"Electronic medicine box" solution for patients with chronic disease

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Abstract

In healthcare, not following the treatment plan often leads to patients' treatment failure, especially for those who require long-term medication. Yet, strictly following medication schedule still causes many difficulties for patients as they usually have to take a lot of tablets a day, some may be given with more than 2 types of medicine at large quantities and prolonged using time. The "electronic medicine box" solution in this paper will help patients follow the treatment plan. It will remind the patient of the time to take each kind of medicine, monitor use of medicine over a period of time, store a record of the patient's medication schedule, and update electronic medical records to aid the diagnosis and treatment. The electronic medicine box was designed to have compartments to contain tablets, with an alarm function and a notification light in each compartment. Every time the medicine compartment is opened, a notification will send to management software in the computer that the patient has put the medicine into the corresponding compartment. In addition, the medicine box also has a reminder that is applicable in other cases such as reminding the patient to bring along the medicine box when he/she goes to work. The "Electronic medicine box" solution was built on an embedded system combined with hardware. Most of the research objectives have been achieved, some of which could be changed and modified during the work process. Besides, a few additional functions and improvements will be mentioned in the future.

Keywords: *Electronic medicine box, Embedded system, Realtime system, Alarm system, Transfer and store data, Medicine in use solution*

1. Introduction

Today, due to significant technological development, especially in health, the number of kinds and uses of medicine are increasing quickly. Each medicine has a specific time and number in its application which can be adjusted for each patient. As expected, numbers of over 60 years old elders will increase 2.5 times in 2050 as compared to 2013 (Avinash, 2011; Richard et al., 2018).

According to statistics of the World Health Organization, at least 80% of the over 60 years old elders have to take medication from 2 to 4 times per day (Ganesa et al., 2015). These patients frequently make mistakes in remembering the time and/or quantity of medications. In most cases, it is very difficult to monitor the patients' proper use of medications (Edmundo, 2004).

In the cases of chronic diseases, patients are required to take many kinds of medication in order to maintain their life quality and minimize their health risks. With these cases, the patients may be aware of no difference, whether or not they take their medication. This problem proposed a major challenge for patients to strictly comply every day without help (Joshua, 2007). Non-compliance results in the treatment failure, relapse, infection and is one of the main reasons for the emergence of medication-resistant strains of infectious agents (Candace et al., 2003).

A patient's non-compliance occurs, for example, because a patient forgets to take one or more medicines, forgets to comply with various rules of taking one or more medicines, misunderstands rules of taking one or more medicines, or does not want to take one or more medicines (e.g., because taking the medicines is a nuisance, because of adverse side effects related to one or more medicines, etc.)(Jay et al., 2010).

Currently, there are many different ways to remind patients, for example, verbal and written instructions, home-visits, telephone reminder, behavior modification, limited medication access, and pill bottle alarms. According to the International Journal of STD and AIDS, these methods have been successful at many different levels, however, an alarm pill box has been the most effective method until now. (Joshua, 2007).

Diaa and Mohamed (2018) presented Medicine Reminder and Monitoring System. The pill box will remind patients with speaker and light when the pill time has been set. The information on the medications that should be taken will display on the Android application. The information on the medications is set daily by users. This system, however, is not a portable and easy-to-use system.

Aakash, Ganesan, and Ashwin (2015) presented an intelligent pill box. This box has an alarm function with GMS technology to alert users when tablets need to be refilled. There are fewer applications of this system.

Ali (2017) presented a working hardware platform and consistent software combined together to create a prototype version of an embedded system. A low power E-paper display was used, the data was saved and sent wirelessly, and the power supply was managed by a flexible regulator. This system had a lot of functions, and the idea behind the transfer and storage function was also very creative. However, this system was time-consuming and costly and requires many human resources. In developing countries, it is very difficult to implement and operate this system.

It can be seen that the issue of medication compliance is very important in the treatment process. Many researchers have shown interest in this issue, and the idea of an electronic medicine box (smart medicine box) has been developed and some certain results have been achieved. In Vietnam, this issue is still very new and unconcerned, therefore there has been no specific to date regarding this issue.

2. Objectives

The goal of this work is to design an “electronic medicine box” that can be scheduled and remind patients to take medicines at the right time. In addition, the time of taking medicines corresponding to each compartment of the box will be recorded and stored for each patient's treatment process. This electronic box should also be a portable and easy-to-use system and suitable for developing countries where there are limited facilities and technology and the product’s price is their important factor to consider.

3. Materials and Methods

3.1. Overall block diagram

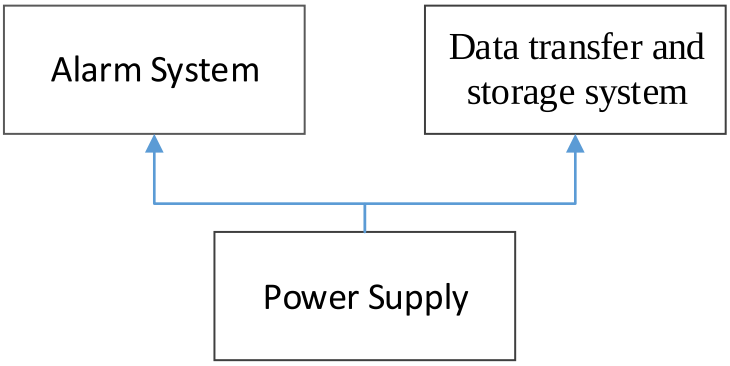

Figure 1 Overall block diagram

The proposed product consists of 3 main blocks: Alarm System, Data transfer and storage system; shown in Figure 1. The main function of the alarm system is setting the alarm with lights and speaker for scheduled times. It should be noted that a multi-compartment alarm setting is available. The data transfer and storage system could detect the patient`s times of taking medication, then transmit the data to a personal computer.

The next two sections will focus on the detailed analysis of the alarm system and data transfer and storage system.

3.2. Alarm System

An electronic medicine box has five compartments, each with its own LED and alarm. The alarm system consists of the following components: a 4x4 matrix keypad, an LCD 16x2, a speaker, and an Arduino Nano MCU. The 4x4 matrix keypad is used because of its user-friendliness and ease of use. The time to take the medicine and quantity of medicines taken will be set by the nurse and the doctor in charge using the 4x4 keypad. The time and numbers of pills display on the LCD screen on each compartment. When it is time for the patient to take the medicine, the LED corresponding to the specific compartment will light, and the speaker will ring to notify the patient. MCU receives a real-time signal from DS1307 via I2C communication. Also, the 16x2 LCD uses I2C module to connect to MCU saving number of pins (ports) on MCU, down to 2 pins (ports). Figure 2 illustrates the structure of the Alarm system.

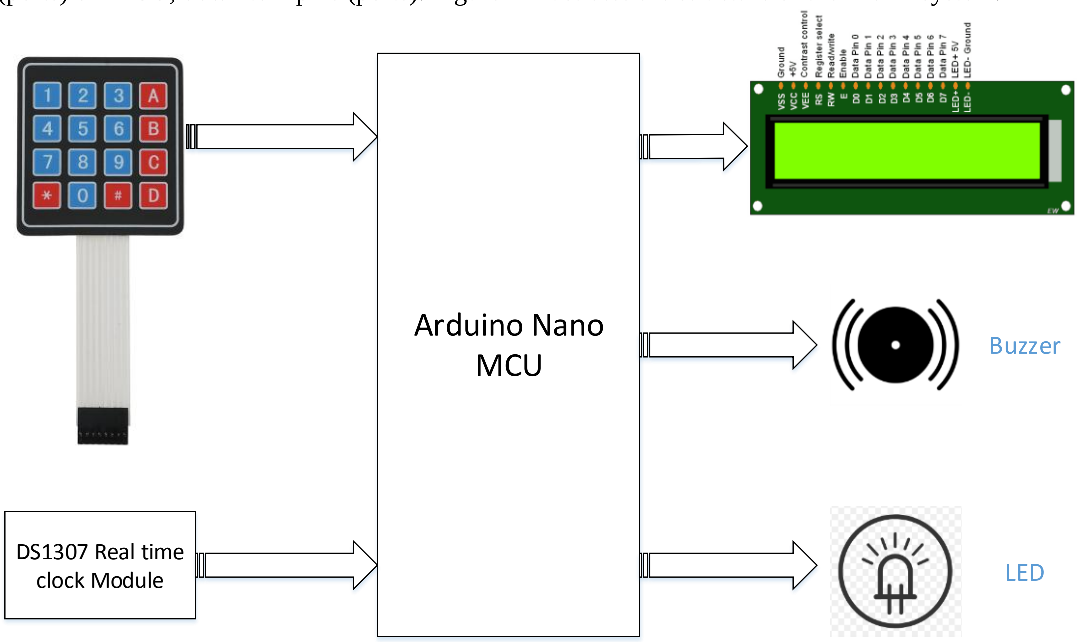

Figure 2 Structure of Alarm system

3.3. Data transfer and storage system

The data transfer and storage system includes NodeMcu v1.0 Lua - ESP8266 ESP12E MCU, Photosensitive Sensor Module, and ThingSpeak website. The data transfer works based on the perception of light in the medicine compartments. When the compartments are closed, the light intensity is low, the photosensitive sensor module will output a 5V voltage. When a compartment is opened, the light intensity will increase because of light from the surrounding environment, at this time a 0V voltage level will be output. These two voltages are collected and processed by MCU. Whenever there is a voltage level change from 5V to 0V, the MCU immediately sends data to ThingSpeak. The structure of the data transfer and storage system is illustrated in Figure 3.

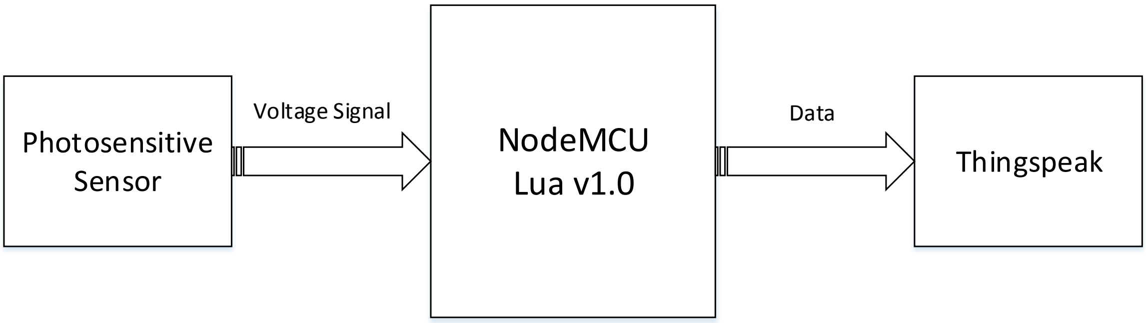

Figure 3 Structure of Transfer and Restore system

In the data collecting and storing process, a ThingSpeak webserver platform is used. ThingSpeak is an open-source Internet of Things (IoT) application and application programming interface (API) to store and retrieve data from things using protocol HTTP over the internet and a social network of things with status updates. Users will use KPI keys from ThingSpeak and then embed them in MCU code, data will be sent and display on the web interface corresponding to the key KPI used (Figure 4).

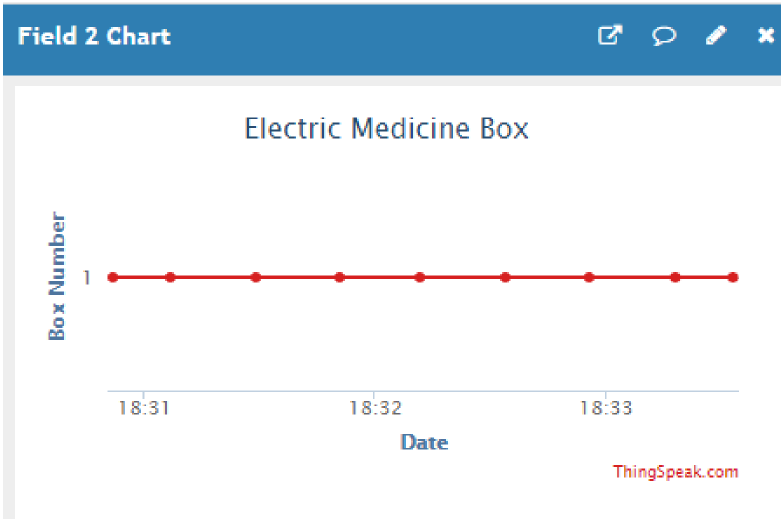

Figure 4 Web interface of ThingSpeak

4. Results and Discussion

An embedded system for an electronic medicine box was successfully implemented and almost all of the aforementioned objectives were achieved, resulting in a working system consisting of hardware and software that were integrated together. The alarm system was running, the data was transferred and stored in the server. The product's user interface is friendly and easy to use for all ages. Besides, the power supply is a direct power from the adapter so this system is not portable. Consequently, all modules were communicated and worked properly. The "Electronic medicine box" is now ready for modification and improvement for future work. Figure 5 illustrates the completed "Electronic medicine box" system.

Figure 5 Image of "Electronic medicine box". The external box size is 17x15x3 (cm)

A study published in the Journal of the American Medical Association in 2008 showed that at least 40 percent of 65 years old and older Americans take five medications a day (Diaa & Mohamed, 2018). Therefore, there will be 5 medicine compartments designed to ensure that the numbers of medicine compartments are sufficient in most cases. The functions of the medicine compartments are to keep the medicines inside and prevent the sensors from light. Users could freely open the compartments. When the compartment is opened, the light will reach the sensor then the system will send the data to ThingSpeak server.

The LCD display interface on LCD of the Alarm system is illustrated in Figure 6.

Figure 6 Performance of LCD in working. From left to right are box number, quantities of medicine, and set times

An example when the preset time comes is shown in Figure 7, two LEDs at compartments corresponding to the numbers displayed on the LCD are lighting.

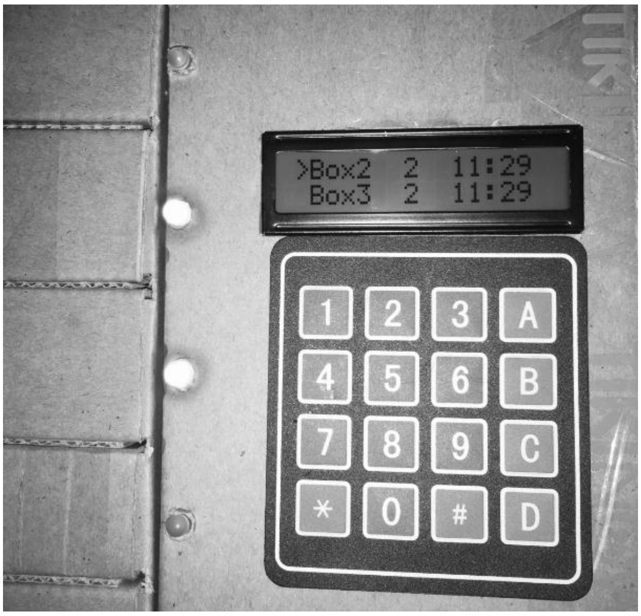

Figure 7 LED is lighting when time set of box2 and box3 come

A chart showing data from NodeMcu is illustrated in Figure 8.

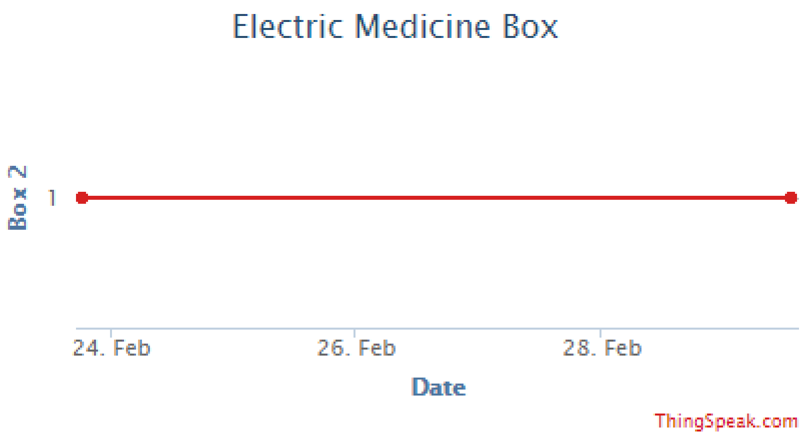

Figure 8 Data was stored in a chart on ThingSpeak

The outstanding advantage of the product is that it is easy to use. The data is quickly transferred and accurately stored. Patients or doctors could also conveniently observe the records of the patient's medication schedule on the ThingSpeak website.

Besides that, due to limited time and resources, both hardware and software will need to be modified and improved in the future, as follow:

- The external box design is currently quite big. We aim to improve the circuit and components to save space. The power supply will need to be optimized to meet the portability requirement.

- The data transfer and storage system in this study is quite simple. A suggested future work is to use “data logging with real-time graphs” method, which is advantageous as programmers can change the interface in a proactive way, and more different kinds of data can be stored and display. In addition, the development of an electronic medical record that can be stored and used to extract data is also an option.

5. Conclusion

In this study, the “Electronic medicine box” was successfully designed with the purpose to remind a patient of the time to take each kind of medicine, monitor the use of medicine over a period of time, and store a record the patient's medication schedule. The “electronic medicine box” can help reduce the rate of mistakes in medicine use in treatment and save time for nurses, doctors, and family members in monitoring the patients. Future studies can improve the size, components, and technology for the hardware, and the transfer and storage data methods in software to increase the practicality of “Electronic medicine box”.

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