

Designing a Smart Drug Box

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ABSTRACT

It is evident that punctuality in taking medicine can be an issue and failure to take appropriate medication as prescribed by the physician on the proper time may lead to health complications. Management of medication is very important for acute illness and long-term health conditions. Smart Drug Box (SDB) connected through a mobile application installed on the patient smartphone can be used to remind the patient as per the prescription by the physician. The construction of the SDB is divided into three phases. The first phase is the box design using Computer Aided-Design (CAD), the second phase is the software design, and the last phase is printing the box. The prototype of our SDB is designed with a miniaturized size and a user friendly-interface. The SDB prototype weighs 350 grams when empty without any medication. This SDB meets the needs of the market in terms of integrating electronic technology and network functionality and can be used by patients at their homes or by nursing facilities. Using the SDB will not only significantly reduce the

chances of errors but also enhance and speed up the caretaker follow-up by letting the SDB to take care of medicine management. The proposed SDB is simple to use, affordable and, has high accuracy. The main purpose of this is to improve health care and patient's overall health condition by giving scheduled reminders, therefore, ensuring patient adherence to the treatment plan in terms of dose time and quantity.

Keywords: Medicine Adherence; Medicine Reminder; Smart Phone; Prescription Tracker.

INTRODUCTION

Regularity in taking medicines is important for curing patients regardless of age. It is a well-known fact that medications are the primary approach for treating the majority of human illnesses [1]. In addition, routine monitoring and assessment of the individual's adherence to take medication is necessary to keep a track of their recovery [2]. Since it is important to take the medication as directed by their healthcare professional [3]. Complete adherence to medication dose and timing is required for the drug to give it's optimum effectiveness as recommended [4]. Unfortunately, adherence to medication remains a common issue for the healthcare providers especially elderly age group. To overcome these issues strict adherence to medication is required that can remind and maintain the timing and quantity for the patient [5]. There are plenty of individuals who need constant care and assistance, especially people with a busy lifestyle, the elderly aged and the ones with special needs. The most common of them is elderly people who tend to forget to take the recommended medication at the prescribed time. According to a study, it is estimated that 30% to 50% of elderly patients fail to take the recommended treatment at the appropriate time due to memory loss, loneliness, decreased intellectual capacity ,and sensory deficits [6-8]. Tactlessly, patients with chronic illnesses are admitted to hospital admission as they tend to fail and follow their medicine prescription [9]. Plenty of devices exists that can remind patients to take their medicine at the appropriate time but still, there is room for improvement in the currently available smart pillboxes. Different approaches have been used for monitoring medication adherence since improving adherence to medical treatment has been shown to significantly contribute to both health and economic benefits [8].

Due to the advancement and improvement in technology, we have utilized it to assist the patients in taking their medications appropriately with respect to time and dosage. Although there are many mobile applications that can help to remind the patient to take medication on time, they are unable to check the status of whether the patient has taken the medication after the alarm or not [10]. The aim of this study is not only to remind the patients to take medicines at the proper time but also to make sure that the patient takes the medicine after the alarm.

Our porotype is connected to a smartphone, which will give a reminder of the time for drugs and allows quick visualization for each schedule of the drug delivery [11]. As currently available pillboxes have limitations as are not suitable for elderly people or have a bigger size and weight that makes mobility difficult for the user [12]. To make it really useful, our SDB is user-friendly keeping in mind the usage by elderly people. We also take into account that the box should be as small and light weight so that it can be used everywhere and be portable [13]. We design the box to be compatible with pills and injection medication so that it can help diabetic patients to

remind them to take the insulin dose on time. The drug box is connected to a smartphone with an application to set the alarm. Therefore, the use of the SDB proposed in our study will have an important role in patient recovery as it is designed to contain the patient's medication. The SDB will help the patient to follow the prescription as recommended by the physicians, in addition, it will also help the physicians to ensure that the patients are adequately having recommended medication with expected recovery from the illness. The risk of not adhering to dose intake time or quantity is greatly reduced with the help of a smart drug box, hence increasing the overall effectiveness of the treatment plan.

MATERIALS AND METHODS

The overall process of constructing the proposed SDB is divided into three phases. The first one is hardware designing using Computer-Aided Design (CAD), the second one is the software setup and the last phase is 3D printing the box.

Hardware Phase

The Arduino UNO platform is used to control the load and all other components of the system. It is an open-source microcontroller board that utilizes Microchip ATmega328P microcontroller. Digital and analog input/output (I/O) pins that are required to interface with different circuits are present on this board. It has 14 and 6, digital and analog pins, respectively, that can be programmed by using Arduino IDE (Integrated Development Environment) via type B USB cable. An external 9-volt battery or a USB cable can be used to power an Arduino UNO. To connect it wirelessly with a smartphone we have used Bluetooth HC-05. The Bluetooth module can easily achieve serial wireless data transmission. Its operating frequency is among the 2.4GHz ISM frequency band. It adopts Bluetooth 2.0+EDR standards. Bluetooth 2.0 uses 0.50 seconds as a signal transmitting time to different devices workload of the Bluetooth chip can be reduced significantly and more sleeping time can be achieved [14]. Thus making it easy to use and simplifying the overall design/development cycle. Infrared sensors (IR) are applied to measure the heat and motion, surrounding SDB. IR sensor is used to detect hand motion which is considered as an indication to make sure that the patient has taken the prescribed dose. We have used the LM35 infra-red IR sensor to monitor the surrounding atmospheric temperature. It is a precision integrated-circuit temperature device whose output voltage is linearly proportional to the centigrade temperature. The IR sensor uses analog signals to transmit the signal to the Arduino board. The temperature range is set from -5°C to 45°C with a deviation of $\pm\frac{1}{4}^{\circ}\text{C}$, at room temperatures. Thus, fulfilling our purpose of monitoring room temperature. In order for the caregiver or the doctor to ensure that the patient has taken the right medicine with the right measure, the SDB is equipped with an AREBI HD Mini Camera connected with the motion IR proximity sensor. The camera has a resolution of 1080P, 150-degree wide-angle lens, and R Night Vision. It is an iOS and Android compatible camera. Besides, it has an SD Card recording and a built-in high-quality 300mAh rechargeable lithium-ion battery that can last about one hour without external power.

Moreover, an LCD display compatible with the Hitachi HD44780 driver is used to display messages. The LCD displays are controlled via Liquid Crystal Library. An audio signalling device, (Buzzer 5 V), is used to produce sound at the recommended time of taking the medication. A 9-volt battery is used due to its convenient current, compatibility with our system, and availability. Lastly, three LEDs (green, yellow, and red) have been selected as visual

indicators. The red LED turns on at the appropriate time to take the medication. It turns off when the removal of medication is performed from SDB. Whereas, the yellow LED remains on until the patient confirms taking the medicine, after which the green LED will turn on.

Software Phase

Arduino IDE is used to control the hardware and to connect it with an application installed on a smartphone. Arduino IDE is a text editor to write the program, which when executed, the setup instructions are uploaded to the board and activated.

The smartphone application is developed to control the SDB remotely using the android and iOS applications. The application is a web-based application that uses the Wi-Fi module to connect the SDB device and the smartphone for communication or sending the medical status to the caregiver. Using Arduino IDE, the Arduino ESP8266 Wi-Fi chip was programmed to perform the desired functions such as setting the alarm, recording the number of the medicine consumption by the patient, setting the time of sending notifications to the smartphone application and the SDB, warning the user for the time of pillbox refill and beeping a buzzer when the pill or injection medication is ready to be taken. The yellow LED was programmed to turn after the medication is removed from the SDB.

Box Designing

After setting up the hardware components and the functions, SolidWorks was used to design the SDB casing. Figures 1 and 2, illustrate the 2D and 3D dimensions and designs of the casing, respectively. A 3D printer was later used to print a prototype SDB casing using the material HELIX ABS. The 3D printer prints prototypes that are Acrylonitrile Butadiene Styrene Plus.

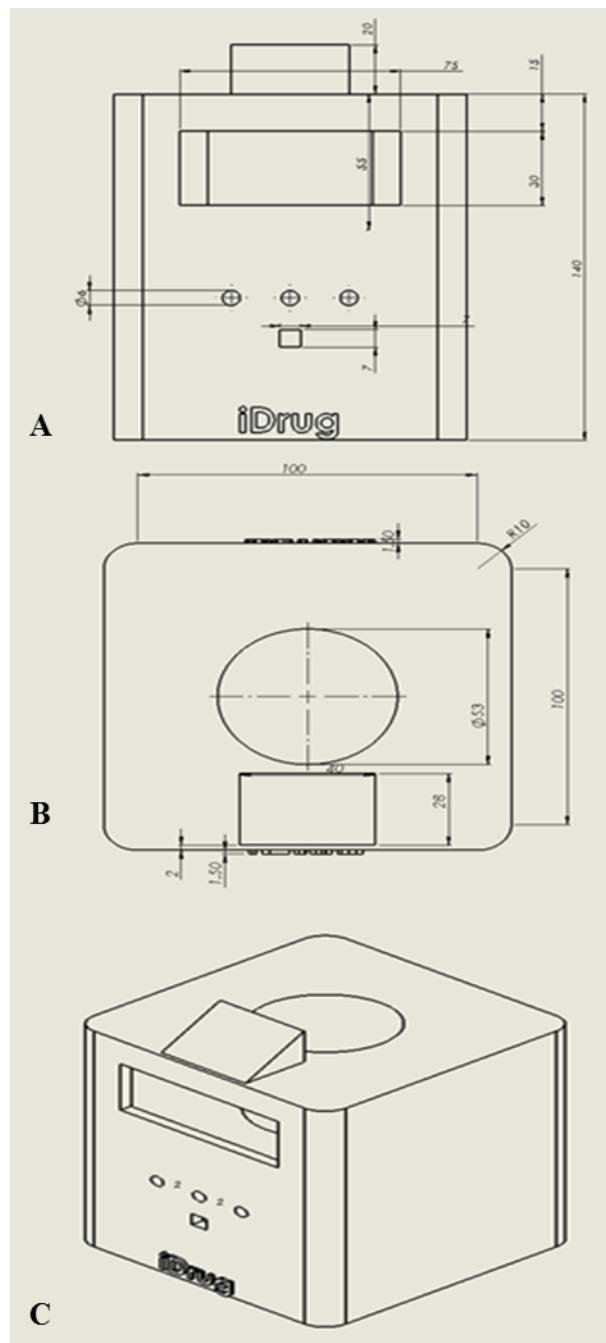


Figure 1 Smart drug box; (a) Front view, (b) Top view, (c) 3D view.

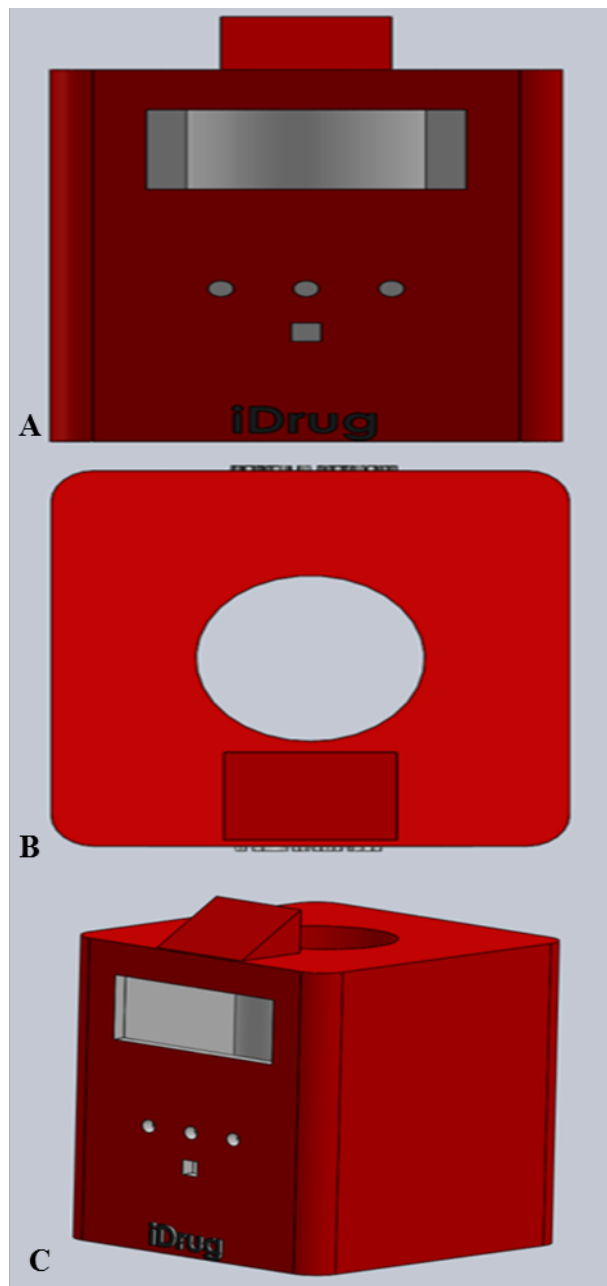


Figure 2. 3D View; (a) Front view, (b) Top view, (c) Above angle view.

RESULTS

In this study, Proteus 8.7 professional software has been used to build the simulation of the plan/design. Proteus 8.7 contains a wide selection of electronic components that can be run virtually on the computer; it can also calculate and indicate the currents and voltages needed by the electronic components on the board. Figure 3 depicts the final prototype with the front and the top view of the SDB. The weight of the SDB is 350 grams without any medication.



Figure 3. Final Prototype.

When the alarm is turned on, the red led will also turn on until the patient has taken the medicine. Once the hand is detected, the yellow led will turn on until the patient confirms "taking the medication" from the mobile application or the drug box. Finally, the green led is turned on to indicate that the patient has confirmed that the drug is taken. Additionally, the drug box also contains a temperature sensor and buzzer to detect if the temperature exceeds the normal temperature and the buzzer will be turned on. The drug box also has the LCD to display messages and to give information to patients for taking proper dosage at the accurate time as per the prescription. Furthermore, the SDB has a camera so that the caregiver can ensure that the patient takes his drug at the right time with the right dosage. The mobile application is used to set the time for dosage and monitor the patient's activity through the camera on the smartphone of the caregivers. In addition, when the pills are consumed, the patient or the caretaker has to refill the pills and the injection medicine manually.

DISCUSSION

The SDB device is designed to assist patients to be adherent to their medications. A significant amount of an elderly population exists in today's world; medication adherence will continue to be an issue. Therefore, we have designed an innovative drug box that can help patient to adhere to take their medication. It efficiently reminds patients for taking their medication on time. Thus reducing the chance of missing or delaying medicines [14]. The use of sensors will increase the accuracy of taking the dosage as prescribed by the doctor. In the proposed design, the Arduino is connected to a smartphone with an application to set the alarm. The SDB is equipped with a buzzer that alarms by blinking the red led when prescribed medication have to be taken. The yellow led is turned on when the IR sensor detects the patient's hand. The green led is turned on when the patient confirms that the prescribed medicine is consumed. Additionally, the temperature sensor detects the temperature in the surrounding, and when temperature exceeds the normal range the buzzer will turn on.

The proposed porotype is designed in such a way that it can be more productive and innovative in comparison with the limitations of commercially available products in the market. No method has been reported to ensure that the patient has taken the dose, and the available

product is only compatible with pills [15, 16]. In an earlier design and study of smart medicine box, the camera feature was used to record video clips at the time of medication consumption by the patient but those videos were sent to Personal Computer's making it inconvenient for caregivers of the patient to view from smart-phone. Moreover, the sensor used is not accurate to check exactly whether the patient has taken the required dose or not [17]. Therefore, we have tried to find a solution to overcome this issue by seeing the video on the smart phone. Another type of available pillbox has a sound reminder and was able to remind the user to take medicine at the recommended time but it merely reminds the user using only SMS alerts [18]. Our designed SDB introduces an advanced feature of sending the reminders on the smart phone of the patient and shows it on the SDB, simultaneously. In case the patient does not consume the medication within few minutes of the reminder, an urgent notification will be sent to the caregivers smart-phone, to tackle the situation. The mobile application is used to set the time for dosage and monitor the patient through the camera. Furthermore, an earlier drug box uses a google service known as google cloud messaging (GCM) to send alerts to the patients [19], whereas, the proposed SDB uses android and iOS applications for better performance and easier access for the user. Another problem associated with drug box is its size. Thus, the issue of reducing the box size is considered one of the design criteria of the proposed SDB. This SDB weighs only 350 grams with access to smart phone application, whereas, Timed Reminder Pillbox weighs around 1270 grams without smart-phone interface [20].

Some aspects of the SDB device still need to be addressed in the future to meet the user needs. First, the SDB needs to be able to contain different types of medicines in one compartment like different pills with partitions. In addition, the device may incorporate a GPS to track the SDB location and send a notification when the user gets too far from the device. The box can also be provided with a magnetic lid for children's safety reasons. Furthermore, the box camera needs to be connected to the sensor so it starts recording when the sensor detects the patient hands. Lastly, the device needs to be equipped with the appropriate sensors for liquid medicine monitoring and management.

CONCLUSION

The proposed SDB is simple to use, affordable, and has high accuracy. The main purpose of this design is to improve health care and patient's health condition by utilizing smart-phone reminders. As it will ensure patient adherence to the treatment plan in terms of dose time and quantity. The temperature sensor alerts help to determine the appropriateness of the box surrounding environment. The design comprises a pillbox that can be carried by the patient and a smartphone to remind the patient of the dosage time. Involving caregivers in the function of the drug box helps give patients the support and care that they need to take their medication and thus adds a social component to the device. Thus, our SDB addresses the functional issues of adherence, portability, monitoring, and notification.

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