Tfy-99.275 - Signal Processing in Biomedical Engineering

Exam 14.10.2003

Listed below are 5 questions - you should answer *all* of them. For each question a maximum of 6 points can be earned (thus: 5 * 6 = 30 points in total). Possible points from the exercises are added on to these points.

You may answer the questions in English as well as in Finnish.

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1. Give short answers to the following questions:

a - What is the basic difference between a stochastic and a deterministic signal? Give an example of a biomedical signal, which can be clearly regarded as 1) a stochastic signal, and 2) a (semi) deterministic signal. (2p)

b - Determine the linear convolution of the sequences $x(n) = \{ 0, -1, 0, 2, 1, 1\}$ and $h(n) = \{ 2, 3, 2, 2, 1, 1\}$. (2 p)

c - Describe aliasing graphically in time and frequency domains. (2p)

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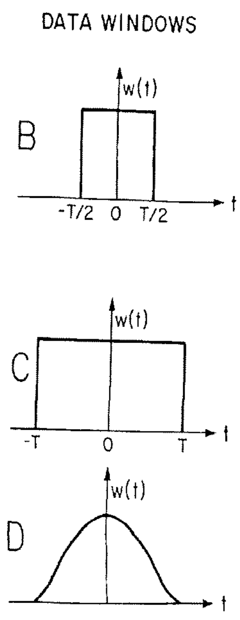
2. Spectral estimation by Fourier transform.
We have a signal $x(t) = \cos(80 \cdot \pi \cdot t) + \sin(70 \cdot \pi \cdot t) + \sin(20 \cdot \pi \cdot t)$, where t is time in seconds. The signal is sampled at 100Hz.

a - Draw the true amplitude spectrum of the signal (2p).

b - The power spectral density (PSD) estimate $X(f)$ of the signal $x(t)$ is dependent on the shape of the data window used. Sketch the PSD estimate $X(f)$ when the different windows depicted right (B – short rectangular, C – long rectangular, D – long gaussian) are used (3p).

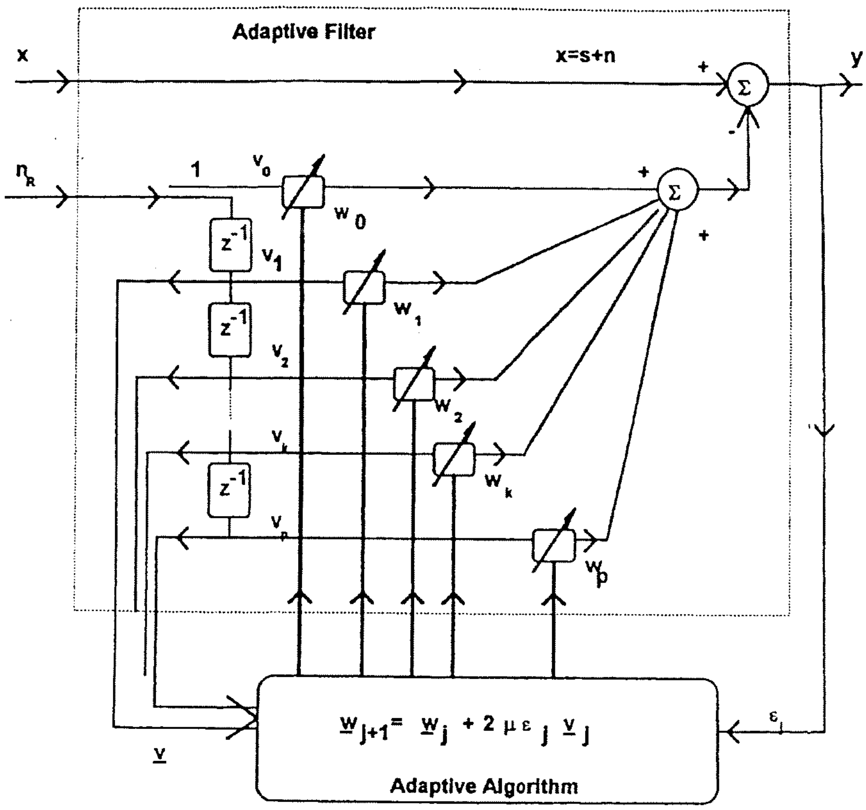


c - Let us assume we measure EEG from an awake person who may perform different types of mental activities during the measurements. What happens if we use in the spectral estimation a very long data window, and what if we use a very short window? (1p)

3. In situations where the frequency contents of signals and noise overlap, one cannot simply use filters with 'straightforward' passbands and stopbands. A filter that would cancel the noise, would also affect the signal that we want to study.

a - Give two examples of biomedical measurements that suffer from this problem (overlap of signal and noise). (2p)

Adaptive filters aim to achieve an optimality criterion in changing environments. One type of such a filter is the LMS-adaptive filter. It can be used for example as an adaptive noise canceller, applications being cancellation of power-line interference and removal of electrosurgical noise that may contaminate ECG signals. A possible recording set-up is given in the figure below.



b - Describe how such an adaptive system works, describe the different components, their function etc. (We assume the, zero-mean, noise, n, to be uncorrelated with the underlying 'clean' signal, s. The recorded data, x, can be described as $x = s+n$). (4p)

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4. In solving biomedical signal processing problems, use of artificial neural networks (ANNs) has become very popular during the last ten years.

a - For what kind of applications ANNs are especially suitable? (2p)

A central point in neural networks' functioning is the training phase during which information is being built-up in the network weights. There are many different training methods that can be employed to perform this task. One group of methods uses so-called unsupervised learning. In this technique, only input samples are presented to an ANN, no desired outputs.

b - Why may such a technique, in which no 'good answers' are provided to the ANN, still be potentially useful for many problems? (2p)

Another popular technique concerns the use of wavelets to describe biomedical signals. Description of a signal using wavelets is quite similar to descriptions using Fourier series in the sense that in both cases an expansion of functions is used

c - How does the frequency resolution of a wavelet reprepresentation differ from that of a Fourier series representation? (2p)

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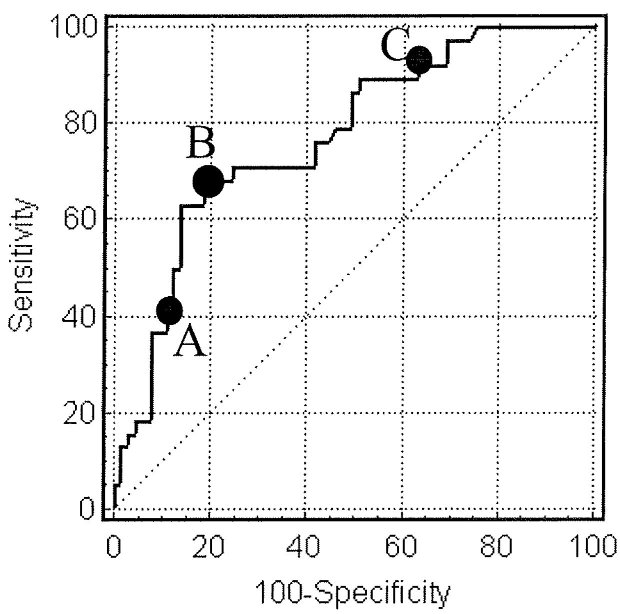
5. Assessment of performance

a - In the figure below an ROC-curve is given for a system that records a patient's heart activity and is supposed to give an alarm when it recognizes a heart failure. Let's assume that we can choose between three different configurations of the system, and their peformances are depicted as the points A, B and C in the ROC curve below. If the ability to always detect a heart failure when one is occurring is far more important than all other properties, which of the configurations (A, B, or C) would you choose, and why? When with that configuration an alarm is generated, what is the (approximate) probability that that is a false alarm? (3p)



b - If we have a set of data available for development/training of a biosignal classification system it is good practice to divide this into 3 subsets;

1 - a set for training classifiers,

2 - a set for testing the classifiers during development, and

3 - a test set that is left untouched during the entire development process and is only used after the development of the system is finished.

Explain why we really need this 3rd set, and why the 2nd one in general gives too optimistic results, even if we don't use that one for training the classifiers. (3p)

[END]