Abnormal Heart Rate Detection Using Signal Processing

Grace O. Diri[1], Ledisi G. Kabari[2]
[1]Department of Computer Science, Ignatius Ajuru University of Education, Rivers State, Nigeria
[2]Department of Computer Science, Ken Saro-wiwa Polytechnic, Rivers State, Nigeria

***Abstract*—Heart attack is the deadliest cardiovascular disease amongst others and is one of the major causes of death recently, both in developed or developing countries of the world. Most of the cardiac disorders arises as a result of irregular rhythm of the heart. As a matter of fact, irregular heartbeats often lead to abnormal PQRST values which can be traced from patient's Electrocardiogram (ECG). The need to predict or detect this has been a major necessity for the improvement of human lives across the globe. This paper presents heart attack detection using ECG signal processing. The methodology adopted for this work is the Dynamic Software Development Methodology. The system was designed using Python programming language and it acquires ECG signal in the form of datasets, processes it and extracts important parameters like PQRST to detect heart abnormalities.**

***Keywords*—ECG (Electrocardiogram), Heart Attack, Cardiovascular Diseases, Signal Processing.**

I. INTRODUCTION

The heart is one of the important muscular organs which supplies the oxygenated blood to all parts of the body. A heart attack occurs when the flow of blood to the heart is blocked. The blockage is most often a build-up of fat, cholesterol and other substances, which form a plaque in the arteries(coronary arteries)that feed the heart. The plaque eventually breaks away and forms a clot. The interrupted blood flow can damage or destroy part of the heart muscle. A heart attack, also called a myocardial infarction, can be fatal, but treatment has improved dramatically over the years. During a heart attack, heart muscle is deprived of oxygen and will literally die if the artery remains blocked. A heart attack is distinct from cardiac arrest, which is a sudden loss of heart function that usually occurs as a result of electrical disturbances of the heart rhythm. A heart attack can lead to cardiac arrest, but the latter can also be caused by other problems [1].

Through the twentieth century, several medical devices have been developed which have helped to save lives. One example of a life-changing innovation is the Electrocardiogram (ECG), which allows physicians to monitor the heart via its electrical activity [2]. Electrocardiogram (ECG) is a graphical recording which indicates electrical activity of the heart. In other words, it represents electrical activity of human heart. ECG provides valuable information about wide range of Cardiac disorder such as presence of inactive parts or an enlargement of heart muscle. ECG is the process of recording the electrical activity of the heart over a period of time using electrodes placed on the skin. The overall goal of performing electrocardiography is to obtain information about the structure and function of the heart.

Heart disease is a major life-threatening disease that leads to death or may have a serious long-term disability. The electrocardiogram (ECG) is the most important bio signal used by cardiologists for diagnostic purposes. Accurate and precise prediction of the heart disease mainly depends on Electrocardiogram (ECG) data. As matter of fact, electrocardiogram is the most widely adopted clinical tool for diagnosing and assessing the risk of cardiovascular diseases. Approximately seventy percent of heart attacks are detectable in the ECG; the remaining thirty percent are not recognizable due to various reasons such as small infarctions, multiple infarctions, etc [3].

Early diagnosis of acute heart attacks, within one hour of the onset of symptoms according to [4], is necessary for successful treatment, including percutaneous coronary intervention (PCI) and for the timely administration of thrombolytic therapy.

Electrocardiogram (ECG) is composite from 5 waves – P, Q, R, S and T. The heart signals are taken from ECG, which is known as Electrocardiography. The heart signals are picked by using electrodes in arms, leg, chest of our body. By using this signal, heart disorder can be found out. Also, depending on the shape of the ECG waveform, we can find out the cardiac health. ECG signal readings and their analysis are carried out from signal processing. The ECG signal provides key information about the electrical activity of the heart. The heart signals are taken from ECG, which is known as Electrocardiography. Time taken to recover from a particular heart disease depends on patient's severity.

II. RELATED WORKS

The heart is the muscle that pumps blood filled with oxygen and nutrients through the blood vessels to the body tissues. It contains four chambers: the upper two chambers (left and right atria) are entry-points into the heart, while the lower two chambers (left and right ventricles) are contraction chambers sending blood through the circulation. The cardiac

cycle refers to a complete heartbeat from its generation to the beginning of the next beat, comprising several stages of filling and emptying of the chambers. The frequency of the cardiac cycle is known as the heart rate measured in beats per minute, bpm [5].

In order to pump blood, the heart muscle must contract, which requires an electrical impulse. This impulse comes from the sinus node (located in the right atrium), which is transmitted via specific pathways throughout the heart, enabling regular contraction and relaxation [6]. The electrical impulse generated by the heart can be detected on the surface of the body using electrodes placed on the skin, which is done during an electrocardiogram (ECG or EKG) test. An ECG trace captures the process of depolarisation and repolarisation of the heart chambers, which causes them to contract and relax. The connection between an ECG and the electrical activity of the heart can be seen from figure 1 below:

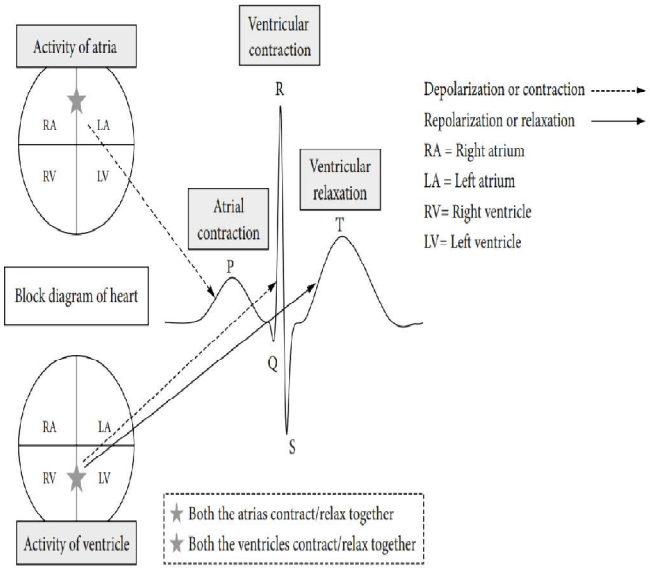

Figure 1: Generation of an ECG trace from electrical activity of the heart (Source: [6])

ECG monitors are used to record the electrical activity of the heart using pairs of electrodes placed on the skin. Each pair of electrodes is known as a lead and provides an electrical view of the heart from a different angle. There are 12 leads that are used in cardiology, obtained from a combination of 10 electrodes. Different ECG monitors are distinguished by the number of leads that they can record [7].

In the view of [7], an ECG trace for a single cardiac cycle consists of several parts:

- PR interval: The time between the beginning of the P wave and the beginning of the Q wave. The PR interval starts with the onset of P wave and ends at the onset of Q wave. It represents the duration of the conduction through the ventricles.
- P wave: Corresponds to atrial depolarisation. During normal atrial depolarization, the main electrical vector is directed from the sino-atrial (SA) node towards the atrio-ventricular (AV) node and spreads from the right atrium to the left atrium. This turns into the P wave on the ECG.
- PR Segment: The time between the end of the P wave and the beginning of the Q wave.
- QRS complex: Corresponds to ventricular contraction or depolarisation.
- ST segment: The time between the end of the S wave and at the beginning of the T wave. The ST segment represents the duration of the ventricular depolarization and the repolarization
- T wave: Corresponds to ventricular repolarisation. The T wave results from the repolarization of the ventricles and is of longer duration than QRS complex because the ventricular repolarization happens more slowly than ventricular depolarization.
- QT interval: The time between the beginning of the QRS complex and the end of the T wave. The QT interval begins with the onset of Q interval and ends at the endpoint of T wave, representing the of ventricular depolarization/ repolarization cycle.

Additionally, we can also measure the RR interval, which starts at the peak of one R wave and ends at the peak of the next R wave. RR intervals can be used to compute the heart rate from a recorded ECG signal. A visualisation of an ECG for a single cardiac cycle is presented in Figure 2 below:

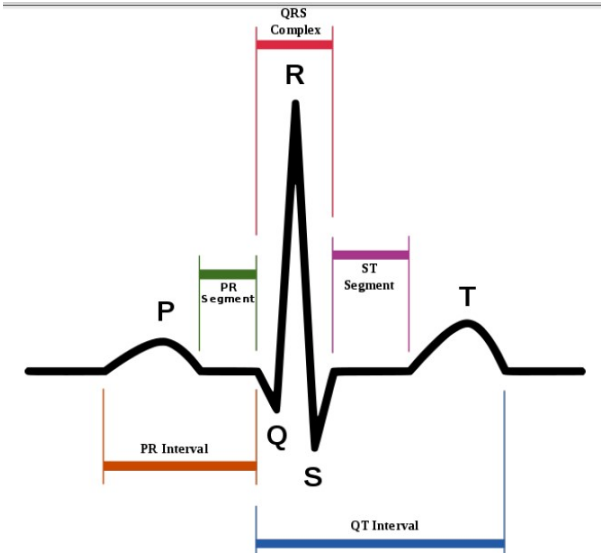

Fig. 2: Single heartbeat waveform (Source: [8]).

A. Electrocardiogram (ECG)

Electrocardiogram is the electrical activity of the heart. It is a graphical demonstration of the variation of biopotential versus time [9]. The leads are placed on specific locations of the body of the person to record ECG either on graph paper or on monitors. The human heart contains four chambers i.e., Right Atrium, Left Atrium, Right Ventricle and Left Ventricle. The upper chambers are the two Atria's and the lower chambers are the two Ventricles. Under healthy condition the heartbeat begins at the Right Atrium called Sino Atria (SA) node and a special group of cells send these electrical signals across the heart [10]. This signal travels from the Atria to the Atrio Ventricular (AV) node. The AV node connects to a group of fibres in Ventricles that conducts the electrical signal and transmits the impulse to all parts of the lower chamber, the Ventricles. To ensure that the heart is functioning properly this path of propagation must be traced accurately [11]. The basic structure of heart is shown in figure 3 below:

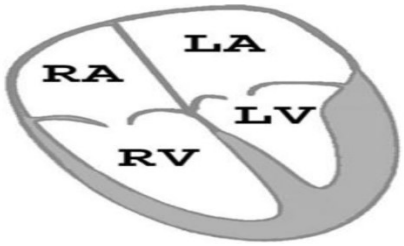

Fig 3. Schematic anatomy of the human heart (Source: [12])

B. Importance of ECG

An electrocardiogram is a vital part of the initial evaluation of a patient who is suspected to have a heart related problem. It provides relevant information about the patient's heart rhythm, a previous heart attack, increased thickness of heart muscle, and signs of decreased oxygen delivery to the heart, and problems with conduction of the electrical current from one portion of the heart to another.

In the view of [13], the basic importance of Electrocardiogram are as follows:

i. It can be used to determine the speed of heart beat.
ii. With ECG, any abnormality in the rhythm of heart beat such as steadiness, disturbances or irregularities can be detected.
iii. With ECG, the strength and timing of electrical signals can also be detected as they pass through each part of the heart.

C. ECG Waveform

Each heart beat displayed is a sequence of electrical waves characterized by peaks and valleys. ECG mainly provides two kinds of information. One is the duration of the electrical wave passing through the heart and it will decide whether the electrical activity is normal or slow or irregular. Second is the amount of electrical activity passing through the heart muscle that helps to find whether the parts of the heart are too large or overworked. The frequency range of an ECG signal is 0.05 – 100 Hz and its dynamic range is 1 – 10 mV. The ECG signal is characterized by five peaks and valleys represented by the letters P, Q, R, S, T. Sometimes U wave is also present. The performance of ECG analysis is based on the accurate and reliable detection of the QRS complex as well as T- and P waves [14]. An ideal ECG wave is as shown in figure 4 below:

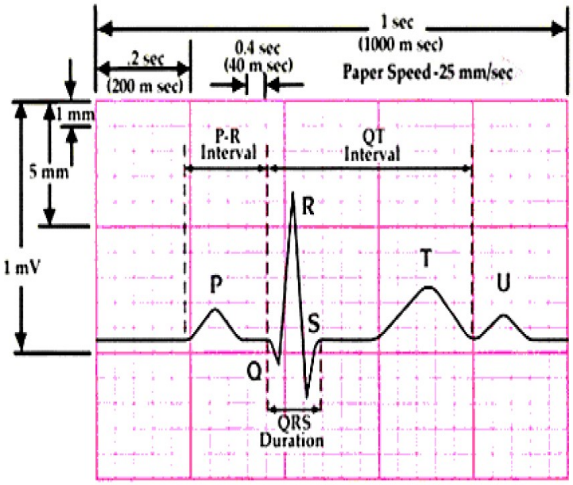

Fig 4: A Typical Cardiac Waveform (Source: [14])

The P-wave represent the activation of the two atria, the upper chambers of the heart, while the QRS complex and T-wave represent the excitation of the lower chamber of the heart, the ventricles. QRS detection is one of the fundamental issues in automatic ECG signal analysis. After QRS complex has been detected a thorough examination of ECG signal is done. The P, QRS and T-waves reflect the rhythmic electrical depolarization and repolarization of the myocardium linked with the contractions of the atria and ventricles [15].

The horizontal section of this waveform prior to the P-wave is termed as the baseline or the isopotential line. The P-wave corresponds to the depolarization of the atrial musculature. The QRS complex gives the combined result of the repolarization of the atria and depolarization of the ventricles, which occurs almost at same time. The T-wave is the wave of ventricular repolarization, whereas the U-wave, if present is normally believed to be the result of after potentials in the ventricular muscle.

So, the duration amplitude and morphology of the QRS complex is helpful in diagnosing cardiac arrhythmias, conduction abnormalities, ventricular hypertrophy, myocardial infection and other disease states. The usual rate of heart is 60 to 100 beats per minute. A slower rate than the

normal range is called bradycardia (slow heart) and a higher rate is called tachycardia (fast heart). If the ECG signal is not normal then an Arrhythmia is indicated [15]. Figure 5 shows the waveform of normal ECG and that of the abnormality ECG waveform is shown in Figure 6, and 7 respectively.

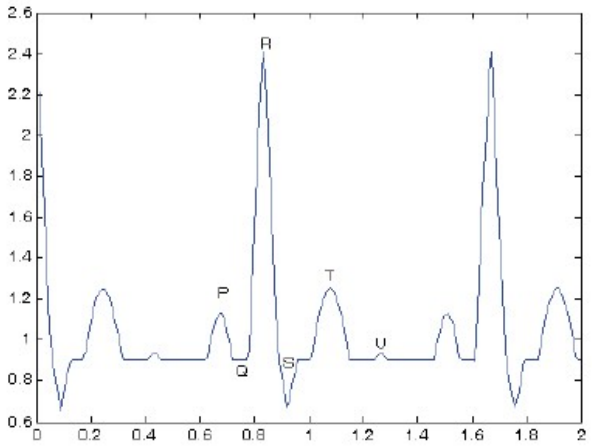

Fig. 5: Normal Sinus rhythm (Source: [15])

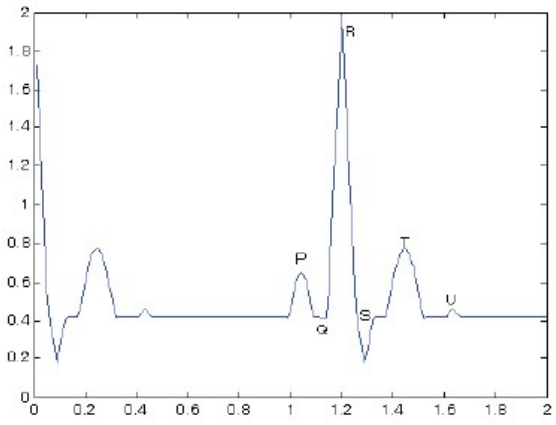

Fig. 6: Sinus Bradycardia (Source: [15])

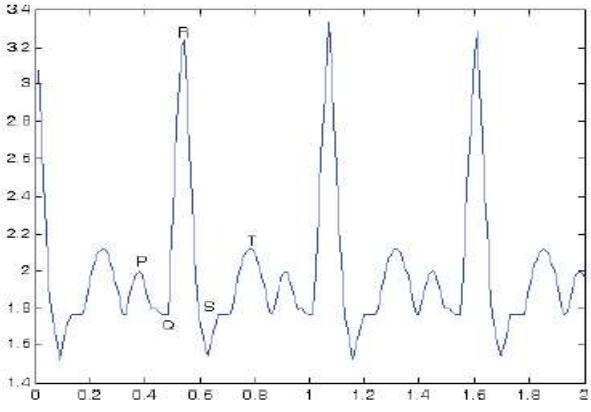

Fig. 7: Sinus Tachycardia (Source: [15])

Kalpana and Panchal [16], in their paper "Heart Attack Warning System Using ECG Processing" implemented a heart attack detection and warning system by real-time ECG monitoring. From their proposed system, to obtain the patient's ECG, a wearable sensor is used. The ECG will be classified as either normal or elevated. The signals are continuously transmitted to healthcare centre where the database of the patient is already recorded. If elevated beats occur for duration of at least thirty seconds (clinically significant), a multilevel system of warnings will begin. The user will immediately be notified via pop-up and audible alerts. Simultaneously a designated physician, ambulance and immediate family member of the patient will be notified via text message that the patient could be experiencing a heart attack.

Harini, et al. [17] presented a study to use handheld tele electrocardiogram (ECG) to identify heart condition in the rural underserved population where the doctor-patient ratio is low and access to health care is difficult. The objective of the study was clinical validation of handheld ECG as a screening tool for evaluation of cardiac diseases in the rural population. The proposed system for the ECG monitoring controlled was composed by the Arduino UNO microcontroller and implemented in the form of android app application.

Chowdhury et al. [18] proposed the development of a wearable system for real-time detection and warning of heart attacks in drivers, which could be enormously helpful in reducing road accidents. The system consists of two subsystems that communicate wirelessly using Bluetooth technology. The sensor subsystem records the electrical activity of the heart from the chest area to produce electrocardiogram trace and send that to the other portable decision-making subsystem where the symptoms of heart attack are detected. The system can help in reducing the loss of lives from the growing number of road accidents all over the world.

Okada et al. [19] developed a wearable ECG recorder for daily stress measurement of a portable electrocardiograph with the case open (left) and closed (right). The size is W44 x D17 x H58 mm and the weight is 45g including a battery and a memory card (1 GB). The memory card and battery can be easily replaced. ECG and the acceleration data are recorded at 1 kHz sampling rate up to more than 24 hours. After measurement, the memory card is dismounted, and the data are transferred to a personal computer (PC) for signal processing (off-line analysis). The system consists of a built-in four channel analog to digital converter, amplifiers (Burr-Brown INA326 and Texas Instruments OPA2335, 50 dB), a filter (0.1 - 100 Hz). 3-axis acceleration sensors (ST Microelectronics Co.), a microcomputer and a memory card. An acceleration sensor is used to monitor the subject's posture and/or body movement simultaneously with ECG. The sensor has a full scale of ±2 G (gravitation in m/s2). This range is

enough to measure an acceleration range of a body in daily life such as walks, works, household tasks, etc. The microcomputer is AduC840 series (Analog Devices Inc.).

Channappa and Nishat [5], in their paper titled "ECG Signal Based Heart Disease Detection System for Telemedicine Application Using LabVIEW" were able to identify heart disorders, using LabVIEW. Using their proposed method, they were able to effectively study and analyse ECG signal using the LabVIEW Biomedical toolkit. The considered device was divided into the following parts: signal acquisition, interfacing data using myDAQ, amplification and feature extraction. The main chunk is the ECG amplifier circuit built via instrumentation amplifier circuit (AD8232), followed by signal conditioning circuit with under taking amplifier (LM741). The DAQ card act as ADC. Using LabVIEW tool, they were able to process the ECG signal after which the ECG features were extracted with help of biomedical tool kit. The extracted features are compared with default parameters set in the code and the results indicates weather the patient is normal or arrhythmic. Subsequently, telemedicine application was provided which let doctor to view his patient's ECG signal remotely and dynamically in web page in real time, and does not need to have any special requirements on his PC except an internet access. They were able to achieve this using TCP/IP protocol which they implemented in LabVIEW.

III. METHODOLOGY

In this paper, the Dynamic Software Development Methodology (DSDM) was adopted which is a member of the Agile Software Development Methodologies.

The system was designed using Python programming language. Dataset obtained from http://www.paulvangent.com/wp(content/uploads/2016/03/data.csv)was used to acquire the ECG signal. The signal was processed and the PQRST was extracted to detect heart abnormalities.

IV. RESULT AND DISCUSSIONS

TABLE I

NORMAL HEART RATE AND RESPIRATORY RATE

Age	Heart Rate (BPM)	Respiratory Rate (Breathes/min)
0-5 months	90-150	25-40
6-12 months	80-140	20-30
1-3 years	80-130	20-30
3-5 years	80-120	20-30
6-10 years	70-110	15-30
11-14 years	60-105	12-20
14+ years	60-100	12-20

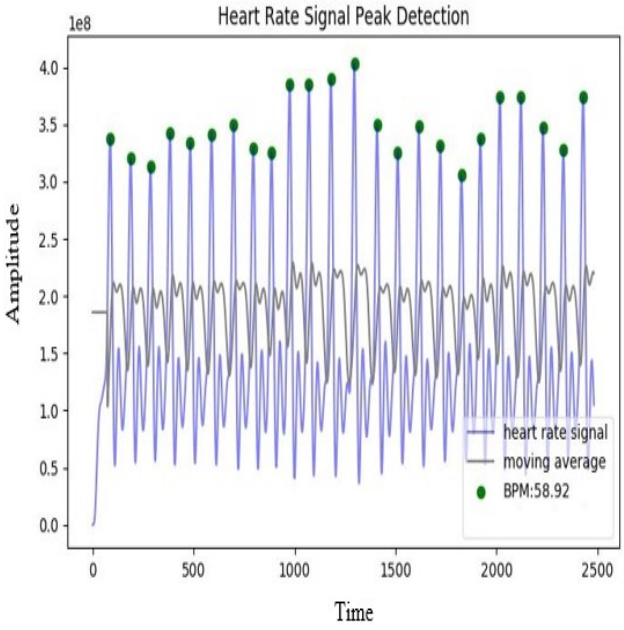

Fig. 7. Heart beat detection using ECG Signal Processing

To find the R-peak, we implemented python using open source libraries. The heart rate peak (R-R peak or R-R interval) is the distance between the first and last peaks of the signal. The heart rate can be calculated by dividing the product of 60 (Number of seconds in 1 minute) and sampling frequency by the average distance between the peaks. We then find the average distance between the peaks by dividing total distance between the first and last peaks by total number of R-Peaks of ECG signal. The heart rate helps us define certain conditions of the heart.

The normal rate of heart is 60 to 100 beats per minute. A slower rate than the normal range is called bradycardia (slow heart) and a higher rate is called tachycardia (fast heart).

Hence, our system calculated; Heart rate = Total number of R peaks of ECG signal / R-R Interval.

Where, R-R interval is the total distance between the first and last peak.

Heart rate = 300 / 5.09

Heart rate = 58.93 BPM

Figure 7, shows the heart beat detection using ECG signal processing. The system recorded BPM (Beat Per Minutes) of 58.92, which is slightly slower than the normal rate. If further care not taken, the person might suffer bradycardia which can be a serious problem if the heart doesn't pump enough oxygen-rich blood to the body.

V. CONCLUSIONS

In this paper, Heart Attack Detection using ECG Signal Processing is presented. Heart attack has been the deadliest

cardiovascular disease in our world today and a lot of persons are suffering from it. Early detection of this health challenge can be useful as the patient or patients involved will be managed properly so to prevent the condition from getting worse. The proposed system, therefore, is designed explicitly to be used to detect heart attack cases in patients and can as well provide a useful approach for continuous heath monitoring. One major advantage of the system when implemented is that it can provide clinically meaningful information to doctors to reduce the harm caused by cardiovascular disease.

REFERENCES

[1]. Vaidehi, A.D., and Thorat, P.R. (2017). ECG Detection Using Controller. *International Journal of Innovative Research in Science, Engineering and Technology*, 6(11), 21586 – 21600.

[2]. Joseph, J.O. (2007). Portable Heart Attack Warning System by Monitoring the ST Segment via Smartphone Electrocardiogram Processing. Retrieved on the 25th of February, 2020 from:https://core.ac.uk/download/pdf/12207951.pdf

[3]. Gertsch, M. (2009). *The ECG Manual*. London: Springer-Verlag.

[4]. Khan, M. (2008). *Rapid ECG Interpretation,* Totowa, NJ: Humana Press Inc.

[5]. Channappa, B. and Nishat, A. (2017). ECG Signal Based Heart Disease Detection System for Telemedicine Application Using LabVIEW. *International Journal of Research and Scientific Innovation (IJRSI)*, 4(9), 54 – 59.

[6]. Nikita, S. (2018). *A Key to Your Heart: Biometric Authentication Based on ECG Signals.* A 4th Year Project Report submitted to the Department of Computer Science, School of Informatics University of Edinburgh.

[7]. Euan, A. and Josef, N. (2004). *Cardiology Explained*. Remedica. Retrieved on the 25th of February, 2020 from: https://groups.inf.ed.ac.uk/tulips/projects/1718 /samarin.pdf

[8]. Komeili, M., Louis, W., Armanfard, N. and Hatzinakos, D. (2016). On Evaluating Human Recognition Using Electrocardiogram Signals: From Rest to Exercise. IEEE Canadian Conference on Electrical and Computer Engineering (CCECE), pages 1 – 4.

[9]. Gautam, A. and Kaur, M. (2012). ECG Analysis using Continuous Wavelet Transforms (CWT), *IOSR Journal of Engineering*, 2 (4), 632 – 635.

[10]. Rajni, P. and Kaur, I. (2013). Electrocardiogram Signal Analysis - An Overview. *International Journal of Computer Applications,* 84(7), 0975 – 8887.

[11]. Nagendra, S. and Kumar, V. (2011). Application of Wavelet Techniques in ECG Signal Processing: An Overview, *International Journal of Engineering Science and Technology (IJEST)*, 3(10), 7432 – 7443.

[12]. Adam, J. and Remigiusz J. (2005). Effective Simulation of Signals for Testing ECG Analyzer, *IEEE Transactions on Instrumentation and Measurement*, 54(3), 1019 – 1024.

[13]. Shital, L. and Nivedita D. (2014).Detection of Various Diseases Using ECG Signal in MALAB. *International Journal of Recent Technology and Engineering (IJRTE)*, 3(1), 120 – 123.

[14]. Anuradha, B., Kumar, K. and Veera R. (2008). Classification of Cardiac Signals usingTime Domain Methods, *ARPN Journal of Engineering and Applied Sciences*, 3(3), 7 – 12.

[15]. Saritha, C., Sukanya, V. and Narsimha M. (2008). ECG Signal Analysis Using Wavelet Transforms, *ARPN Journal of Engineering and Applied Sciences*, 3(4), 68 – 77.

[16]. Kalpana and Panchal (2015). Heart Attack Warning System Using ECG Processing. *International Journal of Advances in Electronics and Computer Science*, 2(6), 63 – 66.

[17]. Harini, R., Murthy B., and Tanveer K (2017). Development of ECG Monitoring System using Android App. *International Journal of Electronics and Electrical Engineering (IJEEE)*, 9(2), 699 – 707.

[18]. Chowdhury, E., Alzoubi, K., Khandakar, A., and Khalifa, R. (2019). WearableReal-Time Heart Attack Detection and Warning System to Reduce Road Accidents. *Multidisciplinary Digital Publishing Institute,* 1 – 22. Retrieved on the 25th of February, 2020 from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6632021

[19]. Okada, Y., Yi-Tsuyoshi, Y., Suzuki, T., and Sugiura, T. (2010). Development of aWearable ECG Recorder for Measuring Daily Stress. International Conference on Information Science and Applications (ICISA) Seoul, Korea, pp 1-5.