Proceedings of the 3rd International Conference on Signal Processing and Machine Learning
DOI: 10.54254/2755-2721/6/20230808

Research on smart health monitoring tool

Qi Luo

College of Engineering, Boston University, MA 02215, USA

tomqiluo@bu.edu

Abstract. The following project comprehensively discusses a cloud-based health monitoring system that can collect patients' health parameters. The data is then transmitted to the internet, where healthcare personnel can access it. The logic behind the project is that data can be transmitted and accessed on a platform on the internet. Thus, facilitating ease of coordination between patients and practitioners. The topic is an intelligent monitoring health tool that collects and transmits data to the cloud. The research method, in this case, combines a literature study and statistical analysis of the collected experimental data. The aim is to assess the consistency of the results produced by the medical devices. In the review, it is concluded that the main weakness of the project is the ability to produce consistent results. For that matter, the project can be improved by using an efficient processor other than the Arduino. Further, highly sensitive sensors should be used to collect accurate data. The aim is to process the data on time while ensuring data consistency is transmitted so it can be confirmed and verified.

Keywords: embedded system, Wi-Fi-Module, algorithm, transmitter, webserver.

1. Introduction

The proposed project is a cloud-based health monitoring device that allows doctors and medical practitioners to remotely collect real-time health statistics on patients. Thus, the doctors may not physically attend to patients. Instead, they would use the information collected from the cloud to diagnose the patients. Hence, it is a remote-based monitoring tool. Technology is rapidly changing healthcare operational needs. With the Internet of Things, communication and coordination between a patient and a doctor are achieved remotely [1]. A doctor only offers a diagnosis if the patient's conditions become severe. Some of the vital medical conditions that are considered include blood pressure, temperature, and heartbeat. Regardless of the ailment condition, the three aspects are part of the diagnostic measures, which is why the results must be collected remotely. For instance, malaria is likely exhibited by high fever, shown in the form of temperature.

Instead of regularly checking on the patient, the medical device can be attached to the client to fetch the primary data continuously. Hence, an alarm can be triggered as soon as the patient records abnormal results. Moreover, the doctor can check on the patient's details in the cloud, a purposely designed platform to facilitate data collection and analysis. The strategy is significant in areas with a limited number of doctors attending to many patients. Moreover, the device is wearable or portable, encouraging home-based care. The following project banks on background information by collecting patients' data and transmitting it to the cloud, where medical practitioners, such as nurses and doctors, can access it and perform correct diagnostics for their patients. The paper is structured as a literature review with adept background information on the system's use, the architecture and the coding embedded in the system, the data collection and results of the analysis, the aspects of enhancing stability, and a review of future research.

The scope of the research is to identify possible loopholes in the smart health care monitoring device as an embedded system. Identifying areas of weakness allows for changes that promote quality health or outcomes in society. Nevertheless, the overall scope is to develop the system within the required time and perform the aspects of data analysis and collection without any interruption. Yet, the consistency of the results is evaluated based on the consistency of the data output. That is, an evaluation of the system is conducted in terms of its capacity to reproduce the same results. Hence, possible alternatives and suggestions will be provided to increase the embedded system's performance. Machine learning aspects, such as the correlation of statistical readings and error analysis, would be applied to compare the device data collected with the actual readings. Thus, machine learning will quantify the system and enhance the efficiency of producing stable results.

The research aims to examine how technology in embedded systems can be used to improve the quality of health for patients. Most importantly, it focuses on how existing systems can be enhanced regarding the stability and consistency of results. As noted in the literature review, most systems developed have at least one weakness ranging from the instability of the recorded results. Thus, one of the research's aims is to examine how an intelligent health monitoring system can be improved to facilitate quality collection and analysis of data. If the system is not stable, then it is of no use. It must prove its efficiency in assisting health practitioners in improving patients' health outcomes.

In most cases, doctors are tasked with the responsibility of monitoring their patients to assess how they cope with medications and whether their conditions are improving or not. However, spending time in the wards with the patients is burdensome. Baig and Hamid state that a patient's outcome depends on how doctors manage their time [2]. That is, doctors have many responsibilities that keep them active. Hence, it is impossible to monitor the patient's health continuously. In that regard, doctors are inconvenienced as they always have to check their patients' status. Usually, nurses can be assigned to monitor them, employing more personnel to care for in-patients. Sometimes, the patients are unmonitored, and the clinicians may take time to respond to emergent needs. Thus, fatal cases result from issues that could be solved if medical practitioners were nearby. Further, it increases nurses' burnout as they must make unending movements from one place to another. Artiga reports that burnout leads to poor service delivery by nursing staff [3]. In that manner, their satisfaction level also reduces, in the long run, meaning that the working environment is not conducive, especially considering that the number of medical practitioners is few compared to their doctors. Generally, it is difficult to continuously monitor the status of patients' health, considering that many activities must be sorted out.

The equipment required contains sensors for measuring health parameters. They include a temperature sensor that is purposefully designed to collect skin temperature readings, pulse sensors for detecting the heartbeat rate, and humidity for assessing the air condition. A Wi-Fi Module is also required to transmit the signals to the cloud. A microprocessor is needed to perform the conversion of analog signals to digital signals. Further, a dedicated web server is required to host the storage and, hence, the accessibility of the data remotely. Coding is of the essence in determining the pulse rate activity and the period in which data should be collected. For instance, if it is 15 seconds or 10 seconds. A data visualization platform should also be integrated to check data movement trends quickly.

2. System architecture

The idea revolves around collecting data about patients' health conditions and the state of the room where they are admitted. The system has three main parts: the web user interface, the data processing module, and the sensor module. The system architecture begins with the collection of data. The data is collected from sensors attached to the patient's body or skin. In that matter, the sensor contains the temperature values and is transmitted to a processor that converts the analog signals to a readable digital format. The operations at the ESP Module convert analog signals through sampling techniques

DOI: 10.54254/2755-2721/6/20230808

embedded within the module. Once the signals have been converted and processed, they are transmitted to a gateway server. The last section is the web interface, where the data is interpreted and visualized. Many applications can be used in visualizations, including ThingSpeak and other customizable applications. Yet, HTTP protocols can manage the connection between the server and the Wi-Fi module. In the case of analytics, data is transmitted to the web server every 15 seconds, meaning it is easy to analyze the information continuously. An alarm system can also be actuated if abnormal signals associated with temperature and pulse rate are noted. Thus, a doctor may not physically attend to the patients until an emergency signal is sent. In that regard, the quality of health patient monitoring is enhanced as the results can be transmitted to the physicians in charge. The following diagram shows the architecture of the smart health monitoring system.

Figure 1. The architecture of smart health monitoring.

Figure 1 is the architecture that displays how data flows from the sensors. The direction shows precisely how data flows. The sensors transmit the data to the ESP Module, where it is processed. The next step is sending the data to a web server and creating a user interface where information can be viewed and collected by medical staff. Karthik et al. suggest that the time for transmissions depends on the ESP Module and processor requirements [4]. A power supply can be in the form of a battery to power the microprocessor where all the sensors are connected. Most importantly, the server can be accessed by multiple people as long as they have server authentication. The web server can be protected to limit access to authorized users only. Yet, authorization can also be customized in terms of classes or categories.

3. Literature review

The field of IoT is broad, and many scholars have applied the technology to examine how the field of medicine can be improved. For instance, IoT could be used to monitor the basic signs of admitted clients, such as temperature increases, movement of the eyes, blood pressure fluctuations, saturation of oxygen, and heart rate. The authors used different sensors in the research, each capturing specific data. They include a temperature sensor, a pulse sensor, and eye blink sensors. The authors' results, however, varied considering that the data were collected from different patients.

Acharya and Patil conducted the same research. However, they added other parameters, including respiration and ECG [5]. Regardless, the same approach of applying different sensors was used in the design. That is, each sensor captures specific data for a particular parameter. The difference was based on the processing device, which was the Raspberry Pi in this case. Nevertheless, the main drawback of the experiment is that the team did not create a data visualization where the audience could monitor the health data collected from the research. In addition, Banerjee and Roy proposed a real-time device that could monitor patients' pulse rates [6]. The plethysmography process used technology, and the results were displayed digitally. The device proved its reliability in recording the pulse rate of patients remotely.

DOI: 10.54254/2755-2721/6/20230808

Another significant research conducted by Gregoski et al. was based on smartphone heart rate [7]. The parameters utilized were fingerprint pulses that were analyzed regarding blood flow rate and processed with a coded algorithm. Hence, the result was an integrated or embedded system that could assist people in checking their heart rates using their mobile phones. Regardless, the device also had shortcomings, considering continuous monitoring could not be achieved in real-time.

Other authors, such as Bhardwaj, have recommended IoT-based systems during pandemics [8]. Bhardwaj reports that IoT monitoring devices are helpful in cases of pandemics where social distancing is a crucial requirement [8]. In that case, the diagnosis of diseases becomes easier. Furthermore, Trivedi and Cheeran added to the research by working on a health-monitoring device that relied on Bluetooth to send transmissions to nearby devices. The experiment was successful in terms of data collection and analysis. However, the Bluetooth transmission meant that data could not be transferred beyond 100 meters. Hence, it was only effective in ward units. Moreover, Kumar et al. added to the research by introducing a three-layered framework device that operated similarly to that of Tamilsevi et al. [9]. Kumar et al. embarked on three main layers: transport, device, and control [9]. As in the case of Tamilsevi et al.’ s research, sensors were used to collect temperature and pulse rate readings [9]. After collecting the data, it was transmitted to the cloud using a Wi-Fi module. The only weakness of the research was the application of Arduino Uno, which is not highly effective in processing data collected from sensors.

4. Method

Generally, many researchers have recorded their interest in developing intelligent or IoT health monitoring systems. However, the primary tussle is the capacity of the devices to transmit reliable and consistent results. Otherwise, the technology would be rendered baseless if it could not apply the three main research concepts: transferability, reliability, and data consistency. The following research examines how data transmission can be improved by incorporating effective procedures and algorithms.

4.1. Code

The research cannot be entirely done without the application of code. Different sets of codes are involved in handling data collection and processing. Most importantly, C++ is an effective tool for coding the application as it is class-based oriented [10]. For example, the code below shows the C++ version of managing pulses as a class and hence, analyzing heart rate. Key attributes include inputs of LED pulses, which are programmed to blink upon the detection of pulses. Nevertheless, the code can be written in different languages, including Python and Java. However, the most common software for low-level coding is C++ [11].

```
//  Variables
int PulseSensorPurplePin = 0;        // Pulse Sensor PURPLE WIRE connected to ANALOG PIN 0
int LED13 = 13;   //  The on-board Arduion LED

int prev = 0;
int timeout = 60000;
int Signal;                // holds the incoming raw data. Signal value can range from 0-1024
int Threshold = 550;            // Determine which Signal to "count as a beat", and which to ingore.

int i;
// The SetUp Function:
void setup() {
    pinMode(LED13,OUTPUT);         // pin that will blink to your heartbeat!
    Serial.begin(9600);         // Set's up Serial Communication at certain speed.
    i=0;
}

// The Main Loop Function
void loop() {
  int curr = millis();

  Signal = analogRead(PulseSensorPurplePin);  // Read the PulseSensor's value.
  // Assign this value to the "Signal" variable.

  Serial.println(Signal);                    // Send the Signal value to Serial Plotter.

  if(curr - prev > timeout){
      Serial.println(i);
      prev = curr;
      while(true);
    }

   if(Signal > Threshold){      // If the signal is above "550", then "turn-on" Arduino's on-Board LED.
     digitalWrite(LED13,HIGH);
     i++;
     Serial.print("Heart beat detected: ");

   } else {
     digitalWrite(LED13,LOW);       // Else, the signal must be below "550", so "turn-off" this LED.
   }
}

Source from: ("Smart Health Monitoring System")
```

For instance, many codes would apply in this context for processing normal and abnormal temperature readings. There is also a specific code for evaluating the humidity ranges and transmitting quality signals for measuring and analyzing the air condition. Object-based programming is particularly applicable in this context [12]. The codes are also relatively simple to design. All the codes are then integrated into a functional program that performs the algorithms.

4.2. Results data analysis

Research cannot be complete without statistical data. In this case, there is a need to examine the statistical data collected and analyzed from similar studies to review the system's stability and how it can be optimized to be utilized in medicine. In this case, the point of interest is to perform a comparative analysis between the values recorded in the health monitoring machine and observed data. Comparative analysis is applicable in this case since there are two variables worth examining, where actual readings as a control variable [13]. If there is a significant deviation in the data collected by the machine and the precise readings, then the technology is regarded as inconsistent and ineffective in analyzing primary data.

DOI: 10.54254/2755-2721/6/20230808

Table 1

Heart rate data collected by analog machine (actual) and developed system (observed)

Subjects	Actual data (bpm)	Observed data (bpm)	Error (%)
S_1	67	68	1.49
S_2	70	73	4.28
S_3	74	77	4.05
S_4	75	73	2.66
S_5	73	72	1.36
S_6	80	83	3.75

Table 1 shows the association of actual data (bpm) and observed data (bpm). As noted in the table, the percentage error value seems to deviate slightly by a marginal percentage for all the subjects. Nevertheless, there are instances where the error recorded is more than 4%. For the temperature readings, the deviations are significant since the highest error attained was 0.71.

Table 2

Body temperature data collected by analog machine (actual) and developed system (observed)

Subjects	Actual data (°F)	Observed data (°F)	Error (%)
S_1	97.3	97.8	0.51
S_2	98.4	97.7	0.71
S_3	98.1	98.6	0.50
S_4	96.9	97.5	0.62
S_5	97.5	97.1	0.41
S_6	98.2	97.0	0.81

Thus, the device is relatively accurate in remotely measuring patients' temperature. Nonetheless, it is still essential to reduce the error to insignificant levels. The same phenomenon applies to humidity scores; there is a notable difference between actual data taken in the air and observed data.

Table 3

Room humidity data collected by analog machine (actual) and developed system (observed)

Experiments	Actual data (%)	Observed data (%)	Error (%)
1	65	63	3.07
2	68	69	1.47
3	63	62	1.58
4	70	72	2.85
5	66	64	3.03
6	61	60	1.63

The highest error is 3.07%, meaning that the observed data is not necessarily accurate in measuring humidity. Furthermore, the difference in data presentation is best visualized using a line graph.

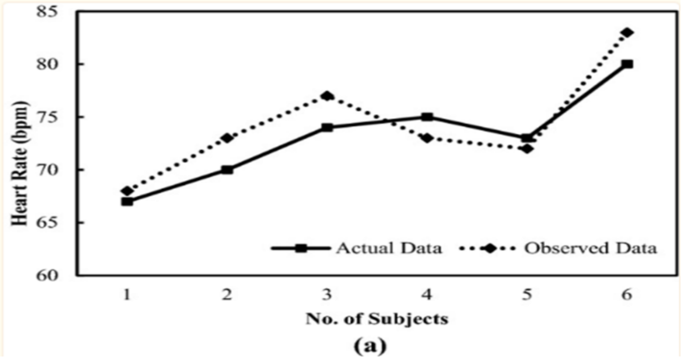

Figure 2. The figure shows the difference between actual and observed data.

From Figure 2, it is notable that there is a slight deviation between actual and observed data. The data was collected from six subjects (participants). There is a slight variation between real and observed data, which necessitates improving the system's performance. In this case, the data can be enhanced by relying on highly sensitive sensors. Possible errors include a faulty electronic device caused by sensitive data readings. Nevertheless, Rodriques et al. point out that errors are handled better with an efficient microprocessor [14]. In addition, the sampling at the ESP modules could be faulty, leading to deviated measurements. Generally, there is no consistency in the results attained, even though they appear to vary slightly. In engineering, a marginal deviation can have an impact on decision-making. For that matter, stability must be emphasized before mass production of medical devices begins.

4.3. Improving the quality of measurement stability

Some key areas that can be enhanced include using an effective microprocessor, such as Intel-based or AMD, to increase processing speed. Kruk states that the quality of health systems is achieved by collaborative research involving different technical stakeholders [15]. For research purposes, Arduino-based microcontrollers have been used. However, a more powerful processor is required in medical device design to reduce the results' instability. As described by Samie, a powerful means of high sensitivity and accuracy of the results generated. Further, the errors are decreased by using microchip sensors that have been built on precision. Currently, the systems available in the market are for research-based purposes. Nevertheless, highly sensitive data can be reached by manufacturing quality sensors that are small.

Moreover, the Wi-Fi module should effectively respond to quality data and signals, transmitting them to the web server. Other aspects worth noting include well-functional algorithms that perform the logical operations within the transmitter. Generally, there is significant instability in the results recorded by the intelligent health monitoring systems. The aspect could be improved by enhancing quality control operations in the manufacture of sensors and utilizing efficient microprocessors to reduce the latency of converting analog signals to digital signals.

5. Future research

The future of healthcare lies on the Internet of Things (IoT). Several technologies have been emulated, such as the electronic health recording system, where data is transmitted in real-time for coordination among medical practitioners' access. Other emerging technologies include incorporating augmented reality to create a smart interactive environment, as Jo and Kim described. In this manner, doctors can make efficient diagnoses remotely [16]. Further, Nilsson suggests that augmented reality is a field worth investing in for future interaction among medical practitioners [17]. Generally, augmented reality is a future technology that will be incorporated into IoT health monitoring.

In this case, the electronic health record system would be enhanced by incorporating smart monitoring to assist doctors and physicians in accessing the real-time status of their patients. In this way, quick decision-making can be made, which is to the patient's advantage. Furthermore, Marques reports that innovative health IoT-based devices would significantly reduce health costs [18]. In addition, if the medical devices are manufactured in large quantities, the number of inpatients would be reduced, as patients may not visit the healthcare facilities unless their doctors summon them based on the results collected. The number of visits will decrease as the patients access personalized care. The patients can be contacted from home and engaged in best practices for managing their health condition, depending on recorded health parameters. Yet, the future is in the production of medical equipment, which may increase employment and investment in the practice area. Moreover, coordination among patients and medical practitioners would even be enhanced to a greater level. Overall, the future of IoT in smart health monitoring centers is promising, as the cost of medical access would be reduced. Yet, mass production of monitoring devices would be initiated for improved personal care.

6. Conclusion

Overall, the purpose of the research was well-achieved, as it involved examining the efficiency of using a smart health monitoring system as an embedded product. The technology helps improve the quality and efficiency of service delivery. Data is collected on the patient's end and transmitted to a module that converts signals into a readable digital format. The digital data is then channeled to a web server, where it can be accessed by specific people who have been granted access to the main systems. A hospital management system or an electronic health record system is an example of a feature that allows limited access for practitioners registered with a healthcare institution. Much research has been conducted in the area to identify formidable ways of enhancing health monitoring. However, there is the instability of the results exhibited, which is primarily attributed to the dysfunctionality of sensors and other devices in the embedded systems. For that reason, there is a need to emphasize the stability of the results by embarking on quality fabrication. Yet, meaningful results would be realized using powerful processors and sampling modules to collect, convert, and process data. In addition, the future of smart health monitoring is promising due to continuous investment in electronic health records. Many companies are developing cloud-based electronic health records, meaning that real-time data concerning patients' health status can be transmitted and updated. Thus, improving the quality-of-service delivery and health outcomes. Furthermore, medical access costs would be significantly reduced as knowledge about personalized care increased. That way, people would reduce the frequency of visiting hospitals and minimize their healthcare costs. Overall, the main goal is to increase the stability of the results of the smart home monitoring system for the mutual benefit of patients and doctors. Hence, the data collected can be used for coordination among medical practitioners.

Reference

[1] Hassanalieragh, Moeen, et al. "Health Monitoring and Management Using Internet-of-Things (IoT) Sensing with Cloud-Based Processing: Opportunities and Challenges." 2015 IEEE International Conference on Services Computing. IEEE, 2015.
[2] Baig, Mirza Mansoor, and Hamid Gholamhosseini. "Smart health monitoring systems: an overview of design and modeling." Journal of medical systems 37.2 (2013): 1-14.
[3] Artiga, Samantha, Kendal Orgera, and Olivia Pham. "Disparities in health and health care: Five key questions and answers." Kaiser Family Foundation (2020).
[4] Karthik, B. N., et al. "Survey on IOT & Arduino based patient health monitoring system." International Journal of Scientific Research in Computer Science, Engineering and Information Technology 3.1 (2018): 1414-1417.
[5] Acharya, Anand D. and Shital N. Patil. "IoT-Based Health Care Monitoring Kit." 2020 Fourth International Conference on Computing Methodologies and Communication (ICCMC) (2020), pp. 363-368.
[6] Banerjee, Srijan, and Subhajit Roy. "Design of a Photo Plethysmography Based Pulse Rate Detector." Int J Rec Trends Eng Res, vol. 2, no. 6, pp. 302-306.
[7] Gregoski, Mathew J., et al. "Development and Validation of a Smartphone Heart Rate Acquisition

DOI: 10.54254/2755-2721/6/20230808

Application for Health Promotion and Wellness Telehealth Applications." International Journal of Telemedicine and Applications, vol. 2012, 1-7.
[8] Bhardwaj, Vaneeta et al. "IoT-Based Smart Health Monitoring System for COVID-19." SN computer science vol. 3,2 (2022): 137. doi:10.1007/s42979-022-01015-1
[9] Kumar, S. Pradeep, et al. "Smart Health Monitoring System of Patient through IoT." 2017 International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC). IEEE, 2017.
[10] Ateeq, Muhammad, et al. "C++ or python? which one to begin with: A learner's perspective." 2014 International Conference on Teaching and Learning in Computing and Engineering. IEEE, 2014.
[11] "Smart Health Monitoring System." Github. https://github.com/aks1103/Smart-Health-Monitoring-System/blob/master/Arduino_Codes/pulse/pulse.ino Accessed 14 June 2022. Accessed 17 June 2022.
[12] Boyle, Peter, et al. "Grid: A next generation data parallel C++ QCD library." arXiv preprint arXiv:1512.03487 (2015).
[13] Esser, Frank and Vliegenthart, Rens. 'Comparative research methods' John Wiley and Sons Library, 2017
[14] Rodrigues, Rance, et al. "A study on the use of performance counters to estimate power in microprocessors." IEEE Transactions on Circuits and Systems II: Express Briefs 60.12 (2013): 882-886.
[15] Kruk, Margaret E., et al. "High-quality health systems in the Sustainable Development Goals era: time for a revolution." The Lancet global health 6.11 (2018): e1196-e1252.
[16] Jo, Dongsik, and Gerard Jounghyun Kim. "AR enabled IoT for a smart and interactive environment: A survey and future directions." Sensors 19.19 (2019): 4330.
[17] Nilsson, Ann-Helén. "Visualizing IoT systems and data with Augmented Reality." Diva Portal (2019).
[18] Marques, Gonçalo, et al. "Internet of things architectures, technologies, applications, challenges, and future directions for enhanced living environments and healthcare systems: a review." Electronics 8.10 (2019): 1081.