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RESEARCH ARTICLE

Inexpensive automated medication dispenser for persons with neurodegenerative illnesses in low resource settings

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ABSTRACT

Neurodegenerative illnesses due to diseases or old age are typical examples of clinical conditions that may affect the proper observation of prescribed medication usage with negative consequence on dose potency. Commercially available medicine dispenser for these populations are expensive, complex to operate and/or beyond the reach of those living in low resource settings due to lack of social protection. This study presents the design and construction of an inexpensive ($49.6) medication dispenser suitable for point of care applications in low resource settings. The dispenser was constructed using a simple control mechanism based on Arduino® IDE that controlled three different micro servo motors to accommodate different shapes of medication. Sequel to the laboratory trials by abled individuals, we were able to demonstrate between 58% and 100% accuracy of the device when the three servo motors were simultaneously used to dispense medication of three different sizes. Following rigorous clinical trials in the target population, we intend to deploy this device for wider and independent usage by users in order to prevent unnecessary hospital admission meant to enforce compliance with appropriate medication usage for the users.

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KEYWORDS
Neurodegenerative illnesses; medicine dispenser; older adults; low resource settings

1. Introduction

People living with neurodegenerative illnesses or cognitive impairment account for about 2.29–21.6% Africa's population [1]. Aged population are most vulnerable to this illnesses especially those with cardiovascular diseases and/or those that are illiterates [2], with "marginally" higher prevalence in women [2,3]. These clinical conditions may suscepts victims to non-adherence to prescribed medication for their often chronic and life-threatening diseases. Prescription of medications to these patients especially those among them with long-term illnesses such as diabetes Melitus, high blood pressure and cancer, could be for a very long term. The available statistics indicated between 11% and 42% [4,5] adherence level to the prescribed medication while between 37% and 80% affected individuals usually discontinued medication unduly [4]. Adherence to the prescribed medication, which is often compromised in these populations [4,5], is directly related to effective and efficient management of these diseases [6–8]. For example, while the prescribed medications are often effectual in managing disease(s), their full potentials are mostly not reached because approximately 50% of patients do not take their medication(s) as prescribed by their physicians [9]. In some instances, multiple medication error may be due to patients' medical conditions or negligence [6].

Interventions to improve this situation hold enormous potentials toward alleviating the clinical conditions of these patients. In the literature, there are various options to prevent non-adherence to adequate medication regimen. For example, medication/pill box can only handle simple regimen [10] and requires sufficient cognitive capability. Medication management procedures [11,12] are also gaining prominence but mainly in developed countries. Dependent lifestyle on family members or hospital admission is another viable option. However, apart from the high care or medical/admission costs associated with this option, most of those services are not available in low resource settings. An inexpensive, automation-based and easy-to-use medication dispenser is of high interest as commercially available options are far beyond the reach of the vulnerable population living in low resource settings. The present study reported the

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implementation of an automated medication dispenser that automates the counting and dispensing process of medications to promote the level of medication use adherence for users in low resources settings.

2. Materials and methods

2.1. Materials

Apart from designing a medication dispenser with standard facilities, affordability is another major target of this study. This modulated the choice of material and technology employed in this study. We also considered availability of materials, their durability and chemical inertness based on the prevailing environmental condition for the dispenser to be able to hold medication. Manufacturability and ease of process were also considered in material selection. These factors were carefully considered in order not to compromise the engineering characteristics of the material selected for the medication dispenser. Table 1 describes the types of material used for the device and the rationale for the material selection. In Table 2, cost analysis of the selected materials is presented.

2.2. System design and description

The medicine dispenser consists of three different pill storages that hold circular pills of different sizes. The construction of the medicine dispenser was divided into three stages: (i) hardware module, (ii) software module and (iii) integration of the hardware and software modules to form a complete dispenser. After the design of the hardware prototype, the isometric and orthographic views of the hardware were developed as shown in Figure 1 while Figure 2 presents the block diagram of the device.

Figures 2 and 3 also depict different components of the automated medication dispenser comprising of a pill box, LCD, LEDs, buzzer, keypad and micro servo motors and microcontroller controlled by Arduino® IDE (Arduino). This device was designed, developed and tested in the Biomedical Instrumentation laboratory of the Department of Biomedical Engineering, University of Ilorin, Nigeria. The Arduino UNO containing the ATmega328 served to perform all the instructions and commands of the medication dispenser. The medicine dispenser was designed to give out the number of medication input by the user through the keyboard at the beep of alarm. When the alarm goes off, the dispenser was designed to accept input through a button press to indicate the number and size of the medication to be dispensed. During dispensing, the pressing interruption will not be

Table 2. Cost analysis of the medication dispenser.

S/N	Item	Quantity	Unit price (USD)	Total price (USD)
1.	Arduino UNO	1	9.6	9.6
2.	Micro servo motor	3	2.5	7.5
3.	Storage	3	0.14	0.42
4.	Propylene (400 mm × 80 mm × 6 mm)	1	1.4	1.4
5.	Liquid crystal display (LCD) 2004	1	7.7	7.7
6.	4 × 4 keypad	1	2.5	2.5
7.	Light emitting diodes	1	0.06	0.06
8.	Buzzer	1	0.7	0.7
9.	Battery (6 Volts, 4.5 AH)	1	0.7	0.7
10.	Vero board	1	0.4	0.4
11.	Soldering lead	1	0.8	0.8
12.	Jumper wires	20	0.06	1.2
13.	Adaptable box	1	2.8	2.8
14.	Miscellaneous including transportation	–	–	13.8
Grand total				49.6

Table 1. Type of material and rational for the material selection.

S/N	Material	Medication dispenser modules	Rationale
1.	Propylene sheet	Hardware module: Dispenser structure including pill storage and collection tray.	Cheap, readily available and easy to process and cut into shapes with a common handsaw. It is chemically inert and highly resistance to corrosion. It is transparent and also has high thermal stability.
2.	Micro Servo motors	Hardware module	Light weight, durable and could generate linear motion for the slider crank mechanism that move the pill from the storage to the collection tray.
3.	An adaptable box	Hardware module	It was selected due to its rigidity, resistance to corrosion and degradation and cost effective.
4.	Alarm/Buzzer and LED	Hardware module: Alarm module	They were used so that the medicine dispenser could be of benefit to patients with either visual or hearing impairment.
5.	Arduino UNO	Software module	Simple to programme, affordable and available.
6.	Membrane Keypad	Hardware module: User interface	It was used to allow easy navigation of the dispenser's options by the user. It is inexpensive, liquid and dirt proof.
7.	Liquid Crystal Display (LCD)	Hardware module: User interface	The colour separation between the character and background promotes legibility of the character even in the dark environment i.e., the white characters displayed on blue background.

Figure 1. Isometric and orthographic views of the dispenser.

Figure 2. Block diagram of the dispenser.

executed by the device. This prevents the device from delivering more than the required dosage to prevent errors that may be due to multiple button press.

A standard 4×4, 16 key alphanumeric keypad was used to enable the user to pre-set the number of medications to be dispensed following the reminders' (buzzer and LEDs) prompts. The alarm module provides both visual and audible notification for the user. When the push button is pressed, the alarms is designed to go off. The micro servo motors were used

Figure 3. Major components of the dispenser.

Figure 4. Construction stages of the dispenser.

to drive the mechanism when it is time to dispense the medication to the medication tray. A 20-character, 4 lines LCD module with white characters displayed on blue background was selected because the white backlight makes it easier for the user to see the characters displayed on it, even in a dark environment.

A propylene sheet of 200 mm × 80mm × 6mm was used for the construction of the medication's holder and tray. The propylene was cut into different sizes with consideration to the desired dimensions needed for the dispenser as shown in Figure 1. The various parts of the propylene before and after assembling are as shown in Figure 4.

The basic component of the microcontroller is the input/output ports that interfaced with the keypad, buzzer, push button, LED, LCD and the micro servo motors (Figure 2). Interrupts were used to allow the user to programme the system, and this was contained within the software module. When it is time to take the medication, the alarm is designed to go off and the LCD displays instruction for the user to input the number of medication(s) to dispense. Once the keypad prompt is pressed, the medications will be dispensed into the collection tray where they can be retrieved by the user.

3. Results

Ten different trials/tests were carried out on each medication storage in order to determine the device's performance through its accuracy estimation. The result obtained is as shown in Table 3 while Figure 5 graphically presents the comparison of the pre-set number of medications and number of medications dispensed.

From Table 3, the accuracy of the device *via* relative error could be obtained as follows.

For pill storage 1,

$$\text{Relative error} = \frac{\text{Dispensed value} - \text{Expected to dispensed value}}{\text{Expected to dispensed value}} \quad (1)$$

$$\text{Relative error} = \frac{11 - 19}{19} \quad (2)$$

Table 3. Reliability of the dispenser system.

	PILL STORAGE 1			PILL STORAGE 2			PILL STORAGE 3		
Trials	PNP	NPD	ERR	PNP	NPD	ERR	PNP	NPD	ERR
1	1	1	0	1	1	0	1	1	0
2	1	0	−1	3	3	0	2	2	0
3	3	2	−1	2	2	0	3	3	0
4	2	1	−1	1	1	0	1	1	0
5	3	2	−1	2	2	0	3	3	0
6	1	1	0	1	1	0	1	1	0
7	2	1	−1	3	2	−1	2	2	0
8	3	1	−1	1	1	0	2	2	0
9	2	1	−1	3	3	0	3	3	0
10	1	1	0	2	1	−1	1	1	0
TOTAL	19	11	−7	19	17	−2	19	19	0

PNP: preset number of pills; NPD: number of pills dispensed; ERR: error.

$$\text{Relative error} = -42\% \quad (3)$$

For pill storage 2,

$$\text{Relative error} = \frac{17-19}{19} \quad (4)$$

$$\text{Relative error} = -11\% \quad (5)$$

For pill storage 3,

$$\text{Relative error} = \frac{19-19}{19} \quad (6)$$

$$\text{Relative error} = 0\% \quad (7)$$

Only pill storage 3 is 100% accurate while pill storages 1 and 2 are 58% and 89% accurate, respectively. The negative sign indicates that the value of dispensed pills is lower than the expected pill to be dispensed. Apart from the storage 2, the accuracy of the dispenser 1 and 3 cold be adjudged high and these values provide a justification for further investigation into the medication dispenser.

4. Discussion

This study presents the design and construction of an automated medication dispenser for persons with neurodegenerative illnesses living in low resource settings. This inexpensive device is designed to reliably automate the counting and dispensing process of medications. With the implementation of this device, the common errors of nonadherence to medication use by patients could be ameliorated, especially for those living in low resource settings. The preliminary assessment of this design has also indicated its effectiveness for potential clinical and independent home use. Unlike the design by Mukund and Srinath [13], this present device can dispense different medication sizes and at either the same or different time intervals. Although Lee et al. [14] were able to create a prototype of an automated pill dispenser which can accommodate and dispense more than one medication size, but the device did not incoperate audio alarm for

Figure 5. A graphical comparison of the preset number of pills and number of pills dispensed. Graphs A, B and C represent each of the three pill storages.

visually impaired users and it was also bulky and expensive for common use in low reseources settings. An android-based medication reminder system built on OCR—Optical Character Recognition using ANN—Artificial Neural Network was also introduced by Ashwini et al. [15]. In their system, the android-based application is meant to remind patients/users about the time for the medication(s). Although the application spontaneously set the reminders based on the prescription and this reminder had the capabilty to prompt users to take medicine properly, the design is only applicable to users/patients who have and could operate an android mobile phone. This is evidently a significant limitation especially if the device were to be deployed to village dwellers in low resource settings. Therefore, the device designed, developed and reported in this present study has demonstrated a simpler alternative with unparalleled simplicity when compared to the commercially available options. In the future, we plan to further this study by integrating other peripherals and features to the device to improve its accuracy for clinical application.

5. Conclusion

In this study, we have reported another medical device designed in low resource settings for use in similar environments. The device can dispense three different sizes of medication simultaneously with accuracy of 58–100% and only needs readily available 6 Volts, 4.5 AH battery for operation. This makes its operation easy in environment with epileptic power supply typical of most settlement in low resource settings. It is our projection that with the device's cost of $49, many potential users in low resource settings would be able to afford it and put it into optimum use. In the future, GSM module will be incorporated to monitor the patients' medication adherence level. We also intend to make this device rechargeable to facilitate its deployment to community dweller without electricity supply.

Disclosure statement

The authors of this manuscript declare that they do not have any financial or personal relationship with other people or organisation that could have inappropriately influenced this manuscript.

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