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NON-CONTACT ELECTROCARDIOGRAM (ECG) SMART CHAIR FOR ST SEGMENT ELEVATION MYOCARDIAL INFARCTION DETECTION

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ABSTRACT

Myocardial infarction (MI) is a medical term for heart attack. MI are classified into ST-segment elevation MI (STEMI) or non ST-segment elevation MI (NSTEMI). The ST-segment elevation MI (STEMI) can be detected by analyzing the electrocardiography (ECG) result. However, an ECG device is only available in hospitals due to its cost and requires an expert to operate the device. A personal ECG device at home is therefore difficult to be acquired. For most STEMI cases, heart problems requires early detection and medication. Unfortunately, frequent visits to the hospital may not be possible for most people. A new way to have personalized ECG reading without the presence of an expert is therefore desirable. One method is to use a non-contact ECG signal detection technique that could help assess cases of heart problems or an initial apoplectic condition. A non-contact ECG chair framework for STEMI is proposed to empower patients in getting personalized assessment to their heart condition at any time. Patients can easily use the ECG device at the comfort of their home or in the office by just sitting on their chair. The ECG signal will automatically be captured and analyzed to intelligently diagnose the heart condition. The implementation of this concept will help the Malaysian community with early intervention by medical experts and significantly reduce the mortality rate.

Keywords: *Capacitive Sensor, Non-Contact Electrocardiogram, ST Segment Elevation, Myocardial Infarction*

1. INTRODUCTION

'Myocardial infarction' (MI) is defined as heart muscle tissue death due to lack of oxygen [1]. MI is also commonly referred to as a "Heart Attack" [2]. A common way to measure heart's activity is by using an ECG. An ECG is a device to record heart's electrical activity. This electrical activity is created by depolarization and repolarization of the atria and ventricles [3]. There are two kinds of myocardial infarctions: ST-segment elevation myocardial infarction (STEMI) and non-ST segment elevation myocardial infarction (NSTEMI). An ST-segment elevation myocardial infarction (STEMI) is a serious form of heart attack in which the coronary artery is completely blocked and a large part of the heart muscle is unable to receive blood [4]. As its name suggest, the presence of STEMI can be seen as the ST-segment part of the ECG signal is rising as shown in figure 2 as compared to figure 1 for a non-elevated ST-segment. A non-ST segment elevation MI (NSTEMI) is a less serious type of heart attack that does not show a change in the ST segment elevation on an electrocardiogram [5].

One of the major roles of taking ECG measurements is to detect abnormalities in the heart. They can be interpreted and used as an aid to diagnose various heart problems like coronary heart disease, heart arrhythmias, heart inflammation (pericarditis or myocarditis) and heart enlargement. An International study by Deckelbaum [6] stated that in developed countries, a heart attack is a major killer disease. Each year, there are about 1.5 million heart attacks in the United States, leading to more than 500,000 deaths; among them more than 300,000 fail to reach the hospital. Malaysia is also seeing an increasing number of cardiovascular diseases. It is the topmost killer disease in Malaysia. In 2011, 43,000 people died due to heart disease; of which 16% of it occurred in the government hospitals [7]. Possibly most victims didn't know that they were having heart attacks.

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A heart attacks can occur at anytime and anywhere. Statistics shows that, about 60% of all heart attack deaths occur within the first hour of initiation. So, an early intervention is a key factor to saving lives. Yet, it is not easy to detect a heart attack. In a study by Leijdekkers and Gay [8], more than two thirds of people in Australia would not call an ambulance if they thought they were having a heart attack. In the US, at least half of the people suffering a heart attack delay seeking help for two or more hours; because it has deceiving symptoms. Patients might think that chest pain comes from heartburn or some other harmless ailment [9]. It is therefore important to be able to identify potential heart attack threats.

When symptoms of heart attack occur, an ECG test is crucial to verify for a heart attack. Doctors rely on ECG readings to detect any abnormalities. Since early symptom detection and fast action is the key to avoid further damage to the heart, patients can rely on self-management in the early and progressive stages of a heart disease to control it [10]. Self-management refers to the ability to manage the symptoms of a disease, and control its medical treatment and its physical and psychological consequences in order to pursue lifestyle changes necessary for living with a chronic condition [11]. For this reason, essential steps to empower the public on health issues by any means, remains a priority in public health care. Providing a non-contact ECG signal detection model will surely provide a self-management approach to patients and the means for detecting heart attack in its early stages of heart disease.

The rest of this paper is organized as follows: section related work discussed the background of this paper, followed by a section of our research methodology and proposed model, and finally ends with our conclusion of this paper.

2. RELATED WORK

The ST segment is an important part of an ECG signal. It represents the interval between depolarization and re-polarization of the ventricles. It can be evaluated by using as baseline reference on both the PQ and the TP segments [12].

An illustration of a normal ECG signal is shown in figure 1 indicating the P wave, PR segment, QRS complex, ST segment, T wave and U wave of the ECG signal. In a patient with STEMI ECG signal, ST Segment is well above the isoelectric line as shown in figure 2. This is a sign of damaged heart muscle in various scales.

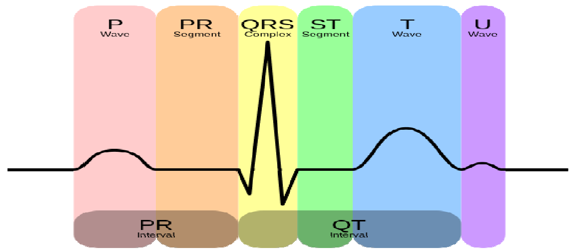

Fig.1. ST segment in green [13]

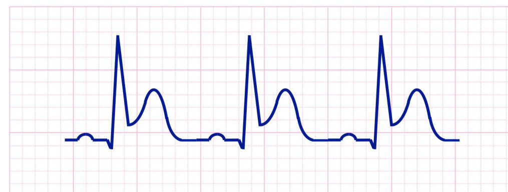

Fig.2. ST segment elevation in ECG

As previously stated in the introduction section, heart-related diseases are the greatest causes of death in Malaysia. They can be managed and detected early. There is a 48-75% chance of survival if heart attack treatment is given between the first minutes it strikes and between the first 12 minutes of an attack, a duration after which survival rate is reduced to 2-4% [14]. Although ST segment elevation always provide a sign of heart attack [15], it is imperative for the individuals to be aware of its own symptoms all the time. Unfortunately, the present technique to verify these symptoms are only employed in hospitals [16]. A game changer in health care management is to have ECG technology available in ordinary homes. Therefore, some attempts of developing a non-contact ECG signal detection techniques have been developed [17] to realize ECG availability in each home. A non-contact ECG signal detector does not need to be applied by an expert since complex setup is unnecessarily.

There are a number of studies considering an ECG reader that are mounted to a chair. These chair-based ECG monitoring devices takes advantage of a common human habitual rituals which is seating since it is one of the most common activities in today's working society. These chair-based systems use capacitive electrode technology which enables non-contact measurements. Unlike traditional ECG devices which requires a sticky electrode to be attached to a patients skin, the non-contact sensors reduces the need to keep on changing electrodes and therefore reduce disposable costs. It also speeds up and simplifies the recording process. In 2011, Ford motor factory collaborated with Aachen University in Germany to develop contactless ECG sensors for automobile

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car seats. The car seats contains six pieces of sensors attached to the back of the driver's seat as shown in figure 3. These sensors generate a similar ECG wavelet signal with single lead ECG. It is reported that the Ford sensor can capture QRS complex from 2.5 mm distance [18] [19].

Figure 3. Ford ECG sensing car seat

Similarly, Professor Makikawa Masaaki's team in Japan has developed their own prototype of ECG chair for topographical ECG measurement as shown in figure 4. The ECG reading is achieved by measuring capacitance of metal plates placed near the human body. Makikawa claimed that ECG readings are measurable when the air gap between the electrodes and the skin is below 1 mm. Additionally, Makikawa noted that when other dielectric material such as paper, cloth or etc. exist between the electrodes and the skin, the device is able to measure ECG readings as far as 50 cm. The drawback with other dielectrics is its difficulty in distinguishing P wave [20].

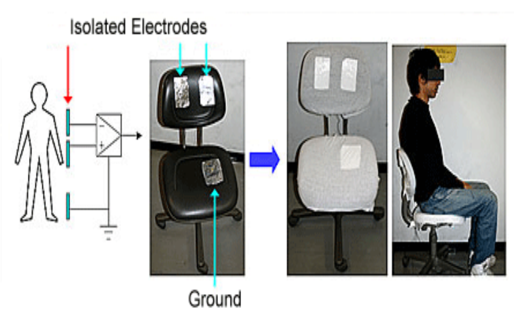

Figure 4. Japanese ECG chair

Hyun Jae Baek *et al.* [21] developed a multi-purpose healthcare chair which includes ECG signal recording alongside with photoplethysmogram (PPG), and ballistocardiogram (BCG) measurements. Figure 5, illustrated the prototype chair developed by Hyun et al. Their experiment showed that air gaps between the capacitive electrode surface and the subject's back produces a low signal to noise ratio (SNR). This result in making a reliable ECG measurements almost impossible.

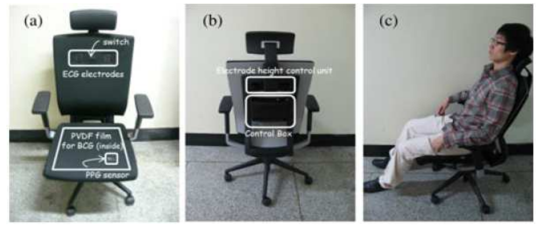

Figure 5. Multi-Purpose Healthcare Chair

Subsequently, Plessey semi-conductors, produces a series of low-powered, low-impedance ECG sensors suitable to be applied for various contact and non-contact ECG devices [22]. These sensors as shown in figure 6, can also be applied to the back rest of a chair, in the mattresses or in human garments as a contact full and contactless manner.

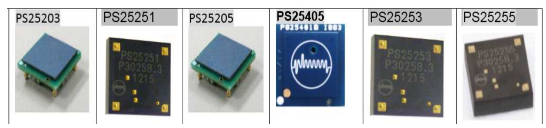

Figure 6. ECG sensor [23]

Research in this area is ongoing. All above ECG chairs have capability to sense through thin cloths; however they cannot pass millimeter boundary. In this paper we propose a cheap contactless ECG sensor which can sense from 10 cm air gap. In view of this fact, the framework in the present paper addresses seamless, non-invasive, non-intrusive method of recording ECG signal.

3. METHODOLOGY

This research adopt exploratory evaluation approach as shown in figure 7. Existing system were explored, their weakness are identified and new system proposed. Therefore, we dwells on proof of concept of the system we're proposing. As a result the following procedure were followed:

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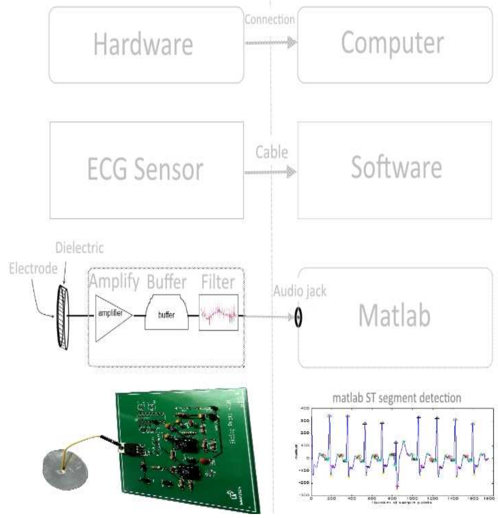

Figure 7. Exploratory Evaluation Approach

The Non-contact ECG sensor consists of 4 principal components: antenna, amplifier, buffer, and filters. Figure 8 illustrates the block diagram of each principal component.

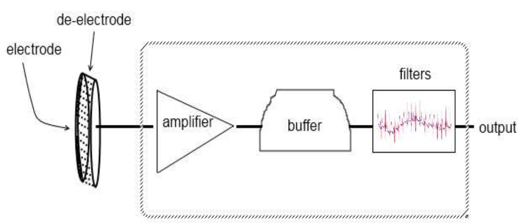

Figure 8. Non-Contact ECG's Principal Components

Each component is important in producing a measurable ECG signal to be use for analysis. Our propose concept ECG reader relies on the following steps:

Step 1 (The Antenna). The ECG device captures a weak signal through the sensors from an individual seating with his or her back facing the back rest of the chair. The sensors are an array of capacitive electrodes used to capture any weak bio-potential signals. The capacitive electrodes does not require direct contact with the body but rely on measuring the displacement current that is proportional to the rate of change of the electric field associated with the ECG signals. This is achieved by coupling the input of the sensor's amplifier to the signal through a capacitance formed by the sensor's metal electrode and the body's surface. A 5 cm diameter aluminum plate is used for this purpose.

Step 2 (Amplification): The amplification stage comprises of a trans-impedance amplifier whose output is buffered by a simple voltage follower. The circuit forming the amplifier is based on two TL082 op-amps and other readily available components. TL082 is a low-power, high input impedance (10^{12} Ω) op-amp with extremely low input noise characteristics (0.01 pA/√Hz, 16 nV/√Hz). The trans-impedance amplifiers (TIAs) is also referred to as a current-to-voltage converters, are op-amp circuits that are well suited for applications where the current produced by the source is of importance. This amplification circuit is shown below in figure 9.

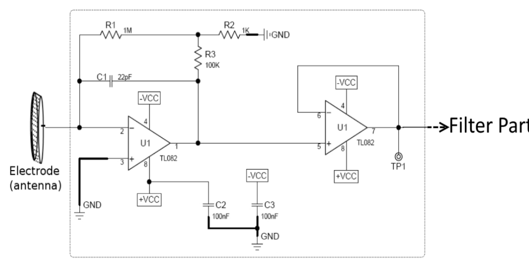

Figure 9. Amplifier Circuit Schematic

Step 3 (Filtering). In order to get a clean ECG signal, all other known noise signals are filtered out. A 50 Hz power line interference, baseline wandering, and movement artifacts are most common noises. Figure 10 shows the circuit diagram used to implement our prototype, while figure 11(a) shows the circuit being implemented on a PCB board. Another option to filtering out noise can be done via software signal analysis through the use of filtering packages available via Matlab and other software analytical tools. [24]:

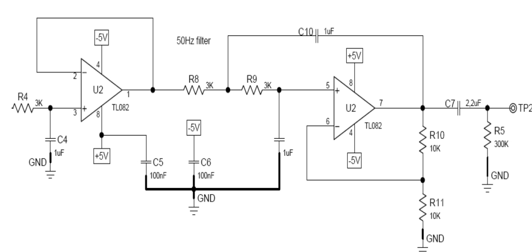

Figure 10. Filters Circuit Schematic

Step 4 (Capturing Output). The sensor is connected to a computer, as shown figure 11(b) where the ECG signal is saved and analyzed for the identification of character points.

Step 5 (Detection Algorithm): ST segment elevation algorithm is used to check if respective parts of the ECG signal is raised to indicate STEMI.

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The prototype of this device is installed in a tube and mounted at the back of chair. Each tube contains the device as shown in figure 11(a).

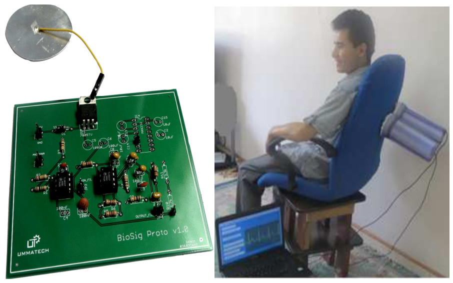

Figure 11. (A) A Non-Contact ECG Sensor (B) ECG Non-Contact Sensors Embedded On A Chair

Two sensors are used to calculate the differential bio-potential of the heart to produce an ECG signal. The operation of signal differentiation and acquisition can be better illustrated in figure 12. The measurable distance A is used to study the performance of our non-contact sensor similar to the study by Mahdi et al. [25].

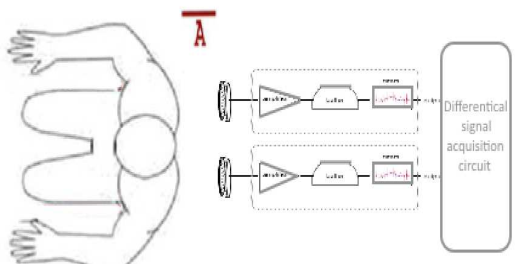

Figure 12. Signal Differentiation

During the process of acquisition, the signal will be filtered to cut out noise further. The signal is then captured and sent to the computer via a shielded cable. A Matlab based program loads the signal and extracts the character points to be analyzed. A specific learning algorithm is used to classify ST segments within the ECG signal. An ST segment that is higher than the isoelectric line will then indicate that the patient has elevated ST segment (STEMI). Therefore, this device embedded in a chair can be use easily to give early warning signs of a heart attack anywhere it is installed such as on a chair at home, office or in the car seat.

4. CONCLUSION

A framework of a non-contact ECG sensor (or ECG smart chair) is presented in this paper. The chair can record heart activates right at patients home in contactless manner. The main objective is to detect fatal heart disease particularly ST segment elevation myocardial infarction (STEMI). Based on this proposed framework, it is possible to monitor an individual's heart condition at home or elsewhere. This implementation can be fabricated and mass produced. Making it potentially available and affordable even in third world countries. The application of this device is not limited to detecting STEMI (heart attacks) only. Using the same techniques with modifications to the detection algorithm, it is also possible to detect over 10 kinds of specific heart diseases. Other related research work can also be applied such as biometric identification.

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