Explain the effect of each step of the procedure on the signal.

(10 marks)

Question 5: A student is interested in implementing methods to distinguish between normal beats and premature ventricular contractions (PVCs) in ECG signals. Help the student with the following:

Sketch an ECG signal including at least four normal beats and two PVCs. Explain the differences in the characteristics of normal ECG beats and PVCs.

Recommend two measures of shape to distinguish between normal ECG beats and PVCs. For each measure, give at least one equation and explain how it may be computed or estimated. Indicate whether the measure is expected to be larger or smaller for a PVC as compared to a normal beat.

(6 marks)

See the next page for the next question.

Question 6: A student new to the area of biomedical signal processing wishes to develop methods to analyze electromyographic (EMG) signals. The student wishes to derive quantitative measures from EMG signals to study the relationship between the EMG signal and the level of contraction or force in a muscle. Help the researcher with the following:

(a) Explain the basic nature of EMG signals including the motor unit action potential, spatial and temporal recruitment of motor units, and the EMG interference pattern. (4 marks)

(b) Explain the notion of waveform complexity. Give equations to compute the mean, the root mean squared (RMS) value, the variance, and the form factor of a signal $x(n)$ with N samples. (4 marks)

(c) Give a step-by-step algorithm to compute the envelope of an EMG signal. Include at least two mathematical formulas or equations in your answer. (2 marks)

(d) Explain how the measures of zero-crossing rate and turns count may be computed. (2 marks)

(e) Explain how the RMS, envelope, and turns count values may be expected to vary with the level of muscular contraction. (2 marks)

(14 marks for Question 6)

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