Smart Pill Dispenser with Smart Cup

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***Abstract*— This research paper describes the design of a pill dispensing device that can assist people with physical or cognitive limitations in taking their prescribed medications. The design is based on the communication between two devices for the purpose of dispensing pills at a scheduled time and identifying if these pills had been properly consumed within a specified time frame. The two devices are based on Arduino RP2040 connect microcontrollers and implement several sensors in the aid of dispensing and detecting of pill consumption. The sensors implemented are an IMU, and distances sensors, such as an ultrasonic sensor and an IR proximity sensor, additionally a real time clock module and stepper motor have been included in the design for the scheduling and dispensing of the pills. The two devices will communicate using Bluetooth for low energy devices (BLE) and the purpose of the devices is to provide aid to the intended target audience in achieving a healthier lifestyle.**

Keywords— Bluetooth BLE, Arduino RP2040 Connect, Stepper Motor, Assistive Technology, IMU, IR proximity, Ultrasonic.

I. Introduction

Assistive technology [1] has introduced various innovations in devices that seek to provide aid to various groups of people that have some number of limitations, and that due to these limitations are unable to perform various tasks that are common or simple to most people without any physical or cognitive limitations. The pill dispenser or pill organizer is a type of assistive technology, given that to many people, the great number of pills required for consumption, based on their prescriptions due to illnesses or other types of medications or pills required, due to age or for general wellbeing, make it difficult to keep track of what type of pill is required at a certain time or day. Furthermore, for seniors or other individuals with cognitive limitations, the difficulty of remembering the required prescriptions increases greatly; thus, these types of devices are created with the purpose of reducing the difficulty of the task or eliminating it completely [2].

In previous research that we have conducted in this area [3], it is mentioned that one of the limitations of these devices, the pill dispenser or pill organizer, is that the devices are designed to automate the organization and dispensing of the pills by collecting information from the user, and based on their medication requirements, are able to dispense the appropriate pills at a specified time; however, they lack the inclusion of a system to verify if pills have been consumed or not. Thus, in this previous research we proposed the idea of designing a device that would rely on the basic movements performed during the consumption of liquids from a cup, given that these movements are commonly performed by the vast majority of people, and the proposed design would include sensors to collect data and identify if these movements have been performed accurately and in the specified sequence that would result in pills being consumed from a cup-like container. This proposed device resulted in the design of a smart cup [3].

Continuing with this project, a smart pill dispenser has been designed, which seeks to complement the purpose of the smart cup in identifying whether pills have been consumed or not. The smart pill dispenser, which will be the focus of this research paper, seeks to aid the smart cup by providing the user with options for organization of their pills into 7 different slots, each pertaining to a specific time and day of the week; additionally, by allowing communication between both devices through Bluetooth, the system as a whole will keep storage of the data shared between both devices, i.e. the smart pill dispenser will save the data obtained from the smart cup to keep record of which pills have been dispensed and properly consumed by the user of the device [4], seeking to aid any type of monitoring by any institution or person involved with the

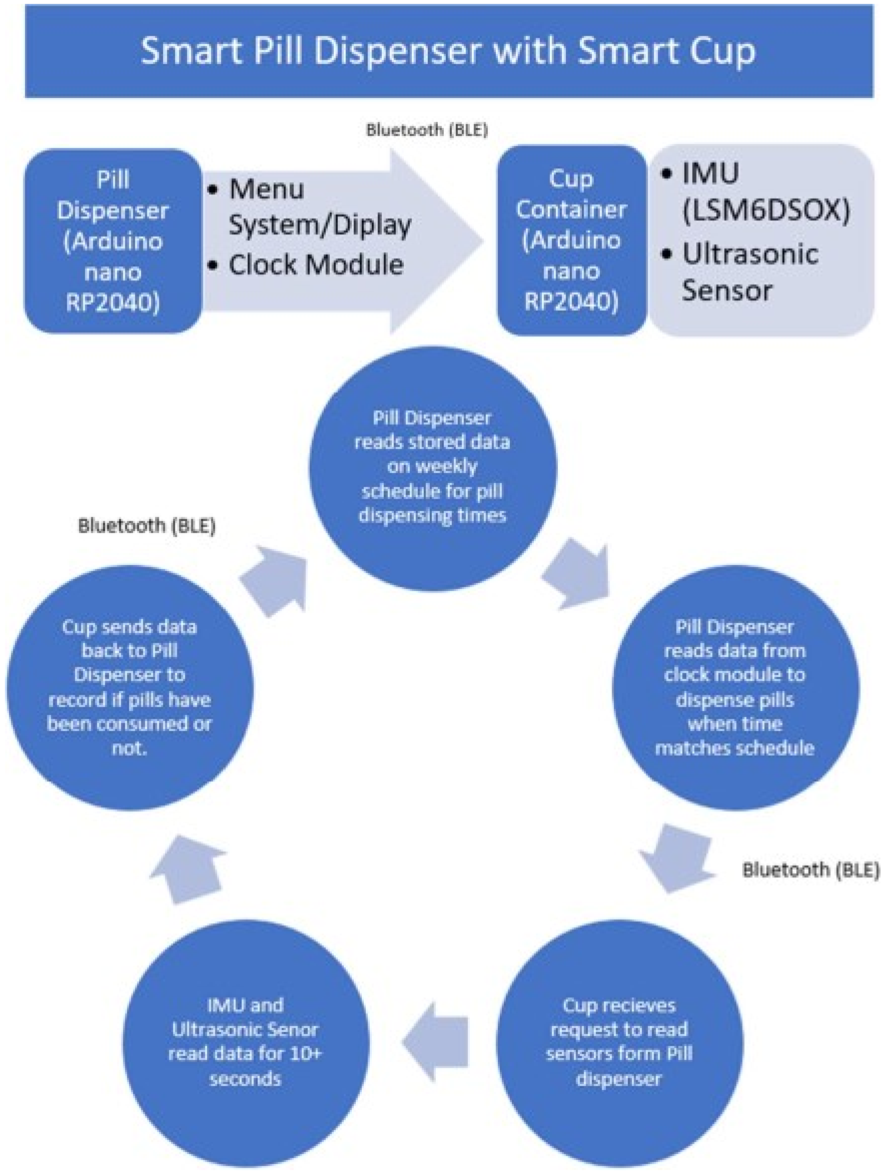

Fig. 1. Smart Pill Dispenser and Smart Cup Diagram of Components for each device and the functionality of the device as a single system

user of the device, with regards to verifying the proper consumption of medications.

II. System Design

A. Device Configuration

As shown in figure 1 and 2, the design consists of a pill organizer placed above a cup-like container, with the inclusion of a stepper motor for the rotation of the slots of the pill dispenser unit. With the implementation of the Arduino RP2040 Connect on both devices, the cup-like container can behave as the smart cup mentioned in the introduction. Given that this Arduino includes an IMU, the IMU allows the smart cup to detect the movements performed on it; thus, allowing the identifying of the proper consumptions of pill or not [3]. Additionally, the pill organizer above the smart cup, includes a real time clock module that will allow the Arduino to have a correct reading of time even if the device is powered down intentionally or by loss of charge. Both devices are wireless and communicate between each other through Bluetooth BLE [5], as shown in figure 1.

Shown in figure 3, is the smart pill dispenser with its components. Figure 4 displays the Arduino pertaining the smart cup with an ultrasonic sensor and an IR proximity sensor, while figure 5 displays both devices side by side. These two devices will be powered individually, each with their own battery and charging system. The smart pill dispenser will allow the devices to be charged through a power outlet while simultaneously charging the smart cup wirelessly.

Fig. 2. Smart Pill Dispenser and Smart Cup intended Placement in Completed Design

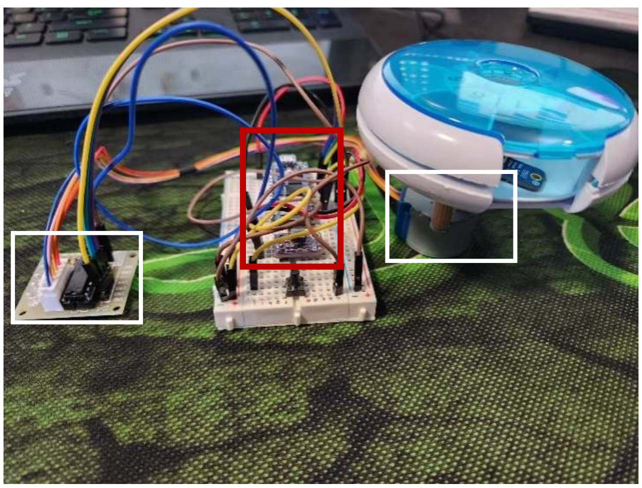

Fig. 3. Smart Pill dispenser with the stepper motor beneath it enclosed in a white box, the motor driver is also enclosed in a white box, while the Arduino is enclosed in a red box.

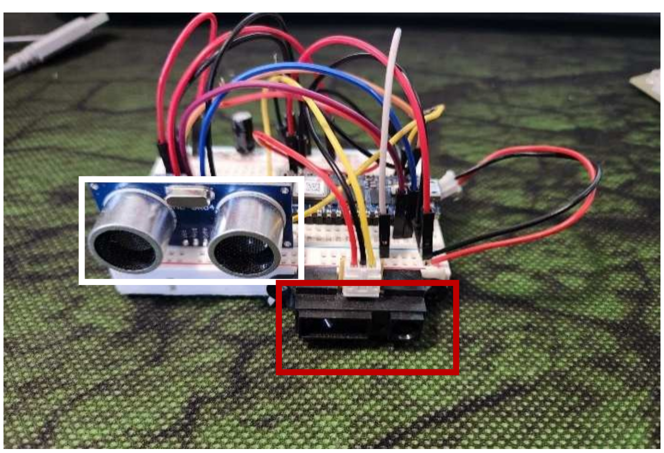

Fig. 4. Arduino for Smart Cup with Ultrasonic sensor enclosed in white and IR proximity sensor Enclosed in red.

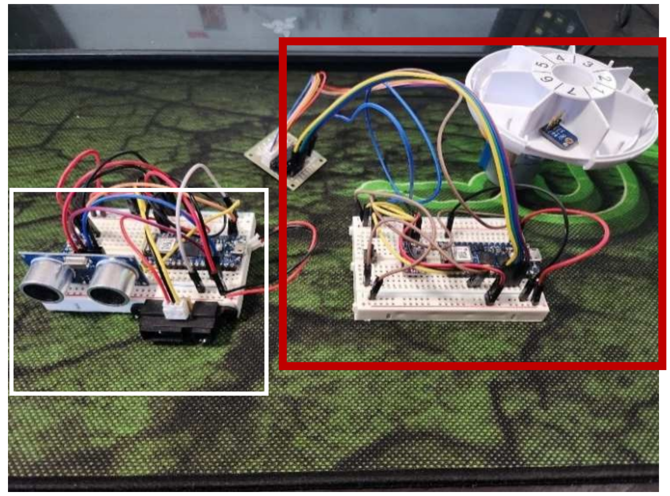

Fig. 5. Smart Cup circuity enclosed in white and Smart Pill dispenser circuity enclosed in red.

III. Evaluation and Results

A. Procedure

Given that the focus of this paper is the smart pill dispenser device of the system, the experimentation performed will focus on the ability of the pill dispenser to accurately rotate to each slot based on the different configurations allowed on the stepper motor implemented in this device. The stepper motor used on this device is the 28BYJ-48 with a 5V operating voltage, this motor was chosen given its size and low supply current, this motor has been paired with the ULN2003 driver board which allows the control of direction, speed, and acceleration of the stepper motor.

In this experiment, the speed and acceleration has been modified for five sets of tests, one for each variation of acceleration, and in each set of acceleration, measurements have been performed for four different speeds. Each speed has been measured ten times for their corresponding completion time, in terms of the slot rotating to the next slot. Each rotation evaluates if the rotation is proper to allow pill dispensing, and finally, a total amount of time has been recorded in which the pill dispenser has rotated to the appropriate slot, dispensed the pills, informed the smart cup to sense the movements on the cup, and have the smart cup communicate back to the smart pill dispenser. This amounts to a total of two hundred measurements performed in this experiment.

On a second experiment, the smart cup has been modified to utilize an ultrasonic sensor instead of the IR proximity sensor [3], this is due to the IR sensor having a low range of detection compared to the ultrasonic sensor, and by having a limited range of distance measurements, the readings from the smart cup could be affected and result in inaccurate predictions when measuring the movements performed by the user. To test this scenario, forty measurements have been performed on the smart cup twice, once for each sensor, in scenarios that could result in improper distance readings with the IR sensor, such as lifting the cup with the arm fully extended away from the user, this could result in the smart cup not properly identifying its proximity to a user: thus, reporting a false negative.

B. Results

Shown in Table 1 through table 5, is the data obtained through the experiment performed on the pill dispenser in conjunction to the smart cup, this data represents the time for completion of forward and backward Bluetooth communication between the smart pill dispenser and smart cup in addition to the time it takes the pill dispenser to move to a requested slot and the success rate in pill dispensing of the slot that the pill dispenser has rotated to. This data from the experiments are represented in graphs in addition to their tables to have a better visualization of the behavior trend of the stepper motor modifications in terms of speed and acceleration; additionally, given that the success rate from all measurements results in a correct delivery of pills, this data has been represented in a form of a graph in fig. 13, which depicts the information gathered from all variations of speed and acceleration, the columns represent the acceleration, while the different colors represent the different speed values. Table 6 displays the experimentation data obtained by comparing the results of the smart cup with an IR proximity sensor and ultrasonic sensor respectively, in terms of the varying distance between the user and the smart cup.

Table 1: Average time to rotate and total task time for an Acceleration value of 50 based on 4 set speeds.

Acceleration	Speed	AVG Time to rotate (s)	AVG Total Time for Task (s)	Success Rate of Delivery
50	250	4.57	18.61	100%
	500	4.47	18.86	100%
	750	4.26	18.86	100%
	1000	4.38	18.86	100%

Table 2: Average time to rotate and total task time for an Acceleration value of 100 based on 4 set speeds.

Acceleration	Speed	AVG Time to rotate (s)	AVG Total Time for Task (s)	Success Rate of Delivery
100	250	2.61	17.31	100%
	500	2.76	17.63	100%
	750	2.50	17.44	100%
	1000	2.90	17.40	100%

Table 3: Average time to rotate and total task time for an Acceleration value of 200 based on 4 set speeds.

Acceleration	Speed	AVG Time to rotate (s)	AVG Total Time for Task (s)	Success Rate of Delivery
200	250	1.92	16..45	100%
	500	1.95	16.45	100%
	750	1.93	16.41	100%
	1000	1.95	16.47	100%

Table 4: Average time to rotate and total task time for an Acceleration value of 400 based on 4 set speeds.

Acceleration	Speed	AVG Time to rotate (s)	AVG Total Time for Task (s)	Success Rate of Delivery
400	250	1.57	16.27	100%
	500	1.58	16.26	100%
	750	1.55	16.25	100%
	1000	1.58	16.25	100%

Table 5: Average time to rotate and total task time for an Acceleration value of 800 based on 4 set speeds.

Acceleration	Speed	AVG Time to rotate (s)	AVG Total Time for Task (s)	Success Rate of Delivery
800	250	1.00	15.37	100%
	500	0.97	15.50	100%
	750	0.94	15.43	100%
	1000	0.94	15.32	100%

Below is the graph representation of table 1 through table 5:

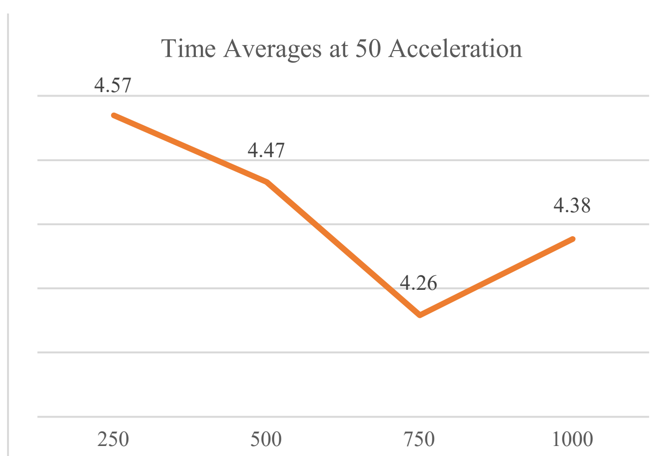

Fig. 6. Graph displaying the time averages for rotation of pill slot at an acceleration value of 50.

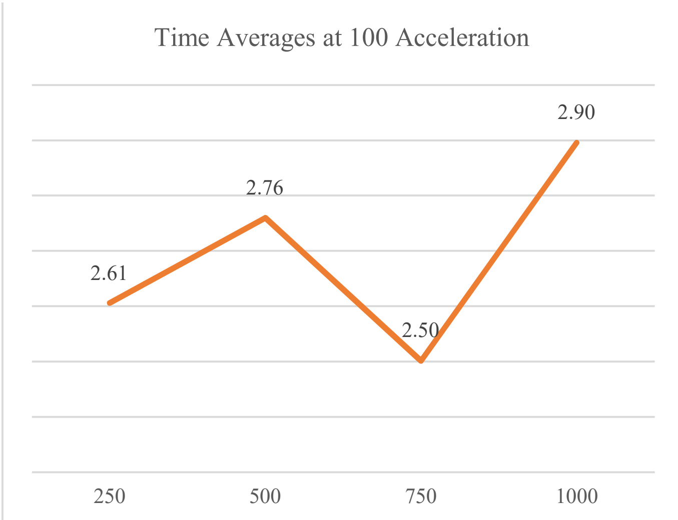

Fig. 7. Graph displaying the time averages for rotation of pill slot at an acceleration value of 100.

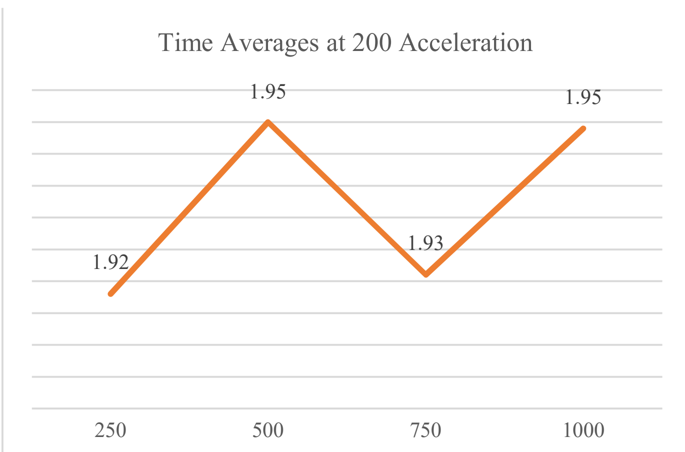

Fig. 8. Graph displaying the time averages for rotation of pill slot at an acceleration value of 200.

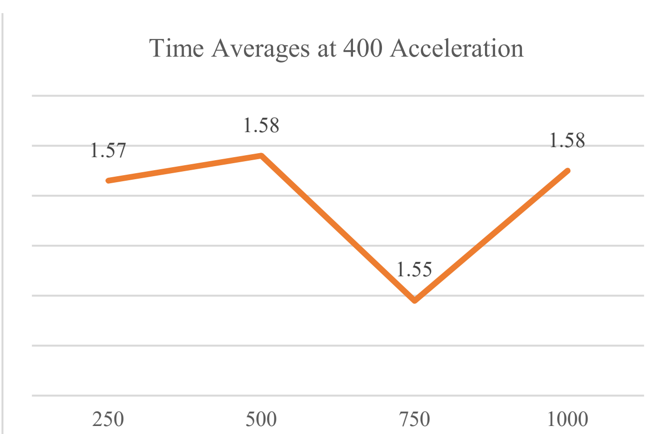

Fig. 9. Graph displaying the time averages for rotation of pill slot at an acceleration value of 400.

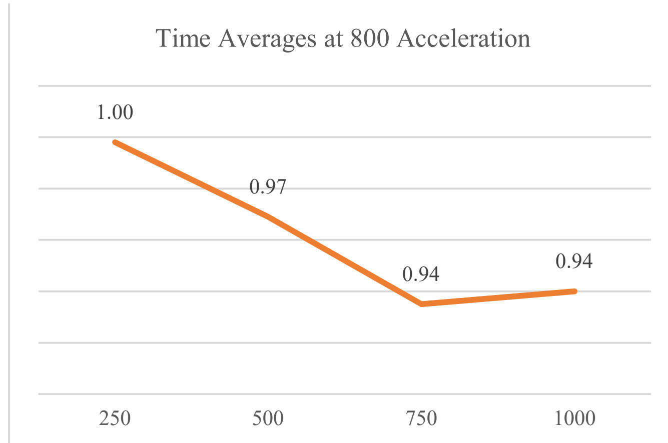

Fig. 10. Graph displaying the time averages for rotation of pill slot at an acceleration value of 800.

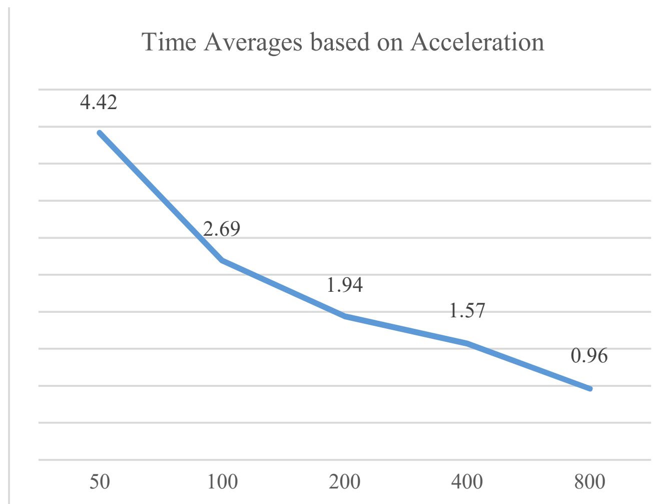

Fig. 11. Graph displaying the time averages for rotation of pill slot at the displayed acceleration values.

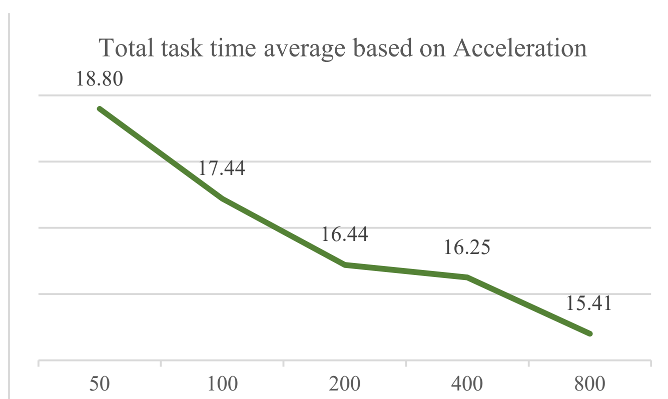

Fig. 12. Graph Displaying the total amount of time for completion of task based on the acceleration values on the graph.

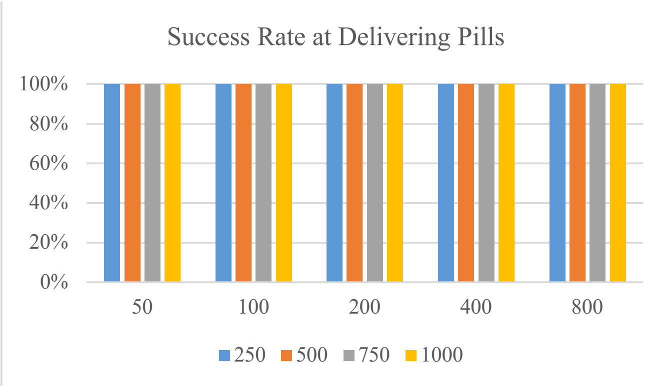

Fig. 13. Graph Displaying the Success Rate of the Delivery of Pills by Pill Dispenser, each color represents a different speed setting, and each column a different acceleration setting.

Table 6: Success rate of prediction of pill consumption with IR sensor and Ultrasonic sensor

IR Sensor		Ultrasonic Sensor
Distance	Success Rate	Success Rate
5 cm	100%	100%
10 cm	100%	100%
30 cm	60%	100%
60 cm	30%	100%

C. *Analysis*

The data obtained through the experimentation, performed on the smart pill dispenser working in conjunction with the smart cup, demonstrates the correct delivery of pills in each iteration of experimentation regardless of the different setting of speed or acceleration on the stepper motor, this is visualized in Fig. 13 of this paper. However, the difference in speed and difference in acceleration does play a great role in its affect in time for the rotation of the slots on the pill dispenser, and in the overall completion of task, which is the delivery of pills and the confirmation of whether the pills had been consumed or not, visualized on Fig 12.

Displayed on Fig. 6 through Fig. 9, it is shown that the difference between each speed setting does not benefit the overall time of the slot rotation on the pill dispenser, it does not behave linearly and does not represent any improvement as the speed is increased; however, this volatile behavior can be a result of friction between the rotating slot of the pill dispenser and its enclosure; thus, this data may not represent an accurate value in terms of the benefits that may come from increasing the speed value of the stepper motor; although, it is of value to note that the data shown in Fig. 10 represents a proper linear behavior of the time decreasing as speed is increased, this could be due to the increased acceleration of the stepper motor aiding in the reduction of the effects of friction between the pill dispenser slots and its enclosure.

Shown on Fig. 11 it is shown that the expected behavior of increasing the acceleration value of the stepper motor results in a decrease of time of rotation of the slots on the pill dispenser; additionally, Fig. 12 displays a reduction in overall completion time for the system; thus, proving the benefits of increasing the acceleration in comparison to the increase of speed of the stepper motor.

Table 6 represents our second experiment, which was to create a new version of the smart cup [3] by replacing the IR proximity sensor with an ultrasonic sensor. The data displayed on this table proves that the ultrasonic sensor is a better and more accurate alternative to the IR sensor, although the particular model chosen on this proximity sensor is rated to detect distances up to 80cm, it is not accurate enough to properly detect the movements done on the cup and the affect that these movements have on the distance readings of the cup; however, given that the ultrasonic sensor has a much higher rating for distance detection, the movements on the cup do not affect the readings obtained from the ultrasonic sensor allowing it to accurately report the correct distance measurement and allowing this data to be used correctly for the decision making of whether the user has consumed the pills or not.

IV. CONCLUSIONS

The purpose of this research paper was to design a pill dispenser as a device to be used in conjunction with the smart cup, that had been developed in previous research pertaining to this area of assistive technology, which is pill dispensers to aid in the consumption of pills, and to have these devices serve as a system of verifying the consumption of pills by the user [3]. The proposed design of the pill dispenser presented in this research paper, consisting of a stepper motor and a real time clock module for rotating of pill slots and scheduling of time respectively as well as the ability of Bluetooth communication, through experimentation shows that the capabilities of the stepper motor of increasing of speed and acceleration benefit in lowering the overall required time for the task to be completed, the task in this case pertains the rotation of the pill slots, dispensing of pills, signaling the smart cup and having the smart cup report back to the pill dispenser, both through Bluetooth.

The data also demonstrates that the pill dispenser can accurately and safely deliver the pills in each iteration of varying values for speed and acceleration; thus, these values of speed and acceleration offer the capability of customization while retaining correct functionality of the pill dispenser. However, it is of value to note that as the acceleration of the stepper motor is increased, the time behavior of also increasing the speed of the device results in a linear trend in time reduction which is what is the desired outcome.

On the second experiment, a version of the smart cup was designed in which the IR proximity sensor would be replaced with the ultrasonic sensor, the data allowed to reach the conclusion that by using a device that had a larger rating of distance detecting, it could circumvent incorrect data from scenarios in which the user of the smart cup could interact with the cup in a way in which the cup could be very far from the user or any surface in which it was placed initially; thus, avoiding the incorrect distance reading from the cup and more importantly avoiding false negative reports to the pill dispenser.

In summary, the proposed implementation of the pill dispenser presented in this paper can fulfil its purpose of accurately delivering pills to the smart cup, and by communicating through Bluetooth, assess if the pills are properly consumed or not; thus, the complete system is a good method for assisting institutions or any entity involved with the user of the device, to monitor proper pill consumption by the user of the device.

V. FUTURE WORK

Mentioned previously, the data shown through experimentation demonstrates that the pill dispensing device is accurate through all tested values of speed and acceleration; thus, as a future component of this system, a feature could be implemented to allow the user of the device to customize the speed at which the pills will be delivered. This customization could be performed by the user themselves or by an institution in charge of monitoring the medications and prescriptions of a patient, and by having this customization, allow this institution to adjust the device to meet the needs of the patient that could be, as an example, affected by a mental impairment, and avoid any negative response by having the pill dispenser rotate to quickly and potentially startling the patient or user.

Additionally, this research paper focused on a pill dispensing device limited to 7 slots, for a given day of the week; thus, to improve the organization capabilities of the device, a larger version of 28 slots is intended to be designed that could allow more options in terms of scheduling for not only several days in a month, but also allow to have multiple prescriptions in a day. Lastly, the capability of modifying and storage of a pill dispensing schedule requires a menu and display as a user interface; thus, a future version of the pill dispenser will include these technologies.

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