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DEVELOPMENT OF ATRIAL FIBRILLATION DETECTION ALGORITHM BASED ON EXTRACTED ECG FEATURES AND HYBRID MULTILAYER PERCEPTRON NETWORK

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ABSTRACT

Heart is made up by bundles of cardiac muscle. It has a pacemaker that generate electrical signal to escalate muscle for contraction and relax. However, when electrical signal undergoes internal or external disturbance, it may lead to cardiac abnormality. Cardiac abnormality refers to the capricious electrical activity of the cardiac muscles. It sometimes does not exhibit any symptom as it's still in the early stage or phase one, but which may lead to sudden end due to the heart cease functioning. In order to reduce the sudden death episode, a lot of research has been done to give early warning to the patient. In this research, a new approach has been developed which capable to detect atrial fibrillation (AF) activity based on electrocardiogram (ECG) signal using the Hybrid Multilayer Perceptron (HMLP) neural network. An intelligent system is designed to solve the problem at the earliest stage. A dataset of ECG signal is taken from the MIT-BIH database used in the research to train and generalize the HMLP network, as well as to test the network performance. Continuous ECG signal dataset needs to be segmented into a complex contains P, QRS and T waves, since information of cardiac abnormality depends on those waves. In this research, the R to R peak interval (RRI) is used to segment the ECG signal in a complex form. At this stage, rectangular pulses are overlapping with a complex ECG then the interception points are taken as ficidual point of the complex. The ficidual point contains the amplitude and duration at each intercept point. Furthermore, the amplitudes and durations are considered as the input vector to HMLP network. The HMLP network is trained by a number of training algorithms which are Levenberg Marquardt (LM), Bayesian Regularization (BR), Back- Propagation (BP) and Resilient (R). Then, it will come out with the prediction performance, including accuracy, sensitivity and specificity performances. The performances are divided into training and testing before overall performance is taken as the average (after 5 or more iterations). In the research, the performance of the classifier is measured by the mean square error (MSE) and regression (Reg) at each iteration. The lowest MSE performance and most approaching to 1 of regression performance may improve accuracy of the network. The Graphical User Interface (GUI) is designed to represent a whole research project with prediction performance of 98.61% accuracy.

ABSTRAK

Jantung terdiri daripada otot-otot kardiak. Ia mempunyai penentu rentak yang menjana isyarat elektrik untuk otot pengecutan dan berehat. Walau bagaimanapun, apabila isyarat elektrik menghadapi gangguan dalaman atau luaran, ia mungkin menyebabkan ketidakstabilan jantung. Ketidakstabilan jantung merujuk kepada aktiviti elektrik yang tidak menentu pada otot jantung. Ia selalunya tidak menunjukkan sebarang gejala seperti yang masih dalam peringkat awal atau peringkat satu, tetapi boleh mengakibatkan kematian secara tiba-tiba akibat jantung terhenti berfungsi. Untuk mengurangkan episod kematian secara tiba-tiba, banyak penyelidikan telah dilakukan untuk memberi amaran awal kepada pesakit. Dalam kajian ini, pendekatan baru telah dibangunkan untuk mengesan aktiviti atrial fibrillition (AF) berdasarkan isyarat elektrokardiogram (ECG) menggunakan rangkaian neural Multilayer Perceptron Berhibrid (HMLP). Satu sistem pintar direka untuk menyelesaikan masalah di peringkat awal. Dataset isyarat ECG diambil dari pangkalan data MIT-BIH yang digunakan dalam penyelidikan untuk melatih dan mengitlakkan rangkaian HMLP, serta untuk menguji prestasi rangkaian tersebut. Dataset isyarat ECG yang berterusan perlu disegmenkan kepada satu kompleks yang mengandungi gelombang P, QRS dan T yang lengkap kerana maklumat abnormaliti jantung bergantung kepada gelombang berkenaan. Dalam kajian ini, selang puncak R hingga R (RRI) digunakan untuk membentuk isyarat ECG dalam bentuk yang rumit. Pada peringkat ini, denyutan segiempat sama ditindihkan bersama kompleks ECG maka, setiap titik pemintasan diambil sebagai titik fisidual kompleks. Titik fisidual mengandungi amplitud dan durasi pada setiap titik pemintasan. Tambahan pula, amplitud dan durasi diambil sebagai vektor masukan kepada rangkaian HMLP. Rangkaian HMLP dilatih oleh beberapa algoritma latihan iaitu Levenberg Marquardt (LM), Bayesian Regularization (BR), Back-Propagation (BP) dan Resilient (R). Kemudian, ianya memberikan prestasi ramalan termasuklah keputusan ketepatan, sensitiviti dan kekhususan. Prestasi dibahagikan kepada latihan dan ujian sebelum prestasi keseluruhan diambil sebagai purata (selepas 5 atau lebih lelaran). Dalam penyelidikan ini, prestasi pengelas diukur menggunakan min kuasa dua terkecil (MSE) dan regresi (Reg) pada setiap lelaran. Prestasi MSE terendah dan prestasi regrasi paling hampir dengan 1 dapat meningkatkan ketepatan rangkaian. Antaramuka Pengguna (GUI) direkabentuk untuk mewakili keseluruhan projek penyelidikan dengan prestasi ramalan ketepatan 98.61%.

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APPROVAL – EXAMINATION COMMITTEE

The Examination Committee has met on **22nd February 2019** to conduct the final examination of **Muhamad Hadzren Bin Mat** on his degree thesis entitled **'Developtment of Atrial Fibrillation Detection Algorithm Based on Extracted ECG Features and Hybrid Multilayer Perceptron Network'**.

The committee recommends that the student be awarded Master of Science (Electrical & Electronic Engineering)

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LIST OF ABBREVIATIONS

AV	Atrioventricular
SA	Sinoatrial
ECG	Electrocardiogram
MLP	Multilayer Perceptron
HMLP	Hybrid Multilayer Perceptron
BP	Backpropagation
LM	Levenberg-Marquardt
BR	Bayesian Regularization
R	Resilient
AI	Artificial Intelligent
ANN	Artificial Neural Network
MSE	Mean square Error
LDL	Low density lipoprotein
HDL	High density lipoprotein
CPR	Cardiopulmonary resuscitation
MIT-BIH	Massachusetts Institute of Technology Beth Israel Hospital
RPD	Rectangular Pulse Domain

CHAPTER 1

INTRODUCTION

1.1 Overview

The heart is an important organ in a human body, made up or cardiac muscle and it is myogenic which contracts without any signal from the nervous system. Unlike other organs in the human body, the nervous system will send an impulse that generates from our brain; Medulla oblogata but in heart pacemaker will generate waves of signal to contract and delay at the AV node. Then, the signal is given to the heart apex and spread throughout the ventricles. It is a process of the heart to pump oxygenated blood to whole of the body. Nevertheless, this organ still has it failure or abnormal activity due to certain causes. Cardiac abnormality will be occurred as the oxygenated blood or deoxygenated blood are failed pump to whole body at the normal heartbeat. This will be happening when a blood clot is blocking the artery, which are connected to the heart. The presence of blood clot will make the artery became narrow and disturbed the transport system in a human's body. In short time, the heart will become weak, and oxygenated blood pumped to whole body will be less than deoxygenated blood, causes cells in body lack of oxygen. This will contribute to heart attack.

Atrial fibrillation could be detected by using the electrocardiogram (ECG). The ECG is a test to show the electrical system in the heart working. During an ECG, electrical leads placed on the chest, arms and legs. These leads detect small electrical signals and tracing on graph paper to illustrate the electrical signals throughout the cardiac muscle. Atrial fibrillation can be detected as the electrical signal illustrated is different from the normal one.

The data from the ECG will be extracted to detect the atrial fibrillation by using Hybrid Multilayer Perception (HMLP) neural network technique. The P, QRS and T peak amplitude will show the abnormality of the heart. A HMLP network consists of multiple layers with each layer are fully connected to each one. This project will train the HMLP neural network using learning algorithm to detect any abnormal activity of cardiac muscle by using P, Q, R, S and T amplitude and duration as the input parameter.

1.2 Problem Statement

The coronary atrial fibrillation or cardiovascular disease can be detected with the aid of the use of ECG test. By placing electrical leads to specific places on the body, an electrical signal that generated by the heart can be measured and recorded by the Holter monitor. ECG consists of P, QRS and T waves. Any abnormal or changes of these waves and segments doubtlessly display that the affected person may additionally have a coronary heart problem. However, an ECG signal may not show the patient has a heart disease, even though there is a serious heart problem. This project is to determine the atrial fibrillation activity by extracting features such as P-wave, QRS- waves and T- wave from the ECG signal to be used as input parameters for the HMLP network.

In this study, the duration and amplitude of the signal are put as high priority and ignored the other information. Most of ECG data are taken from the stationary patient (at rest) or while performing a constant movement (i.e. While on the treadmill with constant acceleration). ECG data collection on the non-stationary patient is performed at a minimum frequency whilst overlooks the high mortality rate during having sport or active activities. At this point, we will investigate best technique to extract the ECG features and try to solve the non-stationary issue. A lot of classifiers are available to be used in the ECG pattern recognition process. The capability of classifiers to give high accuracy depends heavily on how the classifier is trained. The matched selection of the classifier structure and training algorithm allow good classification results to be produced. The complexity and stability of input parameter given also contributed to the performance of the classifier. In this research, we will try to improve the classification accuracy by doing some modification on the current neural network.

1.3 Objective

The objective of this project are:

1. To carry the performance analysis for training algorithm to train the HMLP network.
2. To determine the suitable ECG extraction technique for feature extraction as the input parameter for neural network.
3. To develop algorithm for detection of atrial fibrillation (AF) by using HMLP neural network.

1.4 Research Scope

The main of these researches is to get features extracted from the ECG signal. The noiseless ECG signals are taken from the MIT-BIH database. The data from normal sinus rhythm signal and Atrial Fibrillation (AF) signal make as a training and testing data of this research. Regardless of the noise, ECG signal taken from the MIT-BIH are clean signal.

The artificial intelligence will be basic for generating ECG features. Therefore, HMLP network, which is the improvement of MLP network is used as virtual brain. To develop the network, a few training algorithms undergoes an analysis process to get optimum accuracy. The Bayesian Regularization (BR), Levenberg-Marquardt (LM), Resilient (R) and Backpropagation (BP) act as the training algorithm to train the HMLP network. On the other hand, activation function is the other element that is involved in this network which will activate the network. The most efficient activation function must be examined to be use of the network, which will be utilized for the growth of the research using MATLAB Toolbox.

1.5 Thesis Outline

The literature review described the structure and working principle of the heart. Then, continues by explanation of electrical signal of the heart itself which also known as electrocardiogram (ECG). The structure and features of these ECG signal explained as it have complex features that need to study. Finally, Artificial Intelligent (AI), which included Artificial Neural Network (ANN), which consist neural network structures such as Multilayer Perception (MLP), Hybrid Multilayer Perception (HMLP), and Mean Square Error (MSE). This chapter also explained a simple introduction about MLP and HMLP, including the design and architecture and equation.

Chapter 3 is more focus on the methodology of this project. A brief introduction and details about HMLP are explained, including the structure, equations, previous study on this field, and the training algorithm for this HMLP network whuch include the activation functions. It also explained how the input vector from the ECG signal is inserted into the network and how the performance is indicated.

Chapter 4 is the most necessary part of this thesis, which are analysis and result of this research. It consists of the application of Graphical User Interface (GUI) in detecting cardiac abnormality by inserting ECG data, the diagnostic performance analysis for both training and testing phase, and the overall performance of the HMLP Network. This chapter also incorporates a comparison of performance analysis between training and testing stage.

Finally, the overall discussion about the conclusion of this project. Some recommendations are also has been discussed in the future work of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 ECG Acquisition

AF is an abnormality of cardiac rhythm, detected by ECG. The cardiac structure, anatomy and physiology, and associated abnormalities have to be understood before the arising of AF can be detected. Detailed explanation of electrocardiography and the use of the ECG in detecting and diagnosing cardiac rhythm abnormalities are present. The use of the Holter monitor allows continuous detection and recording of cardiac rhythm for several days. A review of Holter monitor development and its role in medical practice today is furnished. The latest technology used in the development of the Holter monitor in accordance with present modernization is also discussed.

2.2 The Cardiac Muscle

Located behind the sternum (breast bone), the human heart is about the size of a clenched fist and consists mostly of cardiac muscle. The two atria have relatively thin walls and serve as collection chambers for blood returning to the heart from the lungs or other body tissues. Much of the blood that enters the atria flows into the ventricles while all heart chambers are relaxed. The remainder is transferred by contraction of the atria before the ventricle begins to contract. The ventricles have thicker walls and contract much more forceful than the atria- especially the left ventricle, which pumps blood to all body organs through the systemic circuit.