CARDIAC SEISMOCARDIOGRAPHY ANALYSIS USING 2- ELEMENTS ACCELEROMETER SENSOR ARRAY AND BEAMFORMING TECHNIQUE

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DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

Human heart contains a lot of informations that indicate the condition of its operation and health. The informations can be extracted using image, acoustic, electric and vibration signal. The problem with current technology is that it suffers badly with noise and other unwanted interference. To address this noise issue with the latest technology is echocardiography, a diagnostic tool for diagnosing on cardiac contractility and valvular disease. However, this device is quite costly and labour intensive which requires a specialist who is expert and enough experience in using this equipment. Furthermore, most of medical institutes unable to afford the cost of equipment facility. This study aimed to investigate the application of a non-invasive cardiac diagnostic approach using an accelerometer sensor array, coupled with a directional filtering approach to remove the unwanted noise. This work proposed the utilization of directional filtering method to remove noise using body vibration sensor by employing adaptive beamforming method without altering the signal information. Seismocardiography (SCG) was used to capture body vibration signals recorded via vibration sensor that collects information related to the heart pumping activities and later diagnosed the heart disease. The sensor array was used to collect SCG signal for 28 cycle data from normal and abnormal heart conditions of subjects in supine position. It was found that signal of heart disease information in SCG was overlapped with the noise signal. A directional denoising method which comprised of Delay and Sum (DAS) beamforming and Linearly Constrained Minimum Variance (LCMV) beamforming algorithm were applied, and the performance were compared. The result of signal to noise ratio (SNR) for DAS beamforming algorithm on normal subject was 7.11dB and abnormal subject was 4.13dB. For LCMV beamforming algorithm, normal subject was 10.85dB and abnormal subject is 7.04dB. Based on these results, it showed that the LCMV beamforming performed better than DAS as indicated in the SNR improvement by 30%. This SNR improvement represents the better accuracy of heart disease diagnosis.

ABSTRAK

Jantung manusia mengandungi banyak maklumat yang menunjukkan keadaan operasi dan kesihatannya. Maklumat boleh disari menggunakan gambar, isyarat akustik, elektrik dan getaran. Masalah dengan teknologi semasa adalah bahawa ia menghadapi masalah dengan kebisingan dan gangguan lain yang tidak diingini. Untuk mengatasi masalah kebisingan ini dengan teknologi terkini adalah *echocardiography*, alat diagnostik untuk mendiagnosis pengecutan jantung dan penyakit *valvular*. Walau bagaimanapun, peranti ini cukup mahal dan memerlukan tenaga kerja pakar dan cukup berpengalaman dalam menggunakan peralatan ini. Tambahan pula, kebanyakan institusi perubatan tidak mampu menanggung kos kemudahan peralatan. Kajian ini bertujuan untuk menyelidiki penerapan pendekatan diagnostik jantung non-invasif menggunakan tatasusunan penderia akselerometer, ditambah dengan pendekatan penyaringan arah untuk menghilangkan bunyi yang tidak diingini. Kerja ini mencadangkan penggunaan kaedah penyaringan arah untuk menghilangkan kebisingan menggunakan penderia getaran badan dengan menggunakan kaedah penyesuaian pembentuk-alur tanpa mengubah maklumat isyarat. Seismokardiografi (SCG) digunakan untuk merakam isyarat getaran badan yang direkod melalui penderia getaran yang mengumpulkan maklumat yang berkaitan dengan aktiviti mengepam jantung dan kemudian mendiagnosis penyakit jantung. Tatasusunan penderia digunakan untuk mengumpulkan isyarat SCG untuk 28 data kitaran dari keadaan jantung normal dan tidak normal dalam keadaan subjek terlentang. Didapati bahawa isyarat maklumat penyakit jantung di SCG bertindih dengan isyarat bunyi. Kaedah nyahbunyi terarah yang terdiri daripada algoritma pembentuk-alur lengah dan Jumlah (DAS) dan varian minimum terkekang lelurus (LCMV) digunakan, dan prestasi mereka dibandingkan. Hasil nisbah isyarat kepada gangguan (SNR) untuk algoritma pembentuk-alur DAS pada subjek normal adalah 7.11dB dan subjek yang tidak normal adalah 4.13dB. Bagi algoritma LCMV pembentuk-alur, subjek normal ialah 10.85dB dan subjek yang tidak normal adalah 7.04dB. Berdasarkan hasilnya, menunjukkan bahawa pembentuk-alur LCMV menunjukkan prestasi yang lebih baik ia berbanding DAS seperti yang ditunjukkan dalam peningkatan SNR sebanyak 30%. Peningkatan SNR ini menunjukkan ketepatan diagnosis penyakit jantung yang lebih baik.

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LIST OF ABBREVIATIONS

SCG	-	Seismocardiography
ECG	-	Electrocardiogram
PWM	-	Pulse Width Modulation
DAS	-	Delay-And-Sum algorithm
LCMV	-	Linear Constraint Minimum Variance algorithm
MVDR	-	Minimum Variance Distortionless Response
FFT	-	Fast Fourier Transform
SNR	-	Signal To Noise Ratio
AoA	-	Angle of Arrival

LIST OF SYMBOLS

μ	-	Step size
λ	-	Wavelength of signal
c	-	propagation speed of signal
f	-	frequency of the signal
τ	-	time delay

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Cardiac related disease is one of the leading causes of death and similar to cancer, it is very hard to detect without proper diagnostic tools. Although there are some symptoms prior the outburst, victim of these disease often does not have themselves checked due to various reasons such as cost, and time consumed by the check-up. The current approved clinical diagnostic tools for cardiac disease are acoustic stethoscope, electrocardiogram (ECG) and echocardiography. Acoustic stethoscope is familiar to most people. It is used to transmit sound from chest piece to the listener's ear via a hollow tube while ECG is a kind of cardiac electrical activities which provide important information to diagnose certain disease such as myocardial ischemia, infarction and arrhythmias. However, this method is not very effective in identifying cardiac contractility dysfunction and valvular heart disease. Echocardiography on the other hand able to detect them both with ease. It is based on the ultrasound imaging technology which able to capture the heart activity in real-time. Nevertheless, these convenient tools come together with high operational cost and require a highly trained specialist to operate and this medical device only available in specialist hospital but not all medical institute well equipped with it such as clinic. In order to solve the medical cost and shorten the time consuming for patient in assessing to heart diagnosis procedure, a lot of technology improvement need to be done. From this research, introducing beamforming technique applied in sensor array using accelerometer as a device to detect heartbeat vibration signal which known as seismocardiography signal (SCG). Designing an acceleration sensor array to collect heartbeat vibration data with non-invasive method and applying beamforming technique act as directional filter to target the source signal with direction and nulls other direction of interference signal and noise.

1.2 Problem Statement

Heart attack occur on victim usually without given any early signal or symptoms as warning even done medical check-up, there only provide checking on electric pulse generated by heartbeat with ECG device. ECG data only generated by electric pulse of heartbeat but the mechanism motion induced by each valve when in process of cardiac cycle cannot be detected by ECG device (Richard N. Fogoros, 2019). Furthermore, Cardiac auscultation with using stethoscope also has limitation in hearing ability, experience and sensitivity of equipment. Input signal get from stethoscope is acoustic information subjected to noise like movement of hand, room background noise, equipment noise (power line, emc). These will be the factor of reducing the outcome accuracy of heartbeat diagnose tool and make those output data is unreliable. Echocardiography can solve those limitation of ECG device and stethoscope, but to access for cardiac auscultation processes it need take long queue, quite costly and cannot be accessed by patients immediately. Other than that, not every medical institute are well-facilitated of heart diagnostic tools due to the equipment is expensive and often required doctors with enough experience to operate on those equipment for cardiac auscultation.

1.3 Research Question

- Which beamforming technique can be used with accelerometer efficiently to get the accurate signal to measure heart beating frequency while filtering out other non-relevant micro-vibration?
- Is accelerometer being able to detect heart vibration signal from the surface of the chest?
- Would beamforming technique be able to reduce the noise from the heart signal that is collected by accelerometer sensor?

1.4 Objectives

1. Develop a cardiac auscultation system using 2 accelerometers as sensor array,
2. To implement beamforming technique as directional filter to improve signal quality, signal to noise ratio, SNR.
3. To compare between two algorithm delay-and-sum (DAS) and linear constraint minimum variance (LCMV) as a beamforming technique to improve the signal to noise ratio (SNR)

1.5 Scopes

- Non-invasive method for auscultation on heart signal
- Data collection is performed while subject is in sitting position
- Working in indoor environment where need less distortion and less physical motion disturbance environment.
- Utilize accelerometer as sensor array.
- Multi-channel data processing using beamforming algorithm.

1.6 Significance of Research

- Accelerometer, a cost-efficient device can be utilised in heart rate diagnosis tools without sacrificing its performance and accuracy. The output data of accelerometer is collected from vibration of heartbeat which is a mechanism vibration signal.
- Mechanism vibration signal is a signal generated by physical motion but not same as acoustic signal type easy to get interrupted by environment if any sound induced.
- A non-invasive plug and play system as a heartbeat diagnosis tool can be accessed immediately from all medical institute.

- To make sure every medical institute capable of providing the heart auscultation service to patient without impose a high cost of medical fees and reduce time consuming for heart auscultation process.

1.7 Summary

This research is focusing on the accelerometer device and beamforming technique that can be used to enhance the collection of heartbeat signal. A studying on accelerometer capability and do comparison among different model of device to find out which one is more suitable on detecting heartbeat signal through non-invasive method. After that, build a accelerometer sensor array and apply beamforming technique as directional filter to process the heartbeat signal. With the following of scopes mentioned, would need to study on different of beamforming algorithms and then compare which would be get high performance on processing the heartbeat signal with less interference and noise.

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