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Heart Abnormality Activity Detection Using Radial Basis Function (RBF)

Fakroul Hashim, Amir Rashidi, Nik Daud and Nur Zakaria

National Defense University of Malaysia, Department of Electrical & Electronics Engineering, Faculty of Engineering, Sg Besi Camp, 57000 Kuala Lumpur, Malaysia

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ABSTRACT

Heart abnormality refers to the irregular electrical activity of the heart. Heart abnormality sometimes does not show any symptom and it is not sensible which may lead to sudden death due to the heart cease functioning. This paper attempts to develop a program that capable to detect the heart abnormality activity through the implementation of Radial Basis Function (RBF). A certain amount of data of the heartbeat signals from electrocardiogram (ECG) will be used in this research to train the RBF network and to test the network performance.

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INTRODUCTION

Heart abnormality activity means irregular heartbeat which is known as cardiac dysrhythmia or arrhythmia. It refers to a condition where the heart electrical activity is not normal (Mandel, 1995). The abnormality may be caused by the speed of the heartbeat which is slower or faster than normal condition. There are two conditions of the heartbeat that is faster or normal. If the heartbeat rate is faster which is estimated beyond 100 beats per minute, it is called tachycardia and if it is slower which is estimated less than 60 beats per minute, it is called bradycardia. Among these conditions, there exist two possibilities which is whether the heartbeat is normal or abnormal. Arrhythmias do not necessity lead to death but some can cause a sudden or sometimes temporary, cessation of function of the heart (known as cardiac arrest). Arrhythmias may occur at any age. Arrhythmias cause several symptoms. One of the symptoms is abnormal awareness of palpitations which makes the patient uncomfortable. Some arrhythmias do not show any symptom at all but may lead to deadly stroke. Not all arrhythmias are noticeable and sometimes can cause sudden death to patient due to heart stop functioning (Tou and Gonzales, 1974). In fact, arrhythmias are said to be the most common causes of death when patients reaching to a hospital.

Back then when the early detection method was developed, Electrocardiography (ECG) analysis system was introduced in purpose to acquire initiatory information of the patient's heartbeat. The results acquired are then delivered to the hospital for further analysis. The ECG system uses two processing units to obtain the results. The first processing unit does ECG signal acquisition process which it is taken from patients. The second processing unit does noise filtering and filtered signal extraction processes. The noise filtering is used for terminating noise that contaminates the ECG signal whilst the signal extraction is used as the input parameter for the neural network to detect the heart abnormality activity.

On the other hands, Radial Basis Function network is an Artificial Neural Network (ANN) that implements Radial Basis Functions (RBF) as activation functions. As one of the Artificial Intelligence branches, Artificial Neural Network (ANN) has often been utilized in biomedical engineering research to classify data. The ANN is originally inspired by the biological nervous systems of human beings. The ANN is configured for a particular application such as pattern recognition or data clustering and classification. Similarly, Radial Basis Function (RBF) is one of the Artificial Neural Network. RBF is also useful in biomedical field which the purpose is to assist in decision making in medical diagnosis. Radial Basis Function Network has many applications such as system control, function approximation, time series prediction and data classification. RBF was first formulated in 1988 by two researchers at the Royal Signals and Radar Establishment. (Broomhead and Lowe, 1988).

Corresponding Author: Fakroul Hashim, National Defense University of Malaysia, Department of Electrical & Electronics Engineering, Faculty of Engineering, Sg Besi Camp, 57000 Kuala Lumpur, Malaysia.
E-mail: fakroul@upnm.edu.my

Literature Review:

Artificial Intelligence (AI) is one of the computer science branches which is a new technological science with a goal to carry out research and thus developing technologies, methods, theory and applications in the purpose of simulation extension and expansion of human intelligence. The person who propose the term in 1955, John McCarthy defines the Artificial Intelligence as "the science and engineering of making intelligent machines". Artificial Intelligence is an attempt to understand the concept of intelligence in intelligent beings which is human. The understanding on the intelligence is used to produce or create a new intelligent machine possess the ability to act and response in a similar way as human do. There are several of AI areas of research encompassing speech recognition, image recognition, robotics, expert system natural language processing and so forth.

Meanwhile, Artificial Neural Network (ANN) is a branch of Artificial Intelligence. Artificial Neural Network is divided into several techniques such as Multilayer Perceptron (MLP) and Radial Basis Function (RBF).

Radial Basis Function (RBF):

Originally, the radial basis function has been proposed as a solution to the multivariable interpolation problem (Powell, 1995). Broomhead and Lowe (1988) have used this function in the construction of a neural network called RBF network. RBF network is proved to have universal good estimating capabilities (Poggio and Girosi, 1990). After that, some research that contributes greatly to the theory, the construction of the structure and function of RBF network has been carried out by Poggio and Girosi. RBF network has been used in various fields such as system identification (Joilson *et al*., 2014), data classification (Eric, 2009) and the medical field. Research in the medical field often using RBF network as medical image processing (Zhenghao and Lifeng, 2010) and detection of disease (Ali *et al*., 2012).

RBF network is a feedforward neural network comprising an input layer, hidden layer and output layer as shown in Figure 1. The input layer has neurons or nodes (white) responsible for providing input data to the RBF network. Hidden layer has hidden nodes (gray) with a set of radial basis function. Each hidden node consists of an array of nodes containing the vector parameter called the center. The output layer contains output nodes (black) that provide the output response to the activation pattern of input data. Based on Figure 1, the output of the RBF network has *m* output nodes, *n* input nodes and n_h hidden nodes represented by the equation:

$$\hat{y}_i(t) = w_{i0} + \sum_{j=1}^{n_h} w_{ij}\phi\left(\left\|v(t) - c_j(t)\right\|\right), \quad i = 1,2,\ldots,m \qquad (2.1)$$

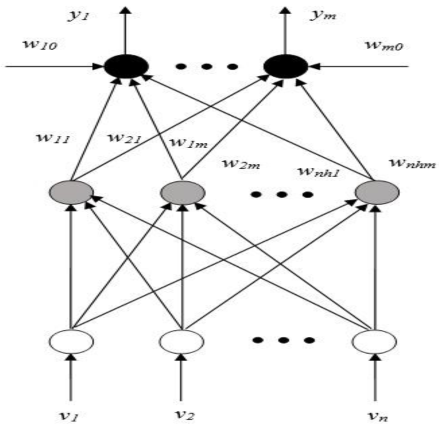

Fig. 1: RBF Architecture.

Powell (1987) has shown that the RBF network performance depends on its local characteristics of the network that is network center location and the selection of the basic functions as the network activation function, $\phi(\bullet)$. Each hidden node can have different activation function with other hidden nodes. There are six typical basic functions which are frequently used in RBF networks, but the most widely used is thin-plate-spline function and Gaussian function:

i. thin-plate-spline function

$$\phi(a(t)) = a^2(t)\log(a(t)) \qquad (2.2)$$

ii. Gaussian function

$$\phi(a(t)) = e^{-\left(a^2(t)/\delta^2\right)} \qquad (2.3)$$

Electrocardiogram (ECG):

The electrocardiogram (ECG) can be defined as a non-invasive device that is used to measure and monitor the heart's electrical activity through the skin (Braunwald, 1997). A distinctive waveform is produced by the electrocardiogram. This particular waveform is in response to the electrical changes that happen inside the heart. The electrical changes that take place inside the heart can be used to detect the following problems:

i. Changes in the hearts ionic environment.
ii. The heart's conduction system defect.
iii. Muscle fibers damage due to lack of blood supply.
iv. Detecting several heart diseases.

The waveform produced by the electrocardiogram monitor shows the electrical changes that take place in the heart. The electrical recharge and electrical discharge that happen in the heart can be expressed as depolarization and repolarization respectively.

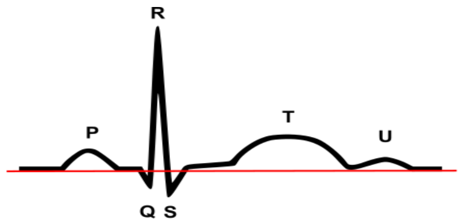

Fig. 2: Normal waveform of ECG signal.

By looking at the waveform in Figure 2, basically there are several waves that can be described as P wave, QRS complex (which often encompasses Q wave, R wave and P wave), T wave and U wave. Each of these waves can be explained as follows:

Table 1: Signal waves and their representations.

Wave	Heart Situation
P wave	Atrial depolarization.
QRS complex	Ventricular depolarization.
T wave	Ventricular repolarization.
U wave	Purkinje fibers repolarization

Methodology:

RBF network is used in this project for the diagnosis of heart disease. Six features of heart rate waveforms on ECG will be used as input data to the network. The features is P wave amplitude, QRS complex amplitude, T wave amplitude, P wave duration, PQRS complex duration, and T wave duration. This means that the network has six input nodes.

Data Collection:

Selection of six features are due to these criteria changed in line with changes in heart rate from normal to abnormal. The number of data for each feature used is 200. All recorded ECG signals were taken from MIT-BIH database and are used in this project. All data are entered into the random neural network. Number of training data used is adequate to train RBF network.

Training the Network:

Based on the six features of ECG waveforms which are used as inputs to the neural network, each neural network is used to classify the heartbeat to normal and not normal. The heartbeat classification into two classes requires a neural network with two output nodes as shown by the block diagram in Figure 3. Each output node is used for detecting a type of heartbeat. The data that will be used for training purpose is 100. Another 100 data will be used for testing the RBF network.

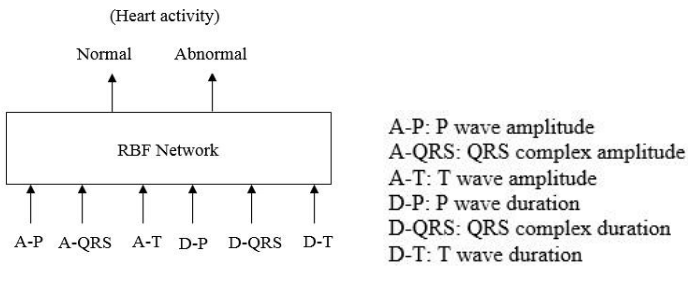

Fig. 3: RBF block diagram for heart abnormality activity detection.

RESULTS AND DISCUSSION

The RBF network measured for its performance, through computational approach with six 6 input parameters which extracted from the ECG signal from Physionet database. The 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; 120 for training purpose and 80 for testing sample. Moreover, the results are compared among the RBF network trained by four different training algorithms which are Genetic Algorithm (GA), K-Mean Clustering (K-Mean), Kalman Filter (KF) and Gradient Descent (GD).

The work applies two different analysis which is to find the optimum structure. The analysis is implemented to determine the optimum number of hidden nodes which could produce the best cardiac abnormality classification. However, in this research, the number of hidden node is limit to 20 nodes only. Table 2 shows the result of the analysis for different types of training algorithm.

Table 2: Performance of optimum structure analysis of RBF network trained using different training algorithms.

RBF Training Algorithm	Optimum number of hidden nodes
GA	3
K-Mean	9
KF	6
GD	12

In second analysis, the performance comparison analysis is then applied using the optimum structure of the RBF 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 3: Performance of accuracy analysis of RBF network trained using different training algorithms.

RBF Training Algorithm	Accuracy Percentage, (%)		
	Training	Testing	Overall
GA	92.13	91.92	92.02
K-Mean	86.52	84.57	85.54
KF	90.25	88.53	89.39
GD	83.50	79.28	81.39

The results shows in Table 2 show the RBF network trained with GA training algorithm forms the simplest network architecture as it only requires 3 hidden nodes as compared to other training algorithms (KF, K-Mean and GD). For the performance analysis, the results obtained as shows in Table 3 show that the RBF network trained with GA training algorithm capable to produce the best performance of accuracy with 92.13% and 91.92% for training and testing phase respectively, which gives overall accuracy of 92.02%.

Conclusion:

This paper shows the capability of RBF network in doing the classification of the heart abnormality activity. This work proves that the RBF network capable to produce high accuracy result and reliable to classify the heart abnormality based on both amplitude and duration of the P, QRS and T peak of ECG signal. An improvement on neural network structure and the use of other training algorithms may improvement the performance of the RBF neural during the optimum structure analysis and the accuracy analysis.

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