Faculty of technology
Electronics department

Advanced physiological signal processing
License biomedical engineering

Practical 𝒲ork N°1

Temporal analysis
of the electrocardiogram (ECG) record

Prepared by:

Med. BAHAZ & R. BENZID

Aim

This practical work is a familiarization with electrocardiogram signals as well as a first step in the analysis of physiological signals like those of MIT.

ECG

The electrocardiogram, commonly abbreviated as ECG, is the manifestation of the electrical activity myocardium, the heart muscle. A typical signal of the derivation II is of the waveform:
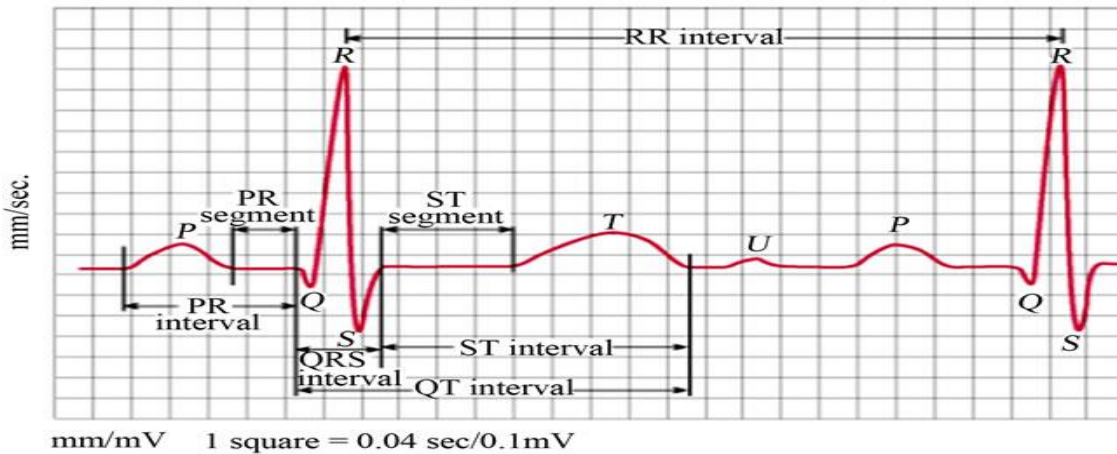

Fig. 1 : *Time intervals and waveforms in a typical ECG signal*

The ECG signals, which will be the subject of the temporal analysis in this practical work, are those of the physionet database of the MIT-BIH Arrhythmia under:

https://www.physionet.org/physiobank/database/mitdb/

The actual data are contained in extension files (.dat). They are acquired at a sampling rate of $360[Hz]$ and 11 bits resolution. Each file (.dat) is structured as follows:

Echantillon N°1 du Canal 1			Echantillon N°1 du Canal 2		
Ch1_11- Ch1_8	Ch1_7- Ch1_4	Ch1_3- Ch1_0	Ch2_11- Ch2_8	Ch2_7- Ch2_4	Ch2_3- Ch2_0

Tab. 1 : *Format du signal ECG dans la* MIT-BIH Arrhythmia data base

Required work

Activity 0, home preparation

A report of an individual home preparation is requested from the student before starting the practical work, failing which the student will be immediately excluded from the session. The preparation report will, of course, be corrected and noted.

Activity 00, order

1- In Matlab interface, please display only the command window and the workspace window.

2- In command window, use the help to understand different Matlab functions.

3- During the practical work, it is recommended to the students to follow the notations as well as the steps in the manuscript.

Activity 1, natural ECG signal

1- Read $10[s]$ of record $121.dat$. Use *fopen.m* and *fread.m* of Matlab.

```
% first script Matlab
clear all
close all
clc
fs = 360;   % ECG MIT records sampling  frequency
T = 10;     % ECG signal length in second
fid = fopen('121.dat', 'r');    % 121.dat 11bits coded
c = fread(fid,T*fs*2,'ubit12'); % 121.dat is in 2 channels
ecg121 = c(1:2:end); % reading of  channel 1 (12 bits)
figure(1), plot(ecg121), grid, xlabel('temps [s]'), title('ecg121')
```

2- Check the resolution of the signal vector. Use *abs.m* and *dec2bin.m*.

3- The sampling frequency f_s of the MIT database records is of $360\ [Hz]$, how many sample will we have in $10\ [s]$ signal duration. Verify that in the Matlab workspace.

4- In a figure(1), plot $ecg121$. Use *plot.m, grid.m, title.m, xlabel.m and, ylabel.m.*

5- In a figure(2), plot $ecg121$ as a function of time.

6- Graphically determine the sampling frequency f_s.

7- Calculate the absolute and relative errors on f_s. Conclude.

8- Manually identify the first six time intervals between R-R wave. Conclusion.

9- In a figure(2), Graphically estimate the mean value of $ecg121$ signal.

10- Now calculate its exact value. Use *mean.m.*

11- In a figure(3), plot $ecg121$ as a function of time without its mean value.

12- Repeat the previous steps for two records of your choice.

13- Conclusion.

Activity 2, synthetic ECG signal

    1- Use Matlab's *ecg.m* function to generate five cycles of a synthetic *ecgs* signal. Each cycle is assumed to be 300 samples and $0.8[s]$ duration long. Use an amplitude of 100.

    2- What will be the sampling frequency f_s in this case?

    3- In a figure(4), plot *ecgs* as a function of time.

    4- Add to the *ecgs* a sinusoidal noise of $0.5[Hz]$ and an amplitude of 50.

    5- In a figure(5), plot *ecgs* with noise as a function of time.

    6- What do you notice? What noise is it? Explain.

    7- In 4-vary the amplitude and frequency until the *ecgs* signal drowns in the noise. Calculate the S/N ratio each time.

    8- Add to the previous *ecgs* a sinusoidal noise of $50[Hz]$ and an amplitude of 50.

    9- In a figure(6), plot *ecgs* with noise as a function of time.

    10- What do you notice? Increase the amplitude if necessary.

    11- What noise is it? Explain.

    12- Calculate the S/N ratio each time.

    13- Conclusion.

Global report

       An individual report must be submitted in the session after and must include:

    1- A theoretical understanding.

    2- Simulation results and interpretation.

    3- General conclusion.

Data base:
       The ECG signals used in this PW are those of the **MIT-BIH Arrhythmia Database** by physionet at
https://www.physionet.org/physiobank/database/mitdb/
The so-called raw data of ecg records are contained in files with the extension .dat. They are characterized by a sampling frequency of $360 [Hz]$ and 11 bit resolution.
ecg100 record presents two abnormal beats, this is a symptom of Premature Ventricule Contraction(PVC).

Notion of signal to noise ratio

    Either the model :

$$x_n(t) = x(t) + n(t) \qquad\qquad\qquad (1)$$

$x_n(t)$ the noised signal.

$x(t)$ the pure signal of power P_x.

$n(t)$ the noise of power P_n.

$x(t)$ & $n(t)$ are uncorrelated.

The quantity S/N below is called signal to noise ratio On appelle rapport signal sur bruit, la quantité :

$$S/N = \frac{P_x}{P_n} \tag{2}$$

En décibels,

$$(S/N)_{dB} = 10log_{10}\left(\frac{P_x}{P_n}\right) \tag{3}$$

Ou,

$$(S/N)_{dB} = 10log_{10}\left(\frac{\sigma_x^2}{\sigma_n^2}\right) \tag{4}$$

Ou,

$$(S/N)_{dB} = 10log_{10}\left(\frac{\sigma_x^2}{\sigma_{(x-x_d)}^2}\right) \tag{5}$$

x_d is the estimated denoised signal.

σ_{signal}^2 is the statistic variance of the signal, and $\sigma_{(noise)}^2$ is the statistic variance of the noise.