Patient Health Monitoring System Development using ESP8266 and Arduino with IoT Platform

Jamil Abedalrahim Jamil Alsayaydeh[1]*, Mohd Faizal bin Yusof[2], Muhammad Zulhakim Bin Abdul Halim[3], Muhammad Noorazlan Shah Zainudin[4]. Safarudin Gazali Herawan[5]

Department of Electronics & Computer Engineering Technology-Fakulti Teknologi Kejuruteraan Elektrik & Elektronik (FTKEE), Universiti Teknikal Malaysia Melaka (UTeM), Melaka, Malaysia[1, 3]

Cetri-Faculty of Electronics and Computer Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Melaka, Malaysia[4]

Department Homeland Security-Faculty of Resilience, Rabdan Academy, Abu Dhabi, United Arab Emirates[2]

Industrial Engineering Department-Faculty of Engineering, Bina Nusantara University, Jakarta, Indonesia 11480[5]

Abstract—The Internet of Things (IoT) has emerged as a transformative technology that has revolutionized the field of healthcare. One of the most promising applications of Internet of Things (IoT) in healthcare is patient health monitoring, which allows healthcare providers to remotely monitor patients' health and provide prompt medical attention when needed. This research work focuses on developing an Internet of Things (IoT)-based patient health monitoring system aimed at providing a solution for patients, particularly the elderly, who face the risk of unexpected death due to the lack of medical attention. The proposed system utilizes a heartbeat sensor and an Infrared IR temperature sensor connected to Arduino UNO and Nodemcu, respectively, to monitor the patient's vital signs. The sensors collect the data, which is then sent to an Internet of Things (IoT) web platform via a Wi-Fi connection. The Internet of Things (IoT) platform displays the real-time data of the patient's health status, including the temperature and heartbeat rate, which can be monitored by doctors and nurses. The system is designed to send alerts to healthcare providers in the event of any medical emergency, ensuring that prompt medical attention can be provided to the patient. The significance of this research work lies in its potential to revolutionize the healthcare industry by providing a more efficient and effective means of patient health monitoring. The system can be used to monitor a large number of patients simultaneously, which is particularly beneficial in hospitals with a large patient load. Moreover, it can reduce the workload of healthcare providers, allowing them to focus on other critical tasks. This innovative system has the potential to improve the overall quality of healthcare services and lead to better health outcomes for the society.

Keywords—Patient health monitoring; Internet of Things (IoT); Arduino UNO; Nodemcu ESP8266; thingspeak; wearable device; temperature value; heartbeat value; remotely

I. INTRODUCTION

In today's digital age, the integration of the internet has transformed various industries, including healthcare. The emergence of Internet of Things (IoT) technology in health monitoring systems has revolutionized the way we approach healthcare [1]. With the widespread usage of the internet, coupled with the increasing efficiency of devices and gadgets, we can now monitor patients around the clock using Internet of Things (IoT)-based health monitoring systems. These devices constantly examine factual data and produce vital signs that can be accessed remotely via web connectivity. This not only enables real-time patient monitoring but also facilitates prompt crisis response services. As such, Internet of Things (IoT)-based gadgets provide both recognition and emergency response services, which are critical components in ensuring optimal patient care.

The traditional approach to patient monitoring in hospitals and healthcare facilities can be tedious and often results in unequal treatment of patients. Medical staff is required to manually check multiple vital signs of patients, which can be time-consuming and prone to errors. Furthermore, patients' families or relatives need to visit them for updates on their condition, which can be inconvenient and burdensome [2]. Additionally, many hospitals still rely on outdated paper-based recording systems, which are prone to errors and can result in missing or illegible data [3]. These issues can lead to a waste of time and resources, as well as compromise patient care. However, the implementation of an Internet of Things (IoT)-based patient health monitoring system can revolutionize healthcare by providing real-time remote monitoring of patients, digital storage of patient information, and immediate check-ups for individuals to maintain optimal health [4]. The proposed work presented in this study marks a new pathway towards solving numerous problems that have been plaguing the healthcare industry and society at large. The current system of healthcare services has been marred with inefficiencies and management issues, which necessitates the need for a more effective and sophisticated approach to healthcare services. The IoT system is the perfect match for this modern era, with its real-time monitoring, sophisticated data collection and storage, and alert systems that have proven to be highly effective. This proposed work represents a step ahead of the current healthcare system, with its ability to solve numerous issues and monitor patients accurately and in real-time. Despite the impressive results of previous studies and proposed projects, the medical industry has been slow to adopt Internet of Things (IoT)-based systems. This study seeks to create an updated, reliable, and innovative healthcare system that will meet the growing expectations of society in terms of saving lives and advancing medical technology development [5][6].

To achieve the lofty goal of this endeavor, it is imperative to concoct a novel and innovative approach to the management

of hospital and clinic system operations, with a thorough and effective methodology in place. The objectives of this work are to assist health staff in monitoring and recording patient data frequently at specific times, which is especially important for hospitals with a large number of patients where unexpected fluctuations can occur. Additionally, with the numerous data collections that occur for each monitored patient, all recorded data will be saved in one place - a cloud-based system - which is more efficient than the current method used. Lastly, an alert system functions as an emergency detection tool that can send notifications via email to the administrator or health staff, allowing immediate action to be taken based on the condition of the patient during panic situations.

This study has made several contributions to the field of healthcare by developing an Internet of Things (IoT)-based patient health monitoring system that can remotely monitor patients' vital signs and provide prompt medical attention in case of any medical emergency. The system uses heartbeat and temperature sensors connected to Arduino UNO and Nodemcu, respectively, and sends data to an Internet of Things (IoT) web platform that displays real-time data of the patient's health status. This innovative system has the potential to revolutionize the healthcare industry by providing a more efficient and effective means of patient health monitoring, which will ultimately lead to a better quality of life and improved health outcomes for the society.

The remainder of this paper has been organized as follows: Section II discusses the related works. The background of the study is described in Section III. Section IV describes the system implementation methods. Section V describes the results, Section VI describes the discussion and finally, the conclusion is described in Section VII.

II. Related Work

To achieve the intended target, it is crucial to delve into the fundamentals and knowledge garnered from prior studies. Previous works have delved into health monitoring systems that utilize wireless technology. As the health monitoring system is an integral part of the Internet of Things (IoT) system, it is imperative to scrutinize past works that employ comparable strategies and aspire to similar objectives as this research endeavor.

A. Classic Health Monitoring

The classic method of patient health monitoring has been a stalwart in healthcare institutions such as hospitals and clinics since its inception in the early 2000s. Despite its extensive use over the years, this approach falls short in terms of its ability to accurately monitor a large number of patients within a set time frame. Health staff, comprising doctors and nurses, is tasked with physically examining and recording patient data. Patients are required to queue or wait their turn for checkups, while those confined to their beds require round-the-clock monitoring. Patient data is painstakingly recorded by hand in a patient booklet and stored in physical form on shelves [7].

B. Wearable Smart Health Monitoring

Pradhan, S., Zainuddin, A. A., and Sahak's research project [8] offers an intriguing insight into the myriad methods employed to monitor health status. The authors devised a plethora of sensors to keep a watchful eye on the real-time health of animals. Their study utilized an array of sensors, including those that measured temperature, respiration rate, heart rate, and humidity rate [9][10]. To control this project, they employed the Raspberry Pi, complete with its built-in Wi-Fi module. Additionally, they created a cloud-based platform to store and transmit sensor data, while an Android mobile application system was used to gather real-time data on the animal's health state. This project effectively underscores the feasibility of wearable devices, which may be a fitting solution for our research endeavor.

C. Real Time Health Monitoring Devices

A trustworthy patient monitoring system that allows medical professionals to keep track of patients in the hospital or during their daily activities has been developed by A. Abdullah, A. Ismael, A. Rashid, A. Abou-Elnour, and M. Tarique [11][12]. The system employs mobile devices for wireless patient monitoring and enables real-time transmission of data on the patient's physical condition. The project aims to collect and analyze vital physiological data from patients to accurately determine their health and fitness levels. Additionally, the system can send text messages or email reports with important health information to patients. Healthcare professionals can provide valuable medical advice by utilizing the information in these messages. The authors utilized multiple sensors, an Arduino microcontroller, and LabVIEW software to develop the system [13][14].

D. Focused Health Monitoring

Masud, Muhammad and Alhumyani proposed a health monitoring system that focuses on three vital signs of patients: temperature, blood pressure, and heartbeat [15]. The system uses a microcontroller and several sensors to collect and visualize the data on a Liquid Crystal Display (LCD) and store it in cloud-based storage. This system is designed to assist healthcare professionals in monitoring multiple patients simultaneously. The authors employed microcontrollers such as Arduino and Nodemcu, as well as Ubidots software, to implement the project [16][17]. The system has been tested and has demonstrated good accuracy in monitoring patients' vital signs introducing a novel tree-based deep model for automatic face recognition in a cloud-based environment that strikes a balance between computational efficiency and high accuracy. The model divides the input volume into multiple volumes and creates a tree structure for each volume, where each branch of the tree is represented by a residual function comprising of a convolutional layer, batch normalization, and a non-linear function. Rigorously evaluated on publicly available databases, the proposed model achieves remarkable accuracies, surpassing the current state-of-the-art deep models for face recognition.

E. Smart Patient Monitoring using Databases and Physically Sensors

Chee Yuan, L. and Kong have proposed a health monitoring system that uses physical sensors [18]. The system involves attaching sensors to the patient's body to monitor their health data, which is then stored in a database built using Personal Home Page (PHP). While this method is effective for storing patient data remotely, it requires the use of contact

sensors that must physically touch the patient's body. Despite this limitation, the system is functional and can be implemented in health departments [19].

F. Internet of Things IoT Health Monitoring

V. Akhila, Y. Vasavi, K. Nissie, and P. V. Rao have utilized IoT and sensor technologies to develop a system that can monitor a patient's health condition in real-time [20]. The authors tested the system by monitoring the health condition of a real individual. The project involved the use of Internet of Things (IoT) and microcontroller like Arduino to gather data from analogue sensors. In the healthcare industry, the combination of IoT with Arduino microcontroller has proven to be effective in monitoring and collecting current patient health condition data [21]. This work describes the use of Arduino UNO as a sensor node and gateway in a remote health monitoring system. The system utilizes GSM for communication between doctors and patients, and Wi-Fi for transmitting sensor data to a web-based IoT platform. The ATMEGA 328p microprocessor, installed within the sensor nodes, measures temperature, pulse rate, and blood pressure readings using the temperature sensor and HP/BP sensor. The data is displayed on an LCD attached to the Arduino and transmitted to the cloud server via the Wi-Fi module. This technology allows for continuous monitoring of the health of severely ill patients and seniors suffering from heart and blood pressure disorders.

G. Contactless Internet of Things IoT Patient Health Monitoring

The framework suggested by Dipti S. Gandhamwar and Sunil Kuntawaris [22] is used to remotely monitor patients' wellbeing. Sensors such as the heartbeat sensor, temperature sensor, and SpO_2 sensor are used to estimate important parameters. The suggested model enables medical professionals to check on patient wellbeing from any location and helps people consult experts anywhere in the world. The system combines the Internet of Things (IoT) and remote sensor technology for effective health monitoring, and sensor data must be available consistently. The data is archived and viewable on the web server [23]. The system is set up to send a message to the specialist if the sensor data exceeds the threshold values. The main benefit is a reduction in the amount of time specialists and patients need to intervene in times of crisis. By recommending a minimally expensive framework for saving lives, with the hope that individuals will be amenable, the goal is achieved. The limitation of the specialist's accessibility is considered, and the proposed model does not include the pulse-checking framework [24].

III. Background of the Study

Smart technology is a combination of sensor-based, data-driven, and programmable technologies that also incorporate artificial intelligence. The integration of traditional medical scaling with advanced technology has resulted in patient health monitoring, which offers numerous benefits, such as monitoring vital signs like heartbeat rate, temperature rate, and respiration rate, which can help facilitate faster medical intervention. Currently, the Internet of Things (IoT) is considered the leading solution for developing innovative health monitoring systems [27]. Patient health monitoring systems provide a more accessible and cost-effective alternative to the traditional clinical conduct, allowing for improved access to healthcare facilities.

The goal of this proposed research is to develop a patient health monitoring system based on the Internet of Things (IoT). By minimizing doctor visits, hospital stays, and daily diagnostic tests, this system aims to reduce healthcare costs [28]. The sensors are connected to an Arduino Uno microprocessor that tracks and transmits the data collected to ThingSpeak, which can generate alerts. Health staff can monitor patients' health using IoT technology and identify any unusual readings in terms of temperature and heartbeat. ThingSpeak can display patient data in real-time. This system can save a lot of time in measuring and monitoring a patient's health at a specific time, making IoT technology reliable and efficient. The use of IoT-based patient monitoring systems has enormous potential for healthcare professionals to observe tiny aspects of a patient's well-being [29]. Therefore, the system must check and analyze the data in detail, with ThingSpeak serving as an IoT platform.

Medical facilities in remote areas are often inaccessible to local communities [20]. As a result, many people ignore minor health issues that could indicate larger problems, such as changes in body temperature or heart rate. When these issues progress to the point of being life-threatening, medical attention is sought, resulting in unnecessary expenses. This is especially important to consider in the event of an epidemic spreading to an area without easy access to doctors. Providing patients with smart sensors that can be remotely monitored could save many lives and help prevent the spread of illness [30].

The main goal of this proposed work is to develop a practical and effective system for Internet of Things (IoT)-based patient health monitoring, and to study its wellness, operation methods, theoretical framework, and impacts [31]. The recommended system is depicted in Fig. 1, and it uses two sensors to detect the patient's body temperature and heartbeat. The sensors are connected to a microcontroller unit that processes the input data from both sensors. The collected data is then sent to or stored in an IoT database. This database allows doctors or health staff to retrieve the data and monitor the patient's current health condition from anywhere via the base station.

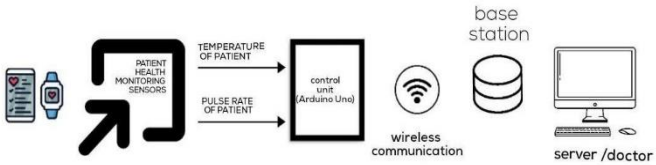


Fig. 1. Smart health monitoring system process flow.

The flowchart of the object recognition process is shown in Fig. 2.

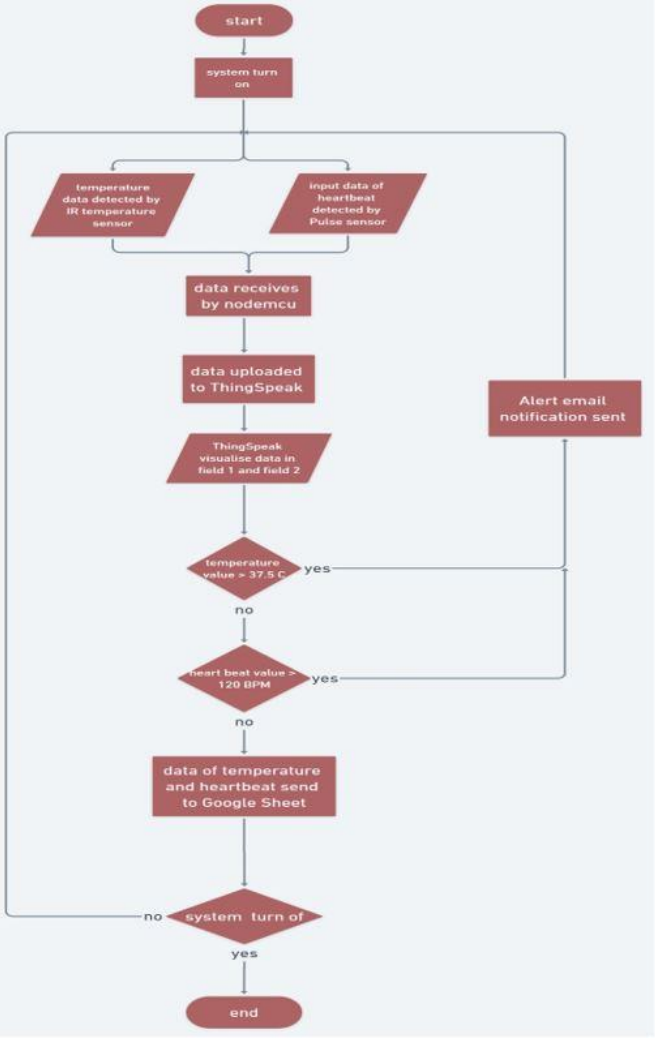


Fig. 2. Flowchart of the system.

IV. System Implementation Methods

Fig. 2 illustrates the steps involved in developing this system. Firstly, the hardware components necessary for the project were carefully selected. The Arduino Integrated Development Environment (IDE) was chosen as the software platform for coding due to its user-friendly interface and ability to process input signals and generate corresponding output signals. The project involves placing sensors on the patient's body to record vital signs. The MLX90614 sensor will be used to measure the patient's body temperature, while the Heartbeat module or pulse sensor will monitor the patient's pulse rate. The microcontroller will process the data obtained from both sensors, checking the condition of the patient against pre-set parameters. All data collected will be converted to a list and notification of any abnormal readings will be sent to the administrator. This feature is particularly useful in cases where the patient's health is at risk, and prompt action is required.

A. Hardware Development

This section provides an explanation of the hardware components used in the system. The Arduino UNO is used as the microcontroller and receives and sends data from the pulse sensor to Nodemcu through UART serial communication. The pulse sensor is not compatible with Nodemcu and needs to be connected to Arduino UNO instead. The Arduino UNO is powered by a 9V battery which is also used to power up the pulse sensor. The connections between the pulse sensor and Arduino UNO are established by connecting the VCC pin to 3.3V of Arduino, GND pin to GND of Arduino, and analog pin to A0 of Arduino. The paragraph also mentions that the hardware components are functioning properly as they indicate light when turned on.

Nodemcu is a microcontroller with a built-in Wi-Fi module that is well-suited for this Internet of Things (IoT) system as it can transmit data via the internet to the desired IoT platform. ThingSpeak platform is used in this system. Nodemcu is powered by a 9V battery. Serial communication with Arduino is established via the Receive RX and Transmit TX pins on each microcontroller, allowing pulse sensor data from Arduino to be read. Infrared (IR) temperature sensor is connected to Nodemcu to read temperature data. The IR temperature sensor requires a voltage of 3.3V, which is provided by connecting VCC to 3.3V of Nodemcu and GND to Ground GND of Nodemcu. The Serial Clock (SCL) and Serial Data (SDA) pins are connected to D1 and D2 of Nodemcu, respectively.

B. Software Development

This section describes the coding and data transmission process for the IoT-based patient health monitoring system. The coding is necessary for the pulse sensor to read the heart beat data, which is then transmitted to the Nodemcu microcontroller via serial communication. The pulse sensor library is included in the coding, and the data is read using the library's provided read data value. The data is then sent from Arduino UNO to Nodemcu, where it is received and combined with the temperature data from the Infrared IR temperature sensor. The combined data is then transmitted to the ThingSpeak platform for monitoring. The system settings provide the ThingSpeak host and Application Programming Interface API key necessary for obtaining the data. Fig. 3 shows how to access this information. ThingSpeak is a useful technology for IoT applications as it allows for remote monitoring and management of data processing. It collects, analyzes, and visualizes sensor data, and can also initiate responses.

ThingSpeak in this work is platform to visualize data receives from Nodemcu which are temperature value and heartbeat value for monitoring purpose in real time using internet. IFTTT is also used in this work by connecting it to ThingSpeak as it acts for alert message via email when there is misreading over the value or threshold that have been set when reading data from Nodemcu such as for temperature value when exceeding 37.5 and for heart beat when exceeding 120 BPM.

```
19
20  const char *ssid = "BEECMANTUL-2.4GHz";  //ENTER YOUR WIFI SETTINGS <<<<<<<<<
21  const char *password = "P@ssw0rdbeec";
22  WiFiClient Client;
23  unsigned long myChannelNumber = 1765756 ;
24  const char * myWriteAPIKey = "P5RBU8P1QH5W056I";
25  //Web address to read from
26  const char *host = "api.thingspeak.com";
27  String apiKey = "P5RBU8P1QH5W056I";  //ENTER YOUR API KEY <<<<<<<<<<<
28
```

Fig. 3. Coding for setup IoT data transmission.

V. RESULTS

Upon completing the hardware and software development for this work, it is imperative to conduct testing to determine if the desired goals have been achieved. To this end, an Infrared IR temperature sensor is connected through ESP8266, while the pulse sensor is connected through Arduino UNO, as depicted in Fig. 4. Both microcontrollers are powered by a 9V battery to initiate the circuit and system. Serial communication, specifically universal asynchronous receiver/transmitter (UART) communication, facilitates interaction between the two microcontrollers. In this transmission of serial data, various serial protocols are employed and adhered to.

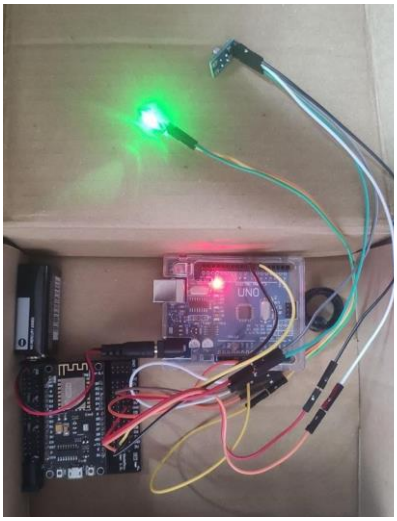


Fig. 4. Complete hardware circuit communication.

To collect data from the patient, the sensors are positioned in a way that aligns with the patient's position on the bed. The pulse sensor is placed on the fingertip while the Infrared IR temperature sensor is placed on the patient's forehead. The sensors are placed in these locations due to their compatibility with the patient's environment and the specifications required for data collection. In Fig. 5, the collected data is uploaded from the Nodemcu to ThingSpeak, with the temperature value on field 1 and the patient's heartbeat value on field 2. The uploaded data is then sent to a pre-set email on IFTTT and uploaded to a Google spreadsheet.

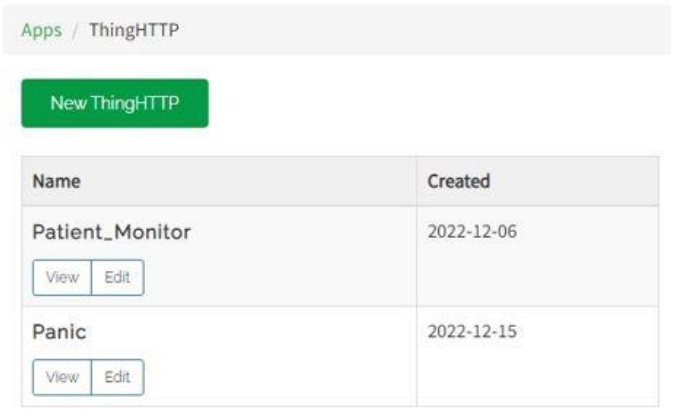
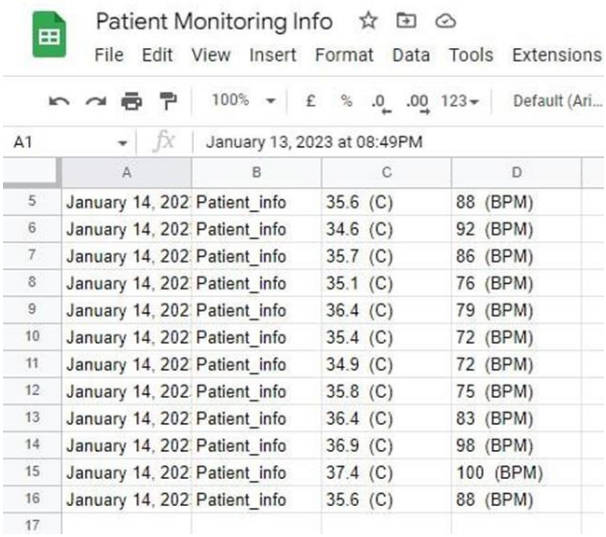


Fig. 5. ThingSpeak channel created.

To set up the IFTTT account, login is required followed by creating a new applet with two actions for triggering. The first action, "Patient_info," involves sending patient data, such as heartbeat and temperature, to a spreadsheet row via email. The second action, "Panic," alerts via email if needed (see Fig. 7). The actions should then be reviewed to ensure proper functioning. To connect the data from ThingSpeak to email, ThingHTTP and React must be configured, and the actions created in IFTTT must be triggered. Finally, save all the data and test the system.



	A	B	C	D
5	January 14, 202	Patient_info	35.6 (C)	88 (BPM)
6	January 14, 202	Patient_info	34.6 (C)	92 (BPM)
7	January 14, 202	Patient_info	35.7 (C)	86 (BPM)
8	January 14, 202	Patient_info	35.1 (C)	76 (BPM)
9	January 14, 202	Patient_info	36.4 (C)	79 (BPM)
10	January 14, 202	Patient_info	35.4 (C)	72 (BPM)
11	January 14, 202	Patient_info	34.9 (C)	72 (BPM)
12	January 14, 202	Patient_info	35.8 (C)	75 (BPM)
13	January 14, 202	Patient_info	36.4 (C)	83 (BPM)
14	January 14, 202	Patient_info	36.9 (C)	98 (BPM)
15	January 14, 202	Patient_info	37.4 (C)	100 (BPM)
16	January 14, 202	Patient_info	35.6 (C)	88 (BPM)
17				

Fig. 6. Google spreadsheet showing data collected.

When the data uploaded to ThingSpeak meeting the condition set in ThingHTTP the alert message will be send through email saying it is panic condition for the patient as well as sending the data values of temperatures and also heartbeat as can see in Fig. 6. The condition set for temperature is when value of data is exceeding 37.5 Celsius while for heartbeat is when value of data is exceeding 120 Beat Per Minute BPM.

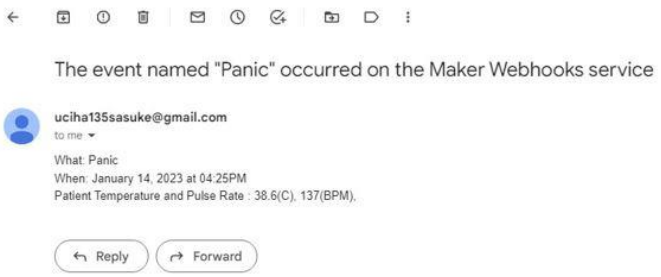


Fig. 7. Alert notification send via email.

Based on the detailed results and implementation of this work, it can be concluded that it holds promising potential for future development in the medical sector. Comparing it to other related works listed in Table I, this system shows good accuracy in collecting data through sensors and efficiency when implemented in the medical sector. However, there are a few areas for improvement to ensure the sustainability of this work. For instance, incorporating additional sensors can enable tracking of more health conditions, while high-quality sensors can stabilize the readings of data for longer periods. Additionally, using MySQL and Personal Home Page PHP as the database can cover a lot of patient data.

TABLE I. COMPARISON BETWEEN CURRENT AND RESEARCHED SYSTEM

YEAR	METHOD	NUMBER OF PATIENT TEST FOR MONITORING PER HOUR	NUMBER OF PATIENT CAN COVERED/ MONITORED PER HOUR	PERCENTAGE OF COVERED PATIENT	DATA RECORDED ACCURACY COMPARED TO ACTUAL DATA	REFERENCE
2009	CURRENT SYSTEM THAT USED WRITING METHOD FOR COLLECTING PATIENT DATA WHEN CHECK UP	50	14	28%	85%	[7]
2015	HEALTH MONITORING USING MOBILE DEVICE	50	36	72%	90%	[11]
2020	MONITORED THREE BASIC HEALTH CONDITION WITH DIFFERENT MODES	50	33	66%	89%	[15]
2019	USING PHYSICALLY SENSORS USING ARDUINO UNO AND NODEMCU WHICH THEN BE UPLOADED TO MYSQL AND PERSONAL HOME PAGE PHP	50	44	88%	93%	[18]
2018	IOT SMART HEALTH MONITORING USING ARDUINO UNO ATTACHED TO PERSONAL COMPUTER	50	40	82%	94%	[20]
2019	DATA FROM SENSORS IS ATTACHED TO ARDUINO UNO AND SEND TO CLOUDS BY RASPBERRY PI 3.	50	42	84%	91%	[25]
2021	CONTACTLESS SENSORS DATA TRANSMITTED BY ARDUINO UNO TO NODEMCU WHICH THEN BE UPLOADED ONLINE TO CLOUD	50	46	92%	94%	[26]
PROPOSED RESEARCH						
PROPOSED SYSTEM OF IOT PATIENT HEALTH MONITORING USING NODEMCU AND ARDUINO UNO	50	47	93%	96%	N/A	THIS WORK

VI. Discussion

The Patient Health Monitoring System, developed with the objective of utilizing ESP8266 and Arduino with an Internet of Things (IoT) platform, has been successfully implemented and tested through various iterations. As indicated in the results section, the hardware circuit connection in Fig. 4 provided the best and most functional means of collecting patient data, including temperature and heartbeat. The collected data is shown in real-time on ThingSpeak, making it easier for medical staff to monitor patients, while also being stored in Google Sheets for future reference. Despite its success, the system still has some limitations, particularly in terms of the reliability of the sensor data due to varying price and quality. This system has significant potential for further development and implementation in the medical sector, including clinics, hospitals, and pharmacies. It is imperative to continue improving the system by adding more features, reliable hardware, and ensuring that it is user-friendly and affordable for commercial use.

VII. Conclusions

In conclusion, the implementation of the Internet of Things (IoT)- Patient Health System brings a positive impact to the healthcare industry by providing an efficient and effective means of patient health monitoring. The Internet of Things (IoT)- Patient Health System and the proposed system presented in the research both aim to remotely monitor the vital signs of patients and provide prompt medical attention when needed. The system has successfully met all the objectives and has been able to monitor patients and alert healthcare professionals in real-time. The system integrates microcontrollers, sensors, and the ThingSpeak Internet of Things (IoT)- platform with email notifications to create a systematic and efficient healthcare system. This system provides a solution to the problem of handling a large number of patients during sudden outbreaks of diseases such as Covid-19, potentially improving patient outcomes and saving lives. Similarly, the proposed Internet of Things (IoT)--based patient health monitoring system presented in the research has the potential to improve the overall quality of healthcare services and lead to better health outcomes for society. The system's ability to remotely monitor the vital signs of patients, display real-time data on an Internet of Things (IoT)- platform, and send alerts in the event of a medical emergency can reduce the workload of healthcare providers, allowing them to focus on other critical tasks. The current system can be further improved by incorporating additional sensors like oximeters and blood pressure devices to provide a comprehensive analysis of the patient's health condition. Upgrading the sensors with newer models that offer advanced features can enhance the accuracy of the collected data. In the future, implementing this system in hospitals and clinics can help address patient data management and monitoring issues. The integration of Internet of Things (IoT)- technology in healthcare paves the way for healthcare professionals to concentrate on urgent issues and emergencies, expanding their roles in the healthcare industry. The utilization of Internet of Things (IoT)- capabilities can make healthcare more efficient and effective in providing high-quality patient care.

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