

Basics of Signals, Sampling, and Fourier series

Exercises in Matlab

1. The signal shown in Figure 1 is the number of steps that a student has walked during the last two weeks. By simple filtering techniques, we want to analyze his behavior.
 - 1) Calculate the average, variance and median of the steps he has walked.
 - 2) The student did not wear his tracking device on two days and was very active during one of the days. We do not want these extreme cases influence our analysis of routine behavior. Therefore, perform a moving median of 3 days to obtain a more uniform data.
 - 3) Perform a moving average of 3 days on the original signal and compare it with the result of part 2. Which one of the two methods retains the trend of the data better?
 - 4) On the signals obtained in the previous step, calculate the slope of number of steps he walked for the days 1 to 7 and 7 to 13. What can you conclude of his progress from comparing these two numbers?

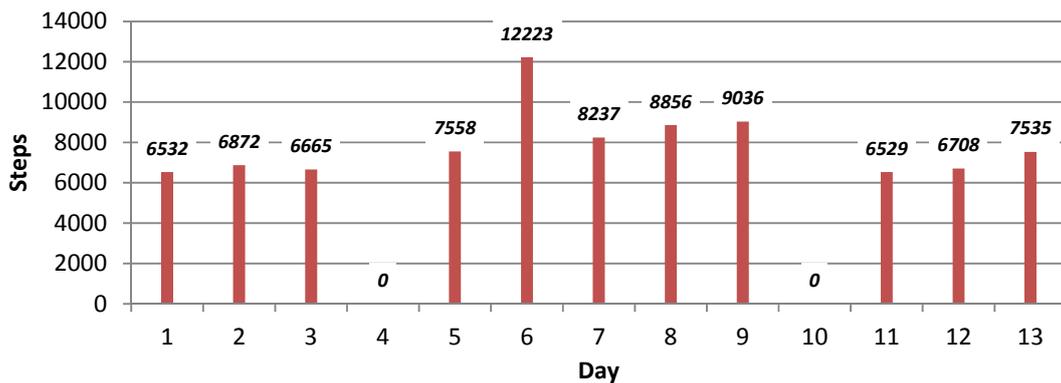


Figure 1. The number of steps a student has walked during the last two weeks.

2. Sinusoids and periodic waveforms
 - 1) In Matlab, create and visualize periodic sinusoids x_1 , x_2 , and x_3 . Define the time variable t with a step size of 0.005s and for $[0, 5]$ seconds.

$$x_1 = \sin(2\pi 3t); \quad x_2 = \cos(2\pi 6t + \pi/3); \quad x_3 = \sin(2\pi 1.5t).$$
 - 2) Calculate and visualize the signal $y_1 = x_1 + x_2 + x_3$ and identify the period T of y_1 by visually inspecting the plot. Explain the result.

3. An electrocardiogram (ECG) records the electrical activity of the heart and is used to examine the heart beat patterns. In an ECG signal, the periodic patterns and peaks correspond to heart beat cycles. The provided ECG signals in this exercise are recordings for 200 seconds with the sampling frequency of 5000 Hz, meaning that the time difference between each two samples (values) is 0.2 milliseconds.

- 1) Read and plot the ECG signal of file ECG1 . mat for the first 10 seconds.
[Hint: define the time t with step size of 0.0002s and plot the first 50000 samples.]
 - 2) Find the peaks of this signal and calculate T, which is the average time difference between each pair of peaks.
[Hint: use findpeaks, diff and mean functions.]
[Hint: choose the minimum peak height as 10000 for findpeaks.]
 - 3) Convert the calculated time T in part 2 to Beats Per Minute (BPM).
4. On the ECG signal of question 3, remove high and low frequency noise components. In order to do this, perform a band-pass filtering, which only allows frequencies between 0.6 Hz and 4 Hz to remain. These frequencies correspond to heart rate of 36 BPM to 240 BPM.
- 1) Using the command below to design and obtain the band-pass filter parameters:
`[b,a] = butter(1, [0.6/2500 4/2500]);` Here, you defined a second-order Butterworth filter to perform the band-pass filtering.
 - 2) Filter the ECG signal with the parameters obtained in part 1.
 - 3) Use the function `fft` to calculate the frequency representation of the filtered signal. In order to plot the frequency components you should calculate the absolute value divided by the length of the signal. Use the following commands to do so and plot the frequency components:

```
L = length(signal);
S = abs(Y)/L;           % Y is output of the fft
F = 5000*(1:L)/L;      % Define frequency variable
plot(F(1:4000), S(1:4000)); % Plot up to 20Hz
```
 - 4) Identify the most dominant frequency component as the heart rate frequency and convert the value from Hz to BPM.
5. 1) Perform tasks of questions 3 and 4 for the signals ECG2 . mat and ECG3 . mat.
 2) Assuming that the heart rate of a healthy person is more stable than a non-healthy person, which subject can have an unhealthy lifestyle? Justify your answer.

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