Remote patient care using a cloud-based IoT-enabled e-Healthcare system

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Abstract. The current work introduces a cost-effective system design for an e-healthcare service, which includes software and hardware components. Vital signs are assessed and sent to a qualified medical professional for consultation from the patient's site of residence. During the first stages of system development, the acquisition of temperature and heart rate signals from a patient is of utmost importance. The data is sent to a remote server located in the cloud, where it undergoes processing and analysis, afterwards made available for examination by medical professionals. The cloud server offers a secure means of transmitting and distributing data, together with an authentication system and a secure storage server that can be accessed by the patient via a mobile device. The prototype has been developed to include all the components of the system for the purpose of conducting testing. Furthermore, the challenges associated with implementing the system in real-time scenarios have been identified and emphasized.

Keywords: Arduino UNO; healthcare; heart rate sensor; temperature sensor, FFT

1 Introduction

Contemporary healthcare services are characterized by their high cost, intricate nature, and demanding time requirements. Due to a growing population, hospitals often have issues of overcrowding, resulting in prolonged waiting periods for patients seeking medical attention. While those deemed deserving get prompt emergency medical care, there exists a persistent queue of others awaiting their turn. The current healthcare systems operate in a way that necessitates individuals to through an extensive procedure, even if their healthcare needs do not warrant substantial attention. Similarly, hospitals are mostly located in metropolitan areas. The use of telemedicine technology provides individuals residing in rural regions with advantageous access to consultations with skilled doctors in metropolitan hospitals. In instances when individuals or communities possess accessible and affordable devices capable of capturing vital sign measurements and transmitting them to certified medical professionals for remote consultation, it is plausible that not all cases would need emergency hospitalization. The severity of the patient's ailment may be evaluated by the physician, who may then recommend a direct consultation and other diagnostic tests if deemed necessary. For the proper operation of this system, it is essential that the gadget provides measurements that are on par with those obtained from clinical devices. These technological devices have the potential to significantly transform the healthcare industry, enabling patients to conveniently get medical treatment regardless of their location or the time of day. This study proposes the implementation of a comprehensive system including a patient portal and a doctor portal, both hosted on a cloud server. The system is intended to be integrated with a fundamental healthcare equipment that has the capability to securely upload collected data to the cloud. Additional components have the potential to be included into the device in order to enhance its functionality, hence enabling the acquisition of supplementary measurements. Furthermore, the collected data may be sent to a cloud server for storage and analysis. The aforementioned cost-effective technology facilitates continuous connectivity between a duly registered patient and a duly registered doctor, enabling round-the-clock communication through a low-bandwidth internet connection. Instead of many trips to the hospital, the system may be used to provide post-medical care and follow-up services inside the patient's residence. To establish a system of this kind, it is important to address many challenges. In order to ensure the confidentiality of patient information, it is important to have the collaboration of doctors, a reliable cloud service provider that offers robust security measures, and adherence to established standards. Numerous service providers have started the provision of software help to facilitate the expansion of healthcare services in the internet realm, notwithstanding the inherent obstacles. The ongoing development of the internet of things architecture and the increasing adoption of this technology by cloud software providers are expected to enable the provision of online access to a certain amount of medical care delivered inside hospital settings.

2 Background and Motivation

In recent decades, there has been a consistent advancement in the field of remote medical aid. In a study conducted by [1], biosignals obtained by smartphone technology were used to monitor the health status of older individuals inside healthcare facilities. The predominant emphasis of Arduino medical support applications lies in monitoring body temperature, body position, heart rate, and other related parameters [3]. The projects' focus has been executed with optimal efficiency using a well-equipped tool [6]. The use of cutting-edge technology enables the reduction of workload for both patients and clinicians. The user's text is not sufficient to rewrite in an academic manner. Please provide more information Researchers have proposed the development of remote medical healthcare as a potential solution for those living in rural areas with restricted access to hospitals [5]. The findings of a study investigating many indicators such as body temperature, posture, glucose levels, and others may be found in reference [2]. Medical personnel have the potential to establish facilities by designing a portable device [9] equipped with wireless connectivity, which may be used on any patient. Furthermore, a study conducted by researchers [7] has been conducted to explore the integration of research with the Android platform, specifically focusing on the potential collection of personal data. Projects such as the one referenced in [8] are now in development with the aim of addressing both personal health monitoring and the assessment of diabetes. The proposed system aims to gather essential data on temperature and heartbeat by exploring the integration of intelligent sensors with cost-effective hardware platforms.

3.Proposed System Design

The proposed system comprises an Arduino board, sensors, and a cloud service that interfaces with patient and doctor portals implemented as software on smartphones. The design of the model is seen in Figure 1. The sensors are used for the purpose of quantifying patient data, while the arduino board is responsible for facilitating the transmission of this data to the cloud service. A healthcare professional has the ability to review the data stored on a smartphone device. The device monitors the temperatures and heart rates of the patients. The use of cloud services is employed for the purpose of doing data analysis on the observed data. Both the patient and the physician should first register for the cloud service. In order to proceed with each session, it is essential that the patient explicitly provides agreement for the healthcare professional to access and review their profile and associated data. The transmission of the collected data to the cloud service is contingent upon the patient's enrollment in the system. The medical practitioner has the responsibility to assess the facts provided and create a judgment on the severity of the patient's health status. The next section provides a comprehensive overview of each individual module of the proposed system.

3.1 Interactive Cloud Storage Cloud storage has emerged as a popular solution for storing and accessing data in a flexible and scalable manner. Interactive cloud storage refers to the ability to interact with stored data in real-time

Patients who have been granted permission are requested to upload their data to the server for further processing after the cloud service gets a signal from the Arduino board. The process of continuous data uploading ensures the seamless addition of new data to existing datasets, hence facilitating the establishment of a comprehensive record of observations over an extended period. Once the data has been processed, it is then shown graphically. The process of segregating the signal patterns in order to infer the characteristics of the signal is an integral component of the data analysis report. The process of conducting online patient examinations has inherent challenges; nevertheless, our system has been specifically developed to ensure ease of use for both medical practitioners and patients alike. The individual or individuals in question have the option to choose the most suitable course of action for a subsequent step by carefully examining and evaluating the facts that have been witnessed. One advantage is that in cases of severe illness, it becomes easier to manage and identify the need for immediate medical intervention. Whenever a consultation is requested via the service, patients have the option to employ the user interface to provide healthcare professionals authorization to access the information provided to the cloud service.

3.2 Healthcare Device

The healthcare device, sometimes referred to as a medical device, is a technological tool designed specifically for use in the healthcare industry. It encompasses a

The hardware components possess the capability to accurately assess the patient's temperature and heartbeat. In order to ensure the security of patient data during transmission, it is standard practice to encrypt the signals prior to their transfer to the server. Data encryption is used throughout patient registration, access control, device authentication, and data access processes. The use of a smartphone is available to patients for all services. Individuals may establish a close association with a healthcare provider due to the convenience and straightforwardness it offers, therefore ensuring access to adequate medical care. The system has four software pieces.

4.1 Patient Portal

Fig. 1. Patient Interface

Patients have the ability to create a profile and user account inside the cloud-based service through the patient portal, by submitting the required documents and photographs. Patients have the perpetual ability to obtain any further information or their own profile. When a patient uploads data during a session with a healthcare professional who is connected to the system, the healthcare professional is alerted. In the context of managing a critical disease, the system functions as a transient healthcare support mechanism. Upon request, the system provides access to the location information of the patients. Moreover, the use of this technology facilitates a chat session that enables direct and uncomplicated contact among the involved individuals.

The Physician Portal, often known as the doctor's portal, is a web-based platform designed specifically for healthcare professionals, particularly physicians. This online portal serves as a centralized hub

The doctor's interface allows for the viewing of assigned patients and their corresponding data for analysis. The physician will review the fundamental analytical findings derived from the collected data. The use of graphical analysis facilitates the identification of abnormalities within data. The data is promptly displayed to enable the physician to observe real-time changes in the data with little delay. Physicians have the ability to provide commentary on data, and afterwards, these comments, in conjunction with the analytic report, are sent to the patients. In order to enhance the diagnostic process for physicians, the technology enables the concurrent and independent plotting of many graphs.

The interface designed for the Interactive Cloud (version 4.3)The analysis of the observed patient data is only conducted on the cloud server. The cloud server is responsible for receiving the unprocessed data sent by the patients. The cloud server plays a critical role as an analyst inside this system, providing essential functionality for the doctor. The physician has the potential to modify the presentation of the data. The Fast Fourier Transform (FFT) technique is used to analyze the patient data with the purpose of detecting any abnormal variations in the recorded signals. The identification of anomalies in frequency may be achieved by the use of these methodologies.

The topic of discussion is data security, specifically focusing on the aspect of data security labelled as 4.4.The cloud service accepts patient signals sent through Wi-Fi from a smart device. The individual is able to use their unique login credentials in order to transfer their data to the server subsequent to completing the registration process and successfully undergoing authentication by the system. Upon the completion of the process, the doctor is automatically notified through a Short Message Service (SMS) notification. Encryption is used on both the patient portal and the doctor portal to safeguard the transmission of data to and from the server, hence ensuring secure data transfer. The physician is able to visually perceive the location of the patient. In the event that the patient's vital signs exhibit any irregularities, it may be necessary to document their location for potential emergency situations. Furthermore, the system is designed in a way that encourages the patient to provide information about their current whereabouts. In the event of a need, the implementation of a chat session between the doctor and patient will facilitate their interaction. This approach facilitates seamless information exchange between both parties involved in a session. The data of the patient is stored in an encrypted way on the cloud server. In order for the doctor to view the data, it is necessary for the patient to send a code generated by the system. This authentication protocol ensures that unauthorized individuals are unable to access patient data without obtaining explicit approval from the patient. Both physicians and patients are required to complete the registration process in order to become users of the whole service. In order to proceed with a specific session, it is essential to authenticate both the medical practitioner and the individual seeking medical attention. Every individual is assigned a unique identification number that may be used to differentiate between a patient and a physician. In instances when a follow-up visit is necessary, patients have the option to directly seek the continuation of care with their primary physician.

The system has five hardware components.
A person's fingertip is utilized as a sensor for temperature and heartbeat. The gadget was created using an Arduino-compatible microcontroller as well as a number of additional technologies. Figure 4 depicts the hardware configuration of the medical device.

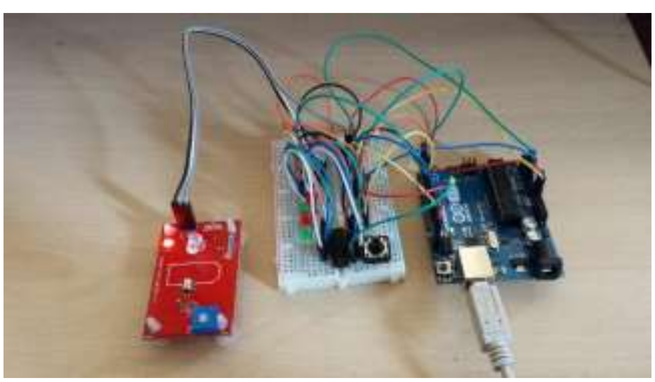

Fig. 2. Physical view of the device

This project uses an Arduino UNO microcontroller, which includes a variety of services for interacting with a computer. The ATmega328 connects to the computer through a virtual com port and achieves serial connection over USB. Additionally, it was difficult to design a gadget that was more advanced than a low-cost device with numerous restrictions, such as memory capacity. When the finger is positioned over the heart beat sensor, 660nm digital impulses are sent. With each heartbeat, the detector causes the LED light to flicker. The microcontroller uses the data from the sensor to help it measure the heartbeat frequency every minute (BPM). The heart sensor is made up of a light detector and a very bright red LED, which can pass the most light for the detectors to pick up. The blood arteries in fingers seem opaque while the heart pumps blood. Arduino creates a baseline of signals, recognizes the peaks, and filters out the noise using two successive operational amplifiers. The temperature is measured using a temperature sensor from the LM35 series, which features a linear temperature sensor, records temperatures in Fahrenheit, and is not affected by constant voltage scaling. Additionally, they do not need any kind of external calibration in order to provide the temperature ranges. The physical and electrical environment, temperature range, precision, reaction time, and thermal coupling all affect the sensor's features. The sensor has three analog pins and has a temperature range of 0°C to 1000°C. It produces a linear output of 10mV0/C with a +/-1.50°C accuracy rate.

6 Result and Analysis

Figure 3 depicts the temporal evolution of the temperature variation observed in a particular patient. The physician may use this data to ascertain the frequency of fluctuations in the patient's body temperature. One peculiar characteristic of these graphs is their capacity to be magnified, allowing for the visibility of numerical values for a duration of up to two seconds. The heart rate variation of the patient during a predefined length of time is shown in Figure 4. The gathered sensor data is sent to a server for further processing. In order to closely monitor the subtle variations of the signal, it is possible for the observer to use the zoom function on the graph due to its specific graphical representation. The abnormality of the patients has been successfully identified based on the observed data. The average temperature and heart rate have been determined. The doctors possess the capability to discern even the most minute alteration in the data. In this approach, temperature is denoted in degrees Fahrenheit, whereas heart rate is denoted in beats per minute. The body temperature of an individual in good health typically ranges between 97.3 to 99 degrees Fahrenheit, while their heart rate falls within the range of 60 to 110 beats per minute.

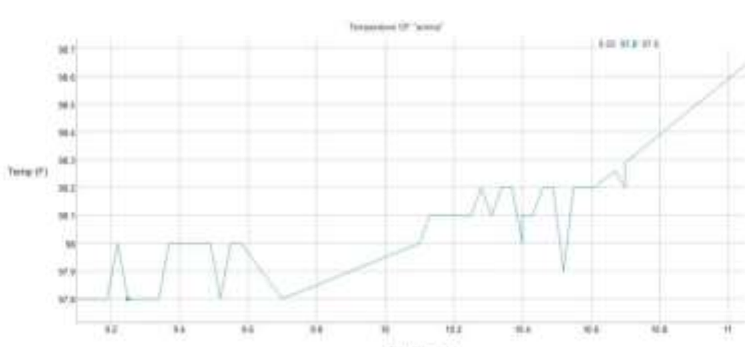

Fig. 3. Temperature Sensor Data

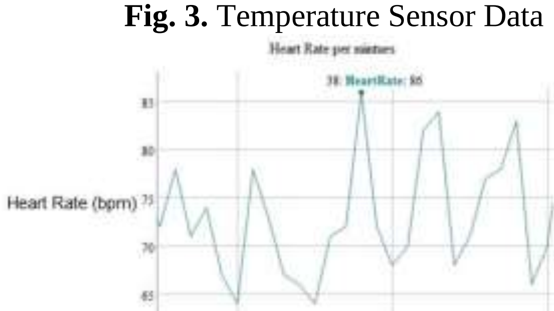

Fig. 4. Heart Rate Sensor Data

In this study, we have discovered the essential variables pertaining to the patients' conditions. For future research, we want to integrate potential modifications to the collected data and assess the patients' conditions accordingly, conducting a comprehensive analysis based on these findings. The aforementioned values may exhibit variation based on factors such as gender, age, physical ability, and other relevant variables. The use of the Fast Fourier Transform (FFT) has been employed as a means to examine signal data. Given its ability to examine even minute variances in obtained data, this approach becomes beneficial in the studies conducted by medical practitioners. The generated Fast Fourier Transform (FFT) graphs are also valuable for doing further analysis on patients. Figure 5 illustrates the Fast Fourier Transform (FFT) graph for a certain temporal interval.

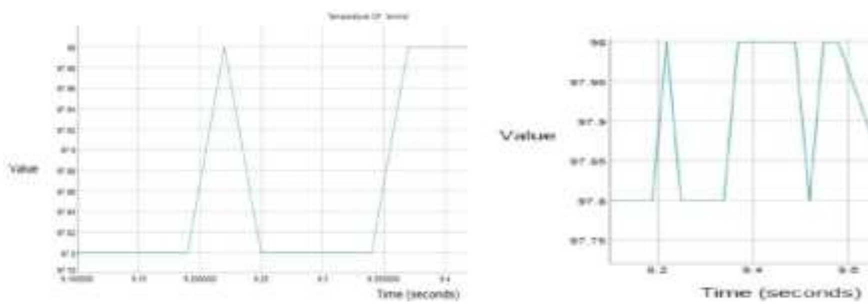

Fig. 5. Analysis using FFT in the temperature graph (a) peaks during the time interval (b) variation during the time intervals

Figure 6 shows the doctor's ability to access specific patient information for an analysis of the patient's present condition. Additionally, users may use the submit button to communicate their feedback to the patient. They may also use a chat window if they wish to speak with the patients for a longer period of time. The see image tab is used to examine all of the information that patients have contributed, including files, reports, and images in the formats of jpg, document, CSV, and pdf.

7 Security and Privacy Concerns

The challenge is in the secure storage of data on cloud platforms. The use of encryption has been employed for the purpose of protecting information during its transmission. However, the main objective is in ensuring the security of data storage via the implementation of cost-effective solutions. In order to address the current issue, it is imperative to identify and implement more effective solutions. The security of the sent data is another critical issue that significantly impacts the operation of the system. In order to ensure the safety of the system for data transmission, the implementation of code generation is used. In the future, it is anticipated that the data originating from the patient's end will be subjected to encryption, therefore ensuring its confidentiality. Consequently, only authorized doctors will possess the capability to decipher and access the sent data. The speed of data encryption and decryption is crucial in order to effectively function within a real-time framework. In order to enhance the precision of the data sent during system registration, it is important to identify a more sophisticated authentication mechanism. It is important to conduct thorough validation of the data that has been supplied.

The system has been designed to prioritize user-friendliness in order to enhance patient healthcare experiences, ensuring happiness and maximizing overall value. This is achieved via fostering stronger connections amongst healthcare professionals. Moreover, this intervention has the potential to reduce patient anxiety levels and mitigate the frequency of unscheduled hospital admissions. Patients have the option to use this device inside the confines of their own homes for the purpose of managing their healthcare, hence resulting in a substantial reduction in the frequency of hospitalizations. The contemporary healthcare industry has underscored the need for enhanced patient management capabilities and improved healthcare facilities. A solitary healthcare professional has the capacity to provide care for a substantial number of patients. The system may be accessed by any smart device with internet connection, allowing individuals to engage in personal health care regardless of their location or time. By using this technology, patients may benefit from an enhanced health monitoring system that effectively analyzes data and circumstances.

8 Conclusion

The system has been intended to provide economical patient care via the use of sensor data routing. The cloud server is responsible for receiving and storing patient data in order to facilitate its processing. Both the monitoring of patient data and the analysis of patient data are readily available. Under the existing methodology, the individual (whether they be a patient or an assistant) is provided with the device and is able to use the sensors in order to capture images or gather data. In order to evaluate the essential physiological measurements of the human body, it is possible to include a diverse range of sensors, such as electrocardiography (ECG) and galvanic skin resistance. The sensors use traditional ways to provide pictures or signals of the blood vessels. In the future, this project has the potential to be built based on an IoT base device, using the current IoT infrastructure. The provision of this service aims to provide individuals affordable access to essential medical care inside their local communities.

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