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Research Article

Rational Drug Management System with Internet of Things

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Abstract – According to World Health Organization data, more than half of the medicines used are used inappropriately. It is important to use medicines, which have protective and therapeutic properties when used correctly, on time and at the specified doses. The use of drugs that are not in accordance with Rational Drug Use may cause undesirable situations such as decreased treatment success and prolonged disease duration. In parallel with the developments in technology in the last century, the internet has become an integral part of our lives. This situation has revealed the concept of Internet of Things, which refers to the connection of different devices to each other with the help of wired and wireless networks to exchange information. In this study, a Rational Drug Use System was developed using Arduino, App Inventor and RESTful API. Through the developed system, the user will enter the hours he/she needs to take his/her medication during the day and the total duration of medication use. According to the usage information entered into the system, it will be possible to track whether the medication has been taken or not. In this way, medication tracking will be automated and the user will be ensured to take his/her medication on time, and the use of medication at the appropriate time and at the appropriate dose will be maximized and optimum benefit will be obtained.

Keywords – Internet of Things, Rational Drug Use, Medication Management System, Pill, Hapmatik

I. INTRODUCTION

Drugs of chemical, herbal and biological origin, which are used for disease prevention, diagnosis, treatment or to change any activity of the body, need to be managed correctly at every stage of the process starting from production to use and disposal of waste. The World Health Organization (WHO) has defined Rational Drug Use (RDU) as 'a set of rules that require patients to take medicines in accordance with their clinical needs, in doses that meet their personal needs, in sufficient time, at the lowest cost to themselves and society' [1], [2]. While drugs have protective and therapeutic properties against diseases when used correctly, they have an important place in terms of public health because they are substances that seriously threaten human life and even end human life when used incorrectly [3]. Inappropriate drug use in RDU may lead to undesirable conditions such as increased mortality and morbidity, adverse outcomes due to drug interactions, prolonged disease duration, recurrence of diseases, decreased treatment success, and increased treatment costs [4], [5].

According to World Health Organization estimates, more than half of all medicines are used inappropriately. Findings on drug use in Turkey show that this estimate is also valid in our country [6]. Factors such as how, at what dose, for how long (how many days), and how often (3 times a day, 8 hours apart) the medication should be used are among the most important problems encountered in RDU for

patients with health problems such as old age, forgetfulness and Alzheimer's disease. Especially in diseases such as Parkinson's, if the patient does not take his/her medication on time, he/she starts to move his/her hand, arm or leg involuntarily. If the patient does not have a constant companion, if the medication is not followed up properly or if the medication is forgotten, great problems arise in the patient [7]. In health problems, regular and timely use of medication is of great importance.

With the advancement of communication technologies and artificial intelligence, the collection, interpretation, recording and monitoring of data in the cloud system and the creation of decision-making algorithms gain great importance in daily life. In parallel with these developments, the internet has become an integral part of human life. The rapid development of mobile technologies has caused the internet to take more place in daily life applications [8]. This situation has led to the concept of Internet of Things (IoT). The Internet of Things refers to a system that allows objects in the physical world, sensors embedded in or next to them, to connect to the Internet via wireless and wired connections [9].

IoT is an innovative and open to development area that directly affects human life in the field of health. It is critical for elderly individuals or chronic patients to take their medication on time for the successful continuation of their treatment processes. However, forgetting to take medication in the busy daily life is a common problem. Failure to take medication on time and at the required dose causes many adverse events such as heart attacks in heart patients, seizures in epilepsy patients, and coma in diabetic patients.

In this study, an IoT-based RDU system that includes reminder and tracking systems has been developed due to these and similar reasons that cause incorrect and untimely medication use such as patients forgetting the use of medication, mixing the medications to be used, unnecessary use of medication, medication application errors by the companions. The developed system is named as Hapmatik. The developed system consists of Arduino (hardware control), App Inventor (mobile application) and RESTful API (data management and real-time notifications) components.

II. MATERIAL AND METHODS

A. Rational Drug Use

The World Health Organization defines a drug as ‘a substance or product used or intended to be used to alter or treat physiological systems or pathological conditions for the benefit of the recipient’ [10], [11]. Incomplete, excessive or incorrect use of drugs both negatively affects the health of patients and reduces the quality of life. Therefore, it is necessary to be rational in the use of drugs in order to prevent the negative effects that may occur in addition to their protective and therapeutic effects. RDU is also defined as the planning, execution and monitoring process that ensures that drug therapy can be applied economically, safely and effectively [12].

Irrational drug use is the use of drugs that are not suitable for rational drug use. In irrational drug use, not using the drugs for the period specified by the doctor, forgetting the use of drugs, using more or less drugs than necessary and using the right drug in the wrong dose, duration and form are the main problems encountered [13].

B. Internet of Things

The Internet of Things refers to the interconnection of various devices, called objects, with wired or wireless networks to communicate and exchange information [14], [15]. The concept of Internet of Things can be used for general and technical connection from computer to computer, object to object, object to computer and computer to object [15]. IoT, which has many different definitions in the literature, is also called the internet of everything, machine-to-machine communication, network of things. Today, IoT applications are becoming increasingly widespread. Internet of Things is used in different fields such as health, agriculture, home automation, smart cities, energy management, industrial studies, logistics and vehicle tracking, security applications. According to the statement made by Thales Group (2020), one of the global companies, there were 26.6 billion active IoT devices worldwide in 2019, and according to the data published by Statista (2020) research company, it is estimated that there will be 75 billion IoT devices in the world by 2025 [16].

The Internet of Things has a layered architecture. There are different number of layered architectures in the literature, but the most general architecture is 3-layered architecture. These are [17], [18].

- Perception Layer / Object Layer (Perceptron Layer): It is the lowest layer of the architecture where objects and identifiers are located.
- Network Layer: It is the middle level layer responsible for communication, which connects the lower and upper layers of the network architecture and the objects in the perception layer.
- Application Layer: It is the complementary layer where the data becomes available and the results can be observed.

Figure 1 shows the 3-tier IoT architecture [19].

Figure 1. 3-tier IoT architecture

C. *Rational Drug Use System Components*

Hapmatik project consists of two parts: hardware and software. Hapmatik system hardware and software components are shown in Figure 2.

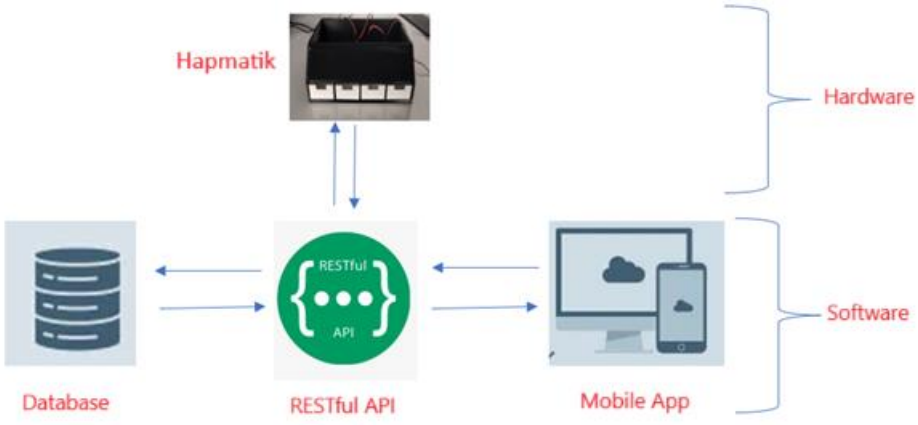

Figure 2. Hapmatik system hardware and software components

In the hardware part, a box with separate drawers where the pills belonging to the patient will be placed was designed. Tinkercad programme was used in the box design. The visuals of the drawings obtained using the Tinkercad programme are given in Figure 3.

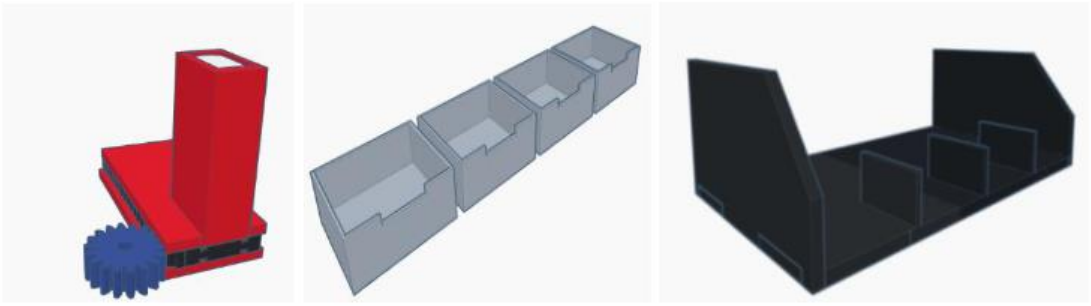

Figure 3. Hapmatic drawings created with Tinkercad programme

The parts whose design was completed in Tinkercad programme were printed on a 3D printer. The printed parts are shown in Figure 4.

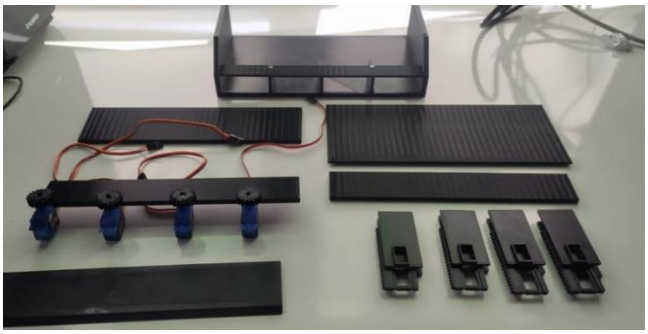

Figure 4. Parts printed from 3D printer

After the parts were produced on the 3D printer, the parts were assembled and the electronic circuit elements were assembled. Figure 5 shows the final version of the Hapmatik design. Other electronic components are placed inside the case.

Figure 5. Hapmatik hardware design

After the hardware design and connections were completed, the connections of Arduino and electronic circuit elements that will control the hardware were realized.

Electronic circuit elements used in the project;

- 1 Ardinuo UNO,
- 1 ESP 8266 module,
- 1 HC06 (Bluetooth module),
- 1 RTC (Real Time Clock) module,
- 4 servo motors,
- 1 buzzer,
- 1 button
- It consists of 8 LEDs.

The electronic circuit elements used are shown in Figure 6 respectively.

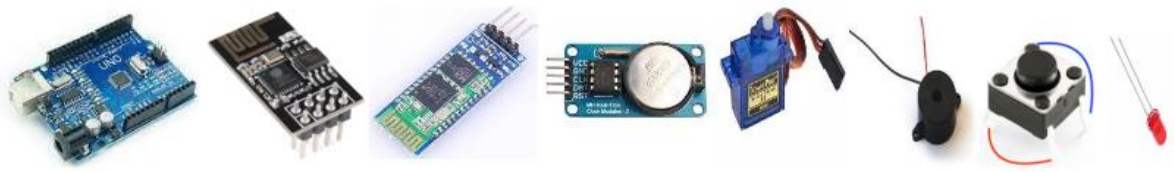

Figure 6. Electronic circuit elements used

Arduino UNO: It is a microcontroller platform that can be programmed through a computer and various electronic projects can be done. With Arduino, it is possible to realize many electronic projects that you can think of such as robotic projects, smart home systems. Buttons, remote controls and different sensors can be connected by using the electronic connections on Arduino as inputs; by obtaining electronic outputs according to the data obtained from these inputs, you can control motors, robotic mechanisms, relays, and even control the change of any data on the internet via Ethernet or Wi-Fi according to the input values you obtain through the programme you write.

ESP 8266 module: It is a self-contained module with built-in TCP/IP protocol that can give any microcontroller access to the Wi-Fi network. ESP8266 Wi-Fi module can easily connect to the Wi-Fi network in the environment, receive and send data packets.

HC06 Bluetooth-Serial Module Board: It is designed for Bluetooth SSP (Serial Port Standard) usage and wireless serial communication applications. The pins required for fast prototyping and easy use in Arduino and various circuits are taken out of the circuit board. Supporting Bluetooth 2.0, this card allows communication at 2.4GHz frequency and has a communication distance of approximately 10 meters in an open area.

RTC (Real Time Clock) module: It is a real-time clock circuit integrated module that you can read the clock information instantly and continuously. The module has DS1302 integration that can continuously hold seconds, minutes, hours, days, months and years.

Servo motor: It is a movement control device. Servo motors are the most widely used motor type in robot technologies. Servos are designed to take the desired position and not change its position unless a new command is received.

Buzzer: It is a kind of sound device that can give different reactions according to the electric current. In this way, sounds in different tones can be received from the same buzzer at different times.

Pushbutton: An electrical switching component, also known as a pushbutton, used in an electrical circuit. The circuit connection is switched on or off by the user pressing a button.

Led: It is an electronic circuit element that emits light operating at a voltage between 1.5-3V.

The software part of the Hapmatik project consists of App Inventor (mobile application) and RESTful API (data management and notifications) Electronic circuit elements used

MIT App Inventor: It is a free application development tool created by Google and later developed by the Massachusetts Institute of Technology, which allows application development with block coding method. The mobile application interface of the project was developed with MIT App Inventor. A sample visual of the developed mobile application interface is given in Figure 7.

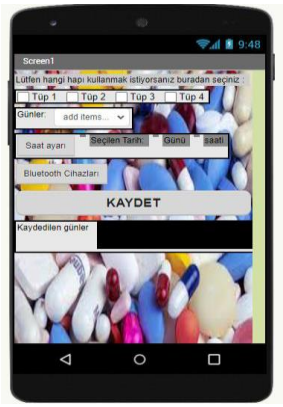

Figure 7. Mobile application interface

RESTful API: REST is an architecture that works over the HTTP protocol that provides communication between client and server. It enables the application to communicate by carrying XML and JSON data between the client and the server. Services that use REST architecture are called RESTful service (RESTful API). The only thing we need to work with a service written in REST is the URL. When a request is made to a URL, the URL returns a response in JSON or XML format, and the service integration is completed by parse the returned response. In other words, the client application does not have to know the structure and details of a REST service. Rest services; Thanks to the separation between client and server, the REST protocol facilitates the independent development of different areas of a project. In the Hapmatik project, the RESTful API saves the data from the Arduino to the database. Incoming data is stored in a cloud-based database. This allows the data to be stored in a centralized location so that it can be used later for analysis or other operations. The data stored in the database can be accessed via the mobile application via RESTful API.

III. RATIONAL DRUG SYSTEM DESIGN WITH THE INTERNET OF THINGS

The working steps of the Hapmatik system are shown in Figure 8.

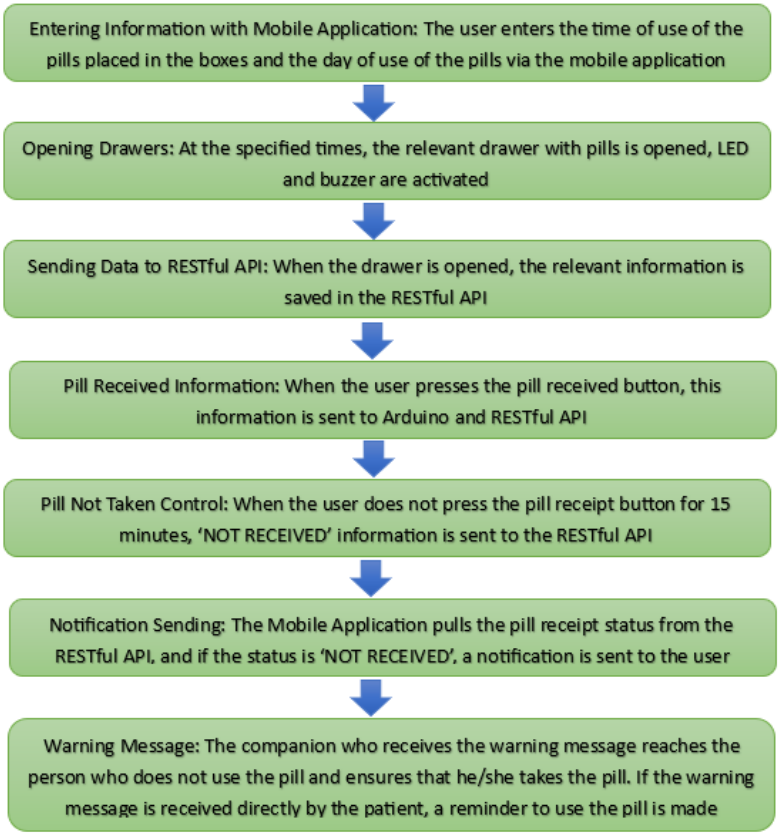

Figure 8. Hapmatik system working steps

Entering Information with Mobile Application: Hapmatik system can be connected to the mobile application in 2 different ways via Bluetooth and internet network. In Hapmatik, HC06 Bluetooth module is used for Bluetooth connection and ESP 8266 module is used for internet connection.

In Hapmatik, there are 4 pill boxes for the user to place different types of pills. The user puts the pills in these boxes and sets the day and time for each box separately via the mobile application. The user must first select the pill box he/she wants to plan from the mobile application interface. Then, the time and day information for the selected box is entered. After entering the data in the mobile application, an HTTP request is sent to the RESTful API by pressing the 'SAVE' button.

Opening Drawers: When it is time to open the boxes for which time and day information is entered via the mobile application, the drawer is opened with the servo motors on the Hapmatik. The LED of the opened drawer lights up and the buzzer is activated and an audible warning is given.

Sending Data to RESTful API: After the drawer is opened, the ESP 8266 module on the Hapmatik, which provides wireless network connection, sends time, day and 'ACTIVE' status information to the RESTful API. The data sent is saved in the database.

Pill Received Information: When the user presses the 'Pill Received' button on Hapmatik, this information is sent to both Arduino and RESTful API and the status of the drug is updated as 'RECEIVED' in the database. The Arduino closes the drawer and disables the LED and buzzer.

Pill Not Taken Check: If the user does not press the 'Pill Received' button for 15 minutes, the status= 'NOT RECEIVED' data is sent to the RESTful API.

Notification Sending: If the user has not taken the pill within the specified time, the status information on the active day and time in the database is checked via RESTful API via the mobile application. If the status data is 'NOT RECEIVED', a notification is sent to the user from the mobile application.

Warning Message: The warning message reaches the person who needs to take the pill or the companion using the application to take the pill. This message can be sent via the mobile application or via SMS/email.

IV. CONCLUSIONS

In this study, a Rational Drug Use System was developed using Arduino, App Inventor and RESTful API. The developed system allows the user to determine the medication hours, determine the duration of medication use, and monitor whether the medication is taken or not. In addition, real-time notifications and warning messages are sent to the designated persons in case the medication is not taken via the mobile application. In this way, the use of medication at the appropriate time and at the appropriate dose will be maximized and optimum benefit will be achieved.

Regular medication use is critical for the successful continuation of the treatment processes of patients who need to take their medication on time, such as elderly individuals, Alzheimer's patients, patients with chronic diseases, diabetics and blood pressure patients. With this study, a rational drug monitoring system that includes reminder and tracking systems has been developed to help people who forget to take medication and confuse which medication to take and when to take it.

With the study, medication tracking will be automated and the user will be able to take his/her medication on time. With the Hapmatik system, the need for a companion to monitor pill use in patients where pill use is important will be reduced. The patient's relatives will be able to track whether the medication has been taken from the mobile application. In this way, the problems of using too much or too little, premature or premature medication will be eliminated for patients. In addition, in diseases that affect the structure of the brain and trigger forgetting, it will be ensured that the patient can be self-sufficient and the positive motivation that this self-sufficiency adds to the person will be achieved.

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