SCREENING SYSTEM FOR HEART VALVE DISEASE

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Screening System for Heart Valve Disease

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LIST OF ABBREVIATIONS

ADC	Analog to Digital Converter
AGC	Automatic Gain Control
ANN	Artificial Neural Network
AR	Aortic Regurgitation
ARM	Auto Regression Model
AS	Aortic Stenosis
ASD	Atrial Septal Defect
AWGN	Additive White Gaussian Noise
BPM	Beats per Minute
CAD	Coronary Artery Diseases
CODEC	Coder and Decoder
CPM	Cycle per Minute
CPS	Cycle per Second
CT	Computed Tomography
CVDs	Cardiovascular Diseases
CWT	Continuous Wavelet Transform
DA	Discriminant Analysis
DFT	Discrete Fourier Transform
DMA	Direct-Memory-Access
DSP	Digital Signal Processor
DWT	Discrete Wavelet Transform
ECHO	Echocardiograph
EGM	Egeneral Medical
EKG or ECG	Electrocardiogram
ESD	Electro-Static Discharge
FFT	Fast Fourier Transform
FIFO	First In First Out
FPGA	Field-Programmable Gate Array
GPIO	General Purpose Input/Output

GUI	Graphical User Interface
HTF	Hospital Tuanku Fauziah
HVD	Heart Valve Disease
I/O	Input and Output
JRE	Java Runtime Environment
KMD	Kuwait Medical Department
kNN	K-Nearest Neighbour
ksps	Kilo Sample Per Second
LCD	Liquid Crystal Display
Li-ION	Lithium-ION
MFCC	Mel Frequency Cepstrum Coefficient
MLP	Multi-Layer Perceptron
MMC	Multi-Media Card
MoH	Ministry of Health
MR	Mitral Regurgitation
MRI	Magnetic Resonance Imaging
MS	Mitral Stenosis
N	Normal Heart Sounds
OS	Operating System
PC	Personal Computer
PCB	Printed Circuit Board
PCG	Phonocardiograph
PDA	Personal Digital Assistant
PGA	Programmable Gain Amplifier
PR	Pulmonary Regurgitation
PS	Pulmonary Stenosis
PWM	Pulse Width Modulator
RISC	Reduced Instruction Set Computing
SBC	Single Board Computer
SFZ	Short-Time Fourier Analysis
SNR	Signal to Noise Ratio

SPI	Serial Peripheral Interfaces
STFT	Short Time Fourier Transform
S1	First Heart Sound
S2	Second Heart Sound
S3	Third Heart Sound
S4	Fourth Heart Sound
TCE	The Cardiac Exam
TEE	Transesophageal Echocardiogram
THI	Texas Heart Institute
TR	Tricuspid Regurgitation
TRAINLM	Levenberg-Marquardt training
TS	Tricuspid Stenosis
TSC	Thinklab Stethoscope Community
UART	Universal Asynchronous Receiver/Transmitters
UOW	University of Washington
VSD	Ventricular Septal Defect
WHO	World Health Organization
WT	Wavelet Transform

Sistem Saringan Untuk Penyakit Injap Jantung

ABSTRAK

Teknik pertama yang digunakan oleh doktor dan kardiologi untuk mengesan penyakit jantung adalah teknik auskultasi terhadap bunyi jantung. Namun begitu, satu jangka masa yang panjang diperlukan bagi memperolehi kemahiran auskultasi tersebut. Menyedari pentingnya teknik auskultasi, kajian ini dilakukan untuk membina satu sistem saringan yang boleh mengenalpasti bunyi jantung normal dan abnormal serta mengelaskan bunyi jantung abnormal tersebut kepada empat kategori umum penyakit injap jantung. Penyakit-penyakit tersebut adalah *Aortic Regurgitation* (AR), *Aortic Stenosis* (AS), *Mitral Regurgitation* (MR) dan *Mitral Stenosis* (MS). Sistem saringan ini boleh memproses pensegmenan, pengekstrakan ciri dan pengelasan isyarat bunyi jantung secara automatik. Proses pensegmenan yang diperkenalkan dalam sistem ini adalah berasaskan informasi masa dari isyarat bunyi jantung. Ia digunakan dalam penghasilan sampel untuk pengekstrakan ciri-ciri isyarat bunyi jantung. Sampel dari domain masa ini ditukarkan ke dalam domain frekuensi dan spektrum kuasa bagi sampel ini dikira. Spektrum kuasa ini pula akan digunakan untuk mendapatkan ciri-ciri isyarat bunyi jantung dengan menggunakan kaedah kolerasi silang. Kaedah kolerasi silang yang dicadangkan ini adalah sangat teguh di mana tempoh masa sampel, jujukan kitaran sampel dan kekuatan isyarat bunyi jantung tidak memberikan kesan ketara kepada spektrum kuasa itu sendiri. Sampel yang telah diekstrakkan ini kemudiannya akan dikelaskan dengan menggunakan sistem Rangkaian Perseptron Berbilang Lapis biasa dan Rangkaian Perseptron Berbilang Lapis berhierarki. Keputusan kajian menunjukkan pengelasan isyarat bunyi jantung yang menggunakan Rangkaian Perseptron Berbilang Lapis berhierarki memberikan ketepatan pengelasan sebanyak 100%, lebih baik daripada Rangkaian Perseptron Berbilang Lapis biasa iaitu 85.71%. Ini disebabkan kekompleksan dalam pengelasan 5 isyarat bunyi jantung berbeza dapat dikurangkan dengan membahagikan 5 kelas bunyi jantung itu kepada dua bahagian dengan menggunakan Rangkaian Perseptron Berbilang Lapis berhierarki. Sistem lengkap yang terdiri daripada proses pensegmenan, pengekstrakkan ciri serta pengelasan isyarat bunyi jantung dibina di dalam sistem berasaskan komputer dan seterusnya diimplementasikan ke dalam satu sistem terbenam. Sistem terbenam ini terdiri daripada elektronik stetoskop, papan multimedia lengkap (VC21PC1) dan papan komputer tunggal (VCMX212) sebagai terasnya. Keberkesanan sistem berasaskan komputer dan sistem terbenam ini akan dibincangkan di dalam kajian ini. Sebanyak 646 sampel dari 39 subjek telah digunakan di dalam kajian ini. Hasil kajian menunjukkan bahawa kedua-dua sistem ini, masing-masing menghasilkan 96.3%, 92.59% dan 94.44% untuk kekhususan, kepekaan dan ketepatan saringan bunyi jantung normal dan abnormal. Ini menunjukkan kaedah yang dicadangkan adalah baik dan boleh dipercayai. Walaubagaimanapun, untuk klasifikasi yang lebih khusus, sistem berasaskan komputer telah menghasilkan ketepatan sebanyak 94.44% manakala sistem terbenam dengan ketepatan 87.04% sahaja. Hal ini berlaku disebabkan beberapa penghampiran yang digunakan di dalam pengiraan spektrum kuasa dan keluaran bagi pengelas Rangkaian Perseptron Berbilang Lapis. Perbandingan juga turut dibuat dengan sistem-sistem yang sedia ada dan didapati bahawa sistem yang dicadangkan ini

telah menghasilkan ketepatan saringan yang standing (94.44%) untuk pengelasan bunyi jantung normal dan abnormal. Ketepatan untuk pengelasan khusus bagi penyakit injap jantung adalah secara amnya lebih baik (87.04%) berbanding sistem-sistem sedia ada yang lain. Perbandingan secara langsung tidak dapat dilakukan kerana data dan kaedah yang digunakan oleh penyelidik-penyelidik yang lain adalah sama sekali berbeza.

Screening System for Heart Valve Disease

ABSTRACT

The first method applied by physician and cardiologists to detect heart disease is heart sound auscultation. However the skill of auscultation takes many years to acquire. Acknowledging the importance of heart sound auscultation, this research is conducted to develop a screening system that can classify normal and abnormal heart sound as well as categorizing the abnormal heart sound signal into four common categories of heart valve disease. The diseases are Aortic Regurgitation (AR), Aortic Stenosis (AS), Mitral Regurgitation (MR) and Mitral Stenosis (MS). The screening system is able to perform automated process of segmentation, feature extraction and classification of the heart sound signals. The segmentation process that is based on the time properties of the heart sound is introduced in this study to produce samples for feature extraction. The sample is converted to frequency domain and power spectrum of the signal is calculated. Power spectrum of the signal is used to get the heart sound features using cross-correlation method. The proposed method is a robust method where samples duration, cycle sequence and amplitude of the heart sound and murmur are not significantly affecting the power spectrum itself. The extracted frequency features are classified using standard Multi-Layer Perceptron (MLP) network and hierarchical Multi-Layer Perceptron network. Classification accuracy obtained from hierarchical MLP network is 100%, better than standard MLP network with accuracy of 85.71%. This is due to the complexity in classification of 5 types of heart sound signals has been reduced to two parts by using Hierarchical MLP network. A complete system that includes the process of segmentation, feature extraction and segmentation of the heart sound signal is developed in PC based platform and implemented in an embedded system. The embedded system is consists of electronic stethoscope, multimedia board (VC21PC1) and a single board computer (VCMX212) as the core. Efficiency of both PC based and embedded system is investigated in this study. A total of 646 samples from 39 subjects have been used in this study. The results show that both PC based and embedded system has produced 96.3%, 92.59% and 94.44% of screening specificity, sensitivity and accuracy for normal and abnormal classification, respectively. This showed that the proposed method is good and reliable. However, for specific classification on the other 4 type of abnormal heart sound signal, the PC based system has produced 94.44% accuracy while the embedded system only produced 87.04% accuracy. The reason is that a few approximations were applied in calculating the features and output of the MLP network. Comparison is also made with other existing systems and it is found that the proposed system has produced a comparable screening accuracy (94.44%) for normal and abnormal classification and generally better accuracy for heart valve diseases classification (87.04%). Direct comparison cannot be made because the data and method used by the other researchers are totally different.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Heart disease is a general term for a variety of different diseases affecting the heart. Heart disease is a type of cardiovascular diseases (CVDs) which is the number one cause of death globally. A report from World Health Organization (WHO) in 2009 stated that an estimated of 17.5 million people died because of CVDs in 2005. More people die annually from CVDs than any other cause. The organization expected that by 2030, almost 23.6 million people will die from CVDs, mainly from heart disease and stroke. These are projected to remain the single leading cause of death. The largest percentage increase will occur in the Eastern Mediterranean Region. The increase in number of deaths will occur in South-East Asian Region (*World Health Organization [WHO]*, 2009).

National Vital Statistic (2009) reported that heart disease was the first cause of death globally with 26 % of total death. The same scenario happens in Malaysia. Statistics provided by Malaysia Ministry of Health (MOH) claimed that the first principal cause of death in MoH hospital is heart diseases and diseases of pulmonary circulation with 16.09% (*Ministry of Health Malaysia*, 2010). Therefore the study of normal and pathological heart behavior became an active research area. In particular, the study of the shape and motion of the heart is important because they are very much affecting the heart sound signal. Many heart diseases are strongly correlated to these two factors (Park, Montillo, Metaxas & Leon, 2005).

Heart auscultation and diagnosis are quite complicated, depending not only on the heart sound but also on other factors such as the acquisition method and patient condition (Stasis, Loukis, Pavlopoulos & Koutsouris, 2004). In the last two decades, many research activities were conducted concerning automated and semi-automated heart sound diagnosis. The researches were concentrated at three major tasks which are segmentation of the heart sound, feature extraction and classification of heart sound using artificial intelligence system. In this study, a screening system that includes the three major tasks is proposed to screen heart sound signal by using an electronic stethoscope. The screening system was developed on two platforms, personal computer (PC) and embedded system platform. The system consists of segmentation, feature extraction and classification of the heart sound signals. An artificial intelligence system is used in this study to classify normal and abnormal heart sound signals as well as classify the abnormal heart sound signals into four common categories of heart sound from Heart Valve Disease (HVD).

1.2 Problem Statements

The problems that motivate this study are limitation of heart sound auscultation technique, lack of intelligence utilization in phonocardiograph instrument, unavailability of advance diagnostic equipments and necessity of robust and reliable technique in signal processing.

A. Limitation of Heart Sound Auscultation Technique

Heart sound analysis has been an essential clinical skill for every doctor and medical student. As a subjective and qualitative method, heart sound analysis by auscultation depends highly on the skills and experience of the listener. It takes many years of experience before one can master the skill of auscultation. Different auscultator might describe the heart sound differently because the heart sound especially low murmurs are very hard to be heard even with the assists of electronic stethoscope (Voss, Herold, Schroeder, Nasticzky, Mix1i, Ullrich, & Huebner, 2003). Despite the importance of auscultation, trainees are not adequately trained in their training program to master the skill of auscultation (Criley, 2000). This is very important matter to dealt with because poor performance given by physicians and cardiologists to recognize the significant cardiac lesions by physical examination might leads to adverse outcomes to the patient as well as unnecessary costs for inappropriate and even potentially hazardous laboratory test. This is why the research is very important in order to replace the auscultation technique using analytical perspective. It will be very helpful to doctors and physician to screen the heart sound signal effectively.

B. Lack of Intelligence Utilization in Phonocardiograph Instrument

The phonocardiogram is a plot of high fidelity recording of the heart sounds and murmurs using a machine called phonocardiograph. This plot is very important since it is proved to be very useful in understanding the heart sound signal and has high potential to detect heart disease (Rangayyan & Lehner, 1988). However, the old analogue phonocardiograph is not having quantitative analysis capability. Digital phonocardiograph adopted traditional stationary analysis and time-frequency analysis such as Short-time

Fourier Analysis (SFZ), Auto Regression Model (ARM) and Wavelet Transform. These methods were used to analyse first and second heart sound and resulted in some achievements (Zehan, Shiyong, Li, Yuli, & Shouzhong, 1998). Nevertheless, in many of these systems, since artificial intelligence technology was not introduced, the difficulties of identifying some components of abnormal heart sounds cannot be properly overcome and the number of diseases which are classified is quite less (Wenhui, Duanrong, Yun & Zhifen, 1997). Hence, it is very advantageous if one can design an instrument that not only can show the phonocardiogram signal but also with the ability to classify the heart sound signals using an artificial intelligence system.

C. Unavailability of Advance Diagnostic Equipments in Primary Healthcare

Advanced imaging techniques such as Electrocardiogram (EKG or ECG), Echocardiograph (ECHO), Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) can provide more direct accurate evidence of heart disease better than heart auscultation. Conversely, these modalities are normally available at advanced hospitals because they are costly, large in size and operationally complex. Consequently it is not suitable for use in rural areas, in homecare and generally in primary healthcare set-ups (Javed, Venkatachalam, and Ahmad Fadzil, 2006). Therefore in numerous cases the heart sound diagnosis is the possible economical and quick alternative to detect the heart condition under emergency conditions. For example, patients will not have to be transferred to diagnostic room or to another room that is near to the diagnostic room, just to examine their heart condition frequently if a portable device can be brought to them and do the same task.