UNIVERSITY OF CALGARY

SCHULICH SCHOOL OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

ENEL 563 BIOMEDICAL SIGNAL ANALYSIS

FINAL EXAM

Tuesday, December 19, 2006, ENA 3

8:00 a.m. – 11:00 a.m. (180 minutes)

Total Marks: 50

Instructions:

1. This is a closed-book, closed-notes exam.
2. Calculators with text/program storage capabilities are not allowed.
3. Answer all questions.
4. In case of problems requiring numerical or algebraic manipulation, show all steps clearly.
5. In case of problems requiring descriptive answers, provide clear statements in point form; long essays are not required.
6. In case of problems requiring algorithms, provide the reason or logic for each step.
7. Specify units or dimensions when appropriate.
8. In drawing plots of signals, spectra, etc., label the axes clearly.

Question 1: (a) Describe the main characteristics of electromyographic (EMG) signals.

(b) Describe **two** applications of EMG signal analysis. Describe the related variations in the features of the corresponding signals.

No equations are required for your answers to this question.

(4 marks)

Question 2: (a) Describe a method to obtain the envelope of a given signal. Give a step-by-step algorithm and all related equations.

(b) Sketch a normal heart sound signal (phonocardiogram or PCG) and its envelope.

(c) Sketch a PCG signal with systolic murmur and its envelope.

Explain the features of the signals and the related characteristics of the envelopes.

(5 marks)

Question 3: (a) Describe the procedure for template matching. Give a step-by-step algorithm and all related equations. Explain how you would acquire all required items of information.

(b) An observed signal $y(t)$ is modeled as

$$y(t) = \alpha_1\, x(t-\tau_1) - \alpha_2\, x(t-\tau_2) + \alpha_3\, x(t-\tau_3),$$

with $1 > \alpha_1 > \alpha_2 > \alpha_3 > 0$ and $0 < \tau_1 < \tau_2 < \tau_3$.

Assuming a biphasic waveform for $x(t)$, sketch $y(t)$. Indicate the values you use for the parameters that define $y(t)$.

Explain how you would use template matching to analyze $y(t)$.

(6 marks)

Question 4: An observed signal $y(t)$ is modeled as

$$y(t) = x(t) + \eta(t),$$

where $x(t)$ is the signal of interest and $\eta(t)$ is random noise that is statistically independent of the process that generates $x(t)$. For simplified notation, the index (t) may be dropped.

(a) Define the statistical expectation operator $E[x]$. Explain how you would apply the $E[\,]$ operator to the signals in this problem.

(b) Using the $E[\,]$ operator, derive an expression for the mean of y in terms of the means of x and η.

(c) Derive an expression for the variance of y in terms of the variances of x and η.

(d) Derive an expression for the autocorrelation function of y.

Show and explain all steps in each derivation above.

(7 marks)

Question 5: A sleep researcher wants to investigate the presence of theta and delta waves in electroencephalographic (EEG) signals. Assist the researcher with the following:

(a) Recommend an appropriate sampling rate for EEG signals in general, along with a suitable anti-aliasing filter.

(b) Provide a complete step-by-step algorithm to detect and indicate the presence or absence of theta and delta waves in an EEG signal. Give at least one significant equation related to a major step in your algorithm.

(c) Explain how the researcher could use your algorithm to find the total durations of theta and delta waves in an EEG signal recorded over eight hours.

(8 marks)

Question 6: Design and describe a complete procedure to obtain two separate averaged estimates of the power spectral densities (PSDs) of the **systolic** and **diastolic** parts of a heart sound signal (phonocardiogram or PCG) using synchronized averaging over several cardiac cycles.

(a) Provide a complete step-by-step algorithm to perform segmentation of the PCG signal as required. If your procedure involves the use of other signals, plot and describe the relationships between the signals used. Give separate and complete algorithms for the detection of each event or segment boundary.

(b) Provide a complete step-by-step algorithm to obtain the PSD of one signal segment. Assume that a function is available to compute the discrete (or fast) Fourier transform (DFT or FFT) of a given signal.

(c) Explain how the results of your procedure could be used to detect the presence of systolic and/or diastolic murmurs.

(d) Provide at least **five equations** that are significant (non-trivial) and represent important steps in your procedures.

(20 marks)

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