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Remote Cardiac Monitoring System (RCMS)

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Abstract: Cardiac monitoring and rehabilitation is a comprehensive and coordinated program designed to improve cardiac function in patients with heart attack, heart failure, or after heart surgery, or angioplasty. The human population is increasingly concerned about their health condition, especially in this era of the Coronavirus-2019 (Covid-19) pandemic and in the world of fast-growing technology of medical care. This project presents a simple solution for cardiac monitoring that is both economic and easy to use. This is by adopting the Internet of Things (IoT) combined with Arduino-controlled sensors, namely an Electrocardiograph (ECG) sensor (AD8232) and heart rate and pulsatile oxygen saturation (SPO_2) sensor (MAX30100), for remote cardiac monitoring. The use of this prototype for cardiac screening required a patient to measure a complete cycle of his/her ECG signal before screen-shooting it for sending by email using MATLAB for online consultation services by a cardiologist or the physician. At the same time, the recordings of the readings are logged into the Cayenne server in near real-time. This allows the cardiologist to monitor the vital sign of the patient remotely. This technology would allow remote monitoring and access to the results using mobile devices, such as mobile phones, tabs, laptops, etc. It is hypothesized that this effective solution would improve the quality of the healthcare delivery process, especially for those living in rural areas where care may be harder to reach.

Keywords: Monitoring System, Cardiovascular Disease (CVD), Electrocardiograph (ECG)

1. Introduction

Health is a major concern in developing and developed nations. The advancements in the field of microelectronics, wireless networking, and wireless sensors play an ever-increasing role to assist healthcare providers in dealing with the arising problem and social challenges of the ageing population. The recent Covid-19 attack, which has seriously paralyzed the healthcare system on a global scale, is an example of how sustainable health care has grown in importance [1]-[2].

The heart is one of the most vital organs in the human body since it works constantly from birth,

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and does not stop even when an individual is sleeping. The heart pumps about a million barrels of blood over the course of a lifetime, carrying oxygen to various parts of the body, and helping to expel the wastes from the body. As a result, the heart functions as the human body's engine [3]. If something goes wrong with the heart, it would affect all the other organs. Heart disease is becoming an increasingly common health issue in Malaysia. It was once thought to be a disease of the elderly but is now frequently diagnosed in younger people. Statistics in 2020 revealed that 69.4%, which corresponds to 11,330 males, and 30.6% or 4,995 females are suffering from heart disease. This statistic stands at 18% of Malaysians in their forties and fifties. This disease is still the leading cause of death in Malaysia, and it is responsible for nearly one out of every four deaths. World Health Organization (WHO) revealed that cardiovascular disease (CVD) is expected to affect almost 23.6 million people by the year 2030; this is approximately 140 people out of every 100,000 will experience a cardiac arrest by the next decade. Thus, moving healthcare delivery and monitoring from hospital grounds to places where the elderly life could be one effective way to address the issues [4]-[5]. This solution enables the elderly to remain at home for longer periods of time, whilst having continuous access to proper healthcare. This can also provide them with greater independence while monitoring their overall health at a lower cost. The proposed framework is to create a system that uses IoT and market available sensors for monitoring a patient's physiological status [6]-[10].

2. Methodology

2.1 System design and development

Figure 1 shows the block diagram of the project development flow. It consists of three phases, namely Phase 1 (Development Plan), Phase 2 (Software Designing Plan) and Phase 3 (Hardware Designing Plan). A detailed description of each phase is provided in the following subsections.

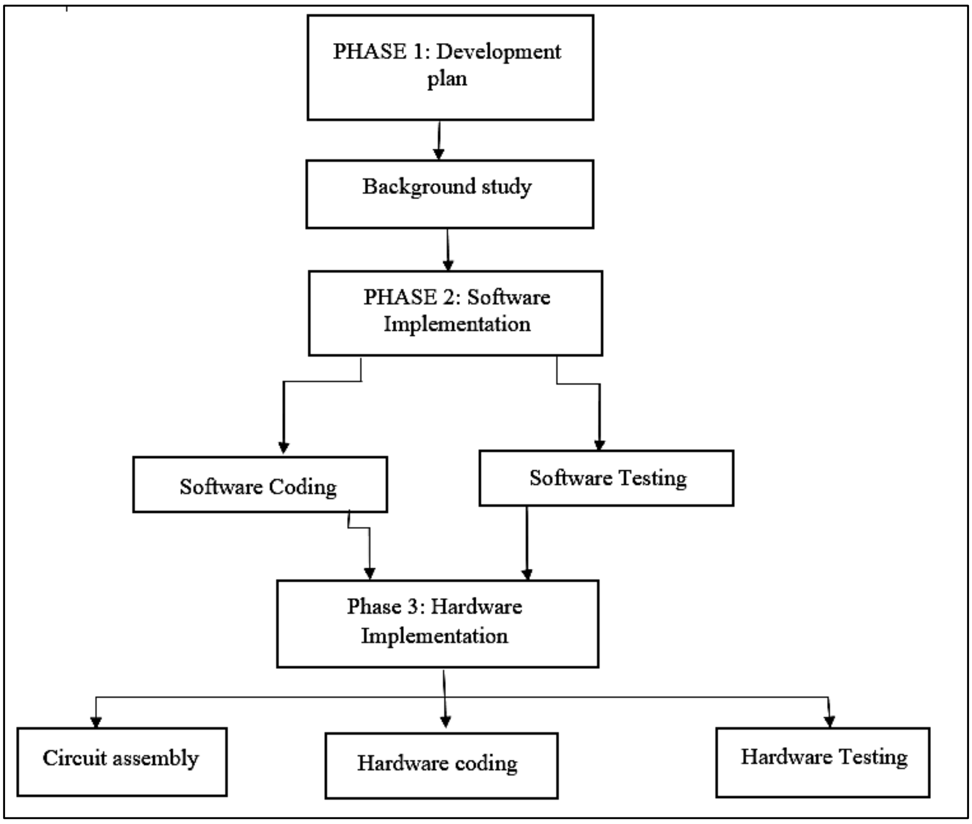


Figure 1: Block diagram of project development phases

The first phase is the design and development plan where the flow of the overall measurement and automation system are determined. In this project, the components used are an ECG sensor (AD 8232) for the measurement of ECG signals, and a physiological device (MAX30100) used for the non-invasive measurement of heart rate and pulsatile oxygen saturation (SPO_2). Meanwhile, the second phase can be divided into two sections: software coding and software testing. The microcontroller and parameter sensors are programmed using the Arduino IDE software. The Arduino IDE is a Java-based cross-platform IDE for Processing programming language and wiring projects. The parameter sensors are coded using the Arduino IDE program, and their output is shown in a serial plotter. Following that, software testing is performed to ensure that the most recent version of the code works correctly with the system. By using a Serial plotter, the readings from the ECG sensor would be displayed. This is in addition to the readings from the heart rate and pulsatile oxygen saturation (SPO_2) sensor. From this project, the users can read the real-time data, which is transmitted to NodeMcu for uploading to the cloud via the Cayenne application. The control of sensors via NodeMcu is shown in Figure 2.

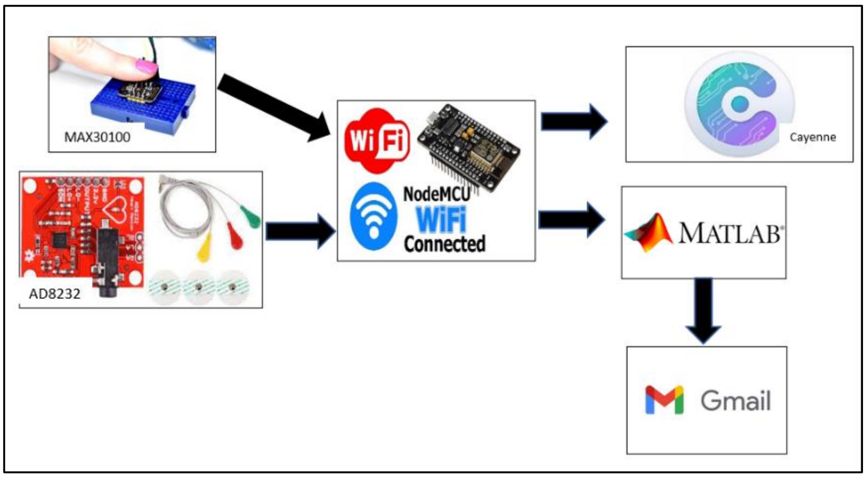


Figure 2: SPO2 and ECG monitoring system flow

The last phase includes circuit assembly, hardware coding and hardware testing. The circuit comprises all sensors used before connecting them with the Arduino Uno. After that, the hardware is tested by using the code to verify the control and automation process is functioning faultlessly. After the testing, the system would be connected with NodeMcu to transfer data to the cloud for mobile applications.

2.2 System flowchart

The project is built using C++ programming language and an Arduino IDE with NodeMcu. The goal of this project is to help cardiac patients to monitor their vital signs before and after physical activity. The project's system design consists of two sensing inputs: measurement from AD8232, and MAX30100. These sensors are connected to the NodeMcu. The output from the sensors is sent to NodeMcu for display on the cayenne platform. The ECG signal can be screenshot using the *sendmail* function in MATLAB. This function sends an email containing the ECG image to the cardiologist or physician notifying consultation is required for the patient. Meanwhile, the patient's vital signs will also be updated and can be accessed from the Cayenne web and a mobile device. This engineering system helps the cardiologist to establish a proper diagnosis based on the ECG signal, BPM and SpO_2 before appropriate treatment is instituted. Figure 3 shows the flow chart of the IoT-enabled system.

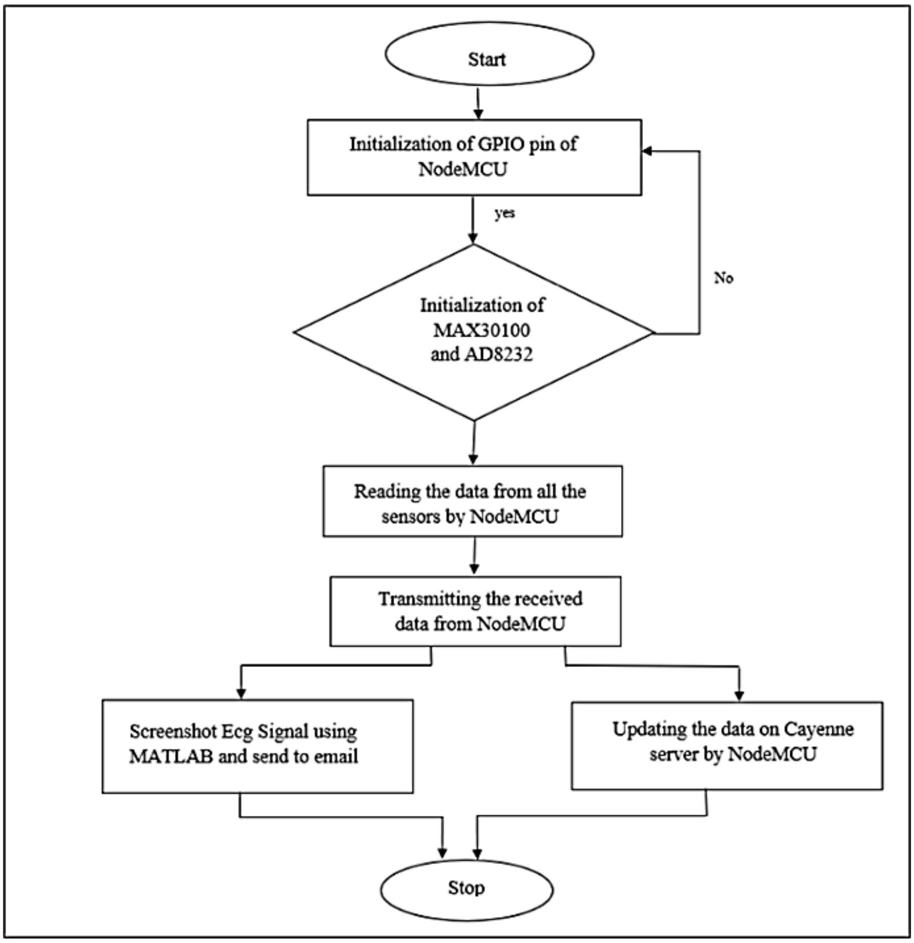


Figure 3: Flow chart of the IoT-enabled system

2.3 Graphical User Interface

This project designs and develops a graphical user interface (GUI) using Cayenne for real-time display of vital signs. This IoT platform is freely available and it allows its users to design their GUI by invoking a drag and drop operation of available components. These components can be customized to allow communication with NodeMcu as shown in Figure 4. Finally, after completing those procedures, multiplication of the interface is required to ensure that this GUI is fully functional.

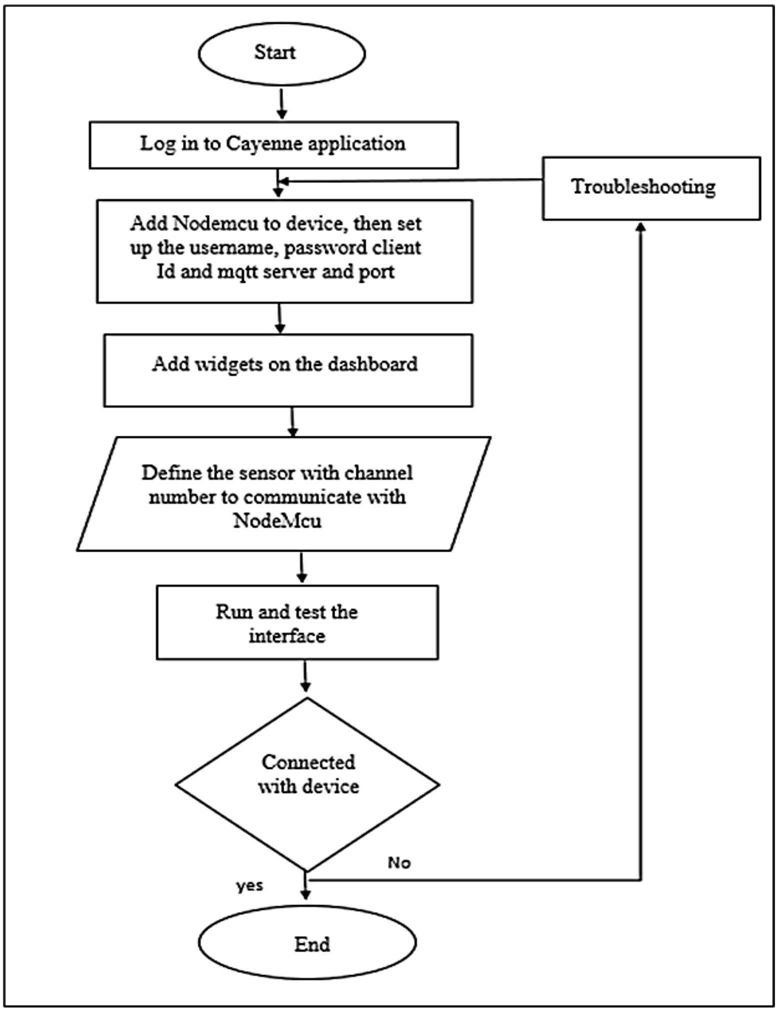


Figure 4: Development of GUI

3. Results and Discussion

3.1 Remote Cardiac Monitoring System setup and testing

Figure 5 shows an overview of the constructed circuit. The written program was first uploaded into the NodeMcu board, which is supplied by a power supply of 9 V and 3 A. This power supply is used to supply for NodeMcu 1.0 with ESP8266 WiFi Module and both sensors e. When NodeMcu is connected to the available WiFi, the built-in WiFi Module would request authentication for connection with the Cayenne. Once the connection is established, both sensors would start displaying their measurement on the dashboard in the cayenne app. All these measurements can also be shown on the serial monitor as shown in Figures 6 and 7. Since the cayenne application cannot import ECG signal directly, so the graph created in cayenne is with values. The ECG signals in Figure 7 can be screenshot and emailed using MATLAB to a cardiologist or physician, providing better image quality and more comprehensive information for improved diagnosis as shown in Figure 8. When the email is received, the healthcare provider can monitor their patient’s vital signs through the cayenne application. Aside from that, there are triggers established in the Cayenne program that will warn patients through email or text messages if their bpm or oxygen level falls below a specific threshold.

Figure 5: Overview of the constructed circuit

```
06:56:05.483 -> Heart rate:88.65bpm / SpO2:100.00%
06:56:05.483 -> ECG Value=
06:56:05.483 -> 567.00
06:56:05.483 -> Beat!
06:56:06.243 -> Beat!
06:56:06.613 -> Heart rate:82.41bpm / SpO2:100.00%
06:56:06.613 -> ECG Value=
06:56:06.613 -> 568.00
06:56:06.894 -> Beat!
06:56:07.608 -> Beat!
06:56:07.723 -> Heart rate:86.99bpm / SpO2:100.00%
06:56:07.723 -> ECG Value=
06:56:07.723 -> 568.00
06:56:08.279 -> Beat!
06:56:08.804 -> Heart rate:86.89bpm / SpO2:100.00%
06:56:08.843 -> ECG Value=
```

Figure 6: The value of the Heart rate and Spo$_2$ display at the serial monitor

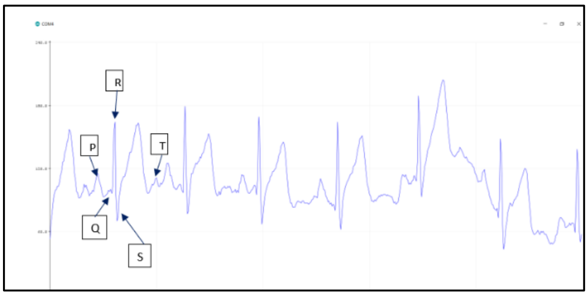


Figure 7: The ECG signal display at the serial monitor

Figure 8: ECG signal received in email

3.2 IoT implementation with Cayenne

Figure 9 shows the measured parameters on the cayenne application web view while Figure 10 shows the corresponding display on a mobile phone. These figures show that a difference exists between the display on the web and mobile phones, which we attributed to the WIFI signal strength that varies with the location. Since the wifi module baud rate is dependent on the mobile hotspot strength, it determines the rate the measurement is updated in the app. Shown in Figure 11 are the data received and stored in the Cayenne cloud.

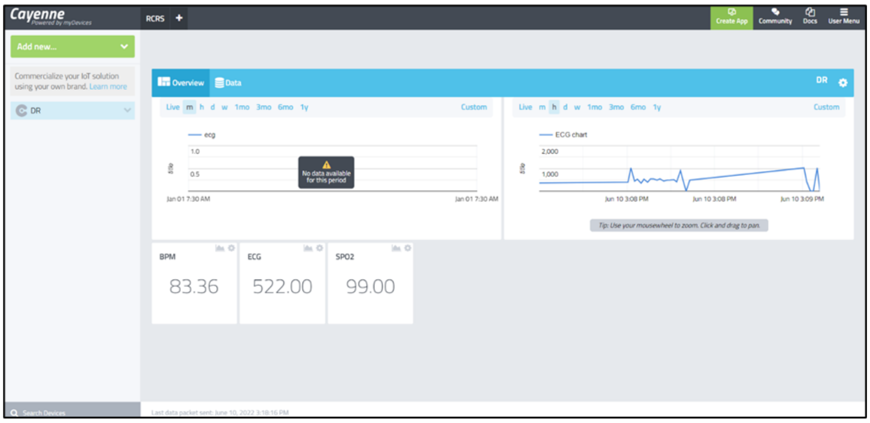


Figure 9: The cayenne application web view with all the parameters

Figure 10: Mobile phone view

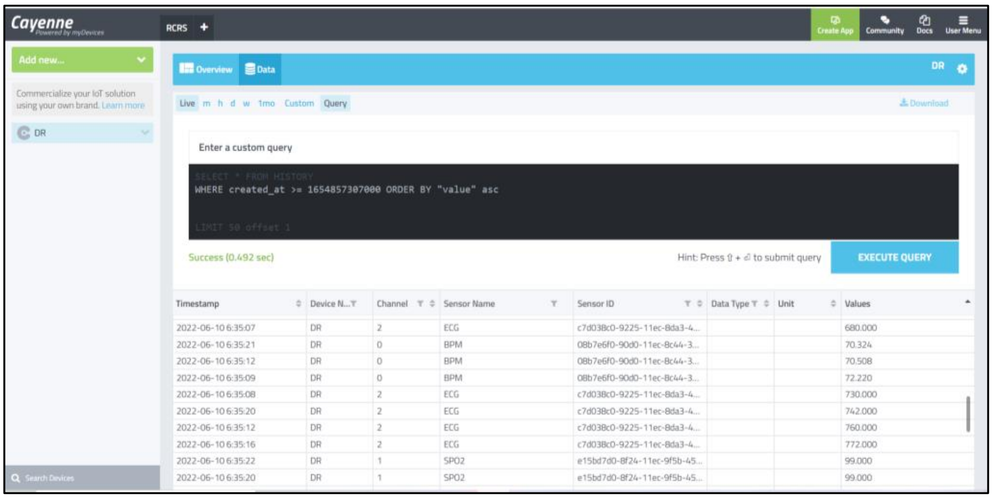
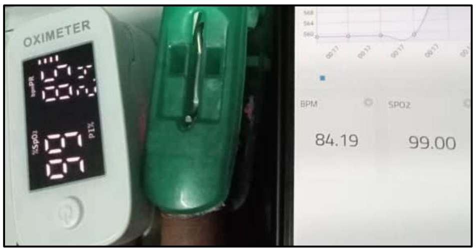


Figure 11: Real-time data storage in the Cayenne cloud

3.3 Analysis of ECG signal between different activities

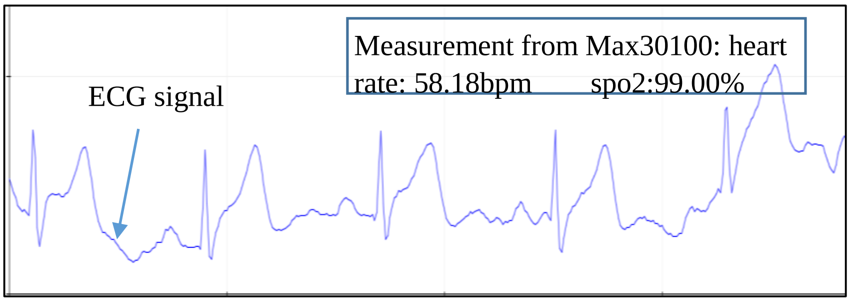
Table 1 shows the comparison made for the Max30100 sensor with the YM 103 model pulse oximeter, which is used as the gold standard, to calculate the system performance in the measurement of heart rate and oxygen saturation. After a comparison has been made, the error is calculated as less than 1%, which implies the feasibility of our system to monitor its user's heart rate and oxygen saturation level.

Table 1: The accuracy and the difference in percentage (error) occurred when using two different experiment tools

Subject Index	Age	Using RCMS	Pulse oximeter YM103 model	Error%	Accuracy %	Results
1	26	BPM:84.19 Spo2:99%	BPM:85 Spo2:99%	0.95%	99.05%	
2	50	BPM:71 Spo2:99%	BPM:71 Spo2:99%	0%	100%	
3	23	BPM:85.58 Spo2:98%	BPM:86 Spo2:98%	0.48%	99.52%	

The 6-minute walk test (6NWT) is a standard test that determines how far a person can walk on a flat, hard surface in that time. It's a good test for determining how well all of a person's body systems respond to exercise. The respiratory and cardiovascular systems, as well as blood circulation and muscle activity, are all examples of testing these systems functionality. Thus, the purpose is to walk as far as possible in the six minutes provided, at one's own pace. It is more likely to indicate a person's functional activity level than intensive exercise because it is a measure of walking, which is a part of everyday life. The 6MWT is a test that assesses exercise tolerance in patients with a variety of illnesses. The test can be used by a physician to track the effectiveness of a current treatment plan and assess if it is helping a patient's condition. Table 2 shows the 6-minute walking test results that were conducted using this system. While the Spo2 remains the same pre-and post-activity, the increase in heart rate can be explained by the body's stress response to increase and replenish the oxygen in the body. Our findings show that the ECG signal has been greatly distorted after the workout, which can be due to the motion artifact caused by chest movement (following rapid breathing/hyperventilation).

Table 2: Physiological measurement for pre-and post-6-minute walking test

<table>
<tr><td>Before Activity</td><td>
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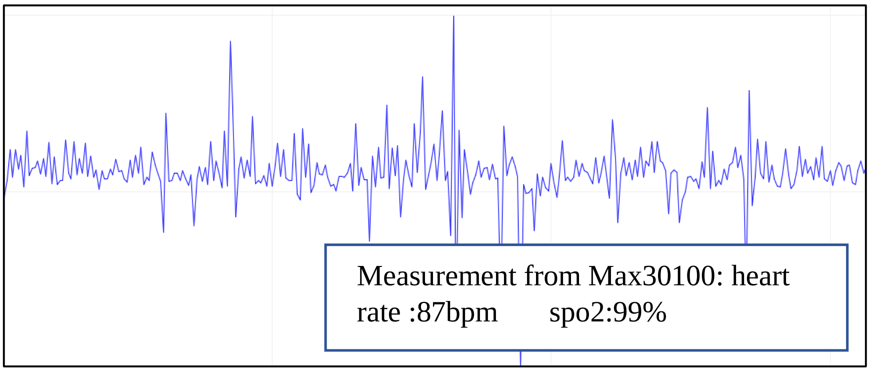
<tr><td>Soon after activity</td><td>
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4. Conclusion

In medicine and healthcare, digital technology can help transform an unsustainable healthcare system into a sustainable one, by equalizing the relationship between medical professionals and patients and providing fast and more effective solutions. In this project, a remote cardiac monitoring system has been implemented with a mean error of less than 1 %. This implies that the system may be useful for people who need to be closely monitored during strenuous exercise or everyday activities, especially those who have risk factors for heart disease or conditions related to the heart. As far as the cost constraints are concerned, once the medical industry implements such technology, its benefits can be realized in terms of the IoT as it will speed up the rehabilitation system measurement process, where the medical staff can monitor the patient's, cardiac activities remotely using the system.

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References

[1] A. Mariya Chithra Mary, S. Veerakumar, R. Babu, "Health Monitoring Systems using IoT," International Journal of Engineering Research & Technology, vol. 6, no. 7, pp. 1-4, 2018. doi: 10.17577/IJERTCONV6IS07074.

[2] Chaithra, C. T. Amrutha, N. K. Rajesh, "Heart Attack Detection System using IoT," International Journal of Engineering Research & Technology, vol. 7, no. 8, pp. 1-4, pp. 1-3, 2019. doi: 10.17577/IJERTCONV7IS08051.

[3] S. Gowrishankar, M. Prachita and P. Arvind, "IoT based Heart Attack Detection, Heart Rate and Temperature Monitor," International Journal of Computer Applications. vol. 170. pp. 26-30, 2017. doi:10.5120/ijca2017914840.

[4] H. Bhardwaj, K. Bhatia, A. Jain and N. Verma, "IOT Based Health Monitoring System," 2021 6th International Conference on Communication and Electronics Systems (ICCES), 2021, pp. 1-6, doi: 10.1109/ICCES51350.2021.9489207.

[5] G. K. Sahoo, S. Ari and S. K. Patra, "ECG signal analysis for detection of cardiovascular abnormalities and ischemic episodes," 2013 IEEE Conference on Information & Communication Technologies, 2013, pp. 1055-1059, doi: 10.1109/CICT.2013.6558254.

[6] P. Leijdekkers and V. Gay, "Personal Heart Monitoring and Rehabilitation System using Smart Phones," 2006 International Conference on Mobile Business, 2006, pp. 29-29, doi: 10.1109/ICMB.2006.39.

[7] B. Sandeep, “Remote Healthcare Monitoring System Using Arduino Board over Distributed Ubiquitous Environment,” International Journal of Innovative Research in Computer and Communication Engineering, vol. 5, no. 4, pp. 816-8195, 2016.

[8] A. Nduka, J. Samual, S. Elango, S. Divakaran, U. Umar and R. SenthilPrabha, "Internet of Things Based Remote Health Monitoring System Using Arduino," 2019 Third International conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), 2019, pp. 572-576, doi: 10.1109/I-SMAC47947.2019.9032438.

[9] A. Rajasekaran, and G. Indirani, “Real Time Health Monitoring System Using Arduino with Cloud Technology,” Asian Journal of Computer Science and Technology. vol. 7, pp. 29-32, 2018. 10.51983/ajcst-2018.7.S1.1810.

[10] A. Archip, N. Botezatu, E. Şerban, P. -C. Herghelegiu and A. Zală, "An IoT based system for remote patient monitoring," 2016 17th International Carpathian Control Conference (ICCC), 2016, pp. 1-6, doi: 10.1109/CarpathianCC.2016.7501056.