Daily Dose

Senior Project

Ken Yasui | Joey Angeja | CPE 462 | Spring 2017
Advisor: Dr. Andrew Danowitz

Introduction

Project Overview

The project goal is to develop a medication and vitamin management device that will sort and dispense pre-configured amounts of pills at designated times . The main clientele of this device is the elderly community with a secondary client base of the general public.

The entire system is designed from scratch, powered by US standard line voltage. The main functionalities of the device are the ability to store multiple types of pills and the ability to accurately handle user input and data transfer. The two engineering specifications that were not met included the desired pill pick up rate and dimensions of the device.

Clients

There are no specific clients backing this concept. With that in mind, the hypothetical clients for this project are primarily the elderly community as well as the general public. The main clientele, senior citizens, often need to implement some method in order to take their medication on time and to keep them organized. This device is also aimed toward the public in general, who have medication or vitamins that they need to take regularly. This system would free up space that would normally be taken up by pill bottles and would help individuals remember to take their pills.

Goals and Objectives

Overall project goal: Develop a medication and vitamin management device for all age groups that will sort and dispense pre-configured amounts at designated times.

Project goals:

1. Develop a mechanical system that will accurately and successfully pick up and dispense various medications and vitamins.
2. Develop supporting software to handle user input and data storage.
3. Achieve a working prototype that incorporates the mechanical design with the software application

Objectives:

- Research other products implementing a similar medication storage concept
- Research methods that will be efficient in picking up variable sized items
- Research any regulations that may apply to this type of product
- Design primary and supporting hardware to implement the most efficient researched method to pick up variable sized medication and supplements
- Design a storage method to implement pill storage in the system
- Design a user interface that efficiently demonstrates the use case of this pill dispenser
- Configure a simple database to correctly store medication and vitamin data inputted by the user

Outcomes and Deliverables

Hardware/Mechanical:

- System Housing
    - Must fit within the specified dimensions
        - 25 cm x 20 cm x 40 cm (l x w x h)

- Proprietary electronics for system
    - Power source
        - US standard line voltage
    - Voltage step down modules
    - DC vacuum motor
    - Stepper motor
    - DC motor
    - H bridge
    - End stop modules
    - Raspberry Pi
- Proprietary mechanical mechanisms
    - Worm drive system
        - Handles vertical movement of the suction apparatus

Software:

- Simple graphical user interface to handle frontend user input
- Program to run pill management application, processing user input

Project Deliverables

Two main products were presented upon the completion of the project. The first item was the pill management system itself. The system includes the housing unit and the proprietary electronic and mechanical hardware needed to perform the device's functions correctly. All related hardware was permanently installed within the housing unit, which ended up having the dimensions of 25 cm x 20 cm x 47 cm (l x w x h).

The second deliverable of the project was the software to handle user input and to operate the system itself. This deliverable included a graphical user interface application that allows user input, an application to handle communication between the Raspberry Pi and the Arduino, and a program to handle the operation of the electronic components within the system.

Background

Problem History

Many individuals who frequently consume medication and vitamins for their well being have limited options when it comes to staying organized with their supplements. According to the Center for Disease Control (CDC) and the American Heart Association (AHA), two-thirds of Americans currently use some type of medication, Older adult and seniors in particular tend to use more medicines and have increased sensitivity to many medicines. With such a large percentage of the population reliant on medication, it is crucial to stay organized when managing these medications, especially if the individual must take different types. Introducing the proposed medication and vitamin management device would help lighten the burden on the time-consuming task of managing medication and help reduce stress if the individual needed to take multiple medicines.

Problem Statement

Currently, the general public has limited options when it comes to organizing their medication and supplements that they receive from the store or pharmacy. One option that is available to the individual is to keep the medication in the factory pill bottle and remember when to take the specified dose. Another option is to purchase a weekly pill organizer and fill each spot in the organizer with the correct medication. The last option is the upcoming technology of pill dispensers, which currently have a small market due to their extremely expensive retail cost. What is currently missing is a pill management alternative that is easily accessible, user friendly, and cheap.

Medication Management Background

For many individuals, managing medications and supplements for themselves as well as anyone else they may be looking after can be quite burdensome. This is especially true for older adults, who are less likely to be able to take care of themselves safely. The ability for this demographic to remain independent in the household often depends on the ability to manage a complicated medication regimen. There are many independent strategies that individuals can follow to stay organized; however, there is a point where medication management safety must be taken to a third party. In fact, in the United State alone, "an estimated 3 million older adults are admitted to nursing homes due to drug-related problems at an estimated annual cost of more than $14 billion" [1].

When medication management becomes too much to handle, caregivers at nursing homes are the most common alternative to choose. The caregivers at these nursing homes provide the much needed medication management as well as various other services. These medication management services often include: reading the medication labels and following all the instructions, giving the right medication at the right time and in the right amount, ordering prescriptions through the pharmacy or the mail, and obtaining refills [2]. Caretakers embody a custom medication management system, catered to the specific individual. All of these services benefit the quality of life for many individuals who require this type of service; however, there are a variety of other methods to managing medicines if the individual is more independent.

For the general population, there are many simply and straightforward medication management solutions that are common practice. One common strategy is to keep a checklist, taking inventory of all the prescription and over-the-counter medication that an individual takes.

This usually requires manually taking note of the amount that should be taken, the time the medication should be consumed, and whether it should be taken with food. Standard locations to store these lists often include the refrigerator door, the place where the individual usually stores pills, or in the individual's wallet or purse [3]. Another strategy often used involves a pill organizer unit, which is a plastic product that has enough individual compartments to store an entire month's worth of medication. Standard locations to store this device are usually the dining room table, somewhere near where the individual usually eats, or the location where the individual usually stores their medications. Other simple strategies for general medication management that will simplify an individual's medication organization include reviewing medical records to keep track of medication that is necessary to take, asking pharmacists to provide the medicine in large, easy-to open containers with large-print labels, determining how medication should be stored, getting prescriptions refilled early enough so it won't run out, and setting timers and reminders to take the medication [3].

Literature Review

Products

See Appendix A

Patents

See Appendix B

Engineering Specifications

Reiterating the goals for this project, the plan was to achieve a working mechanical system prototype that would accurately and successfully pick up and dispense various medications and supplements. Additionally, supporting software would be developed to handle onboard and remote processes necessary for the system's operation. Appendix C goes more in depth about personas and use cases related to the product, justifying the following outlined specifications.

Requirement Table

Spec Number	Parameter Description	Requirement for Target with units	Tolerance	Risk	Compliance
1	Size of system	25 cm x 20 cm x 40 cm (l x w x h)	Max	L	T
2	Pill dispenser operation time	24 hours/7 days a week/52 weeks a year	Min	H	T/I
3	Pill capacity of storage bowls	30 units	Min	M	T
4	Number of unique pills allowed to be stored	7 different types	Min	L	I
5	Pill pick up success rate	75 %	Min	H	T
6	Client data access	24 hours/7 days a week/52 weeks a year	Min	H	T/I

Table 1: Requirements

Requirement Table Index

Compliance methods: Test (T), Inspection (I)

Risk specifications: High (H), Medium (M), Low (L)

The requirements listed in Table 1 were derived from possible customer requirements for the pill management system incorporated into the development process as design parameters. The hypothetical clientele requirements were translated into quantifiable engineering requirements and rated on their comparable risk and compliance measurements.

Pill Management System Requirements

The main requirements for the pill management system are included in the list below.

- The system must be able to store and dispense different types of medications and supplements without cross contamination
    - At least seven unique pill bowls to allow for medication and supplement storage
- The size of the pill management system, including all power sources, wiring, electronic components and housing must not exceed the previously stated dimensions of 25 cm x 20 cm x 40 cm (l x w x h)
- Due to continuous use, the system must be powered by a constant power source, such as the US standard line voltage, and not a battery
- The system must automatically dispense the pills at the specified times
- Use a standard processing unit to handle the system's applications
- Software must be able to handle continuous, uninterrupted use
- Supporting software must handle be able to handle user input

Final Design

The pill management system was first proposed by two Cal Poly students, Joey Angeja and Cameron Wariner, with the goal to create a small appliance unit that would handle the daily overhead of keeping track of medication or supplements that an individual needed for their well-being. This device is designed to be a new method to automate medication and supplement management.

The basic operation of the pill management system follows a user friendly process. First, when the user wants to add pills to the system, the individual must select the “Add Pill To Device” option on the user interface. After selecting this option, a new menu will appear asking for the pill name, the size of the pill in milligrams, the amount of pills added, if the pill is a prescription, and how many times a day the pill needs to be taken. If the pill needs to be taken more than once a day, the menu expands and allows the user to input the times that the pill must be taken. After inputting all the correct data, the individual must select the “Add Pills to System” button and the table inside the housing unit will turn to an empty storage bowl to place the pills in. The user must then select the “Home” button in order to return to the original menu where the newly added pill will be displayed.

Other features available to the user includes manually dispensing a pill, restocking a pill, and removing the pill from the pill management system. When the user wants to manually dispense a pill from the system, the individual can select the “Dispense This Pill” option and system will dispense that specific pill. The “Restock This Pill” option moves the table to the selected pill bowl and allows the user to add more pills to the supply. The last option, “Remove

This Pill," moves the table to the selected pill storage bowl and allows the user to remove any remaining pills. This feature also deletes the pill entry from the main menu, clearing a spot in the database for more pills. Figure 1 below shows a block diagram of level 0 of the functional decomposition.

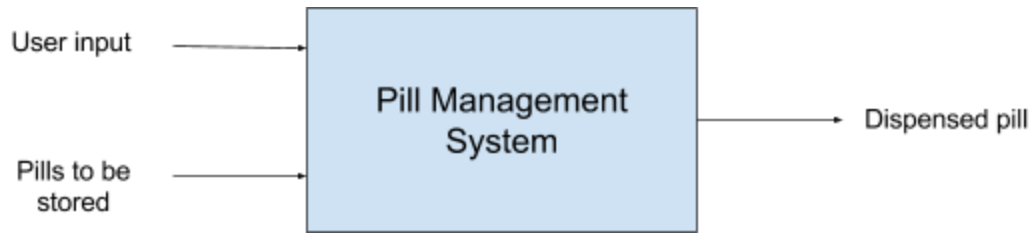

Figure 1: Level 0 (Overall Project Scope)

Figure 1 Discussion:

There are two different types of interactions that the user must execute to correctly operate the system. Those two actions include interacting with the user interface to operate the product and placing the pills into the system. The interface is displayed by a 26 pin LCD touch screen that is attached to an external Raspberry Pi to handle the processing of user data.

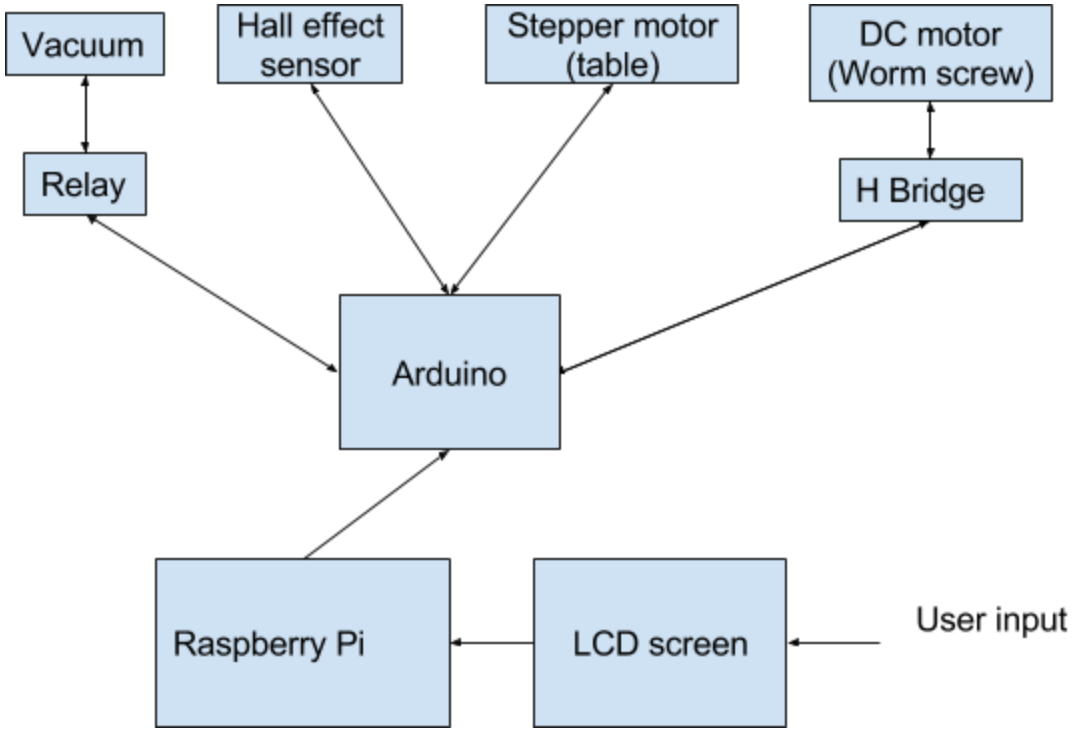

Figure 2: Level 1 (Pill Management System)

Figure 2 Discussion:

The pill management system can be broken down into sub modules which are shown in Figure 2. These modules exhibit the lower level view of what the system is comprised of, focusing on the actual electronic components that are implemented in the design. As previously mentioned, the user inputs data via the graphical interface on the LCD screen, which is then processed by the Raspberry Pi in order to send commands to the supporting hardware. The supporting hardware is managed by an Arduino, which has been programmed to operate the following modules: a relay, a DC vacuum, a hall effect sensor, a stepper motor, a H bridge, and a DC motor.

The relay, as seen in Figure 2, allows the pill management system to provide power to the DC vacuum when the suction method is needed to move pills around the housing unit. The hall effect sensor was implemented to track the orientation of the turn table which holds all the pills.

The stepper motor is directly affected by the hall effect sensor since it is the electronic component that is rotating the storage table inside the housing of the management system. The stepper motor rotates a full 360 degrees at 1 degree increments to provide accurate orientation of the turning table. The final module in the system, shown as the right two components in Figure 2, is the DC motor and H bridge system. These components actuate the worm drive gear arrangement that was used in the final design. The H bridge allows the DC motor to rotate in both a clockwise and counterclockwise direction in order to move the suction apparatus up and down the screw.

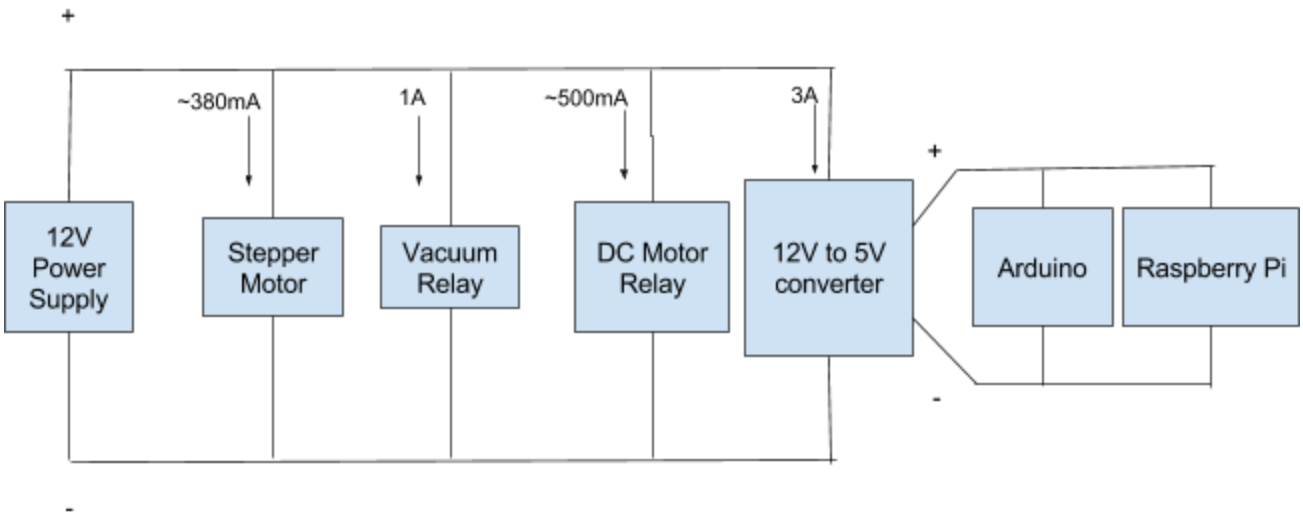

Figure 3: Power Schematic Overview

Figure 3 Discussion:

The electronic components of the system run the simple grid that is displayed in Figure 3. The whole system is powered by a 12 volt power supply which is converted from the US standard line voltage. Each of the components that require power to operate are in parallel. The 12 volt line is then converted into a 5 volt line, since both the Arduino and Raspberry Pi operate on 5 volts. The entire system is wired in a wooden enclosure to ensure the safety of the user.

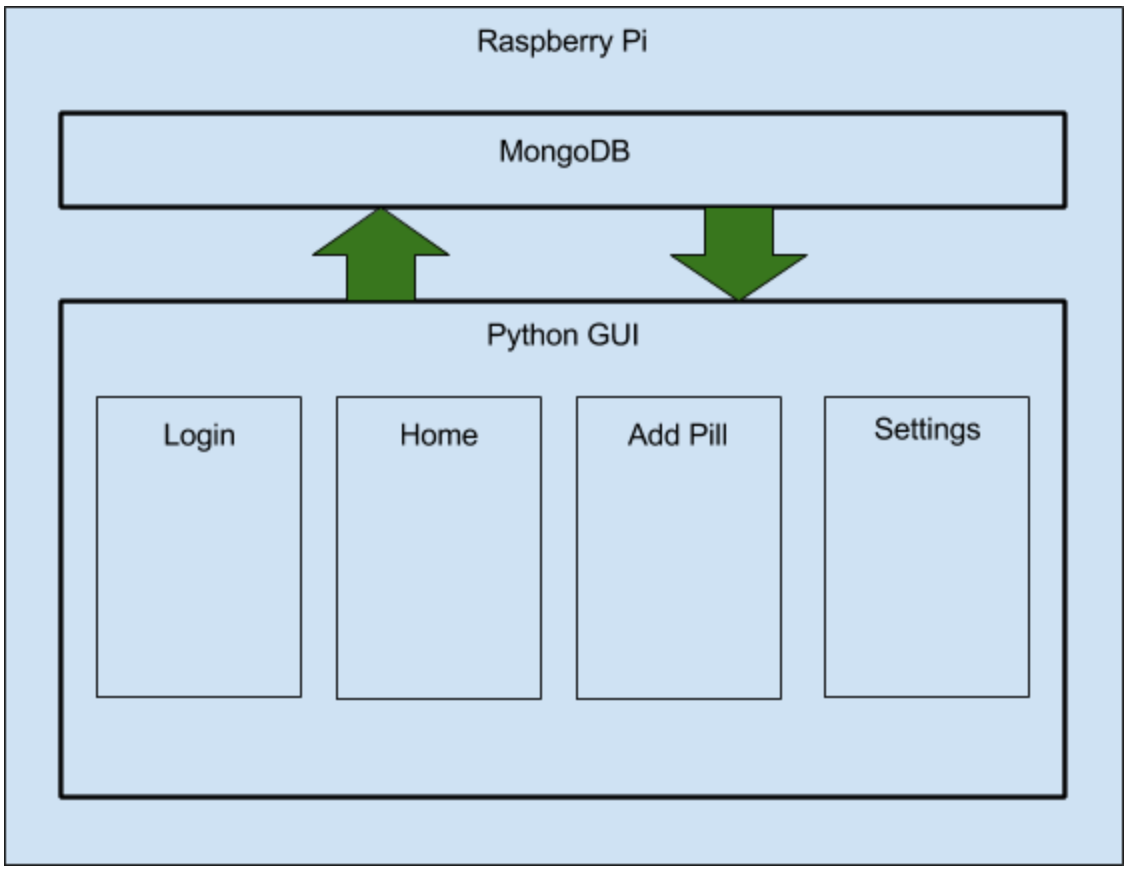

Figure 4: GUI Overview

Figure 4 Discussion:

The Raspberry Pi hosts the python GUI and the Mongo Database. The database contains the user's settings for all the pills that have been added. The database schema is in Table 2. The four controllers Login, Home, Add Pill, and Settings, comprise the GUI. The Login controller is where the user inputs their username and password. The user's password is validated by hashing the password and comparing the result to the hashed value in the mongo database. The Login controller is also responsible for the registration of new users on the system. The Home controller is displayed after a successful login. The Home controller then displays the pills that have been added for the authenticated user. The Add Pill controller is where the user inputs a

new pill to the system. The Settings controller allows the user to view and edit their settings, such as their phone number, email, etc. Each controller sends and receives data from the mongo database hosted on the local Raspberry Pi.

Database Name: Dispenser	
Collection: User	
Fields:	
_id	Unique identifier for each user
username	Username configured upon creation of account
password	Hashed password for security purposes
phone	Phone number entered upon creation of account
email	Email entered upon creation of account
pills	Array of pills added by the user. Each pill is a JSON object containing the fields listed below
Pill Fields	
_id	Unique identifier for each pill added
size_mg	Size of the pills in milligrams
dispenseAmount	Number of pills to dispense for each dispense time
dispenseTimes	Array of times to dispense the pills. If none, then there are no dispense times.
name	Name of the pill. E.g. Advil
amountRemain	Amount of pills remaining in the system
prescription	Boolean value for if the pill is a prescription pill or over-the-counter
location	Integer value that describes the physical container number in the pill dispenser.

Table 2: Database Schema

Design Verification

FMEA

See Appendix D

Design Verification Plan

See Appendix E

Verification Test Results

See Appendix F.

System Analysis

As shown by the verification test results shown in Appendix F, there were two functional requirements that were not achieved in the final design of the pill management system, the excessive height of the system and the low pill pick up rate . The excessive height was due to the worm drive mechanism. To provide the correct travel distance for the suction apparatus, the length of the metal threaded screw used for the worm drive needed to be longer than was initially anticipated. Even though this specification did not meet the original system requirement for this project, it does not affect the functionality of the system and could be addressed on a later prototype.

The second functional requirement that was not met was the pill pick up rate specification. The original acceptance criteria was that the system must have a successful pick up rate of 75%. The logic behind this specification was that the system needed to be able to pick up pills for the majority of the time

and software logic would handle the 25% failure rate by attempting a second pick up. However, the actual pick up rate of the system was close to 10%, significantly lower than the functional requirement. There are a couple factors that led to this low success rate. First, better alternatives could have been implemented for the tip used for the suction apparatus. One alternative would have been to use a proprietary pill suction tip; however, the hardware needed to implement the suction tip would not fit within the housing unit. Another option would have been to develop our own proprietary tip, but time constraints prevented the pursuit of full development and analysis. Currently, the tip is a stylist head with a hole cut out at the end. Other alternatives need to exhibit the same functionality that allows tip to create a sealed contact at any angled surface, to account for any orientation of the pills in the storage containers. A second aspect that could be changed would be the diameter of the tubing used from the DC vacuum motor. Since the diameter of the tubing limits the maximum flow rate, increasing the size give the system more suction to pick up pills.

The system passed the other functional requirements. The system was able to run for 24 hours straight for multiple sessions as well as hold up to a month's worth of pills, with the tested pills ranging from 100 mg pills to 600 mg. Also, there was no data loss when the user input data and no problems arose when commands were inputted into the system through the graphical interface.

Acknowledgments

I would like to thank Cameron Warnier and Joey Angeja who initially came up with the concept. I would also like to thank and acknowledge Joey Angeja in particular for helping develop the graphical interface and database that is used for this system. The last individual that I would like to thank is Matthew Callaghan, who helped develop the mechanical concepts implemented in the project.

References

[1] Marek, Karen Dorman. "Medication Management of the Community-Dwelling Older Adult." *Patient Safety and Quality: An Evidence-Based Handbook for Nurses.* U.S. National Library of Medicine, n.d. Web. 15 May 2017.

[2] United Hospital Fund, comp. *Medication Management: A Family Caregiver's Guide*(n.d.): n. pag. 2010. Web. 15 May 2017.

[3] "Taking Medicines." *NIHSeniorHealth: Taking Medicines - Managing Your Medicines*. NIHSeniorHealth, Mar. 2016. Web. 08 June 2017.

Appendices

Appendix A

Products/Companies

ForgettingThePill.com

Online provider that supplies a multitude of medication management products to the general public. They carry standard pill organizers as well as some electronic pill reminder products.

ForgettingThePill Website

MedMinder

Company that offers an electronic pill dispenser product focused to provide independence for senior citizens by providing a medication management system with many assisted living features.

MedMinder Website

MedReady Inc

Company that offers more electronic pill dispenser products with more of a focus toward medication management automation. Their focus is to combat medication accidents and allow the user to remain independent longer.

MedReady Inc Website

Appendix B

Patents

Electronic Pill Dispenser [US 7359765 B2]

A portable and programmable pill dispenser that incorporates a container with a removable cap attached to the container. The product contains a standard display interface with supporting hardware and software to provide necessary functionality.

Patent available here: Patent 1 Link

Automatic Pill Dispenser and Method of Administering Medical Pills [US 4573606 A]

An automatic pill dispenser designed to administer medical pills the require different prescribed administration schedules. The produce emphasizes storing multiple pills and providing the key functionality to dispense the pill stored medication at predetermined time intervals that correspond to the prescribed administration schedules.

Patent available here: Patent 2 Link

Smart Automated Pill Dispenser [US 20140358278 A1]

Another automated pill dispenser designed to dispense the stored medication at designated times set by the user. The product stores multiple prescriptions in separated storage containers and the pills are dispensed using an auger system with supporting hardware and software.

Patent available here: Patent 3 Link

Appendix C

Personas

Senior citizen:

- The senior citizen is an independent individual of the age of 60 or older who requires medications and supplements to stay healthy. He or she requires a fast, efficient, care-free, and reliable method of managing the medication that they must take.

Average family:

- This persona encompasses the average family who requires an alternative method to organize the daily supplements or medications that each of the members of the family must take regularly. They are looking for a straightforward and innovative way that will ensure that every family member will take their medication and supplements correctly and on time.

Caretaker:

- The caretaker is a third-party that needs to manage multiple medications and supplements for their clients. The caretaker is looking for a product that will help relieve the stressful and time-consuming task of organizing the client's pills.

Use Cases

The following use cases encompass all the personas previously mentioned.

Storing Pills:

- Actor: All personas
- Goal: To successfully add medication and supplements into the pill dispenser.

- Description: The user will use a simple end-user graphical interface on the pill dispenser to add the medication or supplement into the database. If the user desires to add a new pill into the system, the individual must navigate to the main menu where the option to add a new pill to the device is located. Upon clicking on the option, the user must input the type of pill, how often the pill must be taken, as well as the quantity that the individual is adding to the device. After inputting the correct information on the LCD screen, the user will open the lid of the device and add the number of pills that was indicated on the menu screen.

Collecting Pills:

- Actor: All personas
- Goal: To successfully collect medication and supplements that reside in the pill dispenser.
- Description: One of the core features of this product is that this pill dispenser was designed to automatically dispense the user's pills at the designated times that were inputted upon storing the pill into the device. When the specified time of each pill comes around, the device will pick up the required pill and output the pill into an exterior holding area that is easily accessible to the user.

Refilling Pills:

- Actor: All personas
- Goal: To successfully refill medication and supplements in the pill dispenser.
- Description: Once the pill dispenser is in use, it is inevitable that the user must restock the unit. When the supply for a certain medication or supplement runs out, the end user

must use the LCD interface to update the database that the supply for that certain pill has been replenished. After the user has navigated the graphical interface to the correct menu and inputted the correct information that the individual wanted to input, the pill management system would then be ready for normal operation.

Appendix D

FMEA

FAILURE MODE AND EFFECTS ANALYSIS

Item:	Pill Management System	Responsibility:	Ken Yasui	FMEA number:	123456
Model:	Current	Prepared by:	Ken Yasui	Page :	1 of 1
Core Team:	Ken Yasui			FMEA Date (Orig):	6/1/2017 Rev: 1

Process Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Process Controls	Detec	RPN	Recommended Action(s)
Pill Management Unit	*LCD screen failure*	*System termination /Unwanted behavior*	*6*	*LCD screen failure/ damage caused by secondary party*	*3*	*None*	*8*	*144*	*Replace LCD screen and restart system*
	Communication failure between processing modules	*System termination /Unwanted behavior*	*8*	*Software exception occuring during regular routine between processing modules*	*1*	*None*	*8*	*64*	*Reboot the system and run data routine again*
	Communication failure between electronic modules	*System termination /Unwanted behavior*	*8*	*Damage caused to wiring/connections between electronic modules*	*1*	*None*	*8*	*64*	*Replace electronic components that failed/wiring and restart system*
	Fire	System termination	8	Overheating of internal units	1	None	9	72	Replace parts damaged as a result of the fire and restart the system
	Power failure	System termination	8	Power surge/outage from source	1	None	9	72	Reconnect system to functioning power source

Appendix E

Design Verification Plan

TEST PLAN

Item No	Specification	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES		TIMING	
						Quantity	Type	Start date	Finish date
1	Size of system	Measure the size of the system to verify that the desired demensions were achieved.	< 25 cm x 20 cm x 40 cm (l x w x h)	Ken Yasui	DV	1	M	5/28/2017	5/28/2017
2	Pill dispenser operation time	Allow the system to run for extended periods of time and record the status of the system as duration increases.	> 24 hours	Ken Yasui	DV	3	A	5/30/2017	6/3/2017
3	Pill capacity of storage bowls	Place 31 pills into a storage bowl to simulate the quanitity of one month's worth of medication or supplements. Run test with diffferent sized pills.	> 31 pills	Ken Yasui	DV	5	F	6/3/2017	6/3/2017
4	Pill pickup success rate	Allow the system to execute a full run to pick up a pill and dispense the pill from the system.	75% pick up rate	Ken Yasui	DV	20	F	6/3/2017	6/3/2017
5	Client data access	Input user data through the graphical interface and make sure the data saved matches the data inputted.	All data inputted into the system is saved correctly in the database	Ken Yasui	DV	10	U	6/3/2017	6/3/2017
6	Interface application operation	Input user command into the system to make sure the commnd executes on the Raspberry Pi.	All commands are sent, received, and executed	Ken Yasui	DV	10	U	6/3/2017	6/3/2017

Appendix F

Verification Test Results

TEST REPORT			
TEST RESULTS			NOTES
Test Result	Quantity Pass	Quantity Fail	
21.5 cm x 18.5 cm x 47 cm	0	1	The thread used for the worm drive exceeded height criteria
> 24	3	0	
> 31 pills	5	0	Used different pill sizes ranging from 100 mg to 600 mg
10% pick up rate	2	18	Explaination in report section
No data lost	10	0	
No lost commands	10	0	

Appendix G

Timetable

Quarter	Week	Description
1 - Winter 2017	1	Background research
1 - Winter 2017	2	Background research
1 - Winter 2017	3	Requirements documentation
1 - Winter 2017	4	Use case documentation
1 - Winter 2017	5	Prototype methods for pill pick up
1 - Winter 2017	6	Prototype methods for pill pick up
1 - Winter 2017	7	Prototype hardware system design
1 - Winter 2017	8	Purchase all hardware components
1 - Winter 2017	9	Code implementation for hardware components
1 - Winter 2017	10	Code implementation for hardware components
2 - Spring 2017	1	Code implementation for hardware components
2 - Spring 2017	2	Code implementation for hardware components
2 - Spring 2017	3	Code development for graphical interface
2 - Spring 2017	4	Code development for graphical interface
2 - Spring 2017	5	Code development for graphical interface
2 - Spring 2017	6	Code development for graphical interface
2 - Spring 2017	7	Code development for graphical interface
2 - Spring 2017	8	Code development for graphical interface
2 - Spring 2017	9	Complete final report
2 - Spring 2017	10	Submission of final report

Appendix H

Budget

Universal Grabber		
Item	Date	Cost
Plastic Syringe	11/19/2016	$ 3.26
Ballons	11/19/2016	$ 11.96
Total		**$ 15.22**

Vacuum Extraction		
Item	Date	Cost
Vinyl Tubing (Home Depot)	12/4/2016	$ 11.73
Vinyl Tubing (Online)	12/11/2016	$ 20.53
12 V Pump	11/28/2016	$ 21.95
Vinyl Tubing (Online)	12/7/2016	$ 7.62
12 V Pump	11/25/2016	$ 21.95
Suction tips	2/27/2017	$ 7.49
Total		**$ 91.27**

Electronics		
Item	Date	Cost
Rasberry Pi	12/23/2016	$ 6.79
Port expander	12/24/2016	$ 6.49
Stepper Motors	11/7/2016	$ 13.99
LCD	1/19/2017	$ 21.99
Universal Switch	2/3/2017	$ 12.99
DC Step Converter	2/3/2017	$ 7.59
H-Bridge	2/3/2017	$ 6.99
EndStop Switch	2/2/2017	$ 9.99
Cable Wire	2/27/2017	$ 18.99
Male to Female	2/27/2017	$ 8.98
Micro USB	2/27/2017	$ 11.99
Capacitors	2/27/2017	$ 10.99
Total		**$ 137.77**

Linear Actuator		
Item	Date	Cost
1/4 Coupling Nut	1/11/2017	$ 1.24
5/16 Coupling Nut	1/11/2017	$ 1.40
Threaded Rod 12x5/16	1/11/2017	$ 0.98
Threaded Rod 12x1/4	1/11/2017	$ 1.17
STL Square Tube	1/26/2017	$ 6.00
12 V DC Motor	1/19/2017	$ 5.12
Coupler	1/19/2017	$ 6.19
Linear Rail Shaft	4/14/2017	$ 7.99
Linear Rail Shaft Clamps	4/14/2017	$ 15.32
Linear Ball Bearings	4/14/2017	$ 9.99
Total		**$ 55.40**

Frame		
Item	Date	Cost
Magnets (Lid)	12/23/2016	$ 6.99
Hall Sensor	12/23/2016	$ 6.49
Crate	2/3/2017	$ 9.97
Cables	2/3/2017	$ 5.99
Wooden Frame	2/27/2017	$ 21.54
Wood Screws	2/10/2017	$ 5.65
Metal Straps	2/12/2017	$ 4.66
Total		**$ 61.29**

Unaccounted Combined Tax		
Item	Date	Cost
Tubing	12/11/2016	$ 1.65
Linear Components	1/11/2017	$ 0.37
Crate	2/3/2017	$ 1.15
Total		**$ 3.17**

Category	Cost
Universal Grabber	$ 15.22
Vacuum Extraction	$ 91.27
Electronics	$ 137.77
Linear Actuator	$ 55.40
Frame	$ 61.29
Total Expenses to Date	**$ 360.95**

Potential Item	Cost	Quote Location
3-D Printed Frame	$ 50.00	Innovation Sandbox
3-D Printed Rod/Cups	$ 20.00	Innovation Sandbox
Raspbeery Pi 3 Model B	$ 44.00	www.digikey.com
Custom LCD Screen	$ 100.00	www.neweggbusiness.com
Total Cost	**$ 274.00**	

Part Total	**$ 360.95**
Potential Item Total	**$ 274.00**
Total	**$ 634.95**
Check Total	**$ 634.95**