University of Tehran
Department of Electrical and Computer Engineering

Problem 1. The convolution is a mathematical operation on two functions (f and g) that produces a third function ($f * g$) that expresses how the shape of one is modified by the other. In discrete-time domain, convolution is expressed by the following equation:

$$(f * g)[n] = \sum_{m=-\infty}^{+\infty} f[m]g[n-m]$$

You will work on the concept of convolution in this course, and you might confront it again in the rest of your courses. In this problem, we try to implement this operator using MATLAB.

I. Implement convolution operator in MATLAB! Write a function named `myConv` that inputs two arguments, `x` and y, and if an output argument was specified, returns the convolution of these two vectors. Otherwise, the function plots the outcome of operation. So, the following syntax: "`z = myConv(x, y)`" will calculate the $(x * y)[n]$ and assigns the outcome to the variable `z`, while the syntax "`myConv(x, y)`" merely plots the $(x * y)[n]$, returning nothing. Note that you should not use the MATLAB's predefined conv or any other similar functions!

II. Generate two random vectors of length 10000. Use your function to evaluate the convolution of these vectors and measure the time spent on your function. Repeat this step for 100 times and keep the spent time on each of these repetitions.

III. Repeat the previous part, but instead of using your own function, apply the MATLAB's conv function. Then compare the computation duration of these two functions by means of a boxplot.

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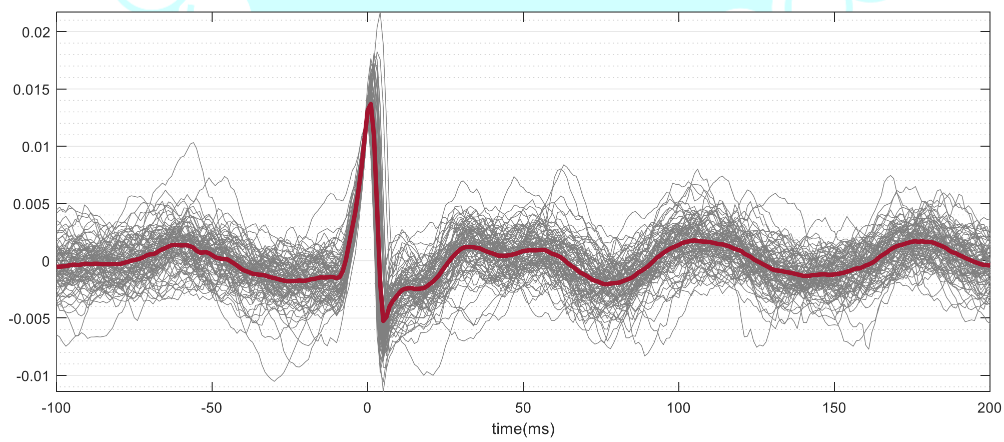
Problem 2. A file named 'ecg.mat' is attached to this assignment. Load it into your MATLAB workspace. It contains a very short signal of an electrocardiogram signal, which is generated in living creatures during heart pumping. This data is already filtered, so the low frequency oscillations are removed from it. Sampling rate of the signal is 1000Hz, meaning that the time difference between each two subsequent samples is 1 millisecond.

I. Plot the signal, in a way that the x axis corresponds to time, instead of samples.

II. As you can see, the ECG data has some sharp peaks that rise above the average of signal. We want to segment our 1-dimensional data into a 2-dimensional matrix and keep some samples before and after these peaks in each of this matrix's rows. First, set a threshold (e.g., 0.01) for this data, and find the indexes of local maxima in which the signal passes this threshold. Then iterate through these local maxima and extract 100 milliseconds prior to them and 200 milliseconds after them and save the corresponding data in different rows of a matrix.

III. Plot all rows of your matrix in one figure with gray, semi-transparent color. Then, overlay this plot with the average ECG plot, which is the average of your matrix across its rows. Your final plot should be something like this:



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Problem 3. Use a microphone and record yourself talking for about 10 seconds.

I. Load that audio chunk into MATLAB workspace and play it.

II. Now we want to add an echo into your voice, using the formula below:

$$y[n] = x[n] + \alpha x[n - n_0]$$

Where the x[n] is you original uncontaminated voice, α is the down toning factor and n_0 is the echo's time delay. Set $\alpha = 0.5$ and consider n_0 such that it corresponds to 0.5 second delay, and generate $y[n]$.

III. Shown that this system is an LTI system. Find its impulse response.

IV. Generate the echoed version of your voice by means of convolving your audio file with the echo system's impulse response.

V. Assume that all characteristic of the system, the input and the output are known except n_0. How can we find n_0? Implement your idea and evaluate it on the data generated in Part 2.

General Notes about Homework!

- Ask your questions about this homework from me!
- Cheating is strongly prohibited in this course. You may cooperate with your fellow classmates but avoid duplicating each other's solutions.
- Refer to course's general rules for further details.