MICA Project

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1 Introduction

The analysis of an electrocardiogram provides important indications about the heart health of a patient. Thus, detecting properly the characteristic features of a heartbeat such as the QRS complex, the P wave and the T wave is determining. Once detected, the aim of the project is to develop an interface gathering all the important information that could be useful to a cardiologist.

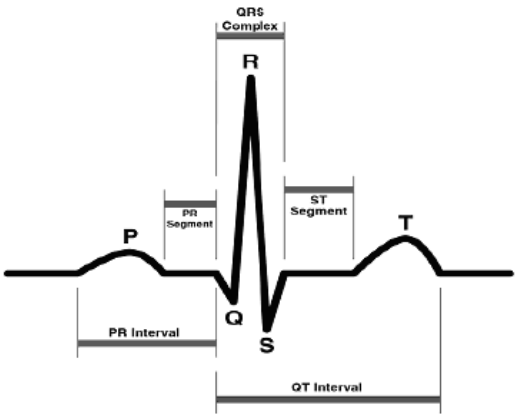

Figure 1: Characteristic features of an ecg

2 Technical Part

In this part, the methods enabling the detection of the particular points in an electrocardiogram will be explained and adapted so as to highlight heart pathologies.

2.1 Pan and Tompkins algorithm

2.1.1 Filtering

To find the QRS complex, the Pan and Tompkins method described below will be used.

The initial signal is first smoothed and amplified through a band pass filter ruled by the

following equation :

$$H(z) = H_1(z)H_2(z) \tag{1}$$

with:

$$H_1(z) = \frac{(1-z^{-6})^2}{1-z^{-1})^2} \text{ and } H_2(z) = \frac{-1+32z^{-16}-32z^{-17}+z^{-32}}{1-z^{-1}}$$

Yet, although the filter reduces the noise that may alter the initial signal, it also adds a delay of 21s on the resulting signal. This delay has to be considered later in order to find the right QRS complex.

Figure 2 shows both the electrocardiogram signal and the filtered one.

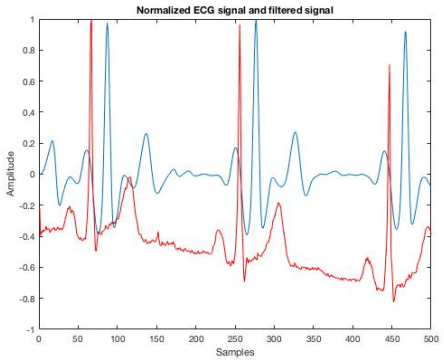

Figure 2: Normalized ECG signal and filtered signal

The filtered signal is then differentiated with a filter whose equation is given by :

$$H(z) = \frac{1}{8T_s}(-z^{-2} - 2z^{-1} + 2z^1 + z^2) \tag{2}$$

As the filter is not causal, we factorize by z^2 and we implement the remaining function :

$$H'(z) = \frac{1}{8T_s}(1 + 2z^{-1} - 2z^{-3} - z^{-4}) \tag{3}$$

Thanks to this differentiation, information about the QRS slope is given. As shown in figure 3, in which the electrocardiogram signal and the differentiated one are ploted, the slope is indeed emphasized. However, by factorizing by z^2 and ignoring it in the implementation, another delay of 2s is introduced and is to be considered later.

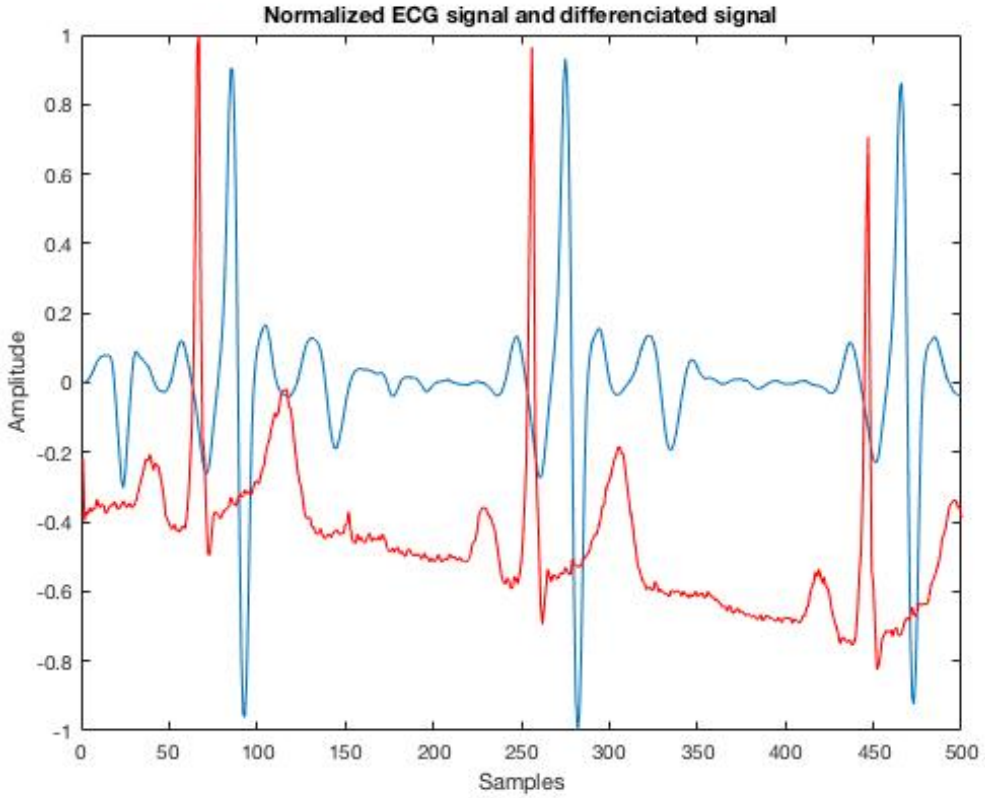

Figure 3: Normalized ECG signal and filtered signal

Then an intensification of local extrema is done. Figure 4 below shows this.

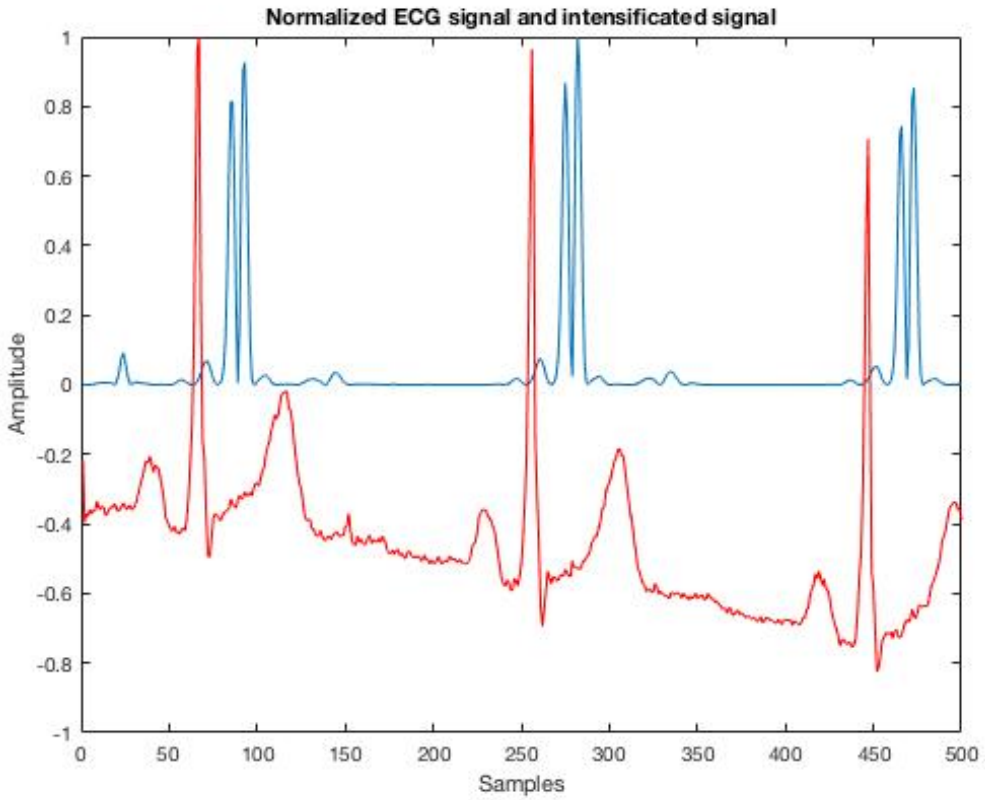

Figure 4: Intensification of signal

Finally, to reduce noise in the signal and obtain some wave-form typical information, a moving window integration is implemented. With this new signal the determination of R peaks will be easier. Figure 5 below shows the useful signal to find R peaks.

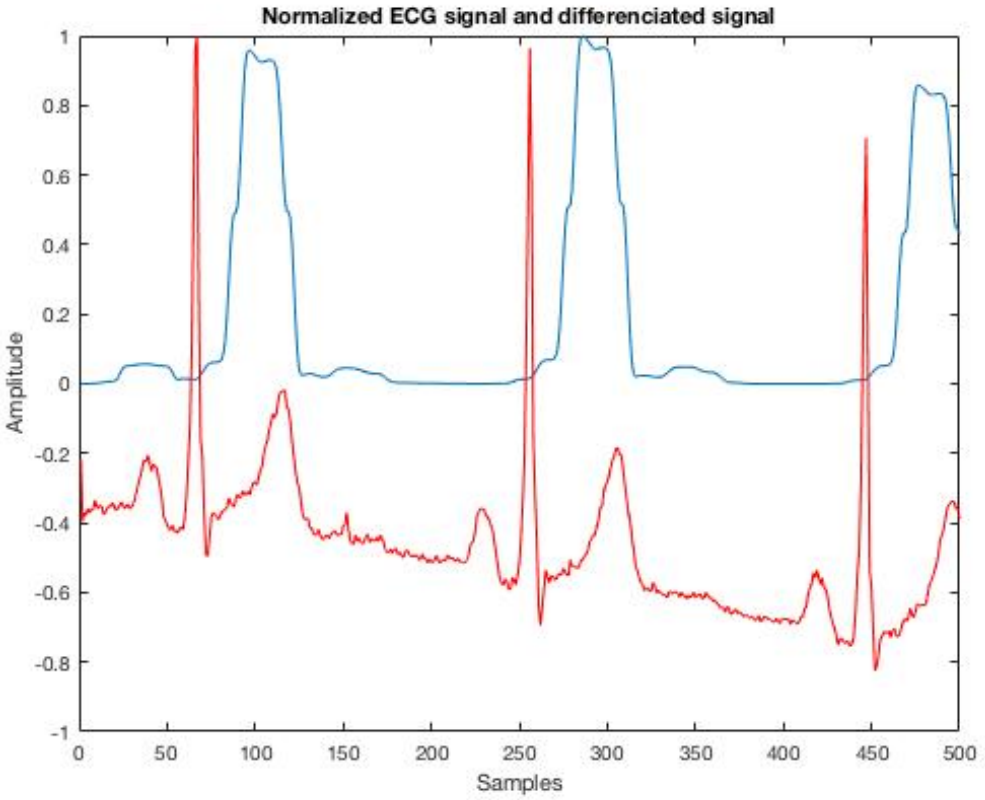

Figure 5: Normalized ECG signal and filtered signal

The last signal is delayed by 15 seconds compared to the signal right before. Therefore, the total delay introduced by all filters is 38s and will be offset for rest of the detection in order to find the exact location of each wave.

2.1.2 Signal thresholding

Once the signal is filtered, the goal is to compute thresholds that will help in finding the R peaks. In the initial algorithm, Pan and Tompkins define two adaptative thresholds.
For our implementation, we have adapted the equations given by the initial algorithm and defined every 400 samples a threshold ruled by :

$$SPKI = 0.125PEAKI + 0.875SPKI \tag{4}$$

and

$$NPKI = 0.125PEAKI + 0.875NPKI \tag{5}$$

where PEAKI is the overall peak, SPKI is the maximum signal peak along the 400 samples interval and NPKI is the maximum noise peak along the 400 samples interval.

With this definition, only one threshold has been useful in our implementation and has been computed as described in the Pan and Tompkins method :

$$THRESH1 = NPKI + 0.25(SPKI - NPKI) \tag{6}$$

2.1.3 R wave detection

The R wave is defined as the largest wave of the QRS complex. Threshold 1 and the signal from the moving window integration will be used to find R peak. Our algorithm consists in searching the interval where the amplitude of electrocardiogram is above the threshold. The next step is to identify the index of each R peak and the ordinate value of this peak through the previous interval. Once all R waves are detected, we are able to identify the RR-interval. It is the number of samples (or seconds) between two R peaks. This interval will be important for the rest of the project because it enables to find some pathologies like tachycardia and bradycardia.

2.1.4 Q and S wave detection

The Q and S waves are defined as the first minimum before and after the R wave. The algorithm we have developed is described below :

Algorithm 1 Q wave abscissa detection

$Q_{abs} \leftarrow 0$
$temp \leftarrow R_{wave}[1]$
for $i = 2 \rightarrow length(numbersamples)$ **do**
  while $ECG[temp] > ECG[temp - 1]$ **do**
    $temp \leftarrow temp - 1$
    $temp = time_axis[i]$
  end while
  $Q_{abs} = [Q_{abs}, c]$
  $temp = R_{wave}[i]$
end for

This algorithm is applied to the initial signal in which R peaks have been defined previously. R_{wave} is the abscissa of the first R wave and $ECG[temp]$ is the value of the signal at the R_{wave} abscissa . When all the abscissa of Q waves are collected, a function finds the amplitude value corresponding to the right abscissa .

This algorithm is able to always find the first minimum before each R peak. Nevertheless , if there is an irregularity in the slope like in the file $'ecg\_PVC.mat'$ the algorithm might make a mistake for certain Q wave.

Finally, the method and the algorithm are the same for seeking the S wave. The research is performed after the R wave instead of before.

2.2 P and T wave detection

Once the QRS complex is found, two important waves have to be still determined : P wave and T wave. To find these waves we use the location of R wave and the R-R interval (see 2.3). Indeed, the T wave is the highest peak between the first R peak and 0.7 times the R-R interval. To process this, a new filtering is applied to the electrocardiogram signal. First, the electrocardiogram is differentiate with:

$$G_1(z) = 1 - z^{-6} \tag{7}$$

Then the signal is filtered with a low-pass filter:

$$G_2(z) = \frac{1 - z^{-8}}{1 - z^{-1}} \tag{8}$$

The combination of these filters brings a delay of approximately 6 seconds. Obviously, this delay will be taken into account in the next processing parts of this project.

Figure 6 below shows the plot of the filtered signal. P and T wave can be considered as the first maximum before and after the signal crosses the level 0.

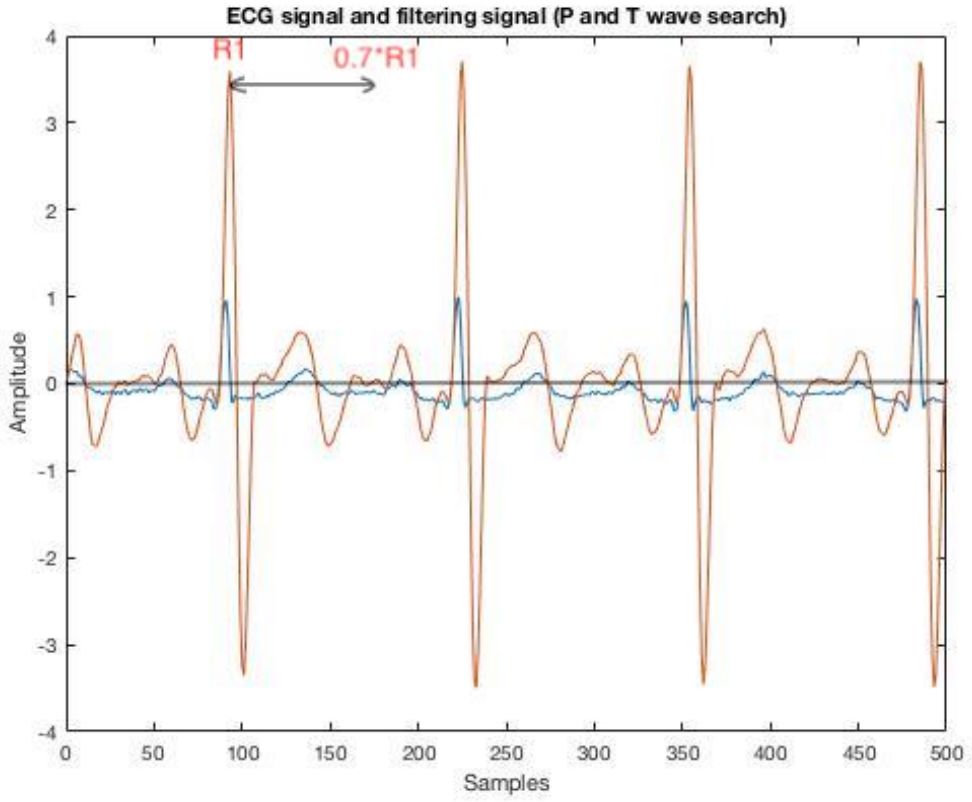

Figure 6: Filtered signal for the research of P and T

To find the T wave, the maximum in the interval $[R_1, 0.7RR_{interval}]$ is searched. For each RR interval, all T waves can be found. However, to decrease the risk of detecting a R wave instead of T wave, a margin error was decided. Indeed the research of T wave was made on the interval $[R_1 + 0.1RR_{interval}, R_1 + 0.65RR_{interval}]$. This enables to be sure to find the right T wave and not misleading it with another point of the electrocardiogram. The method to find the P wave is based on the same approach, it corresponds to the maximum of the filtered signal in the interval $[R_1 + 0.65RR_{interval}, R_1 + 0.9RR_{interval}]$.

After all P,Q,R,S and T waves have been found, it is now possible to detect some pathologies. Next subsection explain how the pathologies had been detected with these distincitve points.

2.3 Pathologies detection

2.3.1 Bradycardia and tachycardia

The detection of bradycardia and tachycardia is base on the cardiac rhythm of a patient. Bradycardia is characterized by a cardiac rhythm under 60bpm and tachycardia is characterized by a cardiac rhythm above 100bpm. therefore the only information required for this diagnostic is the RR interval.

Yet, we can define some thresholds to distinguish different cases. Indeed, depending on the conditions in which the electrocardiogram was recorded, the medical history of the patient and his lifestyle, it may be considered as normal to have a cardiac rhythm slighly above or under the limits. Therefore, we have decided to display different warnings of distincted seriousness, with thresholds enlarged to 110bmp and 50bpm.

2.3.2 Ectopic beat

Ectopic beats are characterized by an alteration of the QRS complex adpect. It is caused by an atrial or a ventricular premature contraction that modifies the duration of RR intervals and makes them last longer.

The condition chosen in this case was the following one : if the difference between two followed RR-intervals is greater than 1.2 the mean RR-interval, than, an ectopic beat is detected and a warning is displayed.

2.3.3 Fibrilation

There are two different types of fibrilation, the atrial fibrilation and the ventricular fibrilation.

To detect them, information about all points is required and is to be analysed.

3 Presentation of the application and the results

In order to enable and help doctors in the examination of electrocardiograms, a clear interface was created. We have chosen to use Matlab App Designer application as it is more recent and clearer than GUIDE interface. Our application is divided in three areas.

In the First area, the clinician can load an electrocardiogram, display PQRST points, zoom on a particular window and reset the view of the signal.

Second area corresponds to the axes. In this area the different plots of the electrocardiogram ar diplayed.

Third area is dedicated to information that may help clinician to diagnose some diseases. It is in this area that warning messages are displayed. Figure 6 below show the interface.

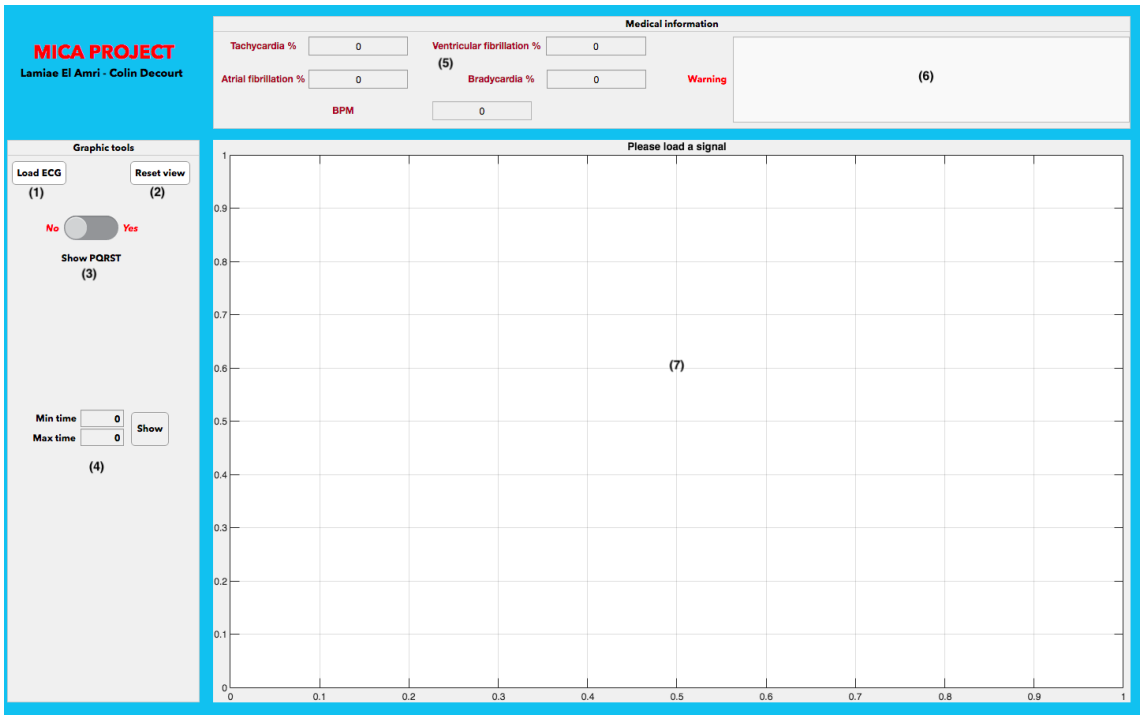

Figure 7: Interface description

Legend:

1. Load electrocardiogram file
2. Reset view after zoom
3. Show PQRST points
4. Display specific period of electrocardiogram
5. Display of useful medical information

6. Display of warning from the electrocardiogram like important disease

7. Display electrocardiogram

4 Conclusion

5 References

[1] J Pan and W J Tompkins. A real-time QRS detection algorithm. *IEEE transactions on bio-medical engineering*, 32(3):230-236, 1985: http://www.robots.ox.ac.uk/ gari/teaching/cdt/A3/readings/ECG/Pan+Tompk