University of Calgary

Schulich School of Engineering

Department of Electrical and Computer Engineering

ENEL 563 Biomedical Signal Analysis

Final Examination

Saturday, 23 April 2011

Noon − 3:00 p.m. (180 minutes)

Room PF 120

Total Marks: 50

Instructions:

1. This is a closed-book, closed-notes exam.
2. No calculator or electronic device of any kind is permitted in the exam.
3. Answer all (seven) questions.
4. For questions requiring numerical or algebraic 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) Draw a schematic sketch, over one cardiac cycle each, of

(a) a normal phonocardiographic (PCG) signal,

(b) a PCG signal with murmur due to aortic stenosis, and

(c) a PCG signal with murmur due to mitral regurgitation.

Draw an envelope for each PCG signal.

Identify all the waves or events in the signals and their typical durations.

Give the typical bandwidth for each wave or event in the signals.

(5 marks)

Question 2: Using the continuous-time (t) and continuous-frequency (f) notation, write an equation to define the Fourier transform, $X(f)$, of a signal, $x(t)$.

Derive the Fourier transform of the signal $y(t) = K\, x(t_0 - t)$. Show all steps and explain the relationships between the various operations involved in the time and frequency domains.

(5 marks)

Question 3: A signal, $x(n)$, is given in terms of its samples as $\{4, 3, 2, 1, 2, 4, 2, 1\}$, for $n = 0, 1, 2, \ldots, 7$. The signal is processed using a linear shift-invariant filter with the impulse response, $h(n)$, having the sampled values $\{1, 2, 1\}$, for $n = 0, 1, 2$. Give the procedure to compute the output of the filter. Derive the output of the filter showing all steps.

(4 marks)

Question 4: Given a sampled signal, $x(n)$, $n = 0, 1, 2, \ldots, N-1$, write an equation to compute the *variance*, σ_x^2, of the signal.

Give the definitions of the parameters *mobility* and *form factor*.

Explain how the three parameters mentioned above may be computed and used to analyze the relationship between the force generated by muscular contraction and the related electromyographic (EMG) signal.

(6 marks)

Question 5: A researcher in signal processing seeks your help to design filters to obtain a smoothed estimate of the first derivative (difference) of a signal digitized at the sampling rate of 200 Hz. Help the researcher with the following:

(a) Give the difference equation and impulse response of a filter to compute the first derivative (difference) of the signal.

(b) Give the transfer function of the derivative filter. Derive the magnitude and phase parts of the frequency response of the filter.

(c) Draw a sketch of the magnitude of the frequency response of the derivative filter. Explain the nature of the filter by deriving the gain at 0 Hz and 100 Hz.

(d) Give the difference equation and impulse response of a filter to compute the average of the current input sample and the previous input sample (that is, a moving average or MA filter of length 2).

(e) Give the transfer function of the MA filter. Derive the magnitude and phase parts of the frequency response of the filter.

(f) Draw a sketch of the magnitude of the frequency response of the MA filter. Explain the nature of the filter by deriving the gain at 0 Hz and 100 Hz.

(g) Derive the impulse response and the difference equation of a combined filter with the derivative and MA filters in series.

(h) Derive the transfer function and plot the pole-zero diagram of the combined filter.

(i) Derive the magnitude and phase parts of the frequency response of the combined filter. Draw a sketch of the magnitude of the frequency response of the filter. Explain the nature of the filter by deriving the gain at 0 Hz and 100 Hz.

(j) Draw a signal flow diagram of the combined filter.

(10 marks)

Question 6: Draw a block diagram of the adaptive noise canceller (adaptive filter).

State the expected relationships between the inputs to the filter.

State the conditions that must be met for optimal functioning of the adaptive filter.

Give equations for the output of the filter using both the summation form and the vectorial form for convolution of signals. Explain the composition of the vectors in the vectorial form of the equation.

(8 marks)

Question 7: A researcher in biomedical signal processing wishes to compute averaged estimates of the power spectral density (PSD) for the systolic parts and diastolic parts of phonocardiographic (PCG) signals. The related electrocardiographic (ECG) and carotid pulse (CP) signals are available. The researcher also wants to derive quantitative measures from the averaged PSD. Help the researcher with the following:

(a) Give a step-by-step algorithm to identify the beginning and end points of the systolic part and the diastolic part for each cardiac cycle in a given PCG signal. Explain how the ECG and CP signals may be used for this purpose. No equation is required for this part.

(b) Give a step-by-step algorithm to compute the PSD of each systolic or diastolic segment and to derive the averaged PSD for systole and diastole over an entire PCG signal.

(c) Explain the notions of cyclo-stationary signals and synchronized averaging. Relate these concepts to the PCG, ECG, and CP signals and the procedure to obtain averaged PSDs as above.

(d) Given the averaged PSD, $S(k)$, $k = 1, 2, \ldots, N$, where N is the number of the samples used in the computation of the discrete Fourier transform, explain how the mean frequency of the PSD may be computed. Give an equation and explain each term or variable used.

(12 marks)

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