Enhancing Medication Adherence with IoT Technology

Taharimul Islam¹*, Rakibul Hassan², Shahriar Raihan Romy³, Douaa Dellal⁴, and Tareq Rageb Ahsan Bin⁵

ABSTRACT

The research focuses on the design and implementation of an Internet of Things (IoT) based Digital Medicine Box that aims to assist patients, particularly elderly individuals, in taking their medications correctly in terms of dosage and timing. The system utilizes affordable and lightweight technology, including a NodeMCU ESP 8266, an OLED display, a buzzer, and a pulse sensor. It provides reminders to users at designated times, reducing the burden of medication management. The research addresses the growing need for assistive products in homes and aims to improve medication adherence, especially among senior patients who often face challenges in remembering their medications.

Keywords: Assistive Technology, Digital Medicine Box, Health Monitoring, Internet of Things, NodeMCU ESP 8266.

1. Introduction

Advanced technologies have evolved to address the challenges faced by the world, including an increasing birth rate, rising demand for resources, and growing health concerns. Automation and robotics have emerged as innovations to tackle these obstacles and ensure survival of the fittest in today's world [1]. However, this has also led to a decrease in human capabilities and health consciousness, resulting in shorter lifespans and reduced memory power compared to traditional days. As a result, older individuals and those with hectic lifestyles struggle to manage their health effectively. To address this issue, the concept of Ambient Assisted Living (AAL) has been developed, with the MEDICINE BOX project being one such solution [2].

Internet of Things (IoT) has revolutionized the healthcare industry, with the concept of Internet of Medical Things (IoMT) connecting billions of medical devices and enabling remote operation. The MEDICINE BOX is a NodeMCU programmed IoT connected box designed to store medicines in specific compartments and measure BPM (Beats Per Minute) for patients. It aims to overcome challenges such as memory loss and forgetfulness related to medication schedules, which often render treatments ineffective. By providing an automatic alert system for prescribed medication schedules and emergency triggers, the MEDICINE BOX facilitates independent living while ensuring timely and proper medication intake (Fig. 1) [1]. Furthermore, cloud storage technology has replaced paper records, offering secure and accessible storage of patient data through Host Management System (HMS) in the cloud [3].

2. Motivation and Context

2.1. Background of Research

The research proposes a smart IoT-based healthcare system that includes an intelligent medicine box connected to sensors and a server for regular health monitoring. The system aims to assist patients in managing their health by leveraging wireless connectivity, reducing healthcare costs, and improving patient care [4]. By utilizing NodeMCU software and wireless data transfer, the system offers a...
cost-effective solution for patient monitoring and eliminates the need for paper records [5]. The project also aims to monitor vital parameters, reducing the need for frequent hospital visits and consultations with clinicians [6], [7].

2.2. Scope of Research
Recent technological advancements in the healthcare industry, particularly in the field of Internet of Things (IoT), have significantly improved healthcare services, making them more accessible and convenient. The integration of smart sensors, cloud computing, and communication technologies has revolutionized healthcare, providing solutions that benefit patients and healthcare providers alike [8]. However, despite these advancements, IoT in healthcare still faces challenges and issues that warrant further research. The following section discusses some of these issues.

3. Review of Literature

The Internet of Things (IoT) architecture consists of five layers: perception, network, middleware, application, and business. The perception layer includes physical devices and objects that collect data and transmit it to the network layer through wired or wireless mediums [10]. The middleware layer processes the information, while the application layer manages device operations. At the top, the business layer oversees the entire IoT system, applications, and services. Additionally, IoT architectures can be customized to meet specific requirements and incorporate functional blocks such as sensing mechanisms, authentication, control, and management (Fig. 2) to support various activities within the IoT.

The IoT system comprises essential functional blocks responsible for I/O operations, connectivity, processing, audio/video monitoring, and storage management. These blocks collaborate to achieve optimal performance in IoT systems. While there are various reference architectures available, there is currently no universally standardized architecture suitable for global IoT implementation. A well-designed architecture is needed to meet the diverse needs of the IoT landscape (Fig. 3). IoT gateways play...
a crucial role in facilitating communication between IoT servers and devices across different applications.

### 3.2 Research on IoT in Bangladesh

Bangladesh is rapidly adopting the Internet of Things (IoT) in various sectors, including smart homes, government organizations, smart farming, smart metering, and smart city applications. By leveraging IoT, Bangladesh can gain a competitive advantage in sectors such as the garment industry, agriculture, the blue economy, and traffic management. Implementing IoT solutions can improve labor efficiency in garment factories, increase fish production, address environmental issues in the Bay of Bengal, and optimize traffic management in Dhaka. It is crucial for Bangladesh to embrace IoT in sectors where it holds an advantage to maintain its competitive edge and maximize the benefits of IoT implementation.

### 4. Methodology

Our project’s objective is to create a specialized medicine box that provides various functionalities. First and foremost, it serves as a reminder system to ensure that patients take their medication at the designated times. With an integrated alert system, it alerts patients when it’s time to take their medicines, promoting adherence to the prescribed medication schedule. Our medicine box incorporates a heart rate monitor capable of measuring the patient’s heart rate, commonly known as beats per minute (BPM). This feature is particularly beneficial for individuals who need to monitor their heart health or have specific medical conditions that require heart rate tracking [11], [12].

Our project focuses on developing a versatile medicine box that serves as a comprehensive tool for patients. It aids in medication adherence, monitors heart rate, provides time and date information, and assists with medication organization.

#### 4.1 IoT based Medicine Box System Design

Fig. 4 shows the design of the medicine box system based on IoT.

#### 4.2 Modules of IoT based Medicine Box System Design

##### 4.2.1 NodeMCU ESP8266

The NodeMCU ESP8266 development board (Fig. 5) comes with the ESP-12E module containing the ESP8266 chip having Tensilica Xtensa 32-bit LX106 RISC microprocessor. This microprocessor supports RTOS and operates at 80 MHz to 160 MHz adjustable clock frequency. NodeMCU has 128 KB RAM and 4 MB of Flash memory to store data and programs. Its high processing power with in-built Wi-Fi/Bluetooth and Deep Sleep Operating features make it ideal for IoT projects. NodeMCU can be powered using a Micro USB jack and VIN pin (External Supply Pin). It supports UART, SPI, and I2C interface.

##### 4.2.2 Pulse Sensor

The Pulse Sensor Amped is a user-friendly heart-rate sensor designed for Arduino/NodeMCU, offering accurate and real-time heart-rate data integration into various projects. It features an optical sensor, amplification, and noise cancellation circuitry for reliable pulse readings, consuming low power for mobile applications. Simply attach it to your earlobe or fingertip and connect it to your Arduino/NodeMCU for easy integration (Fig. 6), with example code and visualization options provided [12], [13].

##### 4.2.3 OLED Display

OLED displays utilize organic light-emitting diodes as their primary light source, emitting light when electric current excites the molecules within the diode (Fig. 7). They...
4.2.4. Buzzer

An audio signaling device, such as a beeper or buzzer (Fig. 8), converts an audio signal into sound and can be electromechanical, piezoelectric, or mechanical. It operates on DC voltage and is used in timers, alarms, printers, and other devices. The buzzer typically has two pins: a positive terminal powered by 6 Volts and a negative terminal connected to the GND terminal.

4.2.5. LEDs

LEDs (light-emitting diodes) are semiconductor devices that emit light when an electric current is applied (Fig. 9). They are commonly used as indicator lamps in electronic devices and in applications such as automotive lighting, billboards, and fiber-optic systems. LEDs operate through electroluminescence, emitting photons due to electronic excitation. The composition of the semiconductor material determines the wavelength and color of the emitted light. LEDs typically emit light in the visible spectrum or near infrared. The brightness depends on power and the eye’s sensitivity. LEDs operate at low voltages, around 2.0 volts, with currents ranging from milliamperes to hundreds of milliamperes.

4.2.6. Google Firebase

Firebase is a platform developed by Google for creating mobile and web applications [16]. It was originally an independent company founded in 2011. In 2014, Google acquired the platform and it is now their flagship offering for app development.

4.2.7. Android App

Android is a mobile operating system based on the Linux kernel and open-source software. It is designed for touchscreen devices and developed by the Open Handset Alliance, supported by Google. While it incorporates proprietary components, its core elements are derived from the Android Open Source Project. Android devices often come pre-installed with proprietary software, including Google Mobile Services (Fig. 12). While alternative ecosystems
and forks exist, the use of the “Android” name and logo is regulated by Google [16].

NodeMCU ESP-8266, Pulse sensor, OLED display, Buzzer, and some LEDs. Those devices will be connected with Google firebase and will take data from the Android app to work accordingly. The mobile app also can give notifications and voice messages about medicine doses [19], [20].

5. Implementation and Analysis

The design of the medicine box is specifically created to facilitate the organized storage of medications according to the prescribed medical schedule. It includes compartments with labels to store optional drugs that are taken before and after each of the three daily meals [18]. These compartments are partitioned to ensure appropriate temperature conditions for drug storage. By utilizing the Peltier effect, the partitions are securely maintained at optimum temperatures, including normal temperature and cold storage (Fig. 11). The compartments can be accessed through a secure servo motor, with the coordination of hardware and software achieved through Arduino programming (Fig. 10) [17].

To track the patient’s medication intake, switches are provided along with separate partitions to record the tablet information. An IoT module enables the system to monitor whether the patient has taken the tablets according to the schedule throughout the day. The data is then sent to a cloud software accessible anytime and anywhere, which provides updates to the designated guardian and clinician. Furthermore, the patient’s body parameters, such as heartbeat, spo2, and body temperature, are continuously uploaded to the cloud through a Wi-Fi module. This occurs as the calibrating sensors detect changes in the patient’s parameters.

To ensure the security of the drugs, the medicine box can only be accessed through the user’s biometrics, preventing misuse (Fig. 13). A reminder alarm is incorporated into the system to fulfill the primary objective of the project. Additionally, an LED display guides the patient on the steps required to access the box whenever the tablets need to be taken. All these modules are operated through the Arduino mega module, and the power supply, supported by a buck converter, is distributed to the various modules inside the box, enhancing user-friendliness and functionality (Fig. 14).

5.1. Development of IoT based Medicine Box System

In this part, a circuit diagram has been designed that showcases the integration of multiple components such as
NodeMCU ESP8266, a pulse sensor, an OLED display, a buzzer, and three LED lights. The NodeMCU ESP8266 serves as the main microcontroller unit and is responsible for controlling the other components (Fig. 15). The pulse sensor is used to measure the heartbeat rate of the user and display it on the OLED screen. The buzzer and LED lights are used to provide feedback to the user in the form of an audible alarm and visual cues respectively. The circuit diagram presented in this paper can also be used as a basis for developing various health monitoring systems.

6. Results & Discussion

Hence, a smart medicines box designed with an embedded system based on IoT technology to overcome the disadvantage of patients Ambient Assisted Living (AAL). The daily activities of the respective patient’s health details and their medication details transfer with the benefit of GSM node alert SMS with the help of Wi-Fi connected smart medicine box (Fig. 16). The cloud system acts as the bridge for doctor-patient relations in order to overcome the inconvenience of handling the record. The doctor suggested treatments become more effective and beneficial when the patients are reminded to take the right drugs at the right time through alarm as per the doctor prescribed schedule and tablets taken by patients.

After installing the mobile app, we have putted the medicine name and doses within the app. Now we have placed medicine to the classified compartment of the box as per prescription.

Now we can keep the medicine box close and keep this connected with 5 volts + adapter. The app will alert the patient with a text and voice message “take your medicine” when the given time and phone’s time is same (Fig. 17).

Also, within the OLED display the time-date medicine name, medicine doses and time will be shown. And the buzzer will also make a sound to draw attention.

After opening the box this will indicate with the LED, in which compartment the medicine is. Starting with a NodeMCU ESP-8266, Pulse sensor, OLED display, Buzzer, and some LEDs. Those devices will be connected with Google Firebase and will take data from the Android app to work accordingly. The mobile app also can give notifications and voice messages about medicine doses.

The compartmentalized box design for thrice in a day helps the patient to store drugs and consume the drugs easily i.e., user friendly. There is no complication in the usage of smart medicine boxes such that people do not need any training to handle medicine boxes. Thus the aim of Ambient Assisted Living (AAL) for a patient is successfully achieved by less complicated design and sensors to monitor vital parameters of patients along with the fingerprint sensor for high security of the medicine box. The updating of patient details in the cloud like their vital parameters assists both doctors and patients in acknowledging the health condition whether abnormal or critical readings are
observed. The observations of readings alert the doctors for further treatment. The less power-consuming modules in the NodeMCU gains the advantages of the construction of the smart medicine box. Finally, the use of emergency switches for the patients assists them in emergency situations which triggers the alert SMS to the caretakers and doctors. Henceforth, the patients can live independently and safely protected through IoT by their doctors and relatives or guardians.

7. Conclusion

The MEDICINE BOX project exemplifies the potential of IoT in revolutionizing healthcare by leveraging automation and cloud storage technologies. By addressing challenges such as medication adherence, memory loss, and data management, it offers a promising solution for Ambient Assisted Living, benefiting older patients and individuals with busy lifestyles. As technology continues to advance, IoT-based innovations like the MEDICINE BOX have the potential to transform healthcare, improving patient outcomes and enhancing quality of life.

In order to enhance the system in the future, numerous ongoing research projects are focused on developing an efficient offline application for storing patient health data. The design of the smart medicine box compartments will be further improved to meet the patient’s specific requirements in a more precise and compact manner. To address the issue of power drainage caused by the Peltier module used for cold storage, upcoming efforts will aim to reduce its impact in order to increase the battery capacity. In the future, an adaptive cooling method will be implemented, which will greatly benefit the storage of drugs. The patient or caregiver will be able to refill the medicine box using a suitable application or cloud platform, facilitated by a pill counter setup equipped with an infrared (IR) sensor. Moreover, additional health sensors will be incorporated to accurately monitor and sense other health parameters, providing comprehensive and precise information about the patient’s health status.

8. Future Work

This is only a start to its health check-up options. This will be helpful for all types of patients in the future, as we will try to include blood pressure and Blood Glucose levels, body temperature, and Oxygen level measures. And also, to improve the accuracy up to 95%–97%. And that will keep these data and use them as the history of a patient. After analyzing the history this will try to give some general medical advice to the patient. Then that will be helpful for doctors to know the history of a patient.

REFERENCES