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Arduino Based ECG of Heart Beat Classification Health Care System

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ABSTRACT

Artificial neural networks (ANN) are useful for function approximation and classification problems also, it has been used in many areas such as medical diagnosis, pattern recognition and so on, Electrocardiogram (ECG) is well known in medical diagnosis processes, but it used to diagnosis heart diseases.In this work, modeling is done by using ANN. The model feed forward configuration structure of two layers is used. The neural network trained using back propagation algorithm and taking 144 instances from the National Centre for Cardiology used registered by the Arduino circle. The results in the training phase were better than in test stage.The testing result show the accuracy of the system register 95% in diagnosing patients with heart diseases for National Centre for Cardiology.

KEYWORDS: Neural Network, back propagation algorithm,

Classification, heart diseases, Electrocardiogram, Arduino.

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تصنيف إشارات القلب الكهربائية باستخدام دائرة الأردوينو والشبكات العصبية الاصطناعية

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الملخص

تعتبر الشبكات العصبية الاصطناعية (ANN) مفيدة لتقريب الوظائف ومشاكل التصنيف أيضًا، وقد تم استخدامها في العديد من المجالات مثل التشخيص الطبي والتعرف على الأنماط وما إلى ذلك، كما أن مخطط كهربية القلب (ECG) معروف جيدًا في عمليات التشخيص الطبي، ولكنه اعتاد على تشخيص أمراض القلب. في هذا العمل، يتم إجراء النمذجة باستخدام الشبكات العصبية الاصطناعية.ويتم استخدام شبكة التغذية الأمامية للنموذج المكون من طبقتين. تم تدريب الشبكة العصبية باستخدام خوارزمية الانتشار العكسي وأخذ 144 حالة من المركز الوطني لأمراض القلب- بنغازي والإشارات تم تسجيلها بإستخدام دائرة اردوينو. وكانت النتائج في مرحلة التدريب أفضل منها في مرحلة الاختبار. وتظهر نتيجة الاختبار دقة النظام بتسجيل 95,35% في تشخيص مرضى القلب لدى المركز الوطني لأمراض القلب –.بنغازي.

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الكلمات المفتاحية: الشبكة العصبية، خوارزمية الانتشار العكسي، التصنيف، أمراض القلب، تخطيط القلب الكهربائي، الأردوينو.

1. INTRODUCTION

For many years doctors have been aware that cardiovascular diseases constitute a class of diseases considered to be one of the main causes of mortality. When a heart condition occurs, the first diagnostic check consists of an electrocardiogram (ECG), which, therefore, is the main diagnostic tool for cardiovascular disease (CVD) [1].

ECG is a heart signal that is used to monitor the health status of heart disease. The reading of such a signal requires an expert that extracts information about the patient from it. The expert taken to writes a report about the case under investigation which requires some time , a very valuable factor for some patients. To help them many ideas were used to accelerate the process of pattern recognition by using a computer with artificial neural techniques to recognize the status of the patient is one of the modern techniques that are used in this field. In this study we use ECG reading microcontrollers and artificial neural networks (ANNs) to distinguish between different patterns of cardiac signals.

According to ECG library [9], the electrical activity of live cells was discovered during the 16th century, since then, the researches and studies on this discovered activity start, and the electrical activity led to the discovery of the heart electricity. Many working papers appeared since 1800 dealing with this newly discovered body of electrical activity especially that related to the heart and the brain.

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An electrocardiogram is a recording of twelve different views of the same electrical activity demonstrated on the ECG graph paper [13], it is shown in Figure (1).

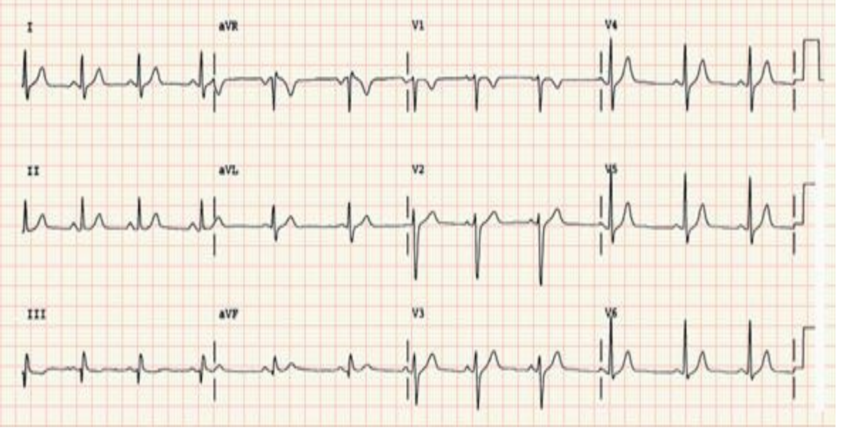

Fig.1 ECG graph show different leads pattern

Some questions will be discussed in this study like:

1. What is the role of artificial neural networks in classifying heart diseases and medical diagnosis in general?
2. How can the signal readers be connected simultaneously through (Arduino) and send it to the artificial neural network to train it to classify the type of signal and the patient's condition?
3. Does the type of data used affect the work of the algorithm used (ANNs)?

The procedure of analysis or measuring the signal of ECG is done manually by expert humans to diagnosis the status of cardiovascular health and determine the kind of disease if it exists, which requires wide experience from experts because this work is very complicated to classify patients correctly[4], in which experts may need time and effort to deal with it and treat the patient, and therefore the study was to shed light on one of the techniques of

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artificial intelligence to help experts and doctors in the diagnosis and discovery of diseases, especially the classification of heart signals (ECG) to know the state of health volatility, and this technique is the use of network algorithms Artificial nerve to make a medical diagnosis and help doctors and save the patient's life. The aim of our research is to propose an approach for heart diseases distinguishing between different classes of heart diseases using Arduino and artificial intelligence techniques, especially ANN, multilayer feed-forward neural network and back propagation algorithm is also used for classification. So it Takes advantage of the capabilities of microcontrollers (Arduino) in reading ECG signals, and linking them to artificial neural networks. This study helps doctors in the process of diagnosing heart diseases and save time and effort on the experts to make the diagnosis optimally.

2. RELATED WORKS

There are many works that are related to the effect of this work Wisnu Jatmiko, et al.(2011)in their work employed Back-Propagation Neural Network(BPNN) and Fuzzy Neuro Learning Vector Quantization (FLVQ) as classifier in ECG classification . In their work they used only the MLII lead as source data. The classes that are considered are Left Bundle Branch Block beat, Normal beat , Right Bundle Branch Block beat , Premature Ventricular Contraction . They used training classification methods namely Back propagation and FLVQ for their experiment. It provides an average accuracy 99.20% using Back Propagation and 95.50% for FLVQ. The result shows that back-propagation leading than FLVQ and back-propagation on has disadvantages to classified unknown category beat but not for FLVQ. FLVQ has stable accuracy although contain unknown category beat.

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Maedeh Kiani Sarkaleh, (2012)in this study proposed a Neural Network based algorithm for classification of Paced Beat, Atrial Premature Beat arrhythmias as well as the normal beat signal. They applied Discrete Wavelet Transform for feature extraction and used it along with timing interval features to train the Neural Network. About 10 recording of the MIT/BIH arrhythmia database have been used for training and testing the neural network based classifiers. The model result shows that the classification accuracy is 96.54%.

Hend M. Farkash, et al.(2019)employed Back-Propagation Neural Network as classifier in ECG classification . The data used in this work represents ECG signals, were collected from different sources, these are MIT-BIH Arrhythmia Database and UCI" Arrhythmia" data set. MIT-BIH Arrhythmia Database signal is processed with a designed algorithm called Average Signal to find the average signal that can be used for signal feature extraction. This work was used with neural network with back propagation algorithm for learning process, which gives high percentage 96% for training process of classification, which can be in increased by training and selection of data type. After testing of ANN with different data given reasonable ratio of testing 66.67%,generally testing of ANN performance gave accuracy were about 90%, the advantage of the ANN classifier is its simplicity and flexible.

Abhishek Santosh Raj et al.(2014) used a new method for automatic analysis of ECG signals was used Using MATLAB it was proposed and implemented this way ,the raw ECG data obtained from the patient passes through a the wavelet packet decay (WPD) process is followed by Extract feature. Classification is also done using Artificial Neural Network (ANN). The Auto analysis of the ECG signals was done using the proposed methodology with an accuracy of 99.7%.The ECG data of patients diagnosed with ailments such

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as Myocardial Infarction, Valvular Disease, Pulmonary Embolism were differentiated from the normal ECG signals this algorithm proves to be the novel solution for accurate diagnosis of Cardiovascular Diseases. The same algorithm can be implemented on hardware based system to assist in faster, accurate and automated analysis of ECG data.

Ayad Ghany Ismaeel and Dathar Abas Hasan (2020) developed a wireless online technology, the proposed Electrocardiogram (ECG) monitoring system consists of ECG sensor AD8382 to read the patient data, Arduino Uno, and ESP8266 WI-FI module and send it via IoT Blynk app for diagnosis.

Anwar Al-Bushra (2018) designed a heart rate detection system by programming the Arduino which the system can display the heartbeat using a pulse sensor, and the readings in BPM (beats per minute) will appear on the serial graphic screen connected to a computer. The heart rate sensor circuit is also designed to give a digital output; by placing a finger on a small sensor.

3. MATERIALS AND METHODS

ECGs were used in the proposed diagnosis system. our study is divided into two stages, each complementing the other.The first stage is Studying how to read the ECG signal through the microcontroller (Arduino) and the second stage is sending it to (ANN) and training it to perform the diagnostic process (see Figure 2). A detailed description of the structure of the system is presentin the following sections.

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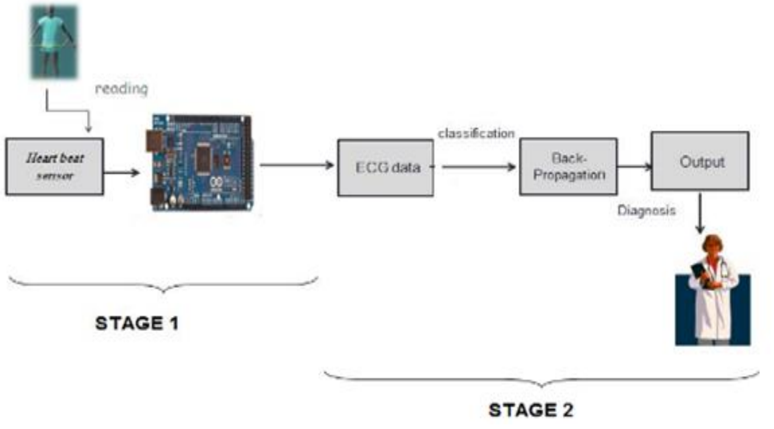

Figure 2. System methodology

3.1 Ecg monitoring system using Arduino

In this part, we present the idea of making a circuit for ECG signal readers using Arduino and how to record and monitor the signal and store it as an excel file to send it to the neural network to work on it and classify the type of disease. The proposed system performs the reading data, processing data, sending data, and displaying data according to the following flowchart shown in Figure 3. The idea includes several steps as follows:

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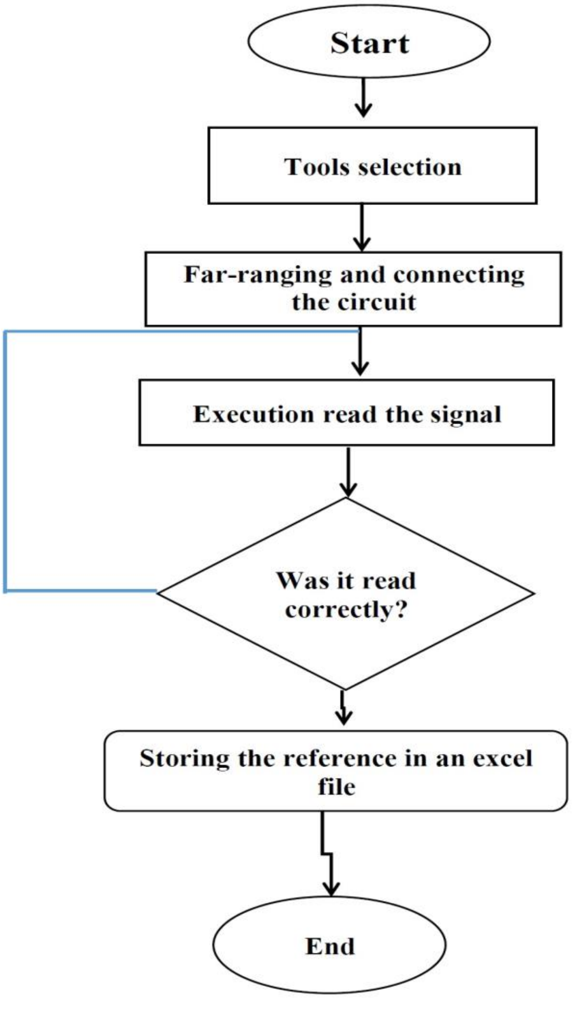

Figure 3. Flow Diagram of the Proposed System.

3.2. Dataset

In this study, for the uses of the classification process for ECG recording from the National Heart Center, which represents ECG signals, this data set consists of 144 cases Each condition includes 147 traits representing ECG parameters: QRS Duration, PR interval,

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QT interval, T interval and P interval. Attribute number 148 indicates arrhythmia class, class 05Refers to a "normal" ECG, and categories 01,02,03,04 and 09 refer to different categories of arrhythmias.

These signals of this data were recorded by the designed Arduino circuit, as its components and how they work were explained in the previous section.

The ANN classifier and attribute 148 (class) represent the target output of the ANN for Recognize arrhythmia. Table 1 shows the number of cases and categories in the data of the National Center for Cardiology and Figure 4 show samples of data set.

Table 1: The number of cases and categories in the data of the National Center for Cardiology

Class no.	Class Name	Number of cases
1	Normal	48
2	Ischemic changes (Coronary Artery Disease)	28
3	Old Anterior Myocardial Infarction	20
4	Old Inferior Myocardial Infarction	4
5	Ventricular Premature Contraction (PVC)	15
6	Left bundle branch block	15
7	Right bundle branch block	4
8	Atrial Fibrillation or Flutter	8
9	Heart failure	8

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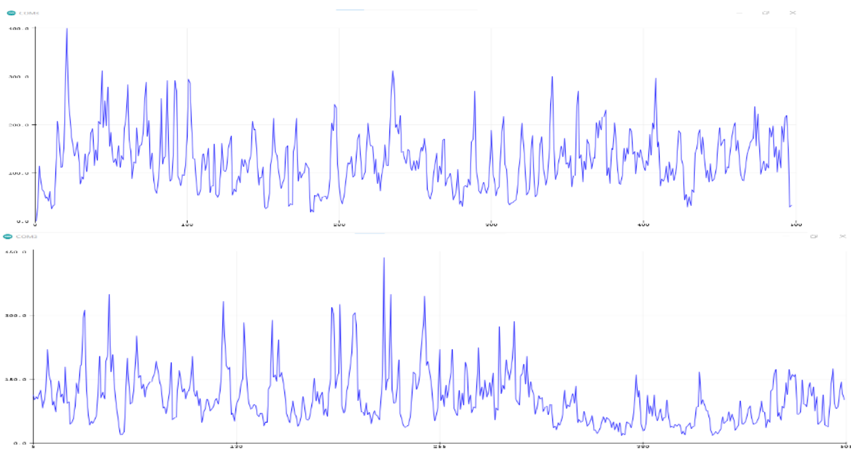

Figure 4. Samples of the National Center for Cardiology data set.

3.3 ANN Design and simulation

To design any neural network, there are some basics, which must be taken into consideration, these are selection/ determination of the neural network type, the number of processing elements/ neurons in the input layer, selection of input variables(once observation effective) that will be used with a designed structure, determination of the target set, which will determine the number of labors and neurons in the affair layer, learning rate, which the parameter determines step length to training process, which must be suitable to the case under study and proper selection of activation function .

The poor selection of these parameters won't give a proper result in proper time but with high computational complexity, a literacy difficulty, an over befitting, a misconception capability, and a poor model delicacy [25]. The evaluation can be tested by using the difference between the desired and the actual outputs. The root mean square error (RMSE), the mean root square error (MRSE) as defined in equations(1 & 2) were calculated for the trained network using the test data .

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(y_{pred,i} - y_{orginal,i})^2} \qquad (1)$$

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$$\text{MRSE} = \frac{1}{N}\sum_{i=1}^{N}\sqrt{(y_{pred,i} - y_{orginal,i})^2} \qquad (2)$$

Where $y_{pred,i}$ and $y_{orginal,i}$ independently, are the compute and the actual outputs and N is the number of samples during the train period .

The rate of correct reckoned value can be determined by relation

$$\text{Chance rate of correct reckoned value} = \frac{C}{T} \qquad (3)$$

Where C is number of points that are nearly equal to target value & T is the total number of points .All inputs is multiplied by a connection weight depending on the hidden neuron (h) it's connected to, these products are added, fed through a sigmoid function, repeat this work with the alternate layer, fed with linear function to induce a result and also the output, determining the number of hidden neurons is represented by the fine symbol h; depending on trail by error, but the number of output neurons depending on the type of classification (one or more class).In other words. The number of output is proper to the result of diagnosis if the person is infected or he/she is not infected, so we have one node in output layer. In this type of structure, the target of this network is the classification of each sample of data set. The topology of the general structure of FFNN model has been sketched in Figure 5

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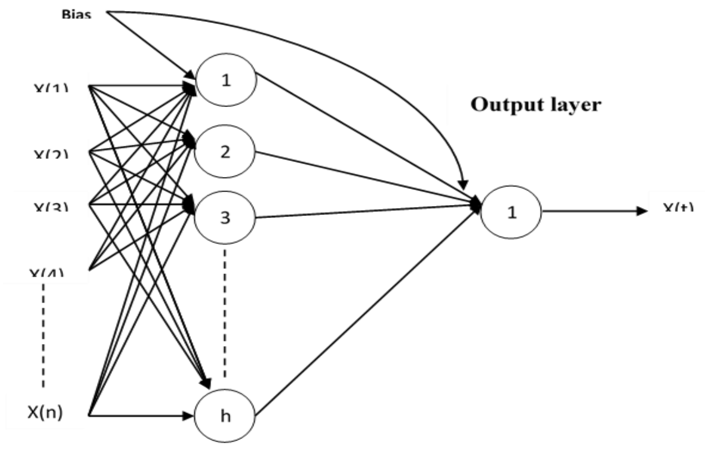

Figure 5. The general structure of feed forward neural network model.

4. Results

4.1Artificial neural network training preparation

Training process taking to determine the optimal value of learning rate, number of iteration, and number of process elements (neurons) in input layer. In the following section, the suitable of these factors are determined empirically by testing changed values to determine the factors that speed up the training process and gives good result.

4.1.1 Determination of the best learning rate

To determine the best learning rate for the designed ANN structure, the number of unknown process elements in the first layer is kept fixed and the learning rate value is changing each time by adding it or dwindling to search for the best value that give the less error value for the fixed number of time.

In this test the number of iteration (epoch) from past test was equal to 5000, the number of process elements in the first layer is kept fixed to 700 process units, The training started when the value of learning rate is kept equal to **0.00001**

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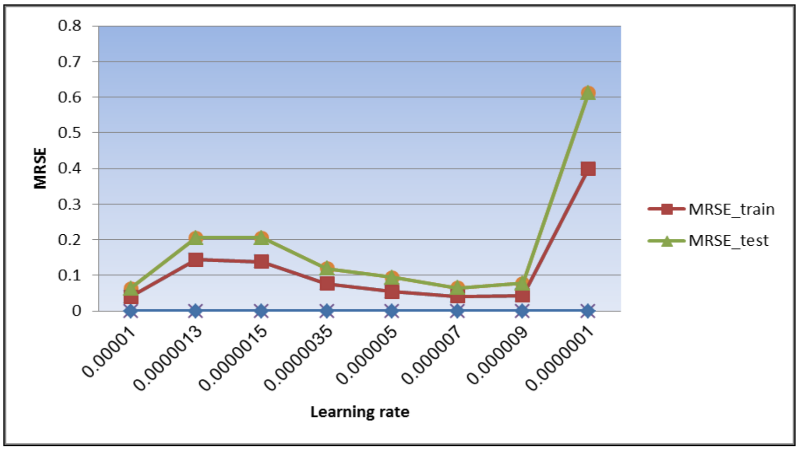

Fig. 6: Determining the value of learning rate for Feed forward neural network of the National Heart Center

In Figure (6), the error rate indicates that the optimal one was on **0.00001** learning rate that give **0.0394** errors on evaluating the training set, and **0.0634** errors on evaluating the testing set for the National Heart Center.

4.1.2 Determination of the Process Units

After determining the best value of learning rate, we need to determine the number of process units in the first layer. In this test the number of iteration (time) is kept fixed to 5000 iteration, learning rate from once test was equal to **0.00001**. In the first we started the training with the lower the number of input nodes in constructing a learning matrix, because the lower the ANN structures will avoid the problem of over befitting, thereby improves the conception capability [4]. The training started when the value of process unit is kept equal to 50 process elements also this value is changing each time by adding it to find the optimal value of the process units.

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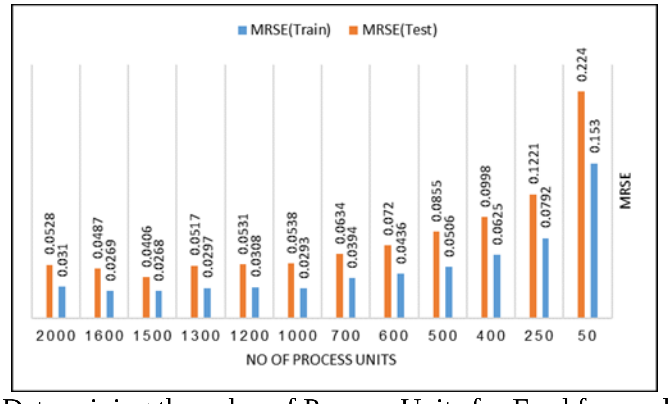

Figure 7 Determining the value of Process Units for Feed forward neural network of the National Heart Center

From the previous figure (7), it has been seen that 1500 process unit are considered as the best choice based on the amount of the error and converge both of curves {training/testing} with **0.0268** , **0.0406 respectively** for the National Heart Center.

4.1.3 Determination the best partitions of the data

After determining the best value of learning rate, and process units, we need to determine the best partitions of data to training the network. The training stared when the value of allowed error is 0.001.

From Figure (8), it is seen that the best results were Experiment No. 2, train 70% test 30% 0.0268 Error rate on evaluating the training set & **0.0406** Error rate on evaluating the testing set **.**

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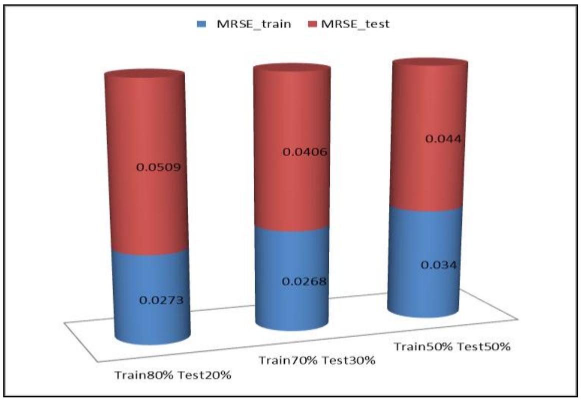

Figure 8 Determination the best partitions of the data for Feed forward neural network of the National Heart Center

4.1.4 Training & optimization results for feed forward neural network

Table 2: Training & optimization results

iteration in thousand	Training set		Testing set	
	MRSE	Accuracy(%) _training set	MRSE	Accuracy(%) _testing set
5	0.0268	92.08	0.0406	90.70
10	0.0237	94.06	0.0337	95.35
30	0.0178	94.06	0.0241	95.35
50	0.0137	94.06	0.0186	95.35

From previous table(2), for National Heart Center dataset, we starting with 5000 iteration and end with 50 as number of iteration in thousand , with fixed value of learning rate, number of neurons in the input layer based on past tests. It is noted that the test results were as perfect as the training results. The reason may be due to (data normalization),so the obtained results depends on the increasing of the iteration , also it is noted that the network was able to train on all diseased cases with a percentage of 94.06%, a classification of test cases with a percentage of 95.35% the data

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partitions was 70% to data set training and 30% to data set testing is considered as the best choice based on the amount of the error, the resulted computed curves is compared to target curve are given in Figure (9) & (10).

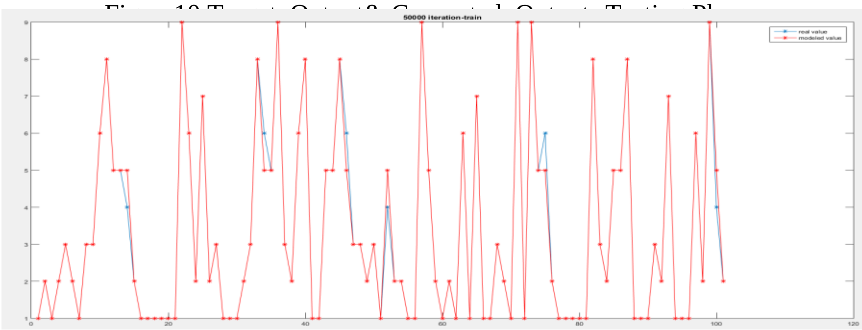
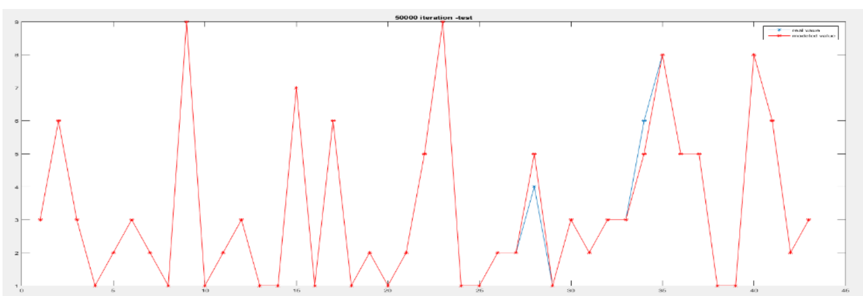


Figure 9 Target Output& Computed Output -Training Phase



5. Conclusions

The aims of this work are to build a system that uses ANN to classify and identify the patient case using ECG signal. As was preliminarily mentioned in the preface, the targets of this work were using (Arduino) in reading ECG signals, and linking them to artificial neural networks by training it to perform the diagnostic process, also the alternate target was determination of proper design of ANN structure that can classify the two dataset, then we can get a proper result. A designed structure of ANN were trained and tested which can process the feature data of ECG and give the class of

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patient. In this work the ECG signal data were collected from the National Cardiology Center. MATLAB 8.4 used to train the neural network for classification purpose. This training a achieved training accuracies of 94.06%. which shows the system will work almost accurately, from the previous results, it is concluded that when trained the neural networks using back propagation algorithm and taking 144 instances from the "National Center for Cardiology", Nine classes of heart disease, i.e., Normal, Old Anterior Myocardial Infarction, Ischemic changes, Left bundle branch block, Right bundle branch block, and Heart failure were considered in the experiments, the testing accuracies of 95.35%, Generally , this works shows the road to build a system based on ANN to diagnosis the cases of patient based of their ECG.

Based on the results and observations of this study, a number of points that appear and can be used as future work points-these points are summarized as follow:-Developing the circuit used for the Arduino and choosing different sensor to record the heart signal that coming from the patient's condition, in other words adding new cases to training data by recording of National Center for Cardiology, this could provide different examples for the neural network to train on. As well as building an expert system that combines the two technologies used the artificial neural network and the heart signal recording circuits, using the Arduino microcontroller.

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