HEART RATE VARIABILITY ANALYSIS SYSTEM IN MOBILE PHONE

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Tarikh : 15 JUNE 2012

For my beloved father, mother and families

Nik Yahya bin Raja Kadir

Che Zainab binti Mat Ali

Nik Mohd Asyraf

Nik Mohd Arif

Nik Nurul Adila

Nik Nurul Adlin

Nik Mohd Azreen

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ABSTRACT

Heart Rate Variability (HRV) is a great tool in assessment of the autonomic function. It is accurate, reliable, reproductive, yet simple to measure and to process. Nowadays there need many equipment to help human work become easier and one of the way to save many human live. In many cases, equipment such as electrocardiograph (ECG) cannot be supplied to clinic or hospital in rural area because of high cost budget to buy it. It is a large equipment and expensive too. As for the public, this device needs to be portable so it can be bring anywhere and anytime. Overall, the purpose of this project is to develop a system that can generate Heart Rate Variability analysis in mobile phone. Signal processing applied to process data from ECG. This project also target to provide a convenient HRV analysis using mobile environment and display heart beat condition base on HRV analysis. Totally, this system developed according to Waterfall software development model, which have five stages of development. This system successfully developed on android mobile platform. This system can analyze HRV analysis using ECG data and shows current heartbeat. HRV analysis system will be an important system in the future.

ABSTRAK

Perubahan Kadar Jantung (HRV) ialah satu alat yang berkesan dalam menilai fungsi autonomi badan. Ia sangat tepat, boleh dipercayai, produktif serta senang dikira dan diproses. Pada masa kini, banyak peralatan digunakan untuk membantu memudahkan kerja manusia dan salah satu cara untuk menyelamatkan nyawa manusia. Dalam kebanyakan kes, peralatan seperti electrokardiograf (ECG) tidak boleh dibekalkan ke klinik dan hospital dikawasan terpencil kerana harga yang tinggi untuk membelinya. Ia merupakan alat yang besar dan mahal. Bagi masyarakat biasa, peralatan ini diperlukan dalam bentuk mudah alih supaya ia dapat dibawa ke mana-mana dan bila-bila masa. Secara keseluruhan, tujuan projek ini adalah untuk membangunkan sistem yang dapat membuat analisis HRV dalam telefon mudah alih. Pemprosessan isyarat digunakan untuk memproses data daripada ECG. Projek ini juga bertujuan untuk menyediakan satu analisis HRV yang mudah digunakan dengan menggunakan suasana mudah alih dan menunjukkan keadaan denyutan jantung berdasarkan analisis HRV. Secara keseluruhan, sistem ini telah dibina berdasarkan model pembinaan aplikasi air terjun yang mempunyai lima peringkat pembinaan. Sistem ini telah berjaya dibina pada telefon mudah alih Android. Sistem ini dapat menganalisis analisis HRV menggunakan data ECG dan menunjukkan denyutan jantung semasa. Sistem analisis HRV ini akan menjadi system yang penting pada masa hadapan.

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LIST OF ABBREVIATIONS

ADC	-	Analog to Digital Converter
ADT	-	Android Development Tool
AVD	-	Android Virtual Device
BPM	-	Beat per minute
DAC	-	Digital to Analog Converter
DSP	-	Digital Signal Processing
ECG	-	Electrocardiograph
EKG	-	Elektrokardiograf
GUI	-	Graphical User Interface
HDTV	-	High-Definition Television
HF	-	High Frequency band
HRV	-	Heart Rate Variability
LF	-	Low Frequency band
NN50	-	The Number of Interval Differences of Successive RR Intervals Greater Than 50ms
PNN50	-	The Proportion Derived by Dividing NN50 by the Total Number of RR Intervals
PPG	-	Photoplethysmograph
PSD	-	Power Spectra Density
RMSSD	-	The Root Mean Square of Standard Deviation RR Intervals
RR	-	Beat to beat interval
SDANN	-	The Standard Deviation of the Average RR Interval
SDNN	-	Standard Deviation of the RR Intervals
SMS	-	Short text system
TINN	-	The triangular interpolation of RR intervals histogram
VLF	-	Very Low Frequency band

VLSI - Very Large Scale Integrated

CHAPTER I

INTRODUCTION

Nowadays, there are many diseases attack human all around the worlds including young man and old man. All of them have tendency to get disease. One example of disease is heart attack, disease that involves human heart. Usually a tool used to analyze or detect this disease in the early level of disease or on critical level of disease. The tool is knows as Heart Rate Variability (HRV) analysis. Source of HRV analysis comes from beat-to-beat variation of heart.

1.1 Overview

Heart Rate Variability (HRV) is a great tool in assessment of the autonomic function. It is accurate, reliable, reproductive, yet simple to measure and to process. HRV represents an instantaneous heart rate signal including the beat-to-beat fluctuation in heart rate. Method used to detect beats include electrocardiograph, blood pressure and the pulse wave signal derive from a photoplethysmograph (PPG). The ECG is considered as the best way to measure beat-to-beat interval (RR data). ECG is a transthoracic interpretation of the electrical activity of the heart over a period of time, as detected by electrodes attached to the outer surface of the skin and recorded by a device external to the body.

HRV analysis system in the mobile phone environment enables continuous HRV monitoring at anytime and anywhere. With the increasing development of mobile phone makes HRV analysis system are available to everyone with easy step of installment and low cost. HRV analysis system important to any period of ages since it is friendly user system. ECG data which is RR data will be used as the input. The system analyses the RR data and generate HRV analysis. Using digital signal processing with HRV analysis to process heart beat sound, the outcome can determine human condition.

HRV analysis can be used to determine heart condition and for the expert, it can be used to determine some kind of disease. HRV analysis system in the mobile phone will help expertise and also other people to determine heart condition more convenient compared to fixed HRV analysis system.

1.2 Objectives

The objectives of this project are:

1. To develop HRV analysis system using ECG data.
2. To provide a convenient HRV analysis using mobile environment.
3. To display heart beat condition base on HRV analysis.

1.3 Problem Statement

Nowadays there need many equipment to help human work become easier and one of the way to save many human live. The equipment such as ECG can be found in lab or hospital. Because of the increasing number of patient regarding to heart diseases or heart problem, equipment to treat the disease becomes more important. In many cases, equipment such as ECG cannot be supplied to clinic or hospital in rural area because of high cost budget to buy it. It is a large equipment and expensive too. Government need to spend a lot of money to supply the medical tool to the whole country.

Since not all medical centers are able to provide this facility for the public, there should have other options for people to get and use this facility especially when there is an emergency. In the case of emergency, public people needed the tool to become portable and easy to bring everywhere. That mean the tool needs to be small in size compared to the equipment at hospital. It is also needed to be low cost equipment, yet the accuracy is same or better as equipment in the hospital.

Patients with chronic heart diseases have to frequent and continuous monitor their heart condition. Monitoring heart condition using ECG at the hospital is not convenient which limit their daily activities. As they are busy with work, they do not need to go to hospital frequently instead just use mobile HRV analysis system. Using this portable device, they can avoid long queue at hospital if their condition are normal. Otherwise, they only need to go to see doctor when their condition is worse or abnormal.

Most ECG available at the hospital is bulky and heavy. They are not designed to be easily carried to anywhere. They are suitable to monitor patients' heart condition, which is located at one permanent location. On the other hand, a mobile HRV analysis use not only for patients but also for healthy person. For example, the sportsmen to monitor their heart condition during training, as it is important for them to maintain a healthy body state can use it.

1.4 Scope of Project

Below are the scopes of the project:

1. The HRV analysis system developed on android platform.
2. The HRV analysis was analyze using ECG data sample only.
3. The HRV analysis was generate in time domain.

1.5 Methodology

This project begins with the research of the proposed title. The result of that research is then discussed with the supervisor. Once the title of project was approved, the background of study for this project was explored as stated in the literature review.

Waterfall model used for the system development. In the requirements phase, the description for the complete system must be developed. For the design phase, a plan will be developed to create perfect system and in implementations phase, real system will be developed and all part of the system will be linked into one perfect system. After that, the verification phase - the system will be tested to determine the performance and to find bugs. Lastly in the maintenance phase, the modification will be made to correct bugs and to improve performance.

CHAPTER II

LITERATURE REVIEW

This chapter contains the literature review on theoretical concepts applied in this project. It contains the information gathering of the project in order to complete the whole project.

2.1 Human Heart

The heart is a muscular organ responsible for pumping blood through the blood vessels by repeated, rhythmic contractions, or a similar structure in the annelids, mollusks, and arthropods [l]. The term cardiac (as in cardiology) means "related to the heart" and comes from the Greek, *kardia*, for "heart." The heart is composed of cardiac muscle, an involuntary muscle tissue which is found only with in this organ [2]. Human heart consists of four chambers. The chambers are atria, which is the two upper chamber and ventricles which two lower chambers. In the heart itself, there are valves located between the atria and ventricles and also there are have major arteries from the heart. A wall of muscle called the septum separates the left and right atria and the left and right ventricles. Figure 2.1 below shows the human heart's anatomy.

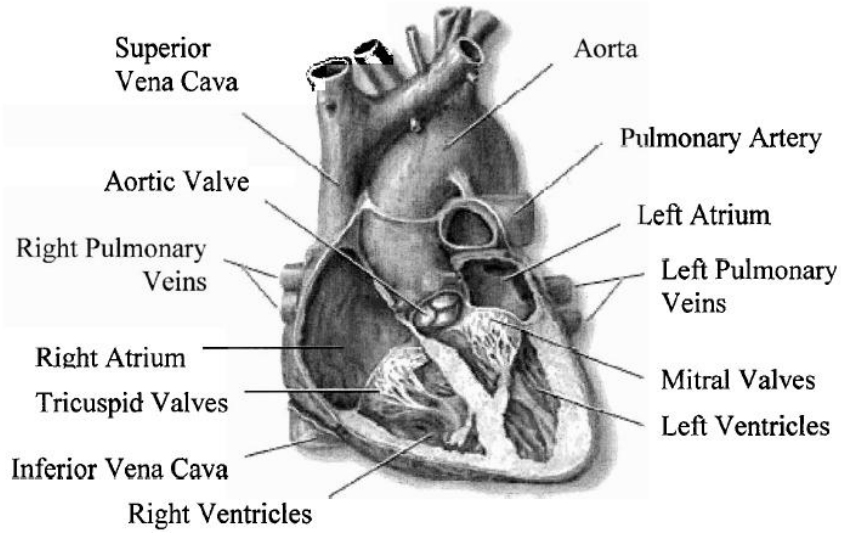

Figure 2.1: Human Heart Anatomy [3]

The average human heart beating at 72 beat per minute (BPM) will beat more than 3.5 billion times by the end of a long life. The heart weighs between 7 and 15 ounces (200 to 425 grams) and is a little larger than the size of our fist [4]. Each day, the average heart beats 100,000 times, pumping about 2,000 gallons (7,571 liters) of blood. Human's heart location is between the lungs (in the middle of the chest), behind and slightly to the left of the breastbone (sternum). Pericardium, a double layered membrane surrounds the heart like a sack. The pericardium outer layer surrounds the roots of the heart's major blood vessels and it is attached by ligaments to the spinal column, diaphragm, and other parts of our body. The inner layer of the pericardium is attached to the heart muscle. A coating of fluid separates the two layers of membrane, letting the heart move as it beats, yet still be attached to the body [4]. There are four types of valves in human's heart, regulating blood flow through the heart. The first valve is the tricuspid valve, which regulates blood flow between the right atrium and right ventricle. Secondly, the pulmonary valve controls blood flow from the right ventricle into the pulmonary arteries, which carry blood to the lungs to pick up oxygen. The mitral valve lets oxygen-rich blood from the lungs pass from the left atrium into the left ventricle. Lastly, the aortic valve opens the way for oxygen-rich blood to pass from the left ventricle into the aorta, the body's largest artery, where it is delivered to the rest of the body. The four cardiac valves are

classified into two types - the atrioventricular (mitral and tricuspid) and the semi lunar (aortic and pulmonic) valves.

2.2 Digital Signal Processing (DSP)

Traditional signal processing was achieved by using analog components such as resistors, capacitor and inductors. However, the inherent tolerance associated with these components, temperature and voltage changes, and mechanical vibrations, can dramatically affect the effectiveness of analogue circuitry. The revolution is coming with something new technology. The digital signal processing is inherently stable, reliable and repeatable. Processing of signal can be done either in analog or digital domain.

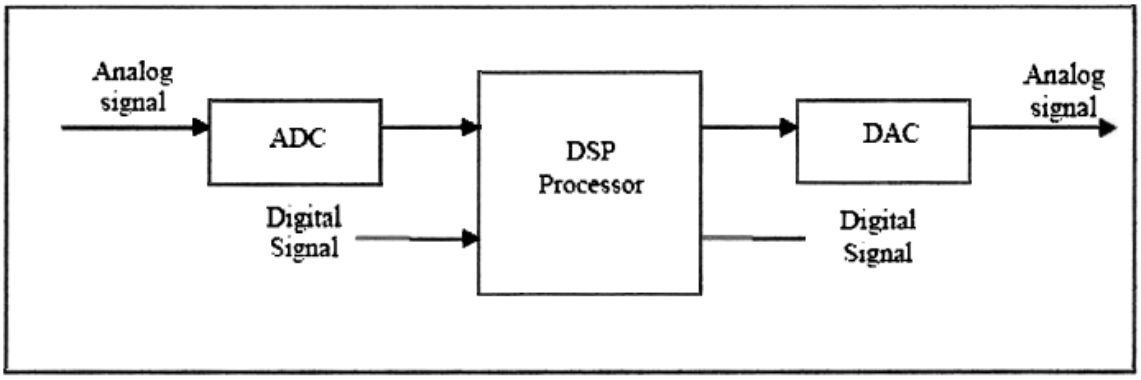

Figure 2.2: Block diagram of Digital Signal Processing

Generally, speech generate analog signal in response to various physical phenomena that occur in an analog manner. Processing of signal can be done either in analog or digital domain. To do the processing of an analog signal in digital domain, it is required that a digital signal is discrete in both time and amplitude. The digitization process is achieved via an analog to digital (ADC) converter. DSP systems use a DSP processor or other digital hardware and a digital-to-analog (DAC) converter to replace analog devices such as amplifiers, modulators and filters. The figure 2.2 illustrates the main component of a DSP system.

A DSP processor performs digital operations based on a specific signal processing algorithm implemented in software to process the digital signals. The output digital signal may be converted back to analog form using the DAC. There are many reasons why one would want to process an analog signal in a digital fashion by converting it into a digital signal. The main reason is that digital processing allows programmability. Another reasons is that digital circuit provide a more stable and tolerant output than analog circuit. The DSP processor processes the digital-input signals, and the output digital signals can be transmitted to or processed by other digital systems without using converters. Programmable DSP processors are especially suitable for designs that require multiple modes of operation and future upgradeability.

The processing of a digital signal can be implemented on various platforms such as DSP processor, a customized very large scale integrated (VLSI) circuit or a general purpose microprocessor .Some of the difference between DSP and a single function VLSI implementation are as follows; I) there is a fair amount of application flexibility associated with DSP implementation, since the same DSP hardware can be utilized for different applications. In other words, DSP processors are programmable. This is not the case for hardwired digital circuit. II) DSP processors are cost effective because they are mass produced and can be used for many applications. A customized VLSI chip normally gets built for a single application and a specific customer. III) In many situations, new features constitute a software upgrade on a DSP processor not require new hardware. In addition, bug fixes are generally easier to make. IV) Often very high sampling rates can be achieved by a customized chip, where as there are sampling rate limitations associated with DSP chips due their peripheral constraints and architecture design.

Digital signal processors are used for a wide range of applications, from communications and controls to speech and image processing. The general-purpose digital signal processor is dominated by applications in communications (cellular). Applications embedded digital signal processors are dominated by consumer products. They are found in cellular phones, faxmodems, disk drives, radio, printers, hearing aids, MP3 players, high-definition television (HDTV), digital cameras, and so on. These processors have become the products of choice for a number of

consumer applications, since they have become very cost-effective. They can handle different tasks, since they can be reprogrammed readily for a different application. DSP techniques have been successful because of the development of low-cost software and hardware support. As a result, digital processing, and hence digital signal processor, is expected to play a major role in the next generation of telecommunication infrastructure including 3G (third generation) wireless, cable modems, and telephones lines (digital subscriber line -DSL modem).

2.3 Electrocardiogram (ECG)

Figure 2.3: ECG device

Heart rate fluctuations can be measured from the electrocardiogram (ECG), a graphical recording of the electrical potentials that is generated by cardiac muscle cells (Figure 2.3). Generally, this signal is recorded by the certain number of electrodes attached to human body [3]. The heart's internal control mechanism consists of specialized fibres including the sinoatrial (S-A) node (located on the rear wall of the right atrium), the atrioventricular (A-V) node, the A-V bundle, and the left and right bundles of conducting fibers (Purkinje) [5]. The S-A node cells create the electricity that makes the heartbeat. In a typical record, three clearly recognizable waves appear with each heartbeat (Figure 2.4).