A SMART ARRHYTHMIA CLASSIFICATION SYSTEM BASED ON WAVELET TRANSFORM AND SUPPORT VECTOR MACHINE TECHNIQUES

CHIA NYOKE GOON

UNIVERSITI TEKNOLOGI MALAYSIA

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CHIA NYOKE GOON

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This project is dedicated to my beloved family

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ABSTRACT

Heart disease is still the most common cause of death and contributes large number of death in this modern world. According to the survey conducted by World Health Organization (WHO), cardiovascular disease (CVD) is the number one cause of death globally in 2016. CVD claimed 801,000 lifes and heart disease killed more than 370,000 asian people which is 23.2% according to David S. Siscovick who is the chair of AHA's Council on Epidemiology and Prevention. Arrhythmia is defined as an irregular heartbeat which will cause abnormal rhythms of the heart that further lead to serious heart disease like stroke and heart attack.Thus, arrhythmia detection and classification is crucial in clinical cardiology to analyze the extracted features from non-invasive electrocardiogram (ECG) testing. However, the arrhythmia classification accuracy based on the commercial classification software is still a remaining issue and it is an extremely time consuming process for manual visual inspection. This research proposed an arrhythmia classification software based on support vector machine (SVM) algorithm due to its advantage of higher accuracy and solve overfitting problem. The proposed system consists of three stages, namely pre-processing, feature extraction using wavelet coefficient and arrhythmia classification using SVM. All the processing stage and intermediate outputs are displayed in user friendly Graphic User Interface (GUI). The system verification is based on offline MIT-BIH database for classification accuracy, benchmarking with the other related works. The classification result shows that the proposed system is able to detect arrhythmia classification up to accuracy of 91.11%. This research output is used as PC-based ECG classification software which able to run at workstation to perform long duration of ECG data, such as 24 hour holter data. For the future work, it is suggested to add an automated R-peak detection algorithm to the system in order to solve the problem of dependency on the R-peak annotation file.

ABSTRAK

Penyakit jantung adalah punca kematian yang sering berlaku dan menyumbang sejumlah besar kematian di dunia moden ini. Menurut kaji selidik yang dijalankan oleh Pertubuhan Kesihatan Sedunia (WHO), penyakit kardiovaskular ialah punca utama kematian global pada tahun 2016. Aritmia ditakrifkan sebagai degupan jantung yang tidak teratur yang akan menyebabkan irama yang tidak normal jantung yang lebih utama kepada penyakit jantung yang serius seperti strok dan serangan jantung.Oleh itu, pengesanan aritmia dan klasifikasi adalah penting dalam kardiologi klinikal untuk menganalisis ciri-ciri yang diekstrak daripada ujian elektrokardiogram tidak invasif (ECG). Walau bagaimanapun, ketepatan klasifikasi aritmia berdasarkan perisian klasifikasi komersial masih menjadi isu yang tunggal dan ia adalah proses yang amat memakan masa untuk pemeriksaan visual secara manual. Kajian ini mencadangkan satu perisian klasifikasi aritmia Matlab berdasarkan algoritma Support Vector Machine (SVM) kerana kelebihan ketepatan yang lebih tinggi dan menyelesaikan penyesuaian masalah. Sistem yang dicadangkan terdiri daripada tiga peringkat, iaitu pra-pemprosesan, pengekstrakan ciri menggunakan pekali ombak dan klasifikasi aritmia menggunakan SVM. Semua peringkat pemprosesan dan output perantaraan dipaparkan pengantaraan muka yang mesra pengguna. Pengesahan sistem adalah berdasarkan offline pangkalan data MIT-BIH untuk ketepatan pengelasan bertanda araskan kepada kerja-kerja yang berkaitan. Hasil pengelasan menunjukkan bahawa sistem yang dicadangkan dapat mengesan klasifikasi aritmia sehingga ketepatan 91.11%. Hasil penyelidikan ini digunakan sebagai perisian berasaskan PC klasifikasi ECG yang dapat beroperasi di stesen kerja untuk melaksanakan data ECG dengan tempoh panjang, seperti 24 jam holter data. Ini adalah dicadangkan menambah R-puncak algoritma pengesanan automatik kepada sistem bagi menyelesaikan masalah pergantungan kepada fail anotasi R-puncak untuk kerja masa depan.

TABLE OF CONTENTS

CHAPTER	TITLE		PAGE
	DECLARATION		ii
	DEDICATION		iii
	ACKNOWLEDGEMENT		iv
	ABSTRACT		v
	ABSTRAK		vi
	TABLE OF CONTENTS		vii
	LIST OF TABLES		x
	LIST OF FIGURES		xi
	LIST OF ABBREVIATIONS		xiii
1	**INTRODUCTION**		**1**
	1.1	Problem Background	1
	1.2	Problem Statement	3
	1.3	Objectives	5
	1.4	Scope	5
	1.5	Research Contribution	6
	1.6	Thesis Organisation	6
2	**LITERATURE REVIEW**		**7**
	2.1	Human Heart Anatomy and Electrocardiogram (ECG)	7
	2.2	Arrhythmia	9
		2.2.1 Premature Ventricular Contraction (PVC)	10
		2.2.2 Left Bundle Branch Block (LBBB)	11
		2.2.3 Right Bundle Branch Block Beat (RBBB)	12
		2.2.4 Atrial Premature Beat (APB)	13
		2.2.5 Aberrated Atrial Premature Beat (AAPB)	13
		2.2.6 Nodal (Junctional) Premature Beat (NPB)	14
		2.2.7 Nodal (Junctional) Escape Beat (NEB)	15

	2.2.8	Ventricular Escape Beat (VEB)	15
	2.2.9	Paced Beat (PB)	16
	2.2.10	Fusion of Ventricular and Normal Beat (FVN)	17
	2.2.11	Fusion of Paced and Normal Beat (FPN)	17
2.3	Arrhythmia Detection Algorithm		18
2.4	Pre-processing		19
	2.4.1	Pan and Tompkins Algorithm (PT)	19
	2.4.2	Derivative Based Method	20
	2.4.3	Heartbeat Segmentation Method	20
2.5	Feature Extraction		22
	2.5.1	Heart Rate Variability (HRV) Analysis	22
	2.5.2	Wavelet Transform (WT)	25
	2.5.3	Hermite Polynomial (HP)	27
2.6	Classification		29
	2.6.1	Artificial Neural Network (ANN)	30
	2.6.2	Fuzzy Logic	31
	2.6.3	Rule Based Algorithm	32
	2.6.4	Support Vector Machine (SVM)	32
2.7	Previous Work		35
2.8	Tools		37
	2.8.1	MIT-BIH Offline Database	37
	2.8.2	MATLAB	37
	2.8.3	Support Vector Machine Library (LIB-SVM)	38
2.9	Chapter Summary		39
3	**ALGORITHM MODELLING AND SOFTWARE DEVELOPMENT**		**40**
3.1	Research Methodology		40
3.2	Overview of Proposed Arrhythmia Detection Algorithm		42
3.3	ECG Pre-processing		42
3.4	Feature Extraction based on Wavelet Transform, Statistical Features and Time Interval Features		46
3.5	Arrhythmia Classifier based on SVM		51
3.6	Arrhythmia Classification Software Development		54
	3.6.1	Software Welcoming Screen	54
	3.6.2	SVM Training	55

		3.6.3 SVM Testing	57
	3.7	Chapter Summary	59
4	**RESULT AND DISCUSSION**		**60**
	4.1	ECG Signal Pre-processing Validation	60
	4.2	Feature Extraction Validation	64
	4.3	Arrhythmia Classification	69
	4.4	Related Work Brenchmarking	76
	4.5	Computation Timing Performance	78
	4.6	Graphical User Interface (GUI) Development	78
	4.7	Chapter Summary	80
5	**CONCLUSION**		**81**
	5.1	Conclusion	81
	5.2	Recommendation of Future Works	82
REFERENCES			**83**
Appendices A – B			84 – 85

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Types of arrhythmia	10
2.2	Comparison of pre-processing techniques	21
2.3	Comparison of three domain	24
2.4	Comparison of feature extraction techniques	29
2.5	Comparison of the classifier	35
2.6	Previous work of arrhythmia detection	36
3.1	Statistical features	50
3.2	Timing interval features	50
4.1	The mean values of absolute value in each sub-band	68
4.2	The accuracy of arrhythmia detection	71
4.3	Results of arrhythmia detection	74
4.4	The exploration accuracy in term of exclusion timing interval features	75
4.5	Previous work of arrhythmia detection	77
4.6	Pre-defined fix parameter setting	79

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	The statistic of United States	2
1.2	ECG signal	3
1.3	Research scope	6
2.1	Human heart anatomy	8
2.2	An ECG signal	9
2.3	ECG waveform sample of MIT-BIH offline database	10
2.4	ECG characteristic of PVC	11
2.5	ECG characteristic of LBBB	12
2.6	ECG characteristic of RBBB	12
2.7	ECG characteristic of APB	13
2.8	ECG characteristic of AAPB	14
2.9	ECG characteristic of nodal (junctional) premature beat	14
2.10	ECG characteristic of nodal (junctional) escape beat	15
2.11	ECG Characteristic of Ventricular Escape Beat	16
2.12	ECG characteristic of paced beat	16
2.13	ECG characteristic of fusion of ventricular and normal beat	17
2.14	ECG characteristic of fusion of paced and normal beat	18
2.15	Overview of arrhythmia detection algorithm	18
2.16	Pan and Tompkins algorithm	19
2.17	Derivative based method	20
2.18	Heartbeat segmentation method	20
2.19	Discrete wavelet transform for feature extraction	27
2.20	ANN layer [6]	31
2.21	Fuzzy logic system [13]	32
2.22	SVM	33
2.23	MATLAB	38
3.1	Work flow	41
3.2	Overview of the proposed arrhythmia classifier	42
3.3	The flow of the ECG pre-processing	43
3.4	The segmentation	44

3.5	ECG pre-processing behavioural flowchart	45
3.6	Six times decomposition of ECG signal	48
3.7	Timing interval features	49
3.8	Feature extraction behavioural flowchart	51
3.9	The concept of SVM	52
3.10	The SVM behavioral flowchart	54
3.11	The welcoming page	55
3.12	SVM training	56
3.13	SVM training behaviour flowchart	57
3.14	SVM testing	58
3.15	SVM testing behaviour flowchart	59
4.1	The raw ECG signal	61
4.2	The filtered ECG signal	61
4.3	The first four heart beat ECG segmentation	62
4.4	The first four heart beat offset removal	63
4.5	The first four heart beat normalisation	63
4.6	The first ECG heart beat in decomposition result of details output, $D_k, 1 \leq k \leq 6$	64
4.7	The first ECG heart beat in decomposition result of approximation feature, $A_k, 1 \leq k \leq 6$	65
4.8	The second heart beat in decomposition result of details output, $D_k, 1 \leq k \leq 6$	65
4.9	The second heart beat in decomposition result of approximation feature, $A_k, 1 \leq k \leq 6$	66
4.10	The third heart beat in decomposition result of details output, $D_k, 1 \leq k \leq 6$	66
4.11	The third heart beat in decomposition result of approximation feature, $A_k, 1 \leq k \leq 6$	67
4.12	The forth heart beat in decomposition result of details output, $D_k, 1 \leq k \leq 6$	67
4.13	The forth heart beat in decomposition result of approximation feature, $A_k, 1 \leq k \leq 6$	68
4.14	Confusion Matrix	72
4.15	SVM Training	79
4.16	SVM Testing	80

LIST OF ABBREVIATIONS

AHA	-	American Heart Association
ANN	-	Artificial Neuron Network
AF	-	Atrial Fibrillation
APB	-	Atrial Premature Beat
AV	-	Atrial Ventricular
BPM	-	Beat Per Minute
CVD	-	Cardiovascular Disease
CVT	-	Cardio Vascular Technologist
ECG	-	Electrocardiogram
FN	-	False Negative
FP	-	False Positive
GUI	-	Graphical User Interface
HRV	-	Heart Rate Variability
LBBBB	-	Left Bundle Branch Block Beat
N	-	Normal
PT	-	Pan and Tompkin
PVC	-	Premature Ventricular Contraction
RBBBB	-	Right Bundle Branch Block Beat
SA	-	Sino Atrial
SVM	-	Support Vector Machine
TN	-	True Negative
TP	-	True Positive
WHO	-	World Health Organisation

CHAPTER 1

INTRODUCTION

This chapter presents the research background, problem statement, research objectives and associated project scope, research significance and the organization of the thesis.

1.1 Problem Background

In this modern world, heart disease is still the most common cause of the death and contributes large number of death even in developed countries. According to the survey conducted by World Health Organization (WHO), cardiovascular disease (CVD) is the number one cause of death globally in 2016. 17.5 millions of people which about 31% of global population died from CVD in 2012 due to coronary heart disease and stroke from WHO [1]. According to a study conducted in 2014, approximately 36% of Malaysians lose their life due to cardiac diseases as shown in Figure 1.1 which contribute the death rate among Malaysians due to heart disease rank at 33 in worldwide [2]. For the country USA in 2016, CVD claimed 801,000 lifes and heart disease killed more than 370,000 Asian people which is 23.2% according to David S. Siscovick who is the chair of AHA's Council on Epidemiology and Prevention and senior vice president for research at the New York Academy of Medicine in New York City [3].

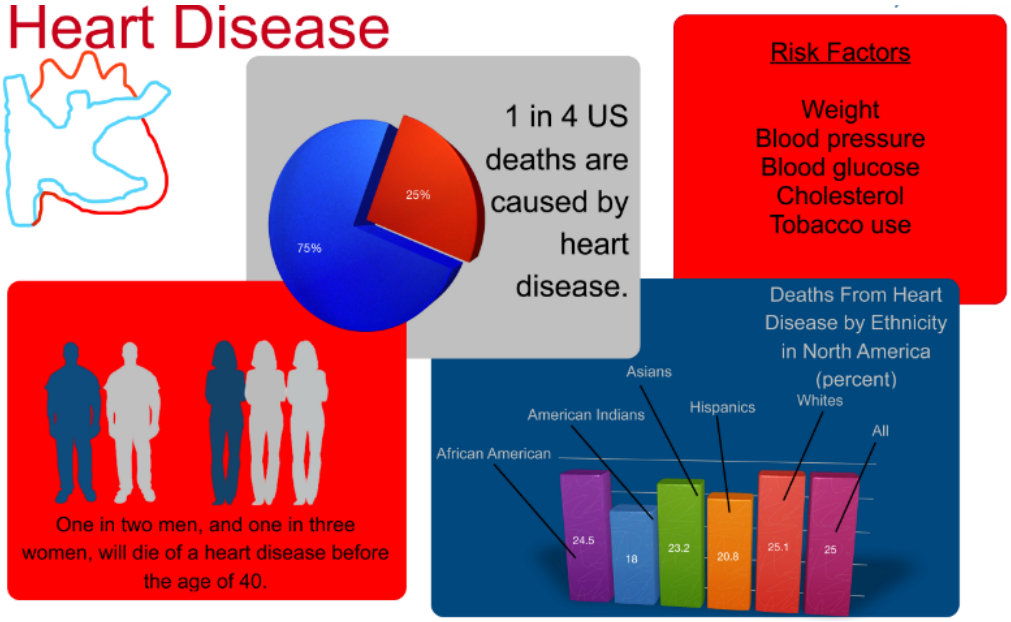

Figure 1.1: The statistic of United States

An irregular heartbeat is known as arrhythmia which causes abnormal heart rhythms [4].This can be treated as an indicator of potential heart problem which may lead to stroke or sudden cardiac death. For instance, Premature Ventricular Contraction (PVC) is one of the most common arrhythmia which contribute approximately 50% of death among the various heart diseases [5].Thus, arrhythmia classification with high accuracy is crucial in clinical cardiology to analyse the extracted features from non-invasive electrocardiogram (ECG) testing.

Electrocardiogram (ECG) is an essential human vital signal which can be used to detect heart rate. It can also be defined as an electrical activation of heart and is a non-stationary signal. A typical ECG heartbeat consists of P wave, QRS complex and T wave as shown in Figure 1.2. This signal is useful for arrhythmia detection and may consist of indicator or alert about various heart diseases [6].

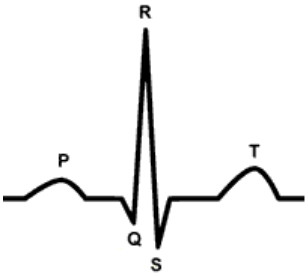

Figure 1.2: ECG signal

The ECG analysis has been proven to be a conventional non-invasive approach for heart disease detection in clinical setting [7]. The characteristic of ECG signal gives important information about the amplitudes, shapes and the duration of PQRST waves. These information are very essential to extract the key features for arrhythmia detection. Moreover, it provides effective information about the heart deficiency [8]. As a result, ECG analysis have been greatly researched and remain as an active research area to detect heart abnormality for early cardiac disease detection to increase survival rate [9,10,11].

On the other hand, Matlab is universally accepted as one of the most powerful software modelling platform and algorithm verification tool. This software have connected with many advanced programming language such as C, Java and Visual Basic and equipped with rich set of toolbox. As a result, this research propose a Matlab-based arrhythmia classification software based on wavelet transform and timing interval as feature extraction and SVM classifier as clinical decision support tool.

1.2 Problem Statement

ECG data obtained from ECG medical devices are normally printed and need to be manually analysed by specialists to detect any heart abnormalities of a patient. For example, the ECG data duration recorded using Holter monitor are normally 24 to 48 hours, hence the human interpretation of the ECG data through visual inspection is a very time consuming procedure during attachment at Institut Jantung Negara (IJN). Therefore, an automated computerized ECG signal analysis and classification software

is desired to reduce the time required by cardiologists or cardiovascular technologists (CVTs) to improve their work effectiveness and efficiency.

ECG biosignal processing, feature extraction and arrhythmia classification are computed intensively and time consuming computations [12,13]. The current commercial arrhythmia classification software take a relatively long time to analyse the patient ECG data, especially 24-hour ECG data retrieved from holter. In addition to that, the arrhythmia classification accuracy of the existing commercial clinical software solution is still a remaining questioning issue. They may not apply the latest state-of-the-art research algorithm to classify the arrhythmia. For example, some of algorithm provide fast computation but low accuracy or high accuracy but great algorithm complexity. Hence, manual visual inspection of the computerized classification result is still required by the CVTs for further verification and confirmation. For example, a CVT at Institut Jantung Negara or the National Heart Institute of Malaysia takes average 15-30 minutes to manually analyse single 24 hour ECG record. This will definitely increase the CVT's workload when there are many ECG data need to be analyse during routine clinical examination. For these reasons, it is important to develop an automated ECG analysis and arrhythmia classififcation software with high accuracy and fast processing performance as clinical decision support tool to help specialists improve their work effectiveness and efficiency.

In order to provide key features for feature extraction, there are many techniques have been carried out such as Heart Rate Variability (HRV) analysis, Wavelet Transform, Hermite Polynomial and many more. Time and frequency domain analysis are the conventional techniques applied in Heart Rate Variability analysis. Due to non-stationationary nature of signal analysis, this technique unable to discriminate some types of arrhythmia clearly and cannot provide time-frequency analysis. In addition, timing interval features are also important to extract arrhythmia features. For example, Premature Ventricular Contraction (PVC) can be identified clearly by using timing interval features. Therefore, wavelet transform and timing interval features are proposed for feature extraction technique.

In terms of arrhythmia classification, there are many methods have been proposed such as Artificial Neuron Network (ANN), fuzzy logic, rule based algorithm and Support Vector Machine (SVM). However, each technique has their own drawback and limitation. For example, ANN generally provides a high accurate classification result but it does not extrapolate the result and has over fitting problem. Ruled based algorithm is a simple algorithm but it provides low accuracy meanwhile fuzzy logic

required prior knowledge for the computation. Therefore, SVM has also been proposed as a solution to overcome these limitations. SVM is used due to its generalisation ability. Thus, computer based monitoring system is needed and proposed to the clinical applications based on support vector machine.

1.3 Objectives

Based on the aforementioned problems, this research derives the objectives as described below:

1. To propose a smart arrhythmia detection algorithm based on combination of ECG pre-processing, wavelet transfrom feature extraction and arrhythmia classification based on support vector machine technique.
2. To develop a MATLAB based arrhythmia classification software based on proposed algorithm in (1) as clinical decision support system.

1.4 Scope

Figure 1.3 shows the overall research scope of the proposed work. The arrhythmia classifier is developed using Matlab modelling tool with user-friendly Graphical User Interface (GUI). The system will take three types of files obtain from MIT-BIH ECG offline database measured by lead II as the input data which are the offline ECG raw data, beat annotation file and arrhythmia symbol labelling file to compute the SVM training and testing process.

The system will perform ECG pre-processing, feature extraction at time-frequency domain using wavelet transform method, as well as some statistical parameters and time-interval information and arrhythmia classification based on SVM. The targeted 11 arrhythmia types are Premature Ventricular Contraction (PVC), Left Bundle Branch Block (LBBB), Right Bundle Branch Block (RBBB), Atrial Premature Beat (APB), Aberrated Atrial Premature Beat (AAPB), Nodal (Junctional) Premature Beat, Fusion of Paced and Normal Beat, Fusion of Ventricular and Normal Beat, Nodal (Junctional) Escape Beat, Ventricular Escape Beat and Paced Beat (PB).

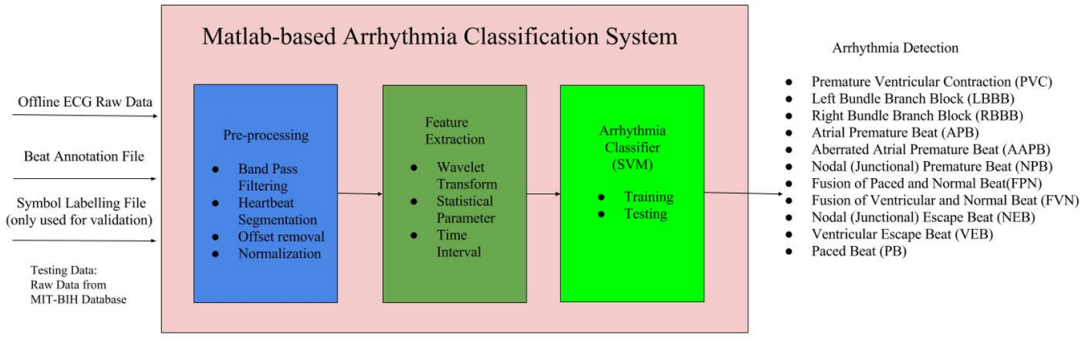

Figure 1.3: Research scope

1.5 Research Contribution

At the end of this research, a high accuracy arrhythmia classification algorithm which able to detect 11 types of arrhythmia with an acceptable processing time is proposed. A Matlab-based arrhythmia classification software tool with user friendly GUI is developed based on the proposed algorithm to execute ECG pre-processing, feature extraction using wavelet transform and other statistical and time interval parameters, as well as classification using SVM technique. The classification software is designed in a novel and easy way to use GUI which can train SVM classifier, to test ECG input data and can investigate each arrhythmia heart beat in details to assist the cardiologists, physician, CVT as a clinical support tool.

1.6 Thesis Organisation

There is a total of five chapters in this thesis. Chapter 1 explains the overview of this research in term of research background, problem statement, research objectives and the scope of the research. Chapter 2 will cover the literature review for ECG foundation, types of arrhythmia, ECG pre-processing techniques, feature extraction and classification as well as their related research work. The research methodology will also be discussed in this chapter. Chapter 3 will focus on the modelling of the proposed arrhythmia classification algorithm and development of clinical decision support tool. Chapter 4 will discuss the result analysis of the research. Finally, the last chapter will conclude the work and provide the recommendation for future work.

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