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Micro-ECG-monitoring system based on arduino with bluetooth feature

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Micro-ECG-monitoring system based on arduino with bluetooth feature

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Abstract. Cardiovascular disease (CVD) is one of India's most deadly diseases, with a 4.77 million annual death rate in 2020 [1]. CVD rates have risen from 1.6 percent to 7.4 percent in rural areas and from 1 percent to 13.2 percent in urban areas [1]. Electrocardiogram (ECG) devices, which monitor the heart's activity, are far too expensive to be used for personal care. In this project, we created a low-cost device using an Arduino (UNO/MEGA) microprocessor and a Real-time ECG graph display feature. The main instrument for measuring the pulse is the AD8232 sensor, which converts the sense-voltage obtained from ECG electrodes placed on the body. Integrating Arduino microcontroller (Uno/Mega) and Bluetooth module HC-05, the ECG readout may be presented on a mobile phone's monitor in real-time 24x7. The ECG simul externally attached can provide the accurate 12-lead ECG that depicts the patients' current health status in real time. This portable ECG has produced a satisfactory outcome in terms of production costs.

1. Introduction

An electrocardiogram (ECG) is a graphical representation of data generated by an electrograph that monitors the myogenic activity of the heart over specific time frames. The ECG is used to analyse the cardiac-conduction network and provides a clinical report on the health of the heart. Emergency assistance is required for people who are experiencing physical distress or have a background of cardiac disease. The precision of a patient's evaluation improves diagnostic performance and, as a result, lowers long-term mortality risk.

Figure 1. ICU Patient Monitor

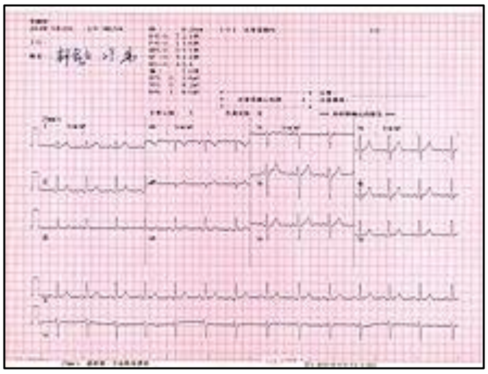

Figure 2. ECG Graph Display

An instance of commercial patient monitor used in ICU beds in hospitals is shown in Figure 1. The patient's status is monitored using a patient monitor, which displays information such as body temperature, oxygen saturation (Sp02), pulse rate over time, and a real-time ECG. A graphical picture of the patient's heart status is shown in Figure 2. It is expensive and requires a professional operator due to the accuracy of its monitoring. By 2030, CVDs are anticipated to affect more than 23.6 million people [1]. It's critical to recognize cardiovascular irregularities such as angina, dyspnea, atrial fibrillation, and syncopial attacks as soon as possible. ST-segment rise, i.e., myocardial ischemia in more than 90 percent of cases, ST-segment depression in 60 percent of cases [2], abnormalities in heart chambers, blood serum electrolyte levels, certain drug toxicities, and arrhythmias can all be detected with an ECG. A Holter monitor that is worn 24 hours a day improves diagnostic accuracy by 15 to 39 percent [2]. In mobile patients who can visit clinics or hospital OPDs, a 12-lead ECG can be performed promptly. Patients who are unable to be transported or who have other problems, such as paralysis or being bed-ridden, are, however, limited to their homes due to their advanced age. As a result, in an emergency, it may be important to record their heart rhythm at home.

Intermittent arrhythmia can also be identified with long-term continuous (Holter monitor) or short-term repetitive ECG monitoring with a portable 3-lead ECG monitor (PEM). The PEM technology used to identify Atrial Fibrillations in patients with past stroke/cardiac arrest/myocardial infarction was found to be more cost-effective in a current study comparing it to a supervised 24 h continuous Holter ECG. Coronary disease is responsible for 45 percent of the deaths cited. In a general practice setting, a low-cost and simple-to-use PEM device could help with a quick diagnosis of AF.

2. Working principle & theory

The sinoatrial node (SA node) controls the cardiac cycle through electrical stimulation. The SA node is made up of a group of cells or tissues that can produce an electrical impulse that controls contraction through a network of specialized fibers (atrioventricular AV node, His bundle, Purkinje fibers). The SA node is known as the natural pacemaker because it is in charge of regulating the heart's rhythm. The underlying principle behind the electrocardiogram (ECG) data is the heart's electrical conductivity. Each ECG unit represents a different phase of the heart cycle. The atrial and ventricular chambers relax (diastole) at the start of the cardiac cycle, and blood flows again into the right and left atria from the vena cava and the four pulmonary veins, respectively. Blood effuse out from the atria to the ventricles when both the tricuspid and mitral valves are dilated. The atrial muscles contract consecutively from the superior atrium toward the atrioventricular septum after atrial depolarization (marked by the P wave), pumping blood into the ventricles through the dilated atrioventricular valves. The ventricles are normally filled to around 75 percent–80 percent of their capacity at the start of the atrial systole, and the ventricles gradually fill as the atrial systole progresses [3]. The atrial systole lasts around 100 milliseconds and is followed by the ventricular systole. The QRS complex on the ECG represents the depolarization of the ventricles, which is followed by the ventricular systole. The pressure created in the ventricles is insufficient to transfuse blood from the heart at first. The blood returns to the atrioventricular valves and closes them. Because the volume of blood remains constant, this is the iso-volumetric contraction phase. The T-wave of the ECG represents ventricular relaxation, or diastole, which is followed by ventricular repolarization [3]. The P wave, which usually lasts less than 120 milliseconds, shows atrial depolarization during atrial systole. A rise or fall in the P-wave can indicate hypokalemia or hyperkalemia, respectively. P-wave morphology can also be used to detect left and right atrial hypertrophy. With an average duration of 60 to 100 milliseconds, the QRS complex signals ventricular depolarization and contraction during ventricular systole. Elevated amplitude implies cardiac hypertrophy, a typical issue in sportsmen, and a prolonged sustained period indicates hyperkalemia or bundles branch block. The occurrence of infarction is revealed by other irregularities. The heart rate can be calculated using the time between RR-peaks.[3]. The ST-segment is the interval between the S and T waves, and it depicts the phase of ventricular depolarization and repolarization. Its usual duration is between 80 and 120 milliseconds.ST segments that are bland, down-sloping, or low may signify coronary ischemia. The typical indication of myocardial infarction is ST-elevation. Ventricular repolarization is represented by the T-wave. T-wave inversion (negative curvature) can be a sign of a variety of heart conditions. Repolarization of the Purkinje fibers is indicated by a U-wave. Because it is such a minor wave in comparison to the others, it is not usually visible on an ECG graph [3].

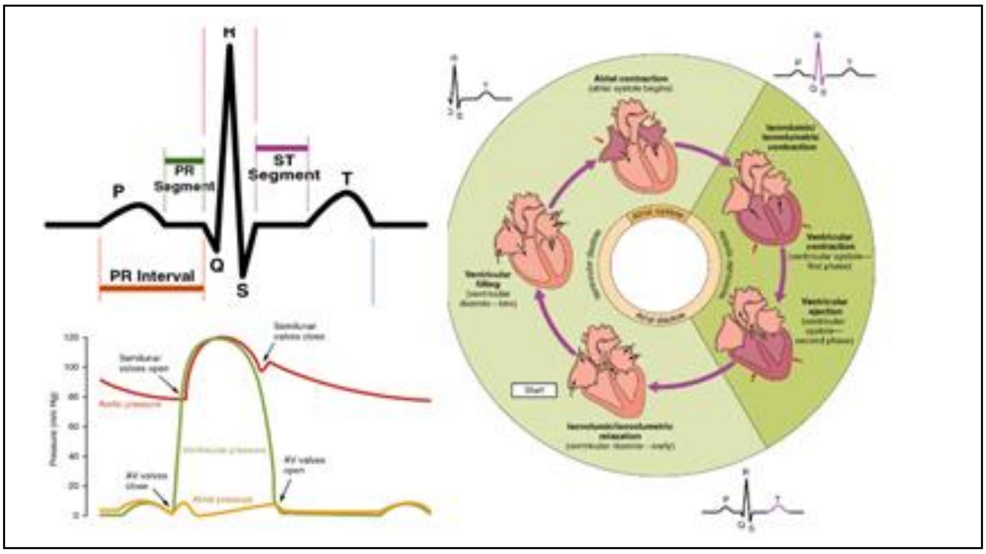

Figure 3. PQRST wave & Cardiac cycle

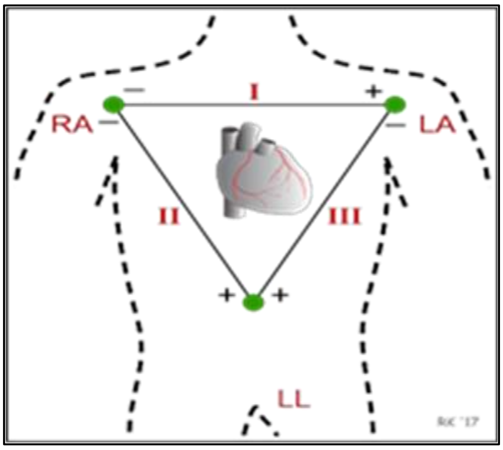

Figure 4. Einthoven's Triangle AND ECG lead placements

2.1. **Einthoven's Triangle:**

Figure 3 depicts three significant territories in the production of the ECG wave. The electrode lead has to be placed on the right arm (RA), the left arm (LA), and the left leg (LL). ECG waves travel from the cathode to the anode in a clockwise direction.[4].The cathode in Wave-I is RA, and the anode is LA. The cathode in Wave-II is RA, whereas the anode is LL. The cathode is LA in Wave-III, and the anode is LL. Einthoven's three original heart waves were the wave-I, wave-II, and wave-III. For precision of those three waves, 'aVR,' 'aVL,' and 'aVF' are introduced. The cathode is the midpoint of LA and LL, and the anode is RA. The cathode is the midpoint of RA and LL, and the anode is LA. The cathode is the midpoint of RA and LA, while the anode is LL. The second wave, which comes from Einthoven's initial group, will be used for data entry. Figure 3 shows where the electrodes will be placed. The anode will be positioned on RA, the cathode will be positioned on LL, and the ground electrode will be positioned on LA. [5].

3. Hardware components

The electrode receives the cardiac activity signal, which is subsequently sent to the AD8232 for processing analog data into digital signals. This is accomplished by amplifying the incoming electric signal, which is then scaled to a voltage range of 0.3 to 3 volts. The results will then be sent to the Arduino microprocessor's recorder. The analog data in the form of voltage will be rescaled to a value between 0 and 1023. From the 5V reference value, the maximum value is 1023, while the minimum value is 0 from the 0.049V scaling value. The highest integer value is 676 as ECG has a peak power of 3.3V [4] [5]. Arduino-Uno is a microcontroller. The AD8232 functions to capture, amplify, and filter tiny biopotential signals in noisy environments such as muscle movements. AD8232 is an integrated signal conditioner component block that monitors heart activity by conditioning electrical impulses generated by the heart [7]. An Instrumentation Amplifier, an Operational Amplifier, a Right Drive Amplifier, and a Mid-reference Buffer are integrated in the interior of the biosensor. The AD8232 additionally includes a Leads on/off Detection function as well as a Fast Recovery circuit for signal recovery once the leads have been connected. Using a specialized instrumentation amplifier, the ECG signal was boosted while noise was rejected. This eliminated the possibility of an "indirect current feedback" architecture, which lowered the size and power consumption even more than the previous implementation. This also improves the accuracy of voltage readings. The Operation Amplifier is a rail-to-rail device with low-pass filtering and improved signal strength. Inside the Special Instrumentation amplifier's input, the Right Leg Drive (RLD) Amplifier inverts the common-mode signal. When the output of Right Leg Drive is fed into the topic, it neutralizes other common-mode variations [8]. The

AD8232 was powered by a single power supply. The reference buffer was utilized to form a barrier between the supplied voltage and the ground system, making the single-supply application easier. The signal requires a particular number of seconds to be available due to the Low Cut-off frequency utilized in the high-pass filter in the ECG application. When electrodes are connected for the first time, this duration of seconds may induce a delay that disrupts data collecting. The Fast Recovery circuit reduced the long delay to milliseconds, allowing for easier and more efficient data gathering [6]. The heart's electrical signal was captured by three electrodes affixed to the body. As a visualization tool to present ECG graphs, a basic monitor designated TFT LCD 2.4” was required. The HC-05 FC-114 served as an information transmitter to a cell phone through Bluetooth. Each component of this hardware is put together, and a program is installed into it to regulate how it works. We may construct ECG independently built on Arduino, specifically Arduino-UNO, thanks to developments in technology, especially open-source technology. Arduino-UNO is a microprocessor that will collect data and present it according to user requirements [7]. Figure 6 shows the AD8232 Module, which is one of the most basic sensors for monitoring heart rate. The electrical signal from the heart is captured by the AD8232 sensor. This AD8232 sensor has been used in a lot of ECG studies [8] [9]. In today's world, a cellphone is one of, if not the most, widely utilized technological gadgets. The convenience provided by a cellphone's application ability makes it attractive to the general public. The primary goal of this study is to develop a portable, low-cost ECG built on the Arduino-Uno that can be linked to a smartphone via Bluetooth for greater mobility.

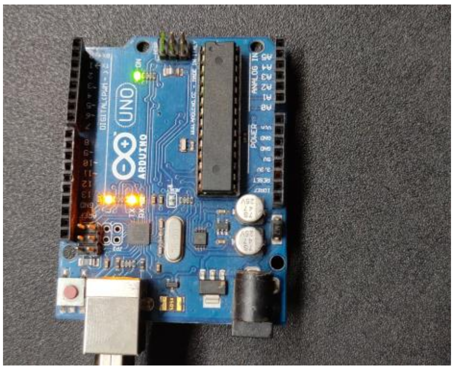

Figure 5. Arduino-Uno

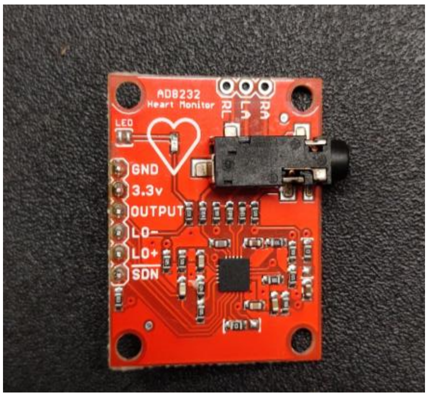

Figure 6. AD8232 Module

Figure 7. Multi-Purpose Monitoring Electrode

Figure 8. Bluetooth HC-05

4. Experimental setup

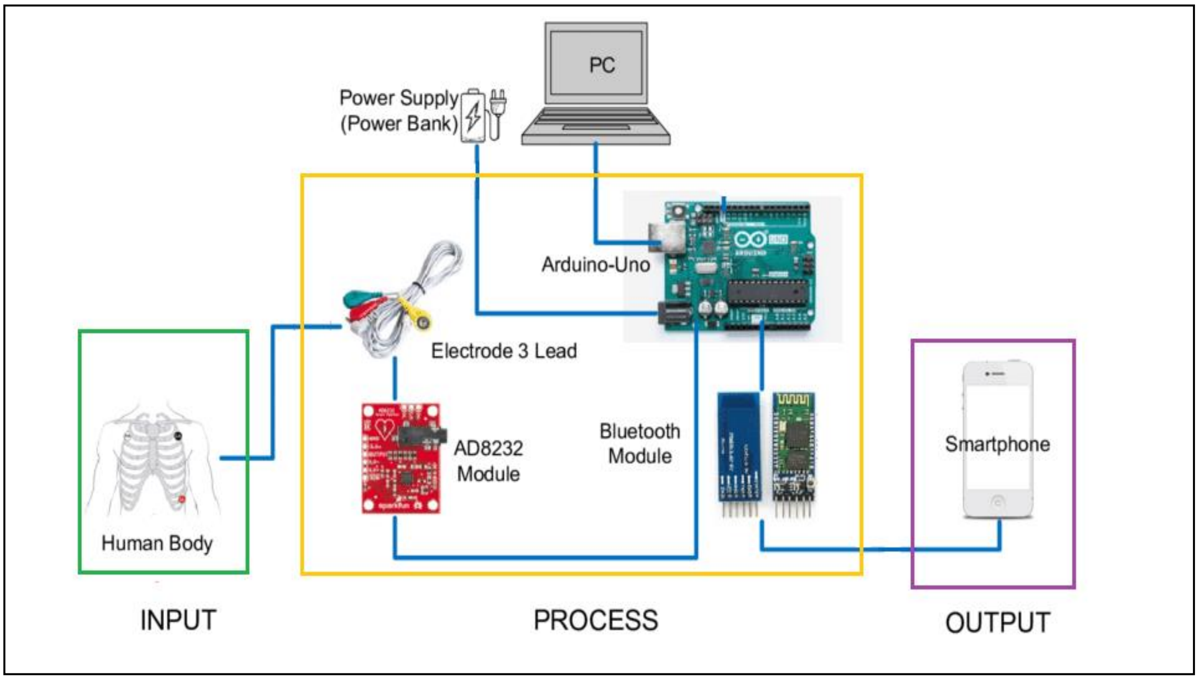

Figure 9. Assembly of a Bluetooth-enabled portable ECG

Analytical data came from a variety of people, both sick and healthy. They received an electrical signal from the three electrodes attached to them and transferred into the AD8232 module. The signal was delivered from the AD8232 to the Arduino CPU. It not only converted them to analog values, but it also converted them to integer values that could be shown. Within the Arduino microprocessor, a program for displaying results had already been installed. Two displays were created from the intended result. The Arduino Serial Plotter is used for one of the displays. The alternative method was to use a cell-phone and a third-party app that we designed to receive the Bluetooth signal from Arduino and present a real-time map on the smartphone's display. The result also produced a horizontal graph when Leads were not correctly joined.

5. Observations

Figure 10 depicts our project's prototype configuration. Figure 11 shows a screenshot of ECG segment wave captured on the cell phone screen in real time. Figure 12 shows the Arduino IDE Serial Plotter displaying one complete cycle of a PQRST wave formed by the sensor. The average heart rate is 60 to 100 beats per minute. It will rise to roughly 110-150 BPM with activity [10]. And when you're sleeping, it'll be approximately 40-60 BPM. A patient's heart should be in a resting state in order to obtain accurate data. It also showed the heart rate going below 60 beats per minute, indicating Bradycardia. It also indicated a tachycardia of more than 100 beats per minute. This device was tested on a human with a serious heart problem. Using therapeutic reasoning and a conclusions, the outcomes were estimated. The spacing between each of the R waves is comparable to others, as can be observed. This led to the conclusion that the heart contains a normal heartbeat. The calculated Heart Rate was 68 BPM, which indicated that it was within the normal range of 65-95 BPM. We noticed contacts between the ECG Test electrodes by looking at the structure of the ECG waves. To begin with, the ECG wave was not as smooth as one would expect from a standard ECG device. The disturbance was generated by the patient's muscle contractions. When compared to the original ECG, the P-wave was fairly identical, but it still needs improvements. The QRS complex was also morphologically identical to the control test system. The T-wave was somewhat modest in size, which could indicate partial clotting in the patient's coronary artery. The patient was found to be suffering from Myocardial Ischemia (Coronary disease).

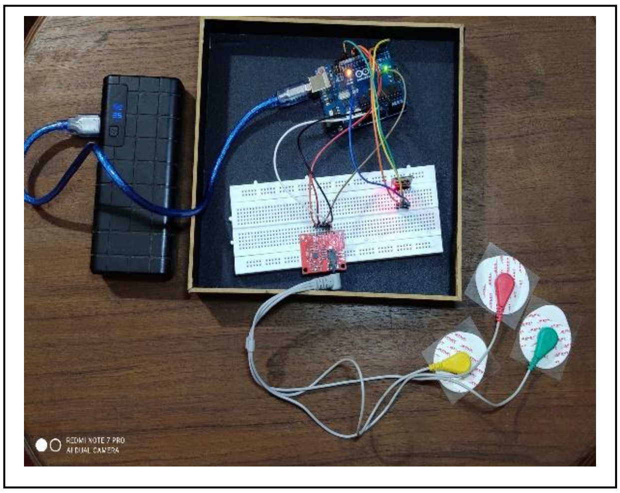

Figure 10. The Experimental Setup

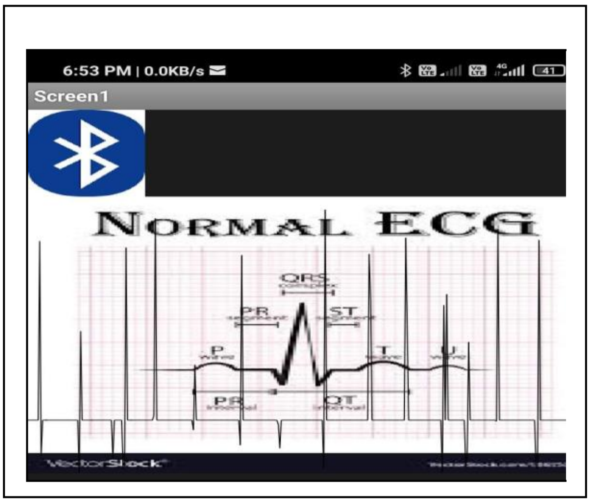

Figure 11. Smartphone's screenshot of data

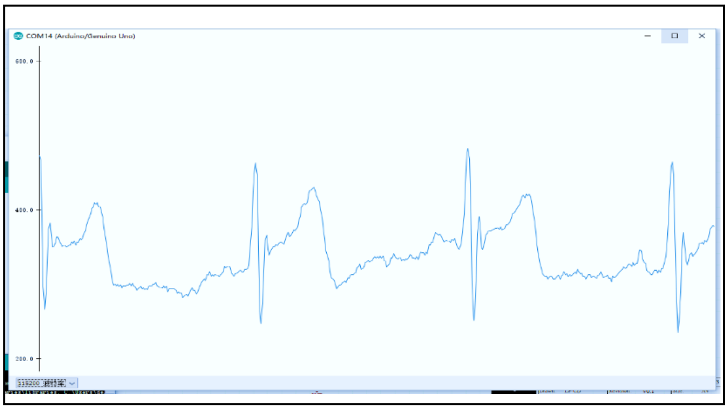

Figure 12. Graph on Arduino IDE Serial Plotter

6. Reviews on industrial products

Table 1. Comparative study of portable ECG devices available in the global market [9]

Commercially available devices in the market	***Advantages & Specifications***	***Disadvantages***
Kardia Mobile	Displays ECG tracing, is portable, has a smoothing filter, and is FDA certified.	This device is not connected to an Android or iPhone wirelessly.
Omron Heart-Scan(HCG801)	It has both chest and finger electrodes integrated.	It cannot accommodate a rechargeable battery.
Zenicore EKG	Can record and store data with cloud analysis	ECG tracings are not displayed readily.
AfibAlert	FDA certified and compact with two finger recording device	ECG records are not displayed.
Miniscope M3	ECG tracing is displayed.	-
Instant Check	Actual ECG records are displayed, and the device is FDA authorised.	Auto-shut down time is relatively quick.
ReadMyHeart	FDA-approved recording and storing device	ECG records cannot be displayed instantaneously.
Dimetek Micro Ambulatory ECG Recorder	Can be used for both short and 24/7 Holter monitoring, and ECG records can be archived.	-
Nuvant mobile cardiac telemetry	Automatically identifies and transmits ECG to an external OS using this 3-lead ECG gadget with wireless patch.	Takes a long time to get accurate readings.
CardioLeaf	Wearable electrodes, 3-lead ECG sensor, LED display, audible alert Data can be uploaded to the web.	-

7. Estimated cost for the project

The market cost of a portable ECG device ranges from 7000(INR) to 12000(INR) [9]. When we developed the project, the raw materials costed a total of 1000 (INR). The Arduino program is coded by us. The time taken to complete the device was very minimal – an estimate of 2-3 days. Hence if this is conducted on an industrial scale, the cost will be very low and the time needed would be lesser. All the materials are available locally and does not need to be imported from foreign countries. It has a very good aspect of business in the coming years.

8. Conclusion

The custom-made portable ECG has worked with a satisfactory result with respect to its manufacturing cost. The system could well record the electrical cardiac responses using the AD8232 sensor. It could also map the analog data on the screen in a graphical style. Our prototype used HC-

05 Bluetooth module which further transmits data to the smartphone app. It can be archived in a picture file format for future use, as well as a screen recording video file to see the data collecting process in real time. Also, we could record the graph in the Arduino IDE serial plotter in the laptop/desktop (which was more accurate).

9. Future steps

- In the future, we are thinking to develop an app that could detect any anomaly in the ECG graph using Artificial Intelligence and Machine Learning.
- It will also send an emergency notification stating the patient's location to the patient's medical guardian.
- We are planning to work up with government agencies so that all the ambulances can use the app so when the time comes there is no delay in its rescue in the hour of need.
- The GPS can be tracked by both the patient's family and the hospital managements may be with the help of IoT. In the way of saving more lives.
- We want to create a Data Base that stores all the Real time data with date and time so when the doctor needs to see the heart's condition at a particular time, he/she can see it without any delay.
- Another point we would like to improve on is the quality of data input through the electrodes because they are subject to noise interference and can easily subject to wear and tear.

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