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DEVELOPMENT OF A WIRELESS WEARABLE HEALTH MONITORING SYSTEMWITH WEBAND MOBILE TRACKING SYSTEM

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ABSTRACT

Health Monitoring Systems (HMS) is becoming increasingly ubiquitous supported by recent technological advances and influenced by high healthcare costs. Health is a necessary aspect in our daily routine and it would make it easier for people to act upon the condition that they are having with these systems. This research paper aims to develop and design a scalable and feasible model of an HMS through advanced sensor and communication technology. The Proof of Concept can be achieved by utilizing low-cost sensors and microprocessors such as heart rate sensors, MAX30205 body temperature sensor, and the NodeMCU. The NodeMCU is an amazing little chip that has onboard WiFi capabilities and will be the way in communicating to Adafruit IO through MQTT protocol. Adafruit IO has feeds and dashboards that will serve as a visual representation of the metadata about the sensor data you push to Adafruit IO from the NodeMCU board. This technology can increase the capacity of physicians to treat and monitor more patients, can offer better access to healthcare, and assures patients to get that daily information about their conditions.

Keywords: health system, mobile tracking, microprocessor systems, control systems, advanced sensors.

1. INTRODUCTION

Remote wireless sensor applications have the prospective to change our lifestyle in different areas in our lives. An area to be considered as a center of attention is the wireless technology application in the healthcare industry. Recent and ongoing technological advances in sensor and communications technology have paved the design for achieving portable, lightweight, and intelligent medical sensor nodes that can be equipped strategically to a body part. Health parameters such as blood pressure, heart rate, and temperature can be easily known through an assortment of sensors and integrated into a control system to process the respective sensor data. Measurements should be indeed given practical criteria such as it should be appropriate & relevant, it should be brief and easy to administer and feasible for routine use.

Sensory systems can either be implemented as wearable or as implantable in healthcare applications [1]. These systems or devices have set foot in both biology and medicine applications such that it can monitor, track and record physiological signs of people significantly improving the supervision of health [2]. Wearable technology can be positioned on different body parts such as your head, body, arm, and foot dependent on the parameter the user or medical professional needs. Reducing healthcare costs which is a huge load to the marginalized is vital as it can be used as clinical tools providing improved and ease for users.

Consideration must be evaluated and regarded during the design and usage of wireless technology such as Bluetooth, IEEE 802.11, medical telemetry, and wireless service such that it should achieve minimum interference within its operation frequency of other nearby RF devices. ISO 14971 is established for this reason and establishes the standard of risk management associated with medical devices to control these kinds of systems [3].

2. BACKGROUND OF THE STUDY

In 1625, Santorio of Venice produced methods and techniques for measuring body temperature using a spirit thermometer and timing the pulse rate with a pendulum. He demonstrated the operation of a thermometer using a glass globe linked to a glass tube that was submerged in a bowl of water. As the globe was being heated, water was sucked into the tube as the temperature went down and the level of the water reached was marked every variation of temperature [4].

Additionally, pulse diagnosis is a vital part of understanding our health conditions and has served a purpose in the earliest times [5]. It was only with the dissemination of "Pulse-Watch" by Sir John Floyer back in the year 1707 that the first research-based report concerned with the pulse rate emerged.

The next reasonable step was to develop a system to enable medical professionals in a single, indefinite time to monitor important signs of heart rate, respiratory rate, temperature and blood pressure. In the 1952 'cardiac tachystoscope' invention of Himmelstein and Scheiner and in the 1960 improvement of company physiological surveillance systems resulted in the continuous improvement of HMS technology.
As monitoring and logging of vital patient signs in the course of medical care was long carried out, medical professionals were only able to see essential sign portrayals on the screens of early patient monitors through advances in digital electronic technology

As technology continued to grow exponentially through the 1990s and 2000s, patient monitor systems have been easier to use and distribute to every patient and medical professional globally. Innovations in mobile and electronic healthcare have changed fundamentally relationships among doctors and patients by spreading out the capabilities of health monitoring devices. These devices can be unified into routines that supply essential information for administrations in both healthcare providers and patients [6]. The conceptualization of remote monitoring systems has already been introduced before but lately, a lot of investment and notice has been given attention to smart wearable body applications.

3. STATEMENT OF THE PROBLEM

Cardiovascular diseases (CVD), including heart attack and stroke, are among the top 5 causes of death in the country according to the Department of Health (DOH). Half of 579,237 registered deaths were not addressed and not taken care of. It was the opposite circumstance within these sevenregions namely in CALABARZON, NCR, CAR, Western Visayas, Northern Mindanao, Caraga, and ARMM [6]. This given fact alone emphasizes the necessity and opportunity of remote health monitoring through wearable devices.

Ischaemic heart disease has grown over the years and has been determined the fundamental cause of death in 2017 here in the Philippines while deaths related to hypertensive diseases have decreased. It is generally defined as a group of clinical-pathological syndromes which results due to an imbalance between oxygen supply and demand to the myocardium. Paths in either the large coronary arteries and branches may be constricting or closing which will lead to a critical condition. Heart attacks can be very difficult to anticipate even without evident signs, but heart rhythm disturbances can be discovered even before the incident can happen. With, this study proposes a feasible and low-cost wearable device that can measure heart pulse rates and physical activity to aid and prevent the shortcomings of unattended deaths as well as for improved health surveillance of patients.

4. SIGNIFICANCE OF THE STUDY

The possibility of remote health surveillance technologies is built from non-invasive and portable sensors, electronic circuitry, and advanced communication and information technologies. It is a huge opportunity in providing continuous patient monitoring and can improve our quality of life through timely detection and utilizing cost-efficient equipment. It can allow people to be reassured knowing their conditions such as heart rate, temperature, and physical activity in their respective workplaces, homes, and communities. These remote systems can keep an eye on very important physiological parameters in real-time, come up with feedback accordingly, and provide medical professionals ease in remotely monitoring their respective patients. It can be an impressive measure of prevention, life support, and long-term surveillance among disabled or ill patients [7]. The main advantage of this system is that anyone can bring it anywhere they see fit because the device is designed to be pocket-sized, simple, and wireless. Patients' necessities can easily be addressed by providing real-time data to someone's mobile phone, computer, smart display, or any devices that can be connected to the Internet [8]. It is also designed to provide services a vast quantity of biomedical information from a variety of patients with a variety of physiological conditions. On that account, huge demand can be met in developing and continuously producing these systems which are uncomplicated to operate for patients and the elderly.

5. DESCRIPTION OF THE SYSTEM

The proposed study is comprised of a control system that will be placed on a wristband for the sole use of monitoring, observing and tracking one's health parameters. The control system consists of a heart rate sensor, body temperature sensor, 0.9 inches OLED screen display and the NodeMCU board. A lithium-ion rechargeable battery rated at 3.7V, 1A will be utilized in powering the whole system. The system will be making use of the MQTT protocol in communicating with the sensor data to Adafruit IO which is an internet service platform that enables IoT devices to post data. The pulse sensor's operation is a PPG used for non-invasive heart rate monitoring. It is composed of an LED beside an ambient light sensor on one side which is controlled by the circuitry on the other side. Its circuitry is made up of amplification and noise cancellation. To detect the internal temperature of a user, the MAX30205 temperature sensor is used. The resulting data of the sensors will be displayed on a 0.9-inch OLED screen display which is also attached to the wristband to be able to see the data in real-time. The resulting data will also be published to the internet service platform Adafruit IO which can be visually seen in web browsers or on a mobile application.

6. METHODOLOGY

In Figure-1 the general block diagram on how the methodology was created was shown.

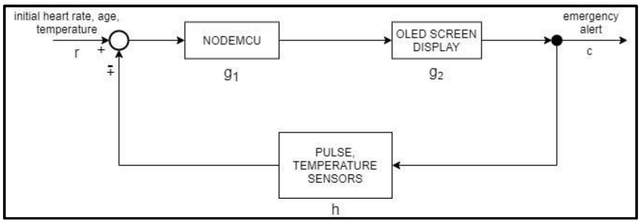

Figure-1. General block diagram.

6.1 Microcontroller

The NodeMCU is very popular open-source hardware and has a wide range of applications that are composed of a very affordable SoC called the ESP8266. Its pin layout is illustrated in Figure-2 and is powered through a 3.7V 1000mAh lithium-ion rechargeable battery and will respectively power the sensors and OLED display through the microcontroller. Figure-2 shows the pin layouts.

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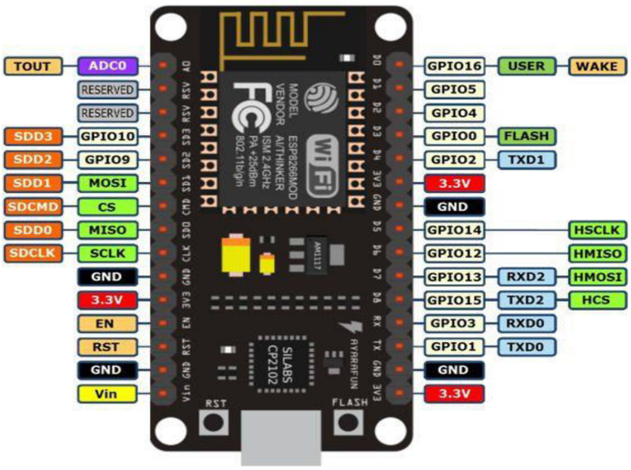

Figure-2. NodeMCU pin layout.

6.2 Data Acquisition Unit (D.A.U.)

The D.A.U. is mainly composed of the NodeMCU microcontroller, pulse sensor, and MAX30205 body temperature sensor. The pulse sensor is responsible for measuring the user's heart rate variability and hands over the data to the microcontroller. MAX30205 is placed strategically to the wrist for body temperature measurement. The microcontroller processes the information received from the sensors, compares to the values from the inputs, and then evaluates the user's condition accordingly. It sends the values to the OLED screen display for a visual representation to the user and as well as to the internet service platform Adafruit IO to access the data remotely from web browsers or mobile applications.

6.3 Telemetry

Message Queuing Telemetry Transport or popularly known as MQTT enables devices to publish or subscribe data from sensor nodes to a server, which is also called as a broker, and can be utilized as a means of wireless communication between machines. It is designed for devices with low bandwidth and the protocol is very ideal to use due to its battery power conservation. Applications of the protocol cover a wide range from home automation, healthcare technologies, and other real-world experiences.

6.4 Expected Output and Results

Heart rate is a very important health gauge that everyone should consider. It would vary from person to person but a normal range is between 60 and 100 beats per minute (bpm). Factors such as stress, anxiety, activeness, etc. can affect the pattern of your heart rate. According to the American Heart Association (AHA), the maximum heart rate during physical activities can be calculated by subtracting the age of a person from 220. Table-1 shows the normal heart rate according to [9].

Table-1. Normal heart rate [9].

Age	Normal heart rate (bpm)
Up to 1 month	70 to 190
From 1 to 11 months	80 to 160
From 1 to 2 years	80 to 130
From 3 to 4 years	80 to 120
From 5 to 6 years	75 to 115
From 7 to 9 years	70 to 110
Over 10 years	60 to 100

50-70% of the maximum heart rate is the ideal heart rate during modest physical activities while 70-85% in strenuous activities of the maximum heart rate. Table-2 shows the maximum average heart rates according to [10].

Table-2. Average max. heart rate and target heart rate zone [10].

Age	Target HR Zone 50-85%	Ave. Max. Heart Rate 100%
20 years	100-170 bpm	200 bpm
30 years	95-162 bpm	190 bpm
35 years	93-157 bpm	185 bpm
40 years	90-153 bpm	180 bpm
45 years	88-149 bpm	175 bpm
50 years	85-145 bpm	170 bpm
55 years	83-140 bpm	165 bpm
60 years	80-136 bpm	160 bpm
65 years	78-132 bpm	155 bpm
70 years	75-128 bpm	150 bpm

*** beats per minute (bpm)

Body temperature is substantial regard in biological conditions and diagnosis. The normal human body temperature is usually between 36.5 °C and 37.5 °C. Several factors can greatly influence body temperature such as age, time of the day, activeness, etc. of the user. Table 3 shows the effects of Body Temperature according to [11].

Table-3. Variations of body temperature and its effects [11].

BODY TEMPERATURE	EFFECTS ON BODY
44 ºC (111.2 ºF) or greater	Death will occur almost certainly.
43 ºC (109.4 ºF)	Usually death, serious brain damage, Cardio-respiratory collapse, continuous convulsions, and shock.
42 ºC (107.6 ºF)	The person might turn pale or remain flushed and red. One might become comatose, be in severe delirium, vomiting, and convulsions could occur. Blood pressure (BP) might be high or low. Heart rate would be very fast.
41 ºC (105.8 ºF)	Dizziness, fainting, severe headache, hallucinations, vomiting, delirium and drowsiness might occur. Palpitations and breathlessness could occur too.
40 ºC (104.0 ºF)	Begins to be life-threatening. Fainting, headache, breathlessness, dehydration, weakness feeling, vomiting and dizziness along with profuse sweating.
39 ºC (102.2 ºF)	Profuse sweating, flushed and red. Exhaustion, fast heartbeat rate and breathlessness.
38 ºC (100.4 ºF)	Thirsty, uncomfortable, sweating, feeling of hunger, chillness feeling too.
36.5-37.5 ºC (97.7-99.5 ºF)	Normal body temperature.
36 ºC (97 ºF)	Temperature becomes this low while sleeping may be normal.
35 ºC (95 ºF)	Shivering, numbness and grey/bluish colouring of the skin. Heart irritability may occur.
34 ºC (93 ºF)	Disablement of finger movement, shivering.
33 ºC (91 ºF)	Lot of confusion, drowsiness, lessening of reflexes, slow heart rate, breathing is shallow.
32 ºC (90 ºF)	Hallucinations could occur, delirium, a lot of confusion, extreme drowsiness progressively becoming comatose. Absence of shivering.
31 ºC (88 ºF)	Comatose, conscious rarely. Very fewer reflexes. Shallow breathing and slow heartbeat. Serious heart rhythm problems may occur.
28 ºC (82 ºF)	Heart rhythm disturbances to be severe, breathing might stop anytime. The person might appear dead.
24-26 ºC (75-79 ºF) or less	Irregular heartbeat or respiratory arrest usually causes death.

7. REVIEW OF RELATED LITERATURE

Chan, M., Estève, D., Fourniols, J.-., Escriba, C., & Campo, E. (2012) published a journal regarding the current status and future challenges of Smart Wearable Systems (SWS). The researchers reviewed and simplified an abundant amount of research, technological advancements, and prospects of SWS. They discussed various materials and methods on how Smart Wearable Systems have exponentially grown and influenced healthcare services to dependent persons in need of these systems. These technologies will give birth to a smart environment that will assist health care issues at long distances. The journal discussed when, where, and how SWS can be used in providing care, management, and support to patients or individuals anywhere at any time. Vital parameters such as Electromyogram (EMG), Electroencephalogram (ECG), activity, respiration rate, heart rate, blood glucose, etc. that wearable systems can assess have been enumerated. Location of sensing technology systems that can be either worn, implanted, embedded is a necessary understanding to strategically devise and optimize the systems' performance. Electronic device platforms have been highlighted wherein some prototypes were based on microcontrollers, sensors, and GSM-based cellular communication link. A handful of wireless systems were reviewed that are capable of measuring Phonocardiography (PCG), body temperature, blood pressure, ECG, and body movements. The use of SWS should be inclined towards the needs of users for these technologies to be effective and globally accepted [12]. The idea of implementing wireless sensor technologies for biomedical applications has been found positive from the participants. A cost-benefit analysis would be of great interest in viewing this as an opportunity for mass production. Further research, experimentations, and iterations must be considered to be able to make these as fully functional and technologically acceptable products in terms of commercialization, market penetration, and adoption by users.

According to Thamaraimanalan and Sampath (2018), a mixed-signal processor that consists of an Analog to Digital Converter (ADC) and digital signal processor must be present whenever performing or detecting ECG [13]. In their paper, circuit complication and power management are important aspects to consider in terms of their fuzzy logic-based variable resolution controller proposal. Their target is to model the ADC in a well-organized manner and competent way. Preferences in applying wireless ECG technology are inclined towards the elderly, athletes, clinical usage, and ambulances which have some disadvantages which can be high power consumption, range of operations the device can be run on, and portability. The research emphasized how the fuzzy set theory plays an important role in dealing with uncertainty when making decisions in medical applications. This kind of approach can benefit the capabilities of smart health monitoring systems in calculated and improved decision-making for actionable feedback based on the given initial and sensory data. In this paper, the team had to further reduce the power consumption; therefore they adopted a power gating technique for static power reduction. The respective signals are transmitted to the ADC for it to be in digital form which in turn the FLC adjusts accordingly. The software used to process, analyze, and model the proposed design is Matlab R2010a which can handle such computing power [14].

IoT Based Health Monitoring System Using Blynk App is recent research produced by Priyanka and Reji (2019) [15]. The research made use of ESP32 as the microcontroller, DS18B20 as the temperature sensor, a blood pressure sensor, and Blynk, an open-source Android application. Measurements such as temperature and blood pressure in terms of diastolic/systolic are connected through the ESP32 microcontroller in analyzing and storing the data. Programs are configured and coded through the Arduino Integrated Development Environment (IDE) which is compatible with the ESP32. The microcontroller can perform as a complete standalone system or as a slave device with integrated Wi-Fi and dual-mode Bluetooth which is integral in communicating with the Blynk app and server. The system detects whether the user has low or high blood pressure and as well as low or high temperature which is necessary for determining the health condition of the user.

Mukherjee, Bhole, and Sonawane (2019) designed and developed a scalable IoT framework for healthcare applications [16]. The objective of this study is to continue monitoring the physiological parameters of a patient and a customized Matlab-based GUI is designed to perform real-time analysis of sensory data. The system was implemented on a wearable band that can be worn as a wristband by any patient and it consists of temperature, pulse, and ECG sensors. MSP430 microcontroller is utilized in processing the necessary data wirelessly and over the cloud platform. The research is comprised of several blocks in attaining the reliability and success of the system. The transmitter and receiver block is responsible for transferring data to and from the web-based dashboard over Wi-Fi for a visual representation of the data. It enables the sensor block to post and fetch data which are used for monitoring the health status of an individual. The research provided valuable consideration in power management as the MSP430 microcontroller utilizes a flexible clocking system and a variety of operating modes designed to reduce power consumption and hence, extending battery life. The current drawn from the microcontroller is in the range of 100–200 µA/MHz and less than 1 µA during a standby mode and can also operate down to 1.8 V, which is a superior power specification. A detailed power management evaluation translates to extensibility that can cater to larger circuit applications and markdown power consumption costs.

8. THEORETICAL CONSIDERATIONS

Application areas of accessory-based wearable health monitoring systems must be strategically constructed and evaluated especially when using microprocessors and sensors on the human body. It is efficient in utilizing open-source platforms and low-cost sensors to be able to devise such mechanisms and programs. With that in mind, this research made use of the NodeMCU development board which runs on the ESP8266 Wi-Fi System-on-a-Chip (SoC) and the Arduino IDE software to be able to run programs on the board. It will serve as the central processing unit of the system to relay data back and forth to the various sensors, OLED display, and internet service platform Adafruit IO. Adafruit IO can present real-time data, connect your projects online, and has a lot more services to offer in the field of IoT. It can accommodate and integrate several feeds of data and has a dashboard for visual representation which has a lot of choices for your preference as to how you want to display your data. All of which are freely available online and an associated mobile application ready for download.

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MAX30205 body temperature sensor has multiple functionalities besides being able to measure temperature such as having an alarm or interrupt when the maximum limit of the sensor is reached [17]. The acquired data read for temperature is being converted with the use of an Analog-to-Digital Converter (ADC) and can be interfaced through the I2C communication protocol. Through it, you can write, read, send, or receive byte commands to relay the temperature data to over 32 available addresses. The supply voltage range of the device is from 2.7V to 3.3V, can draw current up to 600µA, and is easy to grasp for convenience.

Heart rate information can be very handy whenever you're out for a 3-kilometer run, running on a treadmill, anxious or nervous. Heart rate variability or HRV is one of the techniques that are vital in assessing the health conditions of a person. It is the change or difference in condition at a given time interval in milliseconds between consecutive heartbeats. Reliability will increase as the assessment and measurement of each heartbeat at the given time interval is precise. The usual level of HRV at calm circumstances should be climbing up while HRV at tense and anxious moments should decrease. The pulse sensor used in this research is made up of an LED with a photodetector alongside it and a circuit responsible for the amplification and noise cancellation. The LED with the photodetector must be strategically placed over a vein on our body which will be in control of detecting the blood flow rhythm inside of our veins only when the heart is pumping. If there is a flow of blood identified, therefore we can be able to measure and evaluate the heart rate as well. The LED will emit light which in turn provides the requirements for the photodetector to pick up light whenever a flow of blood passes by. Every time that this will happen, the circuit will be able to analyse the behaviour over a given time interval and will be able to calculate the heartbeat based on these readings.

Placement on the human body is an important consideration concerning the application of wearable health monitoring systems. These systems are more preferred to be positioned on the head, neck, and arms as its size and weight are not recognizable or a disturbance in these regions [18]. This research chose to locate the device on the wrist region because it is one of the best places to find your pulse and resembles in wearing a watch.

9. DATA AND RESULTS

Tables 4, 5 and 6 show the user's corresponding heart rates, resting heart rates and temperatures.

Table-4. Users' corresponding ages and average heart rates.

USER	Age	Average Maximum Heart Rate (100%)	Target Heart Rate Zone (50-85%)
1	22	198bpm	99-168bpm
2	24	196 bpm	98 - 166 bpm
3	20	200 bpm	100 - 170 bpm
4	19	201 bpm	100 - 171 bpm
5	20	200 bpm	100 - 170 bpm
6	22	198 bpm	99 - 168 bpm
7	21	199 bpm	99 - 169 bpm
8	21	199 bpm	99 - 169 bpm
9	22	198 bpm	99 - 168 bpm
10	24	196 bpm	98 - 166 bpm

Table-5. Users' resting heart rates.

USER	Resting Heart Rate (stethoscope)	Resting Heart Rate (wearable)	% Error
1	72bpm	74bpm	2.77%
2	79bpm	79bpm	0%
3	95bpm	94bpm	1.05%
4	82bpm	82bpm	0%
5	84bpm	82bpm	2.38%
6	80bpm	81bpm	1.25%
7	95bpm	95bpm	0%
8	97bpm	96bpm	1.03%
9	83bpm	83bpm	0%
10	92bpm	90bpm	2.17%

Table-6. Users' body temperatures.

USER	Temperature (thermometer))	Temperature (wearable device)	% Error	Effect
1	36.6°C	36.6°C	0%	Normal
2	36.7°C	36.7°C	0%	Normal
3	37.1°C	37.0°C	0.27%	Normal
4	36.6°C	36.6°C	0%	Normal
5	36.4°C	36.4°C	0%	Normal
6	36.5°C	36.5°C	0%	Normal
7	36.9°C	36.9°C	0%	Normal
8	36.5°C	36.5°C	0%	Normal
9	36.7°C	36.7°C	0%	Normal
10	37.2°C	37.3°C	0.27%	Normal

Figures 3 and 4 show the dashboard and mobile app.

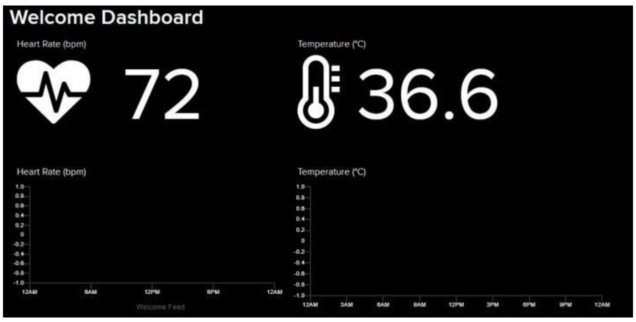

Figure-3. Adafruit IO dashboard

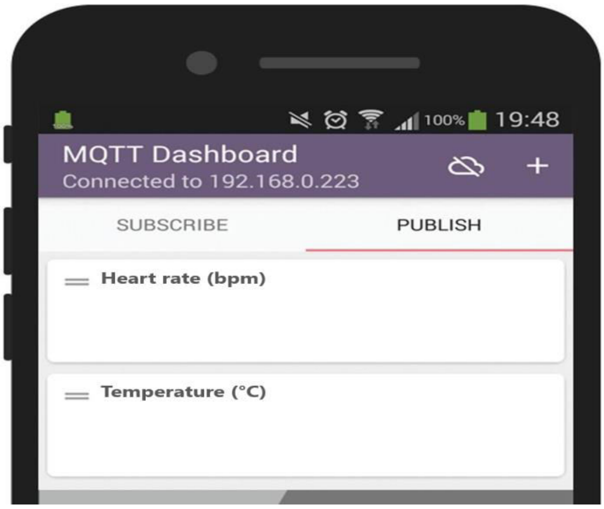

Figure-4. Adafruit IO mobile app.

10. ANALYSIS OF DATA

Resting heart rate can be measured by the number of times your heart beats per minute when you're at rest [19]. The best time to check the resting heart rate is after waking up in the morning. 10 users were evaluated in measuring their respective heart rates after a good night's sleep. Table 2 shows their respective resting heart rates based on measurements of an actual stethoscope and the wearable device. An average of 1.065% error rate was concluded from the measurements. The target heart rate is between 60 and 100 beats per minute (bpm). Factors such as stress, anxiety, obesity, and hormonal imbalance can either be a good or bad influence on the user's heart rate. An active person may have a resting heart rate less than 60 beats per minute and can still be normal [20,21]

The temperature of a patient's body can be measured by the sensor by physically touching the skin of the user. This research made use of the MAX30205 body temperature sensor which offers ±0.1°C maximum accuracy for thermometer applications. The above experiment has been implemented on 10 users on a mixture of identical and non-identical ages. Table 3 illustrates the various body temperatures from the different users that averaged a 0.054% error rate in terms of temperature readings. It also provides the effect of the temperature on the body which all are in Normal condition. This lays out a better and structured way of communicating with doctors or any area of the medical profession for patients that require frequent medical check-ups.

11. CONCLUSIONS

We have successfully developed a system that would monitor the temperature and heart rate of the users and continuously send the sensor values to the OLED display and Adafruit IO. The heart rate is one of the vital signs or important indicators of health in the human body. The system has accurately measured the users' body temperature values and has evaluated the category that is fit for a certain value of body temperature. Visual representation of the data was achieved through the availability of Adafruit IO for publishing and subscribing sensor data. Sensory data are also published onto the OLED screen display for a visible demonstration regarding their present conditions. Communicating from the device wirelessly exhibits convenience and portability for potential consumers. Partnership and understanding among medical professionals and patients are an advantage for the growth and development of economical wireless systems. The evolution of wearable wireless health monitoring systems and their ability to track user behaviour, physiological information, and evaluate symptoms accordingly have paved the way in revolutionizing HMS. Further improvement and rigorous research can provide a better overall experience for users.

12. RECOMMENDATIONS

Wearable devices such as health monitoring systems have made profound progress and primarily helped in technical challenges such as on-body computing, integrating electronics on functional garments and improved user interface. Space constraints, miniaturization, power management, and cost are some challenges to face in devising wearable health monitoring systems. All should be considered and strategically formulated for it to be successful and feasible. As new functionality is added, wearable devices are disruptive to classical uses of accessories and garments. Large and inflexible design affects the physical vibe and should be avoided. Market price and production cost is a key concern for adoption.

At present, toggles and buttons are the main functions in interacting and controlling data for wearable devices. It would be recommended to implement a voice assistant in interacting with the user to evaluate the user's history on certain health parameters. It can also be assisted with machine learning in optimizing the user's data history and being able to give actionable feedback to users. With the continuous progress made in the wearable industry, there is an opportunity to make this part of our daily routine and daily outfit. As it may be a part of our everyday outfit, these devices are exposed to severe stressors that must be heavily considered in designing a prototype and fully functional product as these will affect the performance and reliability.

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