Modeling ECG Signals with regard to the Location and Intensity of Myocardial Infarction

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Abstract

In this paper we used neural network (NN) to generate ECG signals with regard to the location and intensity of myocardial infarction (MI) as input of the model. We can use this model in educational programs and assessment of diagnostic devices. We can also use the model in telemedicine applications.

We used 50 samples of labeled ECG and used 70% of them for training and 30% for test. Addressing of MI location is the standard 17-segments for left ventricle. The measure of Mi intensity was the normalized under curve area of ECG in one cycle. For creating the proper shapes of ECG we used NN and for repeating the ECG cycles we used an Integral Pulse Frequency Modulator (IPFM) with a fixed threshold. However it is possible to use any Heart Rate Variability (HRV) model. We used two kind of NN. One was multi layer perceptron (MLP) with one hidden layer and the second was radial basis function (RBF) NN and compared the results.

After evaluating both NN we realized that the performance of both were more or less the same. The result of evaluation of the model satisfied cardiologist.

A new model for generating ECG signals related to the location and intensity of MI was presented.

1. Introduction

The electrocardiogram (ECG) signal is one of the most obvious effects of the human heart operation [1]. Recording the difference between the potential of two points on the surface of the skin gives us the electrocardiogram (ECG). ECG signal is a biological signal, which contains important information about the heart. There are peaks and valleys in this signal correspond to important events in the heart function. P, Q, R, S and T waves show these events and have much information about how the heart is doing its function[2].

Detecting of the location and strength of MI have been widely under researches. We can use 12-lead standard ECG, Frank lead ECG and body surface potential map (BSPM) using TORSO[3,4].

Many researchers tried to model this strange signal using different mathematical equations[2,3,4,5]. Having a comprehensive model for artificially generating of ECG has many applications. Such a model can be used in training nurses and can be used for ECG diagnostic devices. In addition such a model increase our understanding how the heart works in different conditions.

One of the most complicated situation occurs in myocardial infarction. A myocardial infarction or heart attack occurs when one of the coronary arteries become completely blocked. A part of myocardial that blood supply by coronary artery, loses its blood supply and will remain deprived of oxygen and other nutrients. There are two main to blood supply the myocardium. One of them, Brings blood to the right side of the heart (right coronary artery) and the other covers the left side of the heart (left main artery)[3].

In general, the infarction can be divided into several anatomical groups: Inferior infarction, lateral infarction, anterior and posterior infarction. The combination of these may be observed, such as Anterolateral infarction and Inferoposterior infraction. Almost, all of myocardium infarction involve left ventricle. It is not surprising because Left ventricular muscle has more volume than the other muscle in heart. 12-lead electrocardiogram is a standard tool for clinical diagnosis of heart disease and can provide information about the location and extent of MI. For example, abnormal Q waves and ST waves are important indicators of acute and chronic MI, respectively[3].

In this paper we are going to present a method to generate artificial ECG with regard to the location and strength of MI. Addressing of MI location is the standard 17-segments for left ventricle.

2. Myocardial infarction

When one of the coronary arteries become completely blocked, then we face with a myocardial infarction. There are two main blood supply to the right side of the heart (right coronary artery) and the other cover the leftside of the heart (left main artery). The location of MI can be addressed in 17-segments. The heart model in 17 segments is used as an optimal model to predict and determine location of MI in various diagnostic methods such as imaging methods. This model is now used as a reference model for segmentation of the heart in most studies [3]. In anatomy studies, 102 adults person without heart disease were studied. The heart was named by cutting horizontally into three sections: Apical, Mid-cavity and Basal, that plane sections for each of these components perpendicular to the long axis of the left ventricle, and ratio of unit myocardial mass per total mass of myocardial is 42% for basal, 36% for the mid-cavity, and 21% for apex of heart. In study by Cerqueiraet al, model of left ventricular in 17 segments provides the distribution of mass 35%, 35% and 30% respectively for basal sectors, mid-cavity and the apex of the heart, which this values are very close to the anatomical study. Result of this model is shown in Figure 1.

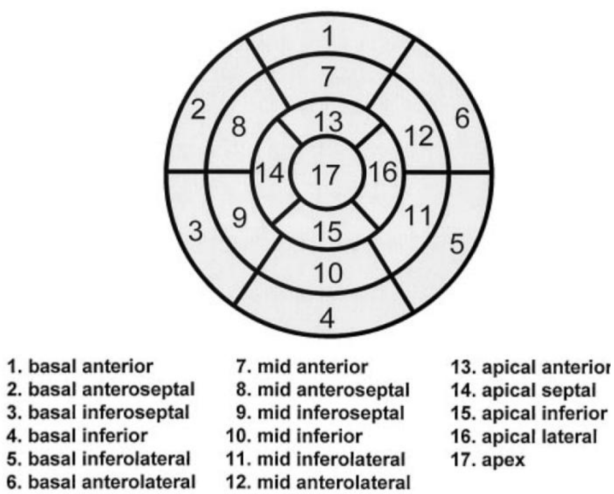

Figure 1. 17-segment standard model of left ventricular with name of each segment.

However we can use the basic description of the local of the MI i.e. Inferior, lateral, anterior and posterior. We can have the combination of these parts such as Anterolateral and Inferoposterior. Therefore each of these basic description may contain more than one part of the 17-segment standard model e.g.:

Anterior (1, 7, 13)

Anteroseptal (2, 8)

Iferoseptal (3, 9)

Inferior (4, 10, 15)

Inferolateral (5, 11)

Anerolateral (6, 12)

For measuring of the strength of MI we use the ST displacement using the following formula:

$$MI\ strength = k \frac{1}{\max(ST\ disp)}$$

3. Proposed model

In order to perform the shape of the ECG we used Neural Network (NN) and for repeating the cycle we used Integral Pulse Frequency Modulator (IPFM) model. In IPFM model we have an integrator which integrates from the input and then the output of the integral is compared with a threshold and as soon as it reaches the threshold the integrator resets and we have a pulse in the output of the comparator[5]. In Figure 2 we see a basic IPFM model.

We used 50 samples of labeled ECG and used 70% of them for training and 30% for test. Addressing of MI location is the standard 17-segments for left ventricle. The measure of Mi intensity was the normalized under curve area of ECG in one cycle. For creating the proper shapes of ECG we used NN and for repeating the ECG cycles we used an Integral Pulse Frequency Modulator (IPFM) with a fixed threshold. However it is possible to use any Heart Rate Variability (HRV) model. We used two kind of NN. One was multi layer perceptron (MLP) with one hidden layer and the second was radial basis function (RBF) NN and compared the results.

In figures 3,4,5,6 and 7 we can find the output of the model for different cases.

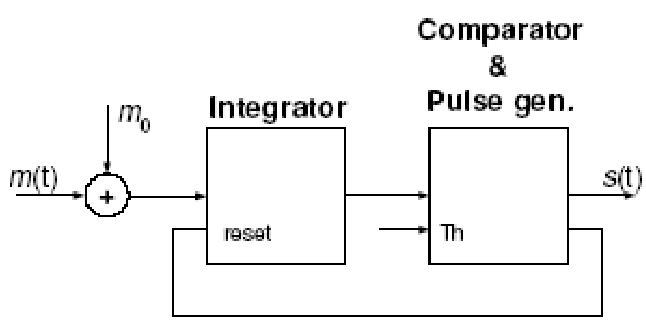

Figure 2: IPFM model block diagram

4. Evaluation

In order to validate the proposed model we presented the outputs to cardiologists and got their confirmation about the accuracy of the outputs.

5. Conclusion

We presented a model to produce artificial ECG with regard to the location and strength of MI. We can use this model in educational coursed and also to assess the ECG diagnostic devices by applying the output of the model and see if the report of the diagnostic device is correct or wrong.

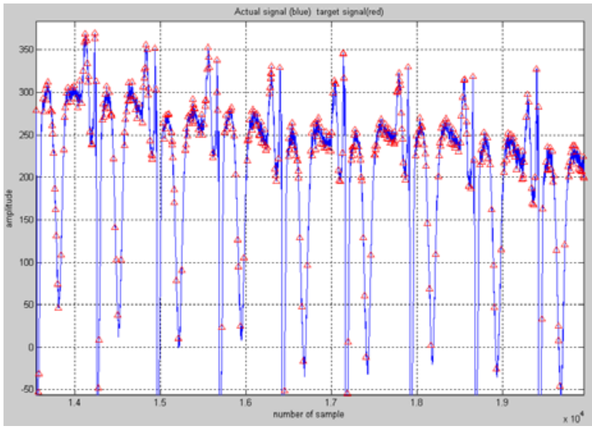

Figure 3: Artificial ECG with regard to MI in Anterior

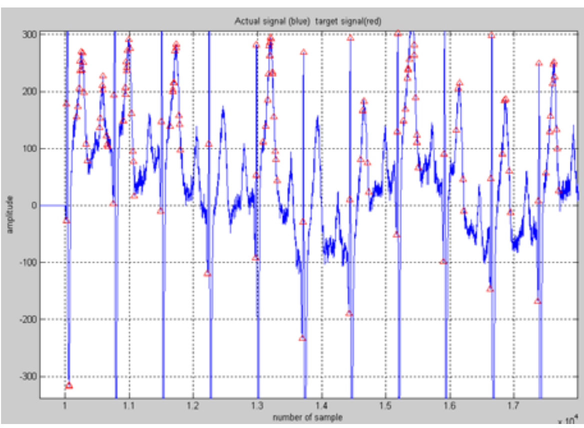

Figure 4: Artificial ECG with regard to MI in Anterioseptal

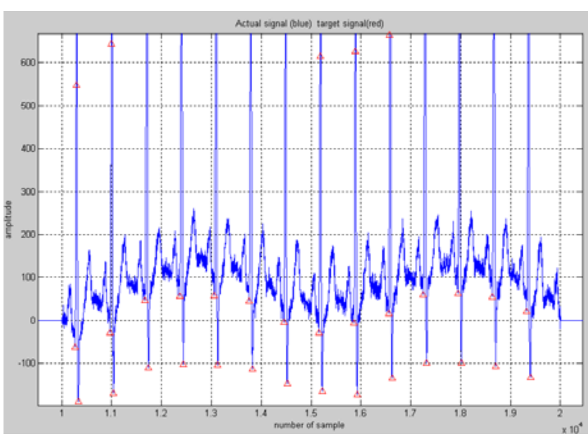

Figure 5: Artificial ECG with regard to MI in Inferiolateral

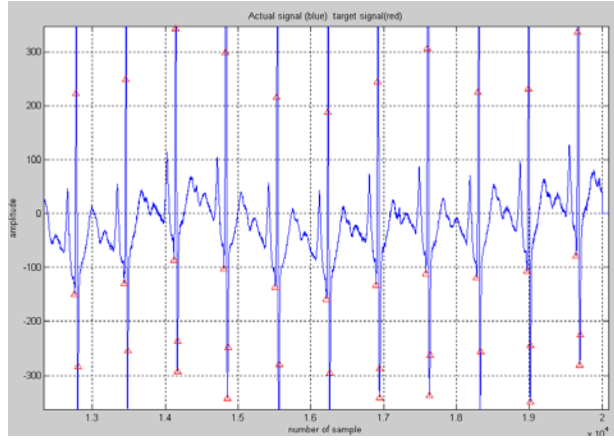

Figure 6: Artificial ECG with regard to MI in Inferior

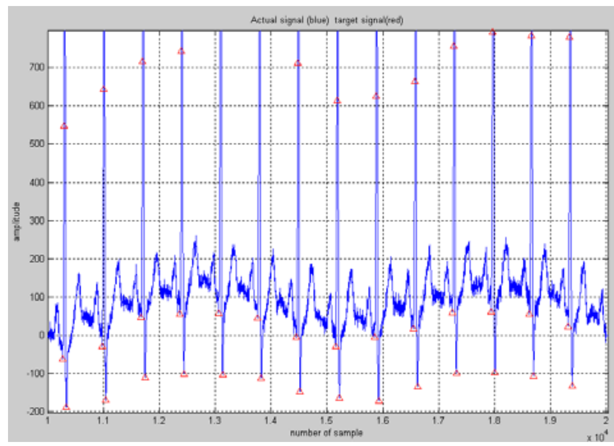

Figure 7: Artificial ECG with regard to MI in Inferiolateral

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