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Detection of Cardiac Arrhythmias Using Different Neural Networks: A Review

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Abstract: This paper describes about the analysis of electrocardiogram (ECG) signals using neural network approach. Heart structure is a unique system that can generate ECG signals independently via heart contraction. Basically, an ECG signal consists of PQRST wave. Normal healthy heart can be simply recognized by normal ECG signal while heart disorder or arrhythmias signals contain differences in terms of features and morphological attributes in their corresponding ECG waveform. Cardiac arrhythmias are classified by abnormal activities in the heart [3]. These abnormalities can be analyzed by an electrocardiogram (ECG). Details from this electrical signal can be used to classify different types of arrhythmias. Multiple data samples of normal ECG characteristics also were read by a neural network (NN) and analyzed for the differences between abnormal signal and an irregular signal. The data was extracted from the MIT-BIH Supra ventricular database and the MIT-BIH Arrhythmia database. A neural network is designed and programmed with this data and then tested to validate the data set. When neural networks are further used to analyze and test medical data samples, the medical community and patients will experience improvements in the diagnosis of heart abnormalities and early detection of debilitating medical conditions.

Keywords-Heart, ECG signal, arrhythmia, neural network, cardiac

I. INTRODUCTION

An electrocardiogram (ECG) contains a large amount of information that can be used for determining many different attributes of the electrical activities of the heart. Typically, an ECG varies from person to person due to the difference in the position, size, anatomy of the heart, age, body weight, chest configuration, and various other factors. An ECG is a representative signal of cardiac physiology, which can be very useful in diagnosing cardiac disorders. The ECG was originally observed by Waller in1899.In1903; Einthoven introduced the electrophysiological concepts still used today, which includes the labels of the waves. To this day, an ECG is the main way of gathering information from the body in order to better analyze the heart's activities [5]. The heart is one of the most important organs in the body due to the fact that it supplies the body with oxygen.

II. GENERATION OF ECG SIGNAL

The corresponding part in the heart plays their respective roles. Sinoatrial (SA) node will excite the beats that caused heart muscles to contract. Below is shown the location of Atrioventricular (AV) node and SA node which are responsible for generating ECG signal in the human's heart. Figure 1 shows the basic structure of heart.
The contraction of heart's muscles soon will be recorded as an electrical activity of the heart called ECG signal. Based on the pattern of ECG recording, heart status could be identified whether possessed of any cardiac arrhythmias or otherwise. As known, heart muscle possessed the characteristic of depolarization and repolarization. Depolarization is referred to the electrical potential activity excited by heart muscles while repolarization is a relaxation state when the heart changing back to its original position. P wave generated due to the atrial depolarization, QRS complex represented ventricular depolarization while T wave represented ventricular repolarization. Figure 2 shows the corresponding part of heart function with respect to the ECG signal obtained.

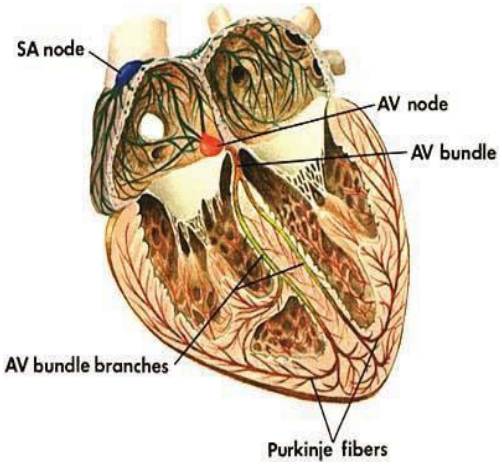

Figure1: Location of SA and AV node

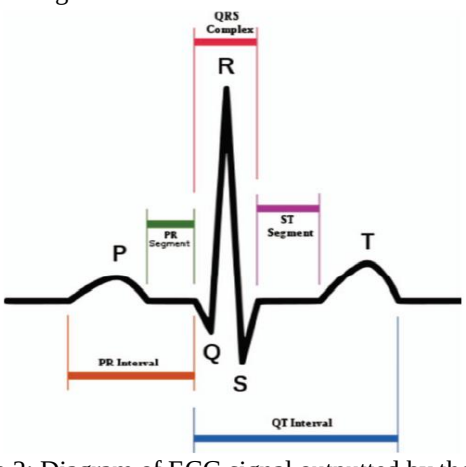

Figure 2: Diagram of ECG signal outputted by the heart.

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Abnormalities happened in the respective waves segment will provide ideas to doctors and cardiologists at where the part of heart is having problems.

III. TYPES OF ARRHYTHMIAS

1. SVT (supraventricular tachycardia) is a heart arrhythmia that is due to a fast heartbeat in the atria. This can occur in patients for a few minutes to a few days and can cause dizziness, rapid breathing, and chest pain. SVT is rarely life threatening but it can be treated by a few medications or physical maneuvers that are relatively simple.
2. VT is a heart arrhythmia that originates in the ventricle of the heart. Unlike SVT, this is a life threatening arrhythmia that can cause ventricular fibrillation and sudden death. 80% of cases of sudden cardiac death (SCD) are caused by spontaneous VT.
3. BBB is due to disruption in the normal flow of electrical pulses. Typically, BBB has QRS width duration greater than 120 ms. Right and left BBB are possible and the ECG signal will be shifted left or right towards the P or T waves respectively.
4. Bradycardia is defined as a slow heartbeat below 50 beats per minute (BPM). This can be caused due to drug use or heart disease.
5. Tachycardia is defined as a fast resting heart rate of above 100 beats per minute. Like Bradycardia, this is quite similar other than the heart is racing due to bad diet or poor heart condition.
6. Premature atrial contractions (PACs), also known as atrial premature complexes (APC) or atrial premature beats (APB), Are a common cardiac arrhythmia characterized by premature heartbeats originating in the atria. While the sinoatrial node typically regulates the heartbeat during normal sinus rhythm, PACs occur when another region of the atria depolarizes before the sinoatrial node and thus triggers a premature heartbeat.
7. Accessory pathway tachycardias (bypass tract tachycardias) are a rapid heart rhythm due to an extra abnormal pathway or connection between the atria and the ventricles. The impulses travel through the extra pathways (short cuts) as well as the normal AV-HIS Purkinje system. This allows the impulses to travel around the heart very quickly, causing the heart to beat unusually fast.
8. Atrial fibrillation, a very common irregular heart rhythm. Many impulses begin and spread through the atria, competing for a chance to travel through the AV node. The resulting rhythm is disorganized, rapid, and irregular. Because the impulses are traveling through the atria in a disorderly fashion, it results in loss of coordinated atrial contraction.
9. Atrial flutter, An atrial arrhythmia caused by one or more rapid circuits in the atrium. Atrial flutter is usually more organized and regular than atrial fibrillation.
10. Premature ventricular contractions (PVCs) are early extra beats beginning in the lower chambers of the heart (ventricles). PVCs are common.Most of the time they cause no symptoms and require no treatment. In some people, PVCs can be related to stress, too much caffeine or nicotine, or exercise.

IV. NEURAL NETWORK

A neural network is a type of computational model which is able to solve multi problems in various fields. It processes the information in a similar way as the human brain concept processing the information. Basically, neural network consists of large processing elements called neurons working together to perform specific tasks. As in the human brain, there are thousands of dendrites which contain information signals shown in figure 3. They transmitted the signals to the axon in the form of electrical spikes. The axon then sends the signals to another dendrites causing to a synapse shown in figure 4.This synapse occurred when excitatory input is sufficiently large than the inhibitory input, and this concept of signal transmission also depicted on how neural network process inputs received. Figure below shown dendrites related structures for clearer understanding.

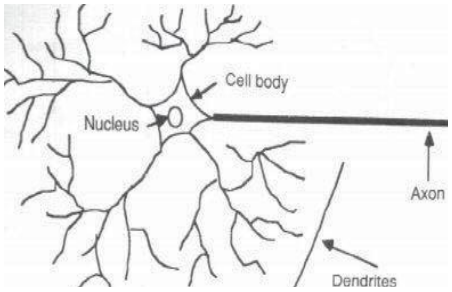

Figure3: Dendrites

In neural network, dendrites carrying signals can be analogy as multiple inputs collected together for summation. Then, the combined inputs will be activated by activation function. Inputs that exceed threshold value will be feed to the output layer for final processing.

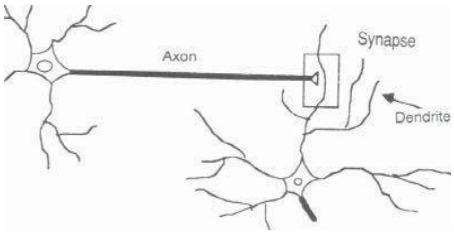

Figure 4: Synapses

During processing stage, inputs will be trained to produce desired target outputs until it come to a generalization stage.

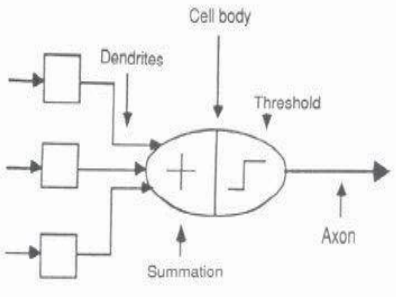

Figure 5: Neuron model

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Generalization means at a condition where the network is able to recognize the inputs and the corresponding targets after undergone the training given. Then, the network will be tested by given new inputs signal to evaluate its performance and to see how accurate the output produced will be comparing to the target. Figure 5 and 6 depicted the analogy of human brain concept process the information to the neural network system [7].

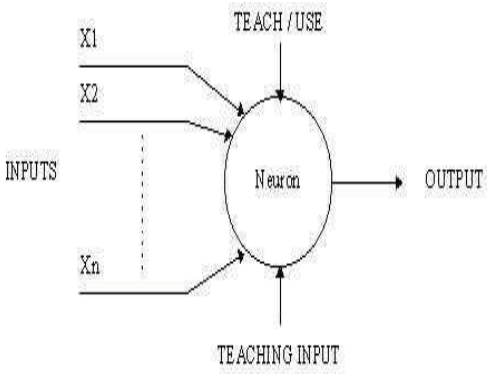

Figure 6: Neural networks

Neural network consists of several architectures, from simple structure until the complicated ones.

A Single-Layer Feed forward Networks

This is the simplest form of network architecture with only single layer output without any hidden layer.

An input layer of source nodes will directly projects onto the output layer of neurons or computation nodes, just in one way but not vice versa.

Single layer is referring to the output layer which is just single output and not considered the input layer of source nodes since no computation performed there. Figure 7 is shown the corresponding network.

B. Multi-Layer Feed forward Networks

This second layer is differing from above since it has one or more hidden layers. The computation also takes place in these hidden nodes.

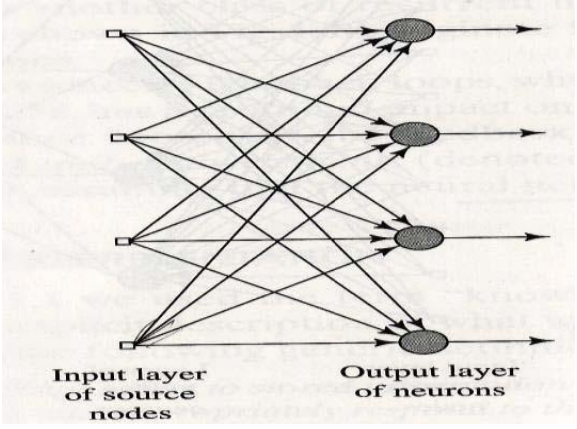

Figure 7: Single layer feed forward networks

The hidden nodes are also used to intervene between the external input and the network output with respect to the network's manner. Figure below shown the network

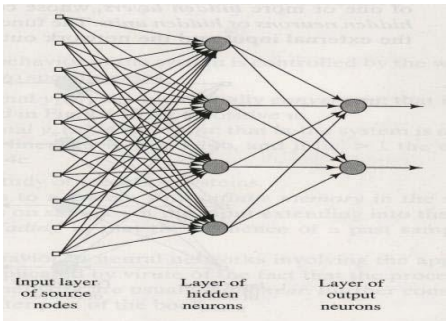

Figure 8: Multi layer Feed Forward network

C. Recurrent Network With No-Self Feedback Loops and No Hidden Neurons

A recurrent neural network has at least one feedback loop. It may consist of a single layer of neurons with each neuron feeding its output back to all the input neurons as illustrated below. The feedback loops increased the learning capability of the network and on its performance. Besides, these feedback loops are also associated with unit delay elements (z-1) which result in a nonlinear dynamical behavior in a condition when neural network contains nonlinear units. Figure 9 shows recurrent network without feedback.

D. Recurrent Network with Hidden Neurons

This structure distinguishes itself from part (iii) with hidden neurons. The feedback connections originate from the hidden neurons and also from the output neurons. The structure illustrated in figure 10.

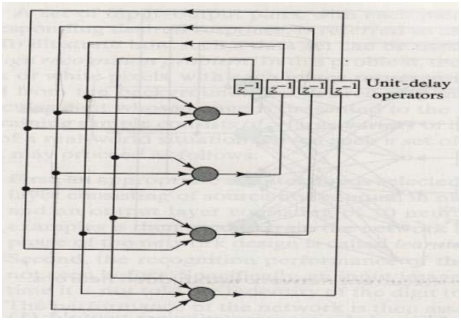

Figure9: Recurrent network without feedbacks and hidden Neurons

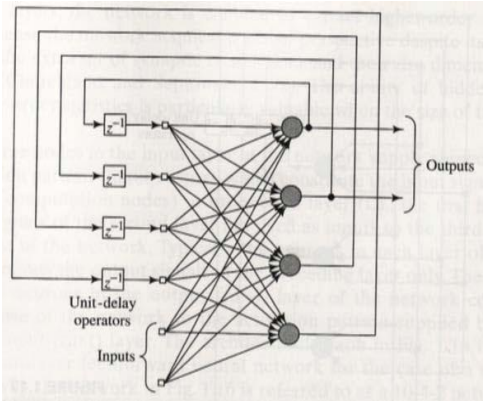

Figure 10: Recurrent network with feedback

In neural networks, the input layer is passive while the hidden nodes and output layer are active and normally

been activated by transfer function. These active nodes will modify weight and bias values to an optimum number where the network is best works at. There are many activation functions can be applied such as radial basis (radbas), competitive transfer function (compet), positive linear (poslin), saturating linear transfer function (satlin) and many more. The most commonly used is including hard-limit transfer function, linear transfer function and log-sigmoid transfer function [1],[2]. Neural networks need to be trained with suitable learning algorithm training functions corresponding to a network type. Among of the training functions are gradient descent backpropagation (traingd), Levenberg-Marquadt backpropagation (trainlm), gradient descent with adaptive learning rule backpropagation (traingda), random order incremental training with learning functions (trainr).

V. CONCLUSION

The result of different neural networks cannot achieve 100% or very high percentage of accuracy since small data set was used. Thus, some recommendations could be suggested to improve network's performance in order to obtain approximately accurate outputs. There are including increase the numbers of hidden neurons and retrain the network several times. Furthermore, use larger data set so that the network will learn more and expose to enough trainings. Do try a different training algorithm as well as adjust the initial weighs and biases to new values. Then, train the networks again for several times until it reaches desired target. These improvements are recommended to be done in the future for better result. Table I shown comparison of different neural networks with different algorithms.

TABLE I
COMPARISON OF DIFFERENT NEURAL NETWORKS

Neural network	Artificial neural network	Back propagation neural network	Fuzzy Kohonen Network	Back propagation neural network
Data analyzed	500 data samples	49 data samples	400 data samples	Near about 60 samples
Accuracy	85%	81.6%	86.21 %	96%
Approach	FFT	Pattern recognition for feature extraction	multifractionality	Emprical mode decomposition(EMD)

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