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COMPARATIVE STUDY ON ACTIVATION FUNCTION BASED HEART ABNORMALITY ACTIVITY

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ABSTRACT

The detection of heart abnormality activity of a patient is important when an abnormal symptom occurred. This project is aimed to detect the disease by using hybrid multilayer perceptron (HMLP) network. Several data from the electrocardiogram (ECG) signal is extracted to be set as input parameters. In order to get the best result, several activation function are used such as logistic, hyperbolic, exponential, step and square root. The result obtained is then compared among the activation function and other detection techniques.

Keywords: heart abnormality; hybrid multilayer perceptron; activation function; electrocardiogram; accuracy.

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1. INTRODUCTION

Heart abnormality activity or heart disease is a very common disease that people in the world have, especially in Malaysia. Heart abnormality or heart disease will be occurred when the blood flow into the heart is blocked by a blood clot [1]. The present of the blood clot will make the artery, which connected to the heart, become narrow. If the blood clots totally block the main artery to the heart, blood supply will eventually stop flowing into it. This will make the heart 'starved' for oxygen because oxygen is important for pumping the blood back to the whole body. In a short time, the heart muscle will become weak and supply less blood to the whole body because of lack of oxygen. This causes the heart attack. One of the most effective ways to detect the heart abnormality is by using electrocardiogram (ECG). ECG is the important source for doctor to detect the any cardiac abnormality or heart disease. It works as a detector of any electrical activity on the surface of a body that generated by the heart [2, 13]. The measurement that is being recorded by ECG is collected by placing several skin electrodes at some specific area of a body.

However, there are known pitfalls in electrocardiography [2]. In particular, an ECG may appear normal despite the presence of serious heart problems. In fact, because the ECG is just a record at one point in time, like snapping a photograph, a patient with a normal ECG may nonetheless (rarely) develop a major change indicative of a heart attack 10 minutes after the test. That is because while the patient may have a history of cardiac symptoms, those symptoms might not have been present when the test was performed. As a result, the test may appear normal in a patient with severe heart disease as it cannot identify a narrowing within an artery unless it is evaluated during physical stress or during a heart attack. Similarly, though the ECG is the definitive test in patients with a rhythm disturbance. If the patient is not in the midst of an arrhythmia when the test is performed, it just may appear normal despite the existence of a serious problem. Hence, by extracting some features from the ECG signal, such as amplitude and duration of P, QRS and T wave, it can be used as an input vectors for the HMLP network to determine the heart abnormality activity accurately. Numbers of activation function are used in order to activate the HMLP network.

2. LITERATURE REVIEW

Artificial Neural Network (ANN) is one of the studies of Artificial Intelligence and is a new computing technology in the field of computer science study. ANN also considers the integration of neural networks with another computing method such as fuzzy logic to maximize the interpretation ability of data. Neural networks mostly used for problem solving in pattern recognition, data analysis, control and clustering [3]. ANN has various features including high processing speeds and the ability to learn the solution to a problem from a set of data or examples. Multilayer Perceptron (MLP) [12] is the most suitable and referred neural networks in the pattern recognition detection. This network can be trained to form various decision surfaces in the input space [3].

2.1. Hybrid Multilayer Perceptron

An MLP network is a feed-forward artificial neural network that maps a set of input onto a set of appropriate output [4]. The network comprises of an input layer, one or more hidden layer and an output layer. The number of nodes in the input and output layers is dependent on the number of input and output variables, respectively [5]. It has been proven that one hidden layer is sufficient for approximation of continuous function up to a certain acceptable accuracy [6]. The input vector x_i is converted to a vector of hidden variables u_j, using activation function φ_1. The output u_j of the j^{th} node in the hidden layer can be expressed in Equation (1)

$$u_j = \varphi_1\left(\sum_{i=1}^{n} w_{ij}\, x_i + \theta_j\right) \tag{1}$$

The weight and bias of the connection between the j^{th} node in the hidden layer and the ith input node are represented by w_{ij} and θ_j, respectively. The HMLP network which is the modified version of MLP was introduced as an optimized solution that is capable of modeling both linear and non-linear systems [7]. Fig. 1 shows the standard connection for an HMLP network.

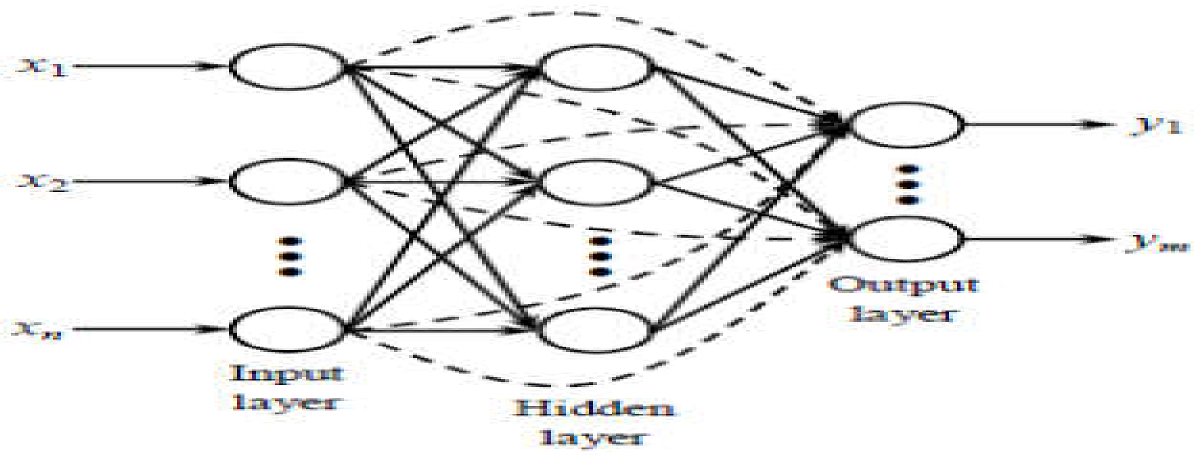

Fig.1. Structure of HMLP network

The network allows the inputs to be connected directly to the output nodes via weighted connections to form a linear model, which is in parallel with the conventional non-linear MLP model [8]. Therefore, the k^{th} output, y_k from the HMLP network can be expressed by Equation (2)

$$y_k = \varphi_2\left(\sum_{j=1}^{h} w_{jk}\, u_j + \sum_{i=1}^{n} w_{ik}\, x_i + \theta_k\right) \tag{2}$$

2.2. Activation Function

The most important unit in neural network structure is their net inputs by using a scalar-to-scalar function called “the activation function or threshold function or transfer function”, output a result value called the “unit's activation”. An activation function for limiting the amplitude of the output of a neuron. Enabling in a limited range of functions is usually called squashing functions [8-9]. It squashes the permissible amplitude range of the output signal to some finite value. Some of the most commonly used activation functions are to solve non-linear problems. These functions are:

1. Unipolar Sigmoid (US)-Activation function US function is given as follows:

$$f(x) = \frac{1}{1+e^{-x}}$$

This function is especially advantageous to use in neural networks trained by back-propagation algorithms. Because it is easy to distinguish, and this can interestingly minimize the computation capacity for training.

2. Bipolar Sigmoid (BS)-Activation function of BS function is given by:

$$f(x) = \frac{1 - e^{-x}}{1 + e^{-x}}$$

This function is similar to the sigmoid function, it goes well for applications that produce output values in the range of [-1, 1].

3. Tangent Hyperbolic (TH)-This function is easily defined as the ratio between the hyperbolic sine and the cosine functions or expanded as the ratio of the half-difference and half-sum of two exponential functions in the points x and -x as follows:

$$f(x) = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}}$$

TH function is similar to sigmoid function. Its range outputs between -1 and 1.

4. Conic Section Function (CSF)-CSF is based on a section of a cone as the name implies. CSF takes a parameter that determines the angle value of the function. The equation of CSF can be defined as follows:

$$f(x) = \sum_{i=1}^{N+1} (a_i - c_i) w_i - \cos w_i \left(\|a - c_i\|\right)$$

where a_i is input coefficient, c_i is the center, w_i is the weight in MLP.

2.3. Interpretation of ECG Waves

To brief summarize the components of normal ECG readings, it consists of waveform components which indicate electrical events during one heartbeat. These waveforms are labeled P, Q, R, S, T and U [10]. P wave is the first short upward movement of the ECG tracing. It indicates that the atria are contracting, pumping blood into the ventricles. The QRS complex normally beginning with a downward deflection, Q; a larger upwards deflection, a peak (R); and then a downwards S wave. The QRS complex represents ventricular depolarization and contraction. The PR interval indicates the transit time for the electrical signal to travel from the sinus node to the ventricles. T wave is normally a modest upwards waveform, representing ventricular repolarization.

3. METHODOLOGY

Six features from the ECG data reading will be used as input vectors for the HMLP network. The features are amplitude of P wave, QRS segment and T wave. Other features are the duration of P wave, QRS segment and T wave. This means that the HMLP network will have

6 input nodes to be applied to the network structure. The selection of all this 6 features is based on the changes of the ECG signal from normal reading to abnormal reading, explained in Chapter II. The total data used for each condition is 200. All the data are inserted to the neural network randomly. The total data used is suitable for training the network. Based on the six features from the ECG signal that are set as an input vector, the neural network is used to classify the heart condition whether it is normal or abnormal. The classification of the heart condition into normal and abnormal are represented as two output nodes as shown on Fig. 2. Each output node functions as a detector for the heart condition.

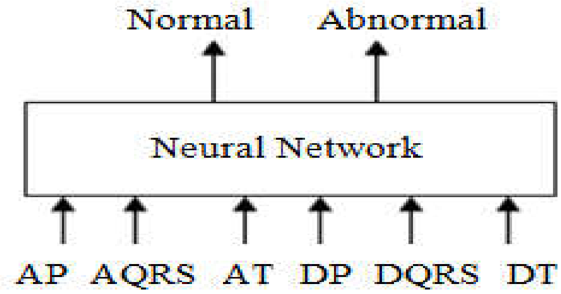

Fig.2. Heart abnormal detection block by using HMLP network

Based on Fig. 2, the input vectors are represented where AP = Amplitude of P wave, AQRS = Amplitude of QRS complex, AT = Amplitude of T wave, DP = Duration of P wave, DQRS = Duration of QRS complex and DT = Duration of T wave.

4. RESULTS AND DISCUSSION

The HMLP is examined for its performance, through computational experiment on 6 input parameters that had been extracting from the ECG signal from [11]. The 6 input parameters are amplitude of P wave, QRS segment, T wave and duration of P wave, QRS segment and T wave. The total data selected is 200; 100 for training purpose and 100 for testing sample. Moreover, the results are compared with HMLP network activated by four different activation functions (US, BS, TH and CSF). The research applies two different analyses which are the optimum structure analysis becomes the first analysis, which is implemented to determine the optimum number of hidden nodes that can produce the best cardiac abnormality classification. In the analysis, the HMLP network activated by four different activation functions (US, BS, TH and CSF). Table 1 shows the result of the analysis for different types of activation function.

Table 1. Performance of optimum structure analysis of HMLP network

Neural Network	Optimum Number of Hidden Nodes
HMLP activated by US	3
HMLP activated by BS	5
HMLP activated by TH	8
HMLP activated by CSF	5

The second analysis, (i.e. the performance comparison analysis) is then applied using the optimum structure of the HMLP network obtained in the first analysis. The analysis is done based on the accuracy of correct classifications of heart abnormality. Table 2 shows the result of the analysis for training and testing phase.

Table 2. Performance of accuracy analysis of HMLP network

Neural Network	Accuracy Percentage, (%)		
	Training	Testing	Overall
HMLP activated by US	96.73	95.92	96.32
HMLP activated by BS	89.50	87.75	88.63
HMLP activated by TH	93.25	92.50	92.88
HMLP activated by CSF	93.50	92.88	93.19

5. CONCLUSION

This paper investigates the capability of neural network to classify the heart abnormality data. This paper study proves that the ANN is capable and reliable to classify the heart abnormality based on both amplitude and duration of the P, QRS and T peak of ECG signal by using four different activation functions. This paper also addresses the selection of appropriate activation function of the neural network may improvement the performance of the network during the optimum structure analysis and the accuracy analysis.

6. ACKNOWLEDGEMENTS

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