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IoT for a More Reliable and Safer Patient Monitoring Healthcare Service during the Pandemic

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ABSTRACT

The internet of things (IoT) has been widely identified as one of the best solutions to make a smart life for human beings. Moreover, it can also be applied to alleviate the pressures on healthcare systems that improve the access and quality of care and essentially reduce the cost of care. This research presents a method to apply the IoT health monitoring method to hospital wings and make a much-developed smart healthcare service that is more comfortable and safer, especially in a pandemic situation. This paper proposes a real-time monitor system consisting of healthcare wearables such as BPM (beats per minute) meter, body temperature meterand central communication hub. This research mainly focuses on making a more comfortable health monitoring system compared to other modern-day systems. Moreover, the purposed system consisted of several data presentation methods for easier data analyzing on the patient.

Key words: IoT (Internet of Things), Real-time patient monitoring, Health Wearables, Smart life, Pandemic situation

1. INTRODUCTION

Internet of Things (IoT) is the network of anyone, anything, anyplace, any service, and any network. IoT is an emerging trend in networking technologies, and it can transfer data over the network without any human to human or human to computer interaction. Therefore, it provides solutions for a wide range of applications which are troublesome such as traffic congestion[1], smart home applications [2] security, emergency services, logistics [3], retails, industrial control [4], and even in health care[5].

IoT has great potential in the medical and health care sector applications, and it will improve the convenience and effectiveness of medical tasks. These healthcare systems also reduce costs, make a more comfortable life, and enhance the user's experience. Some IoT-related medical applications are home healthcare, electronic healthcare, mobile healthcare and hospital management [5]. Not only in pandemic situations, but IoT applications can also be used in chronic disease monitoring [6]. Also, IoT can be applicable for elderly care, infant care and fitness programs.

With the increasing population, the demand for the hospital facilities also increases as well. This demand will cause to have a heavy workload for nurses and doctors. Considering a country like Sri Lanka, the current situation is that doctors have to go around the wards to examine the patients at least twice a day, which happens to be a difficult, time-consuming task. Moreover, it can be risky for doctors also considering a pandemic situation [7]. If there were a method to monitor patients remotely, it would make these tasks easier and efficient for medical professionals, and potentially it will be more secure for both parties in pandemic situations. Currently, this remote monitoring is restricted to patients with particular diseases like diabetes, Parkinson's disease.

Reliability of data and data storing methods of the current manual system is inefficient, and since the data is recorded only in papers, they might lose in unexpected situations. Therefore, a much reliable system for patients' data recording should be introduced.

When considering residence patients' situation, it is not practical and suitable for a patient living far away from a hospital to go to the hospital for vital conditions checking if it is necessary to measure those parameters every day. Remote patient monitoring systems will help the doctors examine the patients from faraway places and give them treatment or inform their condition with ease.

In the first section, introduction about the IoT and how it's used in the medical sector has been discussed and in the second section the related works regarding the research is mentioned. In the section three, the methodology which was used for constructing the IoT based wearable device is mentioned and in the fourth section results have been discussed. The final conclusion is mentioned in the fifth section and in the section six, future work has been mentioned.

This paper provides a comprehensive description of designing wirelessly charged IoT health wearables for real-time monitoring of patients. This system monitors body temperature, beats per minute (BPM) of the patient. These vital conditions are measured using required sensors which are powered by batteries. Reasons for using IoT in this application would be,

- More convenient for a wearable to access data.
- In order to reduce the components inside the wearable to miniaturize the product.
- To connect or view the necessary data with minimum time delay (Real-time monitoring).
- To analyses and gather data in more effective way.

The real-time data from sensors are transferred to a database via Wi-Fi and the data is stored in the database which ensures the reliability of data storing. Users (medical officers) can access the data at any time and they can check the past data.

2. RELATED WORK

2.1 Why is there a trend to use IoT for engineering applications?

The biggest reason is that the IoT concept creates a platform (via the internet) to transfer data between multiple senders and multiple receivers. Therefore, engineering applications involving remote monitoring and controlling can be updated to the global network level with ease. Most of the accessible data on the internet is stored in cloud-based servers, and hence due to the high redundancies, they often become more reliable than local storage solutions. Not only cloud-based storage, due to the improvements in network latencies, it is also more suitable to use cloud-based processing [8] of data which may contribute to lowering the cost of the equipment. Nowadays, many companies supply cloud server storage services for free (up to a specific limit of data size). Therefore, it has become a very reliable, efficient and cost-effective method of storing and sharing data. The IoT concept enables users to create multiple receiving/accessing points for data using cloud server storages.

2.2 Current IoT applications in the medical sector.

On the present day, there are several applications which have acquired IoT concepts such as smartwatches, wearable fitness trackers, etc. Also, there is a product called “MySignals Platform” which is developed by a global company named “Libelium”. My signals Platform device has the ability to monitor some essential conditions of a person. This device is composed of 18 body sensors such as blood pressure, blood oxygen, blood glucose level, etc. [9] Whatever the condition level monitored by this device updates it in their own cloud server where the user has access via a smartphone application.

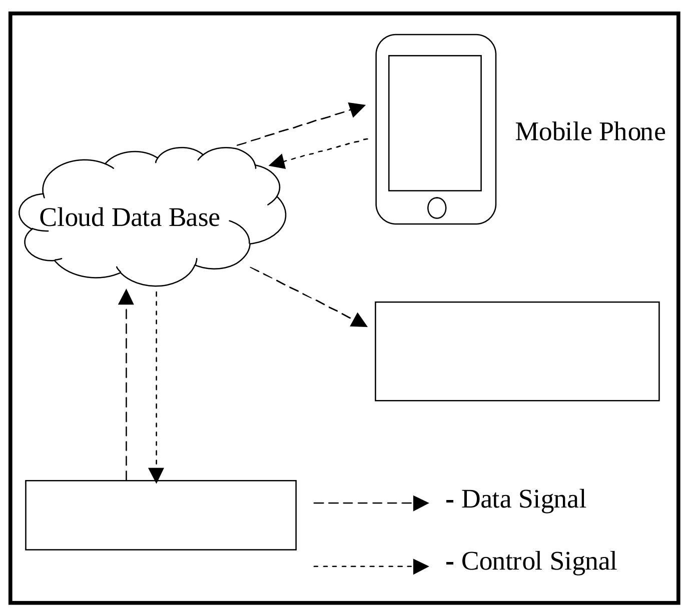
3. DESIGN APPROACH AND METHODOLOGY

3.1 Design Approach

The initial design concept was to design wearables which are able to measure the patient’s vital conditions and send gathered data to a database with low latency, where it’s kept for further processing. Low latency is essential for a situation where the measured data is highly sensitive to time and if in abnormal conditions emergency treatment is required with minimum time delay. The main issue was to select which are the sensors that’s essential for frequent measurements and what should be the communication method with the internet. The sensors have to be compact and should have a low power consumption [10] while being accurate in order to use in the medical sector. Although there are wearable devices which are used for medical purposes, most often the data is encrypted [11] in the communication process. Therefore, we have designed and built our own measuring devices (excluding the sensors) which are able to measure and send data according to our preferences.

The represented project has two types of sensors. A modular approach was implemented for the implemented sensors [12]. This approach will be more useful when implementing the future updates and upgrades to the device in order to be compatible with more and more sensors instead of restricting only to a few initial sensors. Since cost of the device is also a major factor, the modular approach will improve the repairability of the wearable for improved longevity. Our main design comprises three units. They are the main wearable device, Communication hub and real-time monitoring and controlling software platform with cloud storage and processing.

3.2 Methodology



The presented health monitoring system is consisted with mainly three parts.

Figure 1: Basic Structure of the Patient Monitoring System

i.Wearable device
ii. Main communication hub
iii.Mobile application

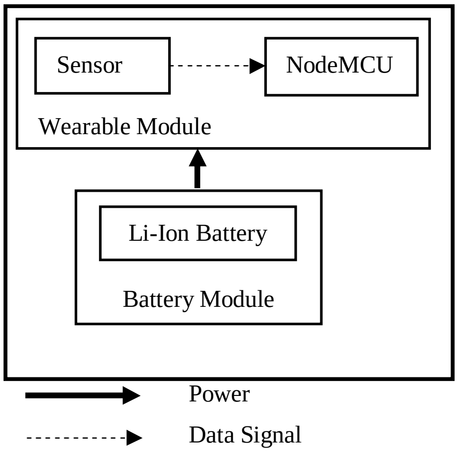


Figure 2: Wearable Device

The wearables can measure vital body conditions such as body temperature and heartbeats per minute. The system uploads the measured data directly to the cloud server database. These data are available through Raspberry Pi-3 microcontroller and mobile phone application. The patient's monitored conditions are displayed through both HMI and mobile phone application.

3.3 Wearable Devices

The main wearable device enclosure has consisted of two rooms to connect the battery module and sensor module.

Two sensors are used in this scenario. They are,

- Body temperature measuring module (sensor module)
- Heart rate (BPM) measuring module (sensor module)

Moreover, the other module is the battery module.

Two approaches were considered in the process of designing wearable. That is either to contain the sensors necessary fixed inside the device or to go with a modular approach. The modular approach was considered due to ease of upgrade over the lifetime and ease of maintenance even though the fixed method uses less space for the wearable device.

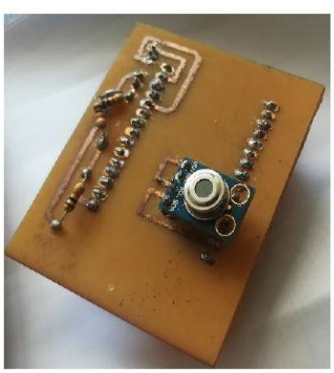


Figure 3:MLX90614 Thermo Sensor with the wearable Circuit

The wearable module is facilitated with NodeMCU, which has an in-built Wi-Fi module. That facility enables to upload the measured data to the cloud database. The two sensors used in this scenario are a contactless body temperature sensor and heartbeats measuring sensor. Two separate circuits were built to two sensors, with NodeMCU microcontroller [13].

The contactless temperature sensor is MLX90614. It is an Infra-Red thermometer. The MLX90614 is factory calibrated in wide temperature ranges: -40…125°C for the ambient temperature and -70…380°C for the object temperature. The MLX90614 offers a standard accuracy of ± 0.5 °C around room temperatures. A particular version for medical applications exists offering an accuracy of ± 0.2 °C in a limited temperature range around the human body temperature [14].

The other used sensor is KY-039 [15] heartbeat sensor module. This sensor uses bright infrared (IR) LED and a phototransistor to detect the pulse.

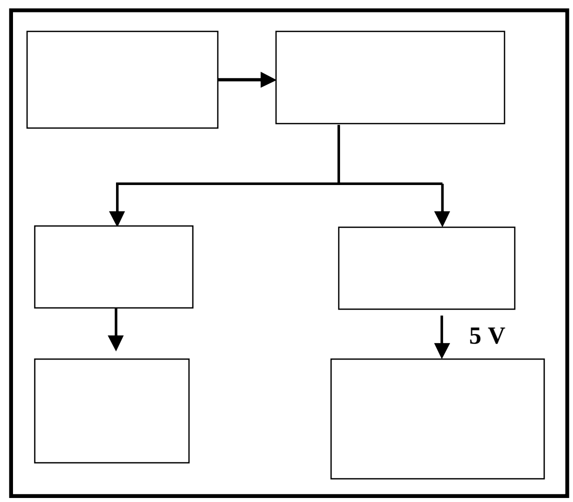


Figure 4: Communication Hub

3.4 Central Communication Hub

The central communication is used to display the patient's data through a HMI display.The Raspberry Pi 3 module is used as the microcontroller of the hub circuit. The Human Machine Interface (HMI) is used to display the patient's real-time monitoring data. It is connected to the Raspberry Pi 3 module, and the Raspberry Pi 3 module receives the patient's data through its built-in Wi-Fi facility. Moreover, the buck converters are used to adjust the DC voltage value for the Raspberry Pi module's required level, HMI unit, and wearable battery charging. ANDROID operating system is installed in the Raspberry Pi - 3 computer. Moreover, the "Appsheet" application is used to display the patient's data.

3.5Operation of the Software platform

For real-time monitoring procedure, two algorithms are implemented. One algorithm for wearable part sensors and one for the spreadsheet which is kept in a cloud database. BPM sensor module's microcontroller has the same algorithm structure as the body temperature sensor module's microprocessor algorithm. When considering the body temperature module, the wearable is automatically connected to the internet using Wi-Fi (Assuming that the proper setting up has been done). When the connection is successful, the wearable will make a communication path between the device and the spreadsheet in the "Google drive" [16]. The script of the spreadsheet is modified to enable, receiving of data in the corresponding column with the recorded time and date.

3.6Calibration Procedure

The calibration procedure for the thermal sensor was carried out in two ways. The first correction was for the thermal sensor distance, and the second one was for the skin temperature, core body temperature difference.

Table 1: Temperature Sensor data vs Standard Thermometer data

Temperature Sensor value (X)	Standard Thermometer value (Y)
29.6	29.4
32	31.0
34	33.2
36	35.1
38	37.5
40	39.6
42	41.8

According to the designed wearable, there is a 4mm distance between the skin and the thermal sensor [17]. Calibration was done for a sensor for an accurate reading. A 2nd order relationship was created using the calibration data, using a standard thermometer and the implemented wearable. "MATLAB" curve fit model was used for creating the model. The following relationship is constructed as a result.

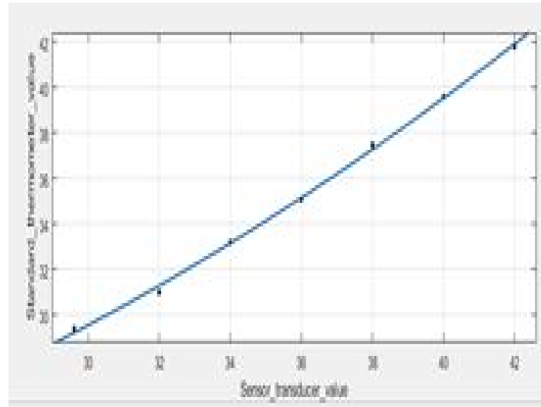
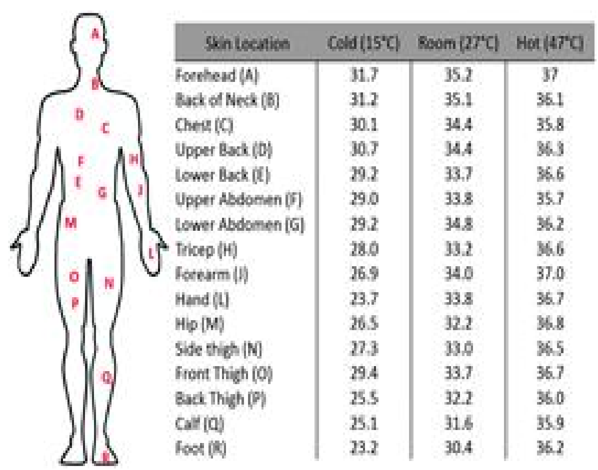


Figure 5: Temperature Sensor data vs. Standard Thermometer Data

$$y = 0.016\,x^2 - 0.1223\,x + 18.83 \qquad (1)$$

After the first calibration, considering the skin temperature vs core body temperature difference, adjustments were made to the code. This adjustment is based on a journal article in "European Journal of Applied Physiology and Occupational Physiology"[18],[19].

The values mentioned above are given for 37^{O}C. The wearables are prepared to wear at triceps. According to temperature correction, 37 ^{O}C – 33. 2 ^{O}C = + 3.8 ^{O}C should be added to the sensor reading at the average room temperature (27 ^{O}C).



Skin Location	Cold (15°C)	Room (27°C)	Hot (47°C)
Forehead (A)	31.7	35.2	37
Back of Neck (B)	31.2	35.1	36.1
Chest (C)	30.1	34.4	35.8
Upper Back (D)	30.7	34.4	36.3
Lower Back (E)	29.2	33.7	36.6
Upper Abdomen (F)	29.0	33.8	35.7
Lower Abdomen (G)	29.2	34.8	36.2
Tricep (H)	28.0	33.2	36.6
Forearm (I)	26.9	34.0	37.0
Hand (L)	23.7	33.8	36.7
Hip (M)	26.5	32.2	36.8
Side thigh (N)	27.3	33.0	36.5
Front Thigh (O)	29.4	33.7	36.7
Back Thigh (P)	25.5	32.2	36.0
Calf (Q)	25.1	31.6	35.9
Foot (R)	23.2	30.4	36.2

Figure 6: Skin Temperature calibration with Body core Temperature

4. RESULTS AND DISCUSSION

1/17/2019	37	65
1/17/2019	37	65
1/17/2019	37	65
1/17/2019	37	65
1/17/2019	36	65
1/17/2019	37	65
1/17/2019	37	65
1/17/2019	37	65
1/17/2019	37	65
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Figure 7: Google document with updated patient's data

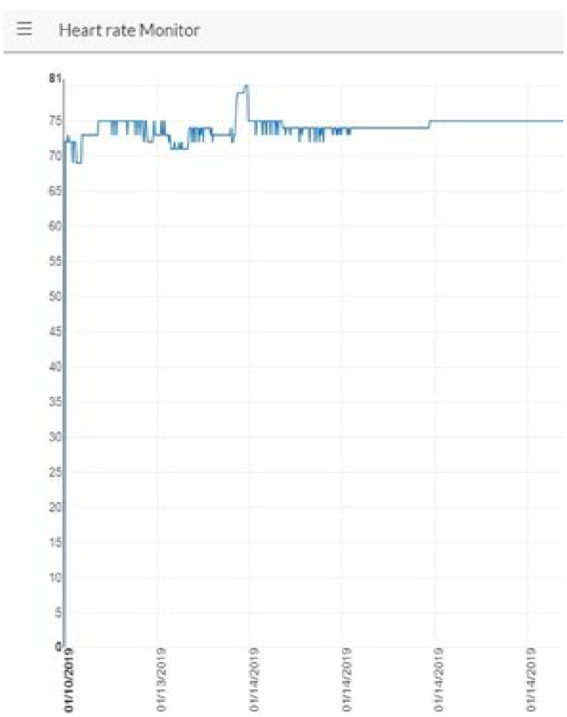

Figure8:“Appsheet” Android application with patient's updated data

Figure 7 shows the real-time data that are uploaded to the google drive.

- The first column shows the date. (For testing purposes, we only used date, not the time)
- The second column shows the temperature values.
- The third column is for testing purposes to check whether the spreadsheet can be accessed through the wearable.

Also, figure 8 shows the patient’s data presented through “AppSheet” mobile application. This application is programmed not only to represent present data but also to present past recorded data. These data can be accessed through from the HMI unit also.

When comparing with the recent research, this research mainly focused on designing a wearable powered with a battery and a central communication hub. Also, wearable devices have a novel design, convenient to patients since both the sensor and the battery can be replaced with another without removing the patient's wearable enclosure.

This design also represents three methods to display patient’s data while most of the systems only focus on one method [20].

5. CONCLUSION

This project represents a convenient process to monitor the patient’s real-time data. Moreover, the researchers have taken the necessary steps to make the project much more reliable with calibration process. This research idea can be applied to both patients in their houses and hospital wings. The purposed method gives the benefit for both the remoted monitoring and non-remoted monitoring methods, as there are several methods to present and store the patient’s monitored data.

6. FUTURE WORKS

1. The communication hub can be developed as a communication and a charging hub.
2. The system can be developed to add more health monitoring sensors.
3. The monitoring system is yet to be developed to present data through a website.
4. Wireless power could be added to the design for more convenience.

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