Medicine Box Reminder for Patients with Chronic Disease with IoT-Based Database Monitoring

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Abstract*— Chronic illness is the highest cause of death in the world, to avoid increasing causes of death due to chronic diseases, it requires appropriate processes which require a long time of treatment and the drug becomes the most important component. Unfortunately, the level of adherence to taking medication in patients with chronic diseases is still low. According to the CDC (Centers for Disease Control and Prevention) carelessly taking medication can cause 30-50 percent of treatment failures and 125,000 deaths per year. Therefore in this study will create a medicine box reminder system for chronic disease patients with database monitoring based on IoT (Internet of Things) which can be monitored in real-time, this research stated reminder system using an android application that will be connected with medicine box reminder devices made using raspberry pi 3 model B, with speaker components and a PAM8403 amplifier. Based on the results of the study, it was found that the system that was made was tested with the user and produced a level of functionality of 100% and an average delay on the reminder system of 4,239 seconds for the reminder when going to take medication, and amounted to 7,298 seconds to inform that it had taken the drug, and amounted to 97% for checking the accuracy of taking drugs with QR code.

Keywords*— IoT, Chronic Illness, Taking Medication, Raspberry Pi, Speaker, PAM8403

I. INTRODUCTION

Chronic Disease or Chronic Disease is the highest cause of death in the world. According to WHO, chronic diseases kill 41 million people each year, which is equivalent to 71% of deaths in the world. Every year, 15 million people die from chronic diseases at the age of 30-69 years, 85% more of these deaths are premature deaths that occur in several countries [1].

Chronic Disease is a disease that lasts 1 year or more and requires ongoing medical care, according to the Centers for Disease Control and Prevention (CDC) 6 out of 10 adults have a chronic disease, and 4 out of 10 adults have 2 or more chronic diseases [2].

The treatment process in patients with chronic diseases such as cardiovascular, diabetes, chronic respiratory diseases (ie chronic obstructive pulmonary disease, asthma), cancer, and others require long-term treatment to stabilize their condition [3]. Therefore, drugs become the most important component in the treatment process, it is estimated that the use of appropriate drugs alone can reduce up to 80% of the burden of chronic disease sufferers in many countries [4].

Unfortunately, the level of adherence to taking drugs in patients with chronic diseases is still low, the lack of compliance levels of taking drugs is also experienced in patients with chronic diseases such as diabetes or hypertension, which only ranges from 43 percent to 78 percent [5] Whereas, according to the Food and Drugs Administration in America The union which is equivalent to the POM Agency in Indonesia, the Centers for Disease Control and Prevention (CDC) states that indiscriminate taking of drugs causes 30-50 percent of treatment failures and 125,000 deaths annually [6]. Therefore, following the rules of taking medication from a doctor is very important, especially for people with chronic diseases who should not miss routine medication even though [6].

From the results of interviews that have been conducted with a patient who has breast cancer named Siswantini Suryandari, it can be concluded that patients often forget to take medication due to their daily activities. Interviews were also conducted with a nurse named Bolan Ria Amanda, who treats patients with lymph cancer, the result is that nurses

often give medicines not on time, and the last one is an interview with Brigita Cika Risda, who is a family member of a patient with leukemia cancer. From the results of the interview, it can be concluded that the patient's family often forgets to give the medicine according to the time and sometimes likes to give the wrong dose of medicine. From the results of the interviews above, it can be concluded that to overcome the problems above, a tool that can help remind and make it easier for patients to take medicine, as well as a tool that can make it easier for nurses or patient families to monitor.

The Internet of Things (IoT) is a system of wireless, interrelated, and connected digital devices that can collect, send and store data over a network without requiring human-to-human or human-to-computer interaction. The IoT promises many benefits to streamline and enhancing health care delivery to proactively predict health issues and monitor patients both in and out of the hospital which can be monitored in real-time [7].

Many studies have been done related to making a system or device that makes it easier for patients to taking medication, such as [8] designing a device to help patients to take the required medication in the right amount at the appropriate time. The tool made is also equipped with a GSM module to remind the patient. In another study, [9] also designed a tool to provide information automatically to the patient to take the right dose at the right time by using the Arduino microcontroller as the mover. In another study as well, [10] designed a smart pillbox with a reminder and consumption function, which is used to alert the user to take pills at a certain time and the pills needed to take at that time out to users to avoid confusion among drugs. The common problem above is that most patients do not take a medication just in time.

Based on the background description above that has been explained, the author wants to design a "Medicine Box Reminder for Patients with Chronic Disease with IoT-Based Database Monitoring"

II. THEORY

A. Chronic Disease

Chronic illness is a condition of human health or persistent disease or its effects last a long time. The term chronic is often applied when the disease lasts for more than three months. Chronic illness is a disease caused by various factors. Starting from lifestyle, transmission, to the abnormality of the body system. Chronic diseases are diseases that require super intensive care and also require large costs [11].

B. Internet of Things (IoT)

Internet of Things or often called IoT is an idea where all objects in the real world can communicate with each other as part of a unified system using an internet network as a link [12].

The concept of what IoT is is very easy for everyone to understand. Simply put, the Internet of Things is a basic concept that connects any device. Including a refrigerator, TV, washing machine, lights, smartphone, car, and much more. In addition to everyday equipment, IoT can also connect various engine components such as aircraft jet engines, oil mining drills, and others. If we have equipment that has an on and off switch, it has a great opportunity to be used in the realm of the IoT (Internet of Things) [12].

C. Embedded Systems

Sugeno Embedded systems are controllers that are inside larger systems to perform special functions. They are used in some modern devices, including household machines such as microwaves, toasters, and washing machines. The immersion system in the washing machine, for example, will be assigned to close and open the valve to let water enter the system at specified intervals (pre-washing, washing) and then exit when it needs to be drained. These processes are controlled by a microcontroller [13].

The complexity of embedded systems can vary greatly depending on the task designed for them, from a single microcontroller to a series of chips with peripherals and connected networks [13]. The embedded system used by the author is the Raspberry Pi.

D. Raspberry Pi

Raspberry Pi is known as a single-board computer, which means exactly like a computer, such as a desktop, laptop, or smartphone, but is built on a single circuit board. Like most single-board computers, Raspberry Pi is small like a credit card - but that doesn't mean Raspberry Pi isn't strong. Raspberry Pi can do anything that can be done by a computer that is bigger and more power-hungry, though not as fast as a computer [14].

Various Raspberry Pi models have been released since Model B, each carrying better specifications or special features for certain use-cases. The Raspberry Pi Zero family, for example, is a small version of the Raspberry Pi that removes some features - specifically some USB ports and wired network ports - supporting a significantly smaller layout and decreasing power requirements [14].

E. Android

Android was originally developed by Android, Inc., and was bought by Google in 2000. The founders of Android Inc. are Andy Rubin, Rich Miner, Nick Sears, and Chris White who later became Google's Teams. Android was officially released in 2007, along with the establishment of the Open Handset Alliance, a consortium of hardware, software, and telecommunications companies that aims to advance the open standards of cellular devices [15].

Android is an open-source software platform for mobile devices. Android contains an operating system, middleware, and basic applications. The Android OS is a Linux 2.6 kernel that has been modified for mobile devices. Android version 1.0 was first used on mobile phones, followed by

version 1.5 (Cupcake), 1.6 (Donut), and so on. The latest Android version is 4.4 (kit-kat) [15].

Android applications are developed with the Java programming language, but not in the J2ME platform which has many limitations. The platform used on Android is equivalent to J2SE, and this is a major advantage of Android [15].

F. REST-API

REST or stands for Representational State Transfer is an API development model. Almost all major web services, such as Google, Facebook, and Twitter, use REST for their API because REST is based on HTTP (which happens to be a protocol that drives almost all internet connections). In addition, REST is very light and flexible and can easily handle large numbers of activities [16].

The idea behind establishing REST is that instead of using complex web services such as SOAP or XML-RPC, REST uses the HTTP protocol to make connections. Therefore, all RESTful applications use HTTP requests to handle CRUD operations, which are created, read, update, and delete. This is what makes REST versatile, and everyone can make by with what they want and use the desired programming language, such as Perl or PHP [16].

III. RESEARCH METHODS

A. Method of collecting data

1. Primary data was used in the form of observations and interviews. At this observation stage, the researchers made observations on the system of someone who has a disease in taking medication, observing the mechanism of action of how patients take medication directly. At the interview stage, two interviews will be conducted, namely before and after the development of the system with patients, nurses, and patient's families.
2. Secondary data used is in the method of data collection using literature study, the authors search for supporting data relevant to the object to be examined. The supporting data is used in the preparation of background, theoretical basis, research methodology, and system development. The search came from 9 books, 10 journals, and 9 websites.

B. Systems Development Method

In this research, the writer uses the prototyping method in developing the system. There are 5 stages of prototyping[17] namely:

1) Communication.

At this stage, the communication that the author does is by finding relevant information through a journal reference about the medicine box reminder system that has been studied, then discussing it with experts or experts in the research.

2) Requirements Gathering.

At this stage, it explains what the system requirements are, which is described as follows:

a) Define the Scope

The scope of this research is someone who has an illness and is actively taking medication, or a nurse who is caring for sick people, and families in which one of the families has a disease. The proposed Medicine Box Reminder system provides a container for putting medicine that has a slot for a week, a slot that owned per day is 4 slots, this container is also accompanied by speakers that will sound when it is time to take medicine, this system can also be connected with the android application, which makes it easier for patients, nurses, and the patient's family knows whether the patient has taken medication or not, because there is a database that stores patient data.

b) Current System Analysis

Based on the results of observations and interviews conducted, it can be seen in figure 1

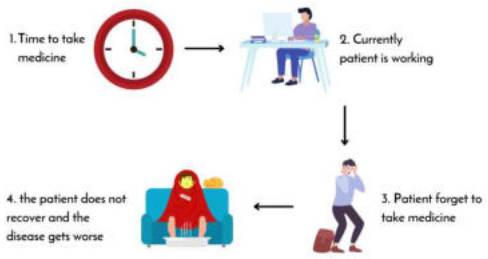

Figure 1. Current System

Based on the results of the researcher's observations, it can be seen in Figure 4.1 where when a patient forgets to take his medicine, it will have a negative impact on the current treatment process.

c) Proposed System Analysis

In this study, it was concluded that there are still many patients who feel that there is no system that can overcome the problem of forgetting to take medication. As a solution to this problem, a Medicine Box Reminder System based on the Internet of Things is proposed using the Raspberry Pi 3 Model B and an android application. The following is a proposed system that can be seen in the image below.

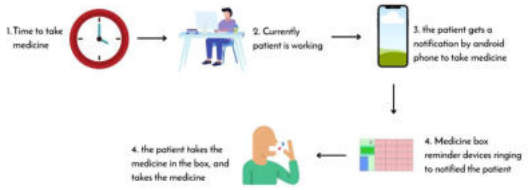

Figure 2. Proposed System

d) Functional Requirements Analysis

This stage contains an analysis of the functional requirements of the system. The main functional requirements of the medicine box reminder system will be presented in Data Flow Diagrams (DFD).

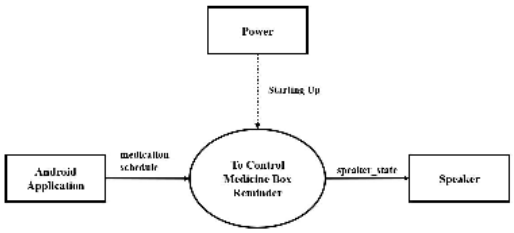

Figure 3. Context Diagram/DFD Level 0

Figure 3 shows data through external input that enters the system process. The data comes from the input results of the android application, namely the patient's treatment schedule. After the system receives it, the data is processed to produce output data to the speaker.

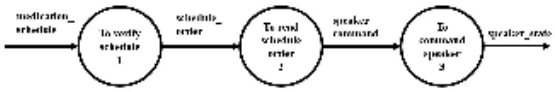

Figure 4. DFD Level 1

Figure 4 shows the Level 1 Data Flow Diagram (DFD) of the Medicine Box Reminder System. The data processing process will be carried out after the input has been entered, the input system will go through several processes until it finally produces an output in the form of speakers.

e) Hardware Requirements Analysis
In making this medicine box reminder system, several hardware devices are needed, such as Raspberry Pi 3 Model B, Android Smartphone, Speaker, and PAM8403.

f) Software Requirements Analysis
In addition to hardware, the software is also needed to support the performance of the medicine box reminder system so that the system can run as expected. Namely Raspbian OS, Android Studio, Microsoft Visio, and Fritzing

3) System Building Stage

At the stage of building this system, it will perform a temporary design of the system that will be made as to the initial stage of making a system before entering the coding stage of the system. At this stage, a system design architecture scenario will be made that makes the hardware used into a unified system so that the circuit can be assembled and programmed at a later stage [18].

1. *Design of medicine box reminder devices*
In the process of designing a medicine box reminder tool, the researcher designs a tool to be used as a benchmark for making tools.

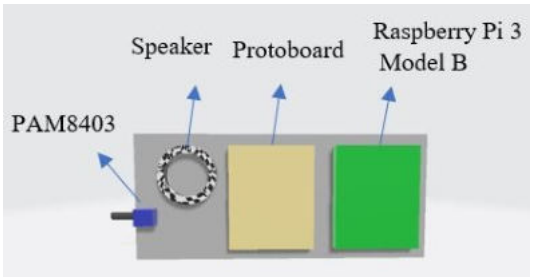

Figure 5. Design tools

2. *Schematic of Raspberry Pi 3 Model B with PAM8403 and Speaker*

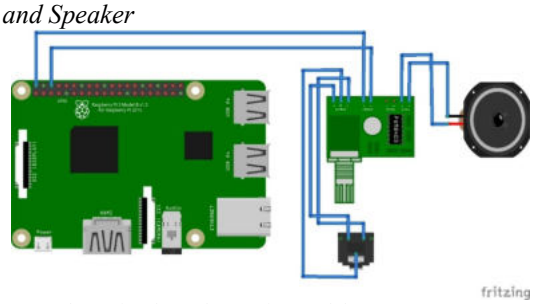

Figure 6. Schematic of Raspberry Pi 3 Model B with PAM8403 and Speaker

Figure 6 will explain how the Raspberry Pi 3 Model B is connected to the PAM8403 amplifier and speakers to produce sound when it is time for the patient to take medicine. Here is a schematic form of the system of the Raspberry Pi 3 Model B connected to the PAM8403 and speakers.

3. *Application Display Design*
The following is a design view of the application that will be created. Consists of several features, to meet the needs contained in the requirements gathering stage.

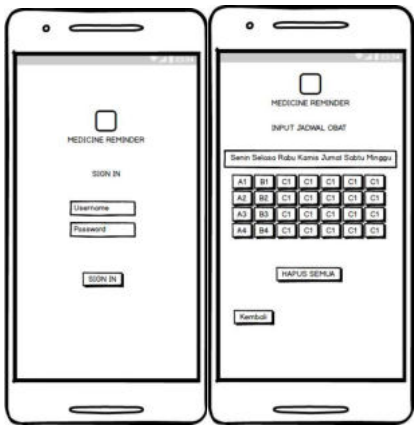

Figure 7. Android Application Mock Up

4. *Stage Encoding System*

The coding stage of the system is the stage of translating the design in the previous stage into a final system that can be used. The steps are:

1. *REST API Programming using Slim Framework*
At this programming stage the REST API uses the Slim Framework with the PHP programming

language, this REST API is used as a web service that also functions as a database.

2. *Programming Medicine Box Reminder devices*
At this stage, Medicine Box Reminder devices are programmed using a Raspberry Pi 3 Model B with the python programming language.

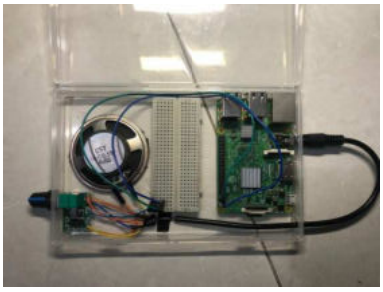

Figure 8. The appearance of Medicine Box Reminder Devices

3. *Android Application Programming using Android Studio.*
The following are the results of developing android applications based on designs that have been made previously. The application consists of 3 navigation options, namely home, menu, and user. This application development uses android studio software.

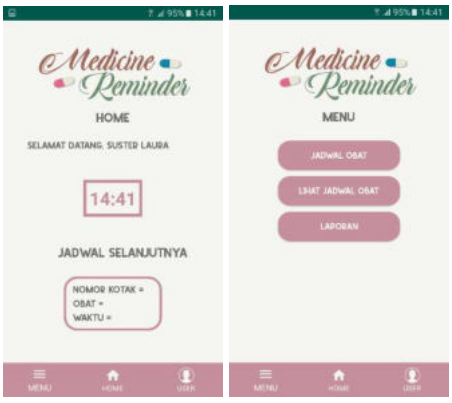

Figure 9. Android Application

5. System Testing Stage

After completing the system coding stage, researchers must test the results of system implementation. Testing is carried out at two levels, namely the system level with the aspect of performance testing and the user level with the aspect of functionality testing. The method used in the test is *black box testing* where the test is based on checking the design details, using structure control of program design procedural to divide the test into some test cases [19].

1. *User Acceptance Test*
User acceptance test is a method to find out the responses of users to the system that has been built [20]. Functionality test is done by user acceptance testing. The tested parameters are arranged based on the main functions needed by stakeholders. This test is carried out by the target of this study, namely the patient, nurse, and patient's family.
2. *Performance Test*
To get performance results from the Medicine Box Reminder system, the researchers made several test scenarios with several parameters, namely the Calculation of the Reminder System Delay in the Medicine Box Reminder and the Accuracy of Patients Taking Medicines Or Not By Checking the QR Code.

TABLE I REMINDER SYSTEM DELAY CALCULATION

Reminder System Delay Calculation on Medicine Box Reminder		
Test Number	*Delay time* (s)	
	When taking medicine	After taking medicine
1	3.810	7.936
2	3.745	10.647
3	4.385	7.431
4	3.415	8.760
5	4.036	4.461
6	5.920	8.517
7	3.621	3.786
8	4.467	2.921
9	4.026	10.023
10	4.968	8.504

TABLE II. ACCURACY OF PATIENTS TAKING MEDICINES

Patient Number	State		Fact	
	Taking Medicine	Not Taking Medicine	True	False
Patient No. 1	15	0	15	0
Patient No.2	14	1	14	1
Patient No.3	15	0	15	0

IV. RESULT

Based on the material that has been presented on the theoretical basis of the medicine box reminder system, this system allows patients who often forget to take their medicine and have the wrong dose of medicine, to get a reminder system in the form of hardware and software. The hardware is a medicine box reminder device and the software is an Android application.

Based on the results of performance testing on the medicine box reminder system, it is obtained as follows.

User acceptance tests carried out by patients, nurses, and patient's families, the data from the functionality test results are simplified in the following table.

TABLE III. RESULTS OF UAT

Test Number	Testing Topic	Total Suitable Value	
		Yes	No
UAT-01A	Testing with Patient's Family	7	0
UAT-01B	Testing with Nurse	9	0
UAT-01C	Testing with Patient	9	0
UAT-02C	Testing with Patient	9	0

In table 3 the number of conformity scores obtained in this study is 34. While the level of conformity expected in this user acceptance test is the number of scores plus a score that does not match the test results, which is 34 + 0 = 34. Then the percentage level of conformity of this application with the user is 100% with the following calculation.

Based on the results of performance testing on the medicine box reminder system, it is obtained as follows.

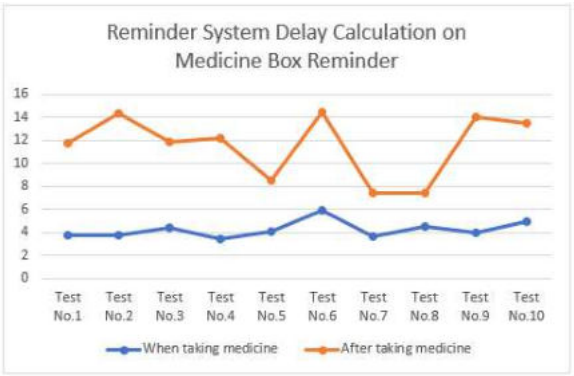

Figure 10. Reminder System Delay Calculation Graph

Figure 10 displays a graph of the test results for calculating the delay in the reminder system on the Medicine Box Reminder. There are 2 reminder conditions in the form of a speaker turning on, namely when the patient is taking the medicine, and when the patient is finished taking the medicine. It can be seen from the results of the graph above in the section when taking medication, the graph did not change significantly, while on the graph after taking medication there was a significant fluctuation. In which the average delay at the time of reminder for patients taking medicine is 4.239 seconds and the average delay when patients have taken medicine is 7.298 seconds. Based on these data, the authors know the delay in the medicine box reminder system, that the delay when the patient has taken the medicine is more volatile due to the checking process after it is time for the patient to take more medicine and some delays are deliberately programmed to meet the needs of the Medicine Box Reminder device.

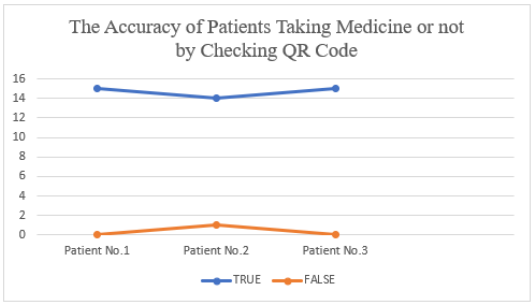

Figure 11. Graph of Patient Taking Medication Accuracy

In the graph in Figure 11. that the success rate, the accuracy of the patient taking medication or not by checking the QR Code, although there are still some who have not succeeded. Based on the results of the calculation of the level of conformity, checking the patient has taken medication or not by using a QR code, the percentage is 97%.

V. Conclusion And Sugestion

A. *Conclusions*

Based on the results of the research and discussion in the previous chapter, it can be concluded that an Medicine Box Reminder for Patients with Chronic Disease with IoT-Based Database Monitoring system can be designed using a Raspberry Pi 3 Model B microprocessor with components in the form of speakers and PAM8403 which will be connected to an android application. With the average delay calculation of the reminder system on the medicine box reminder of 4.239 seconds for a reminder when taking medicine and 7,298 seconds for notifying that you have taken medicine, then with accuracy checking whether you have taken medicine or not by using a QR code of 97% and function suitability is 100%.

B. *Suggestions*

After making a Medicine Box Reminder for Patients with Chronic Disease with IoT-Based Database Monitoring (Internet of Things), there are several suggestions for readers in the next developer. For example, adding chat features, expand IOS applications, adding security to the authentication process, automatically time synchronization, and adding machine learning.

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