IoT Based Patient Monitoring System Using ECG Sensor

Alvee Rahman
Department of Computer Science and Engineering
BRAC University
Dhaka, Bangladesh
alvee9@gmial.com

Tahsinur Rahman
Department of Computer Science and Engineering
BRAC University
Dhaka, Bangladesh
tahsinurrahman5@gmial.com

Nawab Haider Ghani
Department of Computer Science and Engineering
BRAC University
Dhaka, Bangladesh
nawabhaider19@gmial.com

Sazzad Hossain
Department of Computer Science and Engineering
BRAC University
Dhaka, Bangladesh
sazzadhossain1206@gmial.com

Jia Uddin
Department of Computer Science and Engineering
BRAC University
Dhaka, Bangladesh
jia.uddin@bracu.ac.bd

***Abstract*— Patient monitoring is a pivotal part of the health care system nowadays, either at hospitals or at home. This paper proposes an intelligent patient monitoring system that automatically screens the patient's health condition through various sensors. The data is then processed using a Raspberry Pi and useful information is saved to the IoT cloud. Primarily the system would be extracting the bio signal, ECG using an ECG sensor. Through continuous monitoring and graphical representation of the patient's information, doctors/nurses/relatives can remotely check the patient's condition. Furthermore, if the condition becomes critical, a notification is sent to the doctor/nurse/relative to inform them and either party will have the opportunity to start a video call.**

Keywords*— *Patient Monitoring, Raspberry Pi, ECG, Video Streaming

I. INTRODUCTION

Patients need to be monitored constantly, 24 hours a day which is very difficult to do either at hospitals or at home. This system tries to ease this problem through automatic monitoring of some basic variables that governs a patient's health condition. The variables that this system monitors are: ECG signal using single lead heart monitor and temperature using temperature sensor. The information is then saved to the cloud which can be viewed by the doctor, nurses or relatives remotely. It can be accessed from anywhere and on any device, via the cloud. Moreover, if the values become critical, a SMS notification is sent to a predefined emergency number so that necessary steps can be taken to help the patient [1]. +Finally, using a switch, the patient themselves can send a notification if they feel uncomfortable. Along with all these, patients will have the option to start a video call using a button, and the system will automatically call the predefined individual [2]. Users other than the patient will be able to stream live footage, view past medical records, and real time data collected from the sensors using a website we have designed specifically for this monitoring system [3,4].

For this monitoring system, Raspberry pi is used to create and interface between the hardware components and the cloud. ECG sensors are connected to the Arduino Uno board, which is in turn connected to the Raspberry Pi via USB [2,3,5]. ECG data is passed from the Arduino board to the Raspberry pi and then the data is send to the cloud. Graphs are generated on the web interface, which will be only accessible to the users with username and password. The web interface will also allow the users to start a video streaming at any time, and they will also have the option to view the previous records of the patient.

There have been multiple researches in this specific topic in the last couple of years and researchers have come up with various techniques to build the most effective and efficient patient monitoring system. Systems have been proposed using an ECG sensor in [2,3,5,6,7]. They have attached the ECG sensors onto the patient's body, which they use to record continuous ECG data of the given patients, which is then saved onto their databases or is sent to the cloud server for later processing and analysis. Some of the approaches have used Heart Rate monitoring in their system, the sensor used, calculates the BPM of the patient continuously. Temperature sensors have been quite a common approach for the studies done in this particular topic, researchers have proposed a system that takes in temperature reading of the patients at all time, and saves it for future references [1,2,3,8].

Cloud computing has been used in previous researches, where all the readings that has been taken in from the patient has been uploaded and preserved on a remote server [3,4,5,7]. Allowing users to access the recorded data over the internet, and can be viewed by many stakeholders of the system [9,10,11]. One touch call option is a very important feature of any patient monitoring system; this method has been previously used [2,12].

The rest of the paper is organized as follows. Section II describes the proposed model, Section III talks about the experimental setup, Section IV displays the results of the system and Section V concludes the paper and mentions some future plans for the system.

II. PROPOSED MODEL

The block diagram of the proposed model is shown in Fig. 1. It illustrates all the hardware components connected to the raspberry pi, which is in turn connected to the computer. The Components used in the system can be partitioned into 2 parts: hardware and software components.

A. Hardware Components

Fig. 2 shows the hardware components used in the system, starting with Raspberry Pi 3 Model B, Raspberry Pi Camera Module, Arduino Uno and single lead heart rate monitor (AD8232). The Raspberry Pi acts as a small computer and consists of 40 GPIO pins that can be used for connecting with input and output devices. Furthermore, it also has wireless LAN connection and Bluetooth which can be used to transfer data to and from other devices and websites. The Raspberry Pi Camera Module is used to monitor the patient continuously.

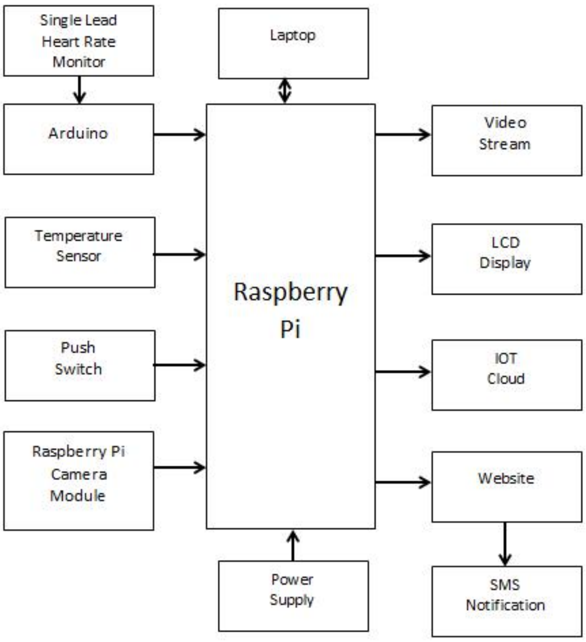


Fig. 1. Block Diagram of Patient Monitoring System.

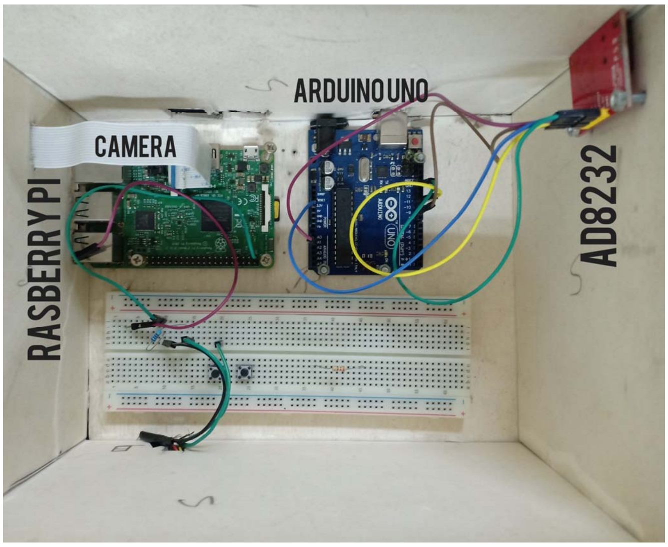


Fig. 2. Illustrates Raspberry Pi 3 Model B, Raspberry Pi Camera Module, Arduino Uno and Single Lead Heart Monitor.

Moreover, the Raspberry Pi Camera Module also streams a video of the current physical state of the patient. The main sensor that is being used is the single lead heart rate monitor (AD8232) that measures ECG signal. An Arduino Uno is being used to transfer the data from the heart rate monitor to the Raspberry Pi. Additionally, a temperature Sensor (DS18B20) is being used to measure the body temperature. The current values of these monitoring variables of the patient are simultaneously displayed in a 20x4 LCD display. There is also a push switch for sending notifications; laptop and power supply to run the Raspberry Pi. A laptop is connected to the Raspberry Pi via Ethernet cable through which the code of the system is executed.

B. Software Components

In terms of software, python is used as the primary programming language to code in the Raspberry Pi. The python 2 version is used since it has more resources and libraries. Modules like pandas, numpy, biosppy, urllib and etc are used to process the data and visualize it. Along with python, arduino programming language is used for the arduino and HTML, CSS, PHP is used for making the website. ThingSpeak IoT cloud is used to save the data continuously. For the video streaming service, RPi-Cam-Web-Interface is used which is a web interface for the raspberry pi camera module.

III. EXPERIMENTAL SETUP

This section illustrates the working of all components as a whole system to successfully monitor the health of a patient. Fig. 3 shows the complete setup of the system after implementation and packaging.

Fig. 3. Complete Setup of the System.

A. Hardware Setup

In this system, Raspberry Pi is the central device that connects the input and output devices. Primarily, the single Lead heart monitor is used to measure the ECG (Electrocardiogram) signal of a patient by placing electrodes on the right arm, left arm and right leg of the patient. The data is send to the Arduino Uno which in turn transfers it to the Raspberry Pi. The Raspberry Pi then plots the data on a graph. Additionally, the heart rate per minute is measured from the ECG plot. Furthermore, the axillary temperature is measured using a Digital Temperature sensor by placing it under the arm of the patient. This data is sent to the Raspberry Pi and displayed on a LCD.

The continuous monitoring data of a patient is saved to an IOT cloud [14] and to the database of a website from the Raspberry Pi. Both are being used so that one can act as a backup to another in the event that any one of them fails. As mentioned before ThingSpeak is being used as the IoT cloud alongside a custom made website. If the heart rate goes below 60bpm or above 100bpm, a SMS notification is send to a predefined individual which can be a nurse, doctor or relative. Similarly, if the body temperature is below 36°C or above 38°C a notification is send. The SMS notification is send through the website using a bulkSMS API service. Since patient monitoring systems are already very expensive, this mechanism, which is cheaper, is used instead of a GSM module.

In the case of an emergency, the patient presses a push switch when they are feeling uncomfortable and the system sends a SMS notification just like before. However, in this case, alongside the SMS, a video call is made to the predefined individual so that they can see for themselves the condition of the patient. Furthermore, other users with the correct authorization will be able to live stream the current condition of the patient through the website. Both the video call and live streaming would be done using a Raspberry Pi Camera Module which will be placed close to the patient. The cloud and website displays graphs of all the variables over time so that trends could be detected for each patient. Finally, the power is supplied through a 2.5A power supply using 5V micro USB.

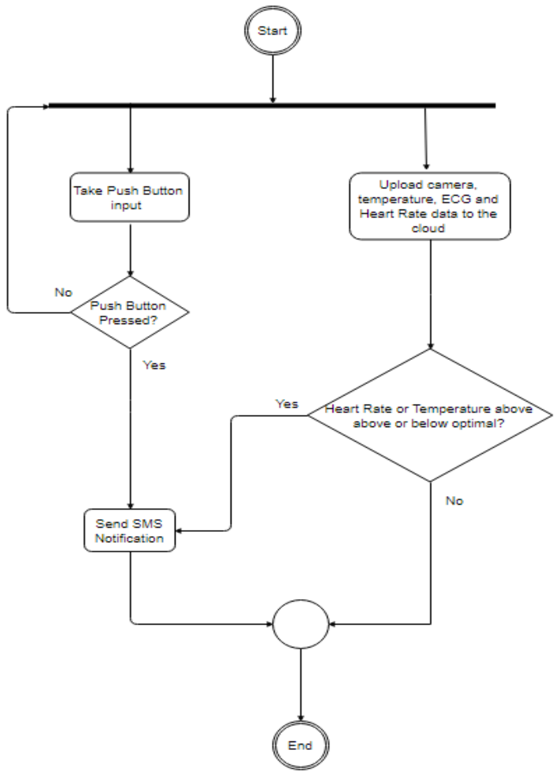


Fig. 4. Work-Flow of the system.

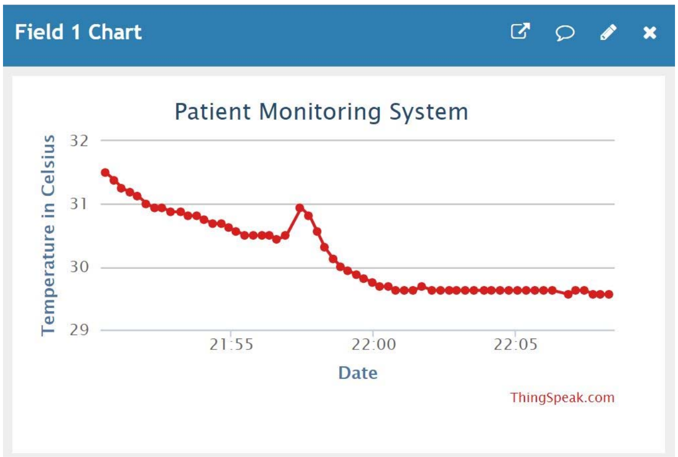
B. *Workflow*

Fig. 4 demonstrates the workflow of the system. The system initializes by taking the input from the Digital Temperature sensor and ECG sensor to read temperature and ECG signal respectively. Then the system calculates the heart rate of the patient from the ECG signal and updates the readings in the cloud. The data is processed in the cloud and then each parameter is visualized through graphs. The system checks the readings of each parameter against the optimal values. If any of the readings is found to be above or below the optimal value, the system sends a SMS notification to the predefined individual. Furthermore, the predefined individual can start a video stream from the website to see the physical condition of the patient. Additionally, the patient can press a push button to send a SMS notification to the predefined individual.

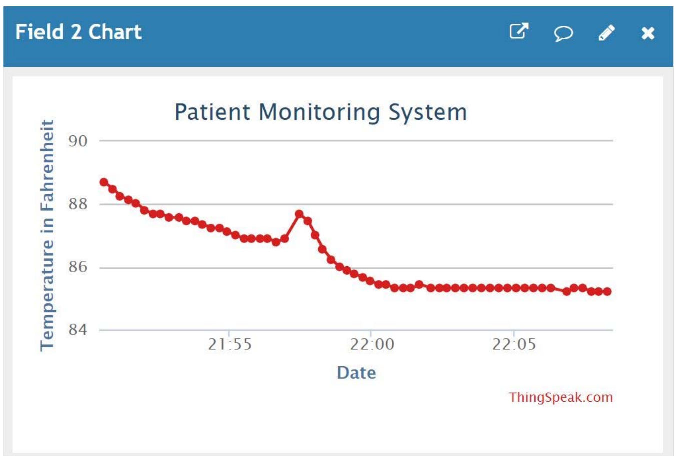
IV. RESULTS

The system works perfectly with the above-mentioned setup. It is taking continuous data from ECG sensor and digital temperature sensor and stores the values in the cloud and MySQL database along with the timestamp and heart rate that is derived from the ECG signal. Fig. 5 shows the graphs generated in cloud from the readings taken from the sensors. It also analyses the values of the temperature and heart rate to set the value of the notification parameter to either 0 or 1. As per the notification value of the latest entry, the website sends SMS to the designated person in case of emergencies.

Fig. 6 demonstrates the web interface of the system. The predefined individuals can login to the website and view the profile of the patient, the previous reports of any tests and access the cloud only to see the condition of the patient as represented in graphs with the sensor input values. A person is also able to start a video stream to monitor the physical condition of the patient through the pi camera.



(a)



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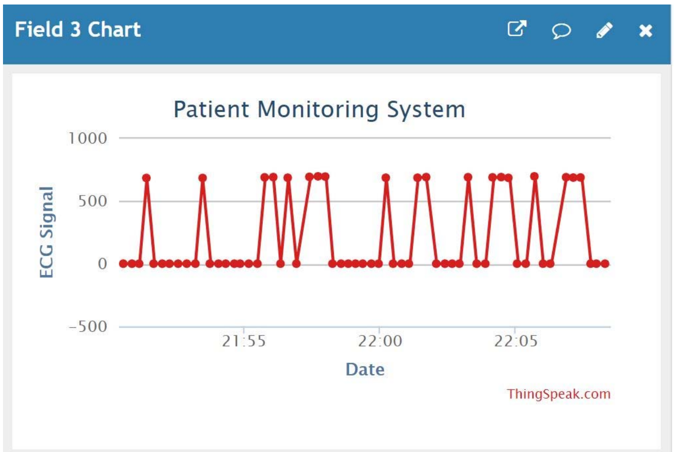
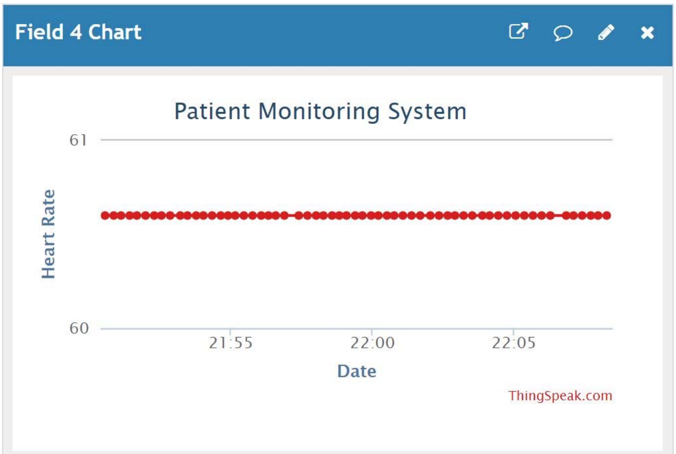


(c)



(d)

Fig. 5. (a) Temperature in Celsius, (b) Temperature in Fahrenheit, (c) ECG Signa, (d) Heart Rate.

Fig. 6. The Profile page of the system's website.

The system proposed in this paper is a simple yet effective patient monitoring system that takes ECG signal and temperature as the input, saves the data to the cloud and takes actions based on the values. The primary goal for proposing a system as such was to provide an inexpensive alternative to existing health monitoring systems. So even though introduction of a GSM module would have made the system better, the less costly option of using a web-based SMS service was used. The SMS service had a pay-per-use system and no initial costs unlike the GSM module, where the module had to be purchased. In the case of ECG, there are other more widely used devices. One such being is the Kardia Mobile ECG device [13]. Compared to the AD8232, Kardia is a more reliable device. However, Kardia is five times more expensive than the AD8232. Since the systems primary goal was to explore an inexpensive alternative to existing systems, AD8232 is the better option. Moreover, the Kardia Mobile Monitor does not record the continuous signal of a patient but rather the signal when a particular event takes place. In general, this paper focuses on a patient monitoring system that is cheaper and easier to use than traditional systems. Such a system can be used effectively in hospitals for any patient or at households for bed-ridden patients without much hassle.

V. CONCLUSION

This paper presents a design and implementation of health monitoring system, within the context of IoT environment. This system will provide a constant health monitoring facilities for the patients who are in the ICU or bedridden at home remotely from any place. ECG sensor and digital thermometer are the two sensors that have been used to allow real-time monitoring of ECG signal and temperature of the patient. Moreover, the data are continuously updated to the cloud at a regular time interval. This helps the doctors, nurses or the relatives of the patient to monitor the health condition of the patient and also helps to take any action at the appropriate time. The system also sends an automated notification via text to the doctors or the relatives if the ECG signals and the temperature reading go above or below the threshold value. It will help doctors in many ways and will enhance the efficiency of monitoring and treatment for patients. In the future, it will be modified by adding the pulse oximeter to measure oxygen saturation in blood for a patient to make the system even more efficient.

REFERENCES

[1] B. Priya, S. Rajendran, R. Bala and R. Gobbi, “Remote wireless health monitoring systems,” Innovative Technologies in Intelligent Systems and Industrial Applications, Monash, pp. 383-388, 2009.

[2] M.S. Uddin, J.B. Alam and S. Banu, “Real time patient monitoring system based on Internet of Things,” 4th International Conference on Advances in Electrical Engineering, ICAEE, Dhaka, pp. 516-521, 2017.

[3] R.T. Hameed, O.A. Mohamad, O.T. Hamid and N. Ţăpuş, “Patient monitoring system based on e-health sensors and web services,” 8th International Conference on Electronics, Computers and Artificial Intelligence, ECAI, Ploiesti, pp. 1-6, 2016.

[4] K. Jaiswal, S. Sobhanayak, B.K. Mohanta and D. Jena, “IoT-cloud based framework for patient's data collection in smart healthcare system using raspberry-pi,” International Conference on Electrical and Computing Technologiesand Applications, Ras Al Khaimah, pp. 1-4, 2017.

[5] P. Singh and A. Jasuja, “IoT based low-cost distant patient ECG monitoring system,” International Conference on Computing, Communication and Automation, Greater Noida, pp. 1330-1334, 2017.

[6] M. Neyja, S. Mumtaz, K.M.S. Huq, S.A. Busari, J. Rodriguez and Z. Zhou, “AnIoT-Based E-Health Monitoring System Using ECG Signal,” IEEE Global Communications Conference, Singapore, pp. 1-6, 2017.

[7] Q. Shen, X. Liang, X. Shen, X. Lin and H. Y. Luo, “Exploiting Geo-Distributed Clouds for a E-Health Monitoring System With Minimum Service Delay and Privacy Preservation,” IEEE Journal of Biomedical and Health Informatics, vol. 18, no. 2, pp. 430-439, March 2014.

[8] R. Kumar and M.P. Rajasekaran, “An IoT based patient monitoring system using raspberry Pi,” International Conference on Computing Technologies and Intelligent Data Engineering, Kovilpatti, pp. 1-4, 2016.

[9] G. Jorge, B. Oviedo, and E. Zhuma. “Patient monitoring system based on internet of things,” Procedia Computer Science, vol 83, pp. 90-97, 2016.

[10] K.F. Aslam, “A cloud-based healthcare framework for security and patients’ data privacy using wireless body area networks,” Procedia Computer Science, vol. 34, pp. 511-517, 2014.

[11] K.M. Hassan, “Intelligent hybrid remote patient- monitoring model with cloud-based framework for knowledge discovery,” Computers and Electrical Engineering, 2018.

[12] M.S. Mahmud, M.A. Majumder, A.K. Tushar, M.M. Kamal, A. Ashiquzzaman and M.R. Islam, “Real-time feedback-centric nurse calling system with archive monitoring using Raspberry Pi,” 4th International Conference on Networking, Systems and Security (NSysS), Dhaka, pp. 1-5, 2017.

[13] “KardiaMobile,” AliveCor, Inc., [online]: store.alivecor.com/products/kardiamobile, Access time, 5 September 2018.

[14] A.I. Alam, M. Alam, M. Rahman, S. Afroz, J. Uddin, “ IoT Enabled Smart Bicycle Safety System,” Joint 7th International Conference on Informatics, Electronics & Vision, and 2nd International Conference on Imaging, Vision & Pattern Recognition (icIVPR), Kitakyushu International Conference Center, Fukuoka, Japan, June 2018.