UNIVERSITY OF CALGARY

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

ENEL 563 BIOMEDICAL SIGNAL ANALYSIS

Final Examination

Monday, December 22, 2003 ENA 3 Time: 12:00 – 3:00 p.m.

Total: 50 Marks

NOTE:
1. This is a closed-book 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.
   In case of problems requiring descriptive answers, provide clear statements in point form; long essays are not required.
   In case of problems requiring algorithms, provide the reason/logic for each step.
5. Specify units or dimensions when appropriate.
6. In drawing plots of signals, spectra, etc. label the axes clearly.

Marks

1. Draw three-channel traces of the ECG, phonocardiogram (PCG), and carotid pulse signals of:

2 a) a normal subject, and

2 b) a patient with systolic murmur.

(6) 2 Label all the components of the signals and relate them to the various phases of the cardiac cycle.

2. Considering the acquisition of the ECG signal, identify and describe one potential source or cause of each of the following types of artifact:

2 a) high-frequency noise,

2 b) periodic artifact, and

2 c) a physiological artifact.

(6) In each case, explain how the artifact is caused, how the artifact gets combined with the ECG, and how you would remove or prevent the artifact.

3. Write the equations defining:

1 a) the convolution of two signals, and

1 b) the Fourier transform of a signal.

4 Prove that the Fourier transform of the convolution of two signals is

(6) equal to the product of the Fourier transforms of the two individual signals. Show and explain all steps.

You may use continuous-time or discrete-time notation.

4. A researcher uses two digital filters in series to:

a) obtain the derivative of the given signal, and

b) smooth the derivative using the three-point moving-average filter.

1 i) Write the input-output relationship of each filter in the form of difference equations.

2 ii) Derive and plot the impulse response of each filter.

2 iii) Derive and plot the impulse response of the combined system.

1 iv) Derive the transfer function H(z) and the difference equation

(6) (input-output relationship) for the combined system.

5. A researcher new to the field of biomedical signal analysis is assigned a project on the analysis of heart sounds and murmurs. The researcher is provided with a database of PCG signals of four types:

a) normal,

b) systolic murmur,

c) diastolic murmur, and

d) systolic and diastolic murmur.

The researcher surfs the internet and obtains two programs to compute the zero-crossing rate (ZCR) using a moving window of 20 ms, and a filtered envelope of a given signal. The sampling rate used is 1000 Hz. Although the programs generated graphs of the given signal, the ZCR, and the smoothed envelope, the researcher encountered difficulties in interpreting the results.

Assist the researcher by providing the following information:

4 X 2 i) For each type of PCG signal listed above, draw plots of a typical PCG signal, its ZCR as a function of time, and the averaged envelope. Explain the important expected characteristics of the results.

2 ii) Estimate the ranges of ZCR values (using a moving window of 20 ms) for typical normal heart sounds and murmurs. Explain your procedure and assumptions.

(10)

6. You have been hired to develop two software packages for the analysis of 10-channel EEG signals for the following purposes:

a) Detection of the presence of the alpha rhythm:

i) in any one single channel, and

ii) jointly in a pair of left-right channels.

b) Detection of spike-and-wave complexes of a prespecified shape in any channel.

Design <u>two signal processing packages</u> to address the two problems mentioned above. <u>For each package</u>, provide the following details:

2 X 2 i) A schematic block diagram representing the various algorithms or signal processing steps that you recommend. Include <u>at least three distinct and nontrivial</u> procedures in your design.

2 X 2 ii) Explain each block or part of your package. Describe the reason or logic behind your recommendation.

2 X 2 iii) Write at least two nontrivial equations related to your procedures.

2 X 2 iv) Provide graphical illustrations representing a typical EEG signal as it is processed by each block of your package.

<u>(16)</u>

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