

Preliminary System and Hardware Design for Guardian, a Low-cost Automatic Pill Dispenser with Pneumatic Technology

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Abstract

This paper presents on-going progress on Guardian, a low-cost automatic pill dispenser aimed to help the elderly to take their medication on time. The device is composed of a cylindrical body with a pneumatically powered rotating robotic arm in the center column. This information in the paper is meant to record the development process that led to the filing of a provisional patent USPTO 15964875.

1 Introduction

Currently, there are mainly 2 types of existing products. One is a of timer, where users are required to compartmentalize different pills beforehand and the machine will only alert them. They will then need to take out the pills. This is problematic as it takes a lot of work and patients can possibly forget to compartmentalize the first before taking them. The second type of devices is similar to ours, but none have been successful in the market because they are over- priced, ranging around \$600 USD. This exorbitant price point makes it extremely unaffordable to the mass consumers. This proposed device will solve

the monetary issue while keeping important functionalities of the proposed device.

The pharmaceutical industry has far exceeded its 3 trillion worth in 2012 and it has been growing fast since. This gives us a great space for our product. The pill dispenser is designed for the elderly and the disabled. However, buyers are not limited to this group of people. Younger adults can purchase them for their parents in need as well, which is a big part of the consumer group. The product will be sold commercially through mainly internet sites. We will promote through our social media such as Facebook and Instagram.

2 Market Analysis

The medical device market is By 2023, the global medical device market is estimated to reach \$409.6 billion. Currently on the market, there are 3 types of devices. One type of device is capable of reminding the patient to take the pills and allows them to compartmentalize the pills, but it does not offer the automatic dispensing feature (Exhibit A). The second type of device has all of the of the first type and it alerts the users through sound (Exhibit B). The third

type of device has all of the features of the first two and it has the automatic dispensing ability, but the price point makes it questionable to persist on the market (Exhibit C).

Research, surveys and interviews were conducted to better understand the need from the market as well as the current market. A representative from a global pharmaceutical company has illustrated the fact that this type of device is extremely important in a patient's life, but large pharmaceutical companies will not spend the human capital as well as financial resources to develop those kinds of products because the project size is too small, and those companies would like to direct their resources elsewhere. However, they would like a device to develop from a startup company so that it can be sold on the market.

A survey was conducted to examine how often a patient will forget to take their medication through creating a scale from 1 to 10 such that 10 signifies most amount of medication forgotten. On average, patients, especially the elderly group, answered a 7 out of 10 on this scale, indicating that there is a huge need for this type of pill dispenser.

Forgetting to take medication has health implications as patients of cardiovascular diseases have to often take up to 5 different types of pills 3 times a day, and forgetting to even taking one of those 3 times can be detrimental to their health.

We conclude that our market segmentation is the elderly as well as the people around the age of 40 years old (vitamin pills). Our valued proposition is the offering of a low-cost automatic pill dispenser that can dispense up to 3 types of pills.

3 System Overview

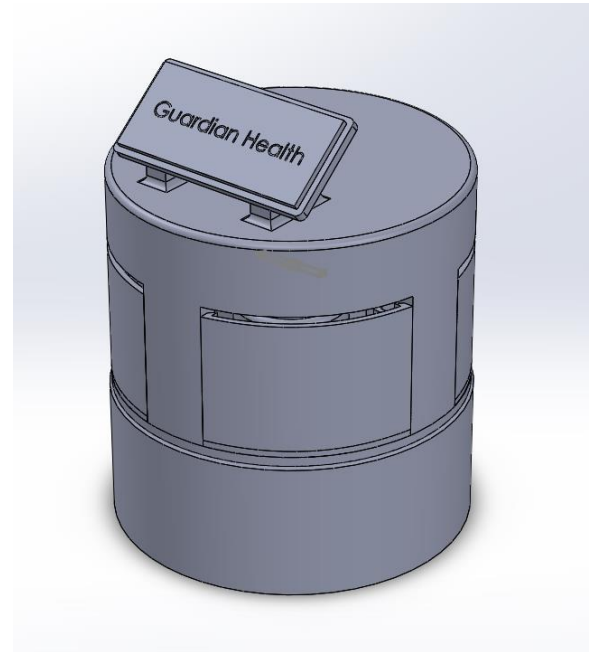


Fig. 1: Overall Configuration of device.

The proposed device has an overall cylindrical structure. A LCD touchscreen protrudes on the top outer surface. The LCD screen is used to display user information during selection process as well as other functionalities such as alerts. Around the perimeter of the device there are four cups in which 3 of them are used for placing pills prior to dispensing them while the final one is used as a collection cup where users can pick up pills after the machine has finished dispensing them.

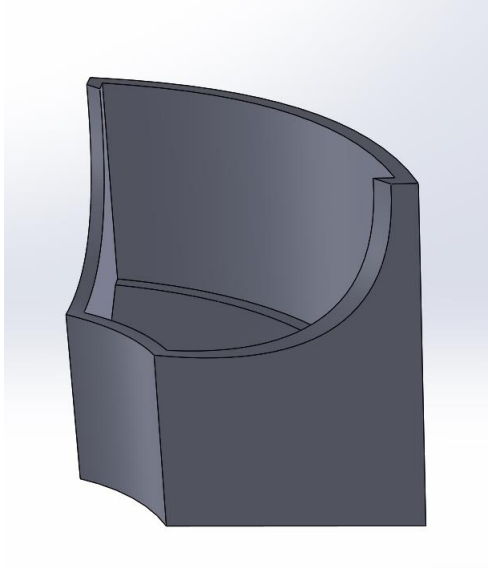


Fig. 2: Cup design for holding pills

Currently, the device is composed of a plastic outer body and the electrical system is Arduino-based, but a custom PCB board is in the design process.

4 Arm Design

The principle design is the parallel lift design. There are several useful characteristics of the parallel lift that we can use. First, the structure is relatively simple, so it can be built and prototyped easily. The main feature of the parallel lift is that the moving arm lifts up and down parallel to the other ground. The design allows the tip to always point in the direction of the pills. It was constructed first in polycarbonate but now is produced in 3D printed plastic.

After prototyping, it was determined that 3D printed parts provide less friction and more accessibility, so it will be used in the design.

A servo motor rotates the parallel lift arm so that it can go to other containers and pick out all 3 different types of pills. After

the arm picks it up, it rotates and drops the pill into one container for the users to collect.

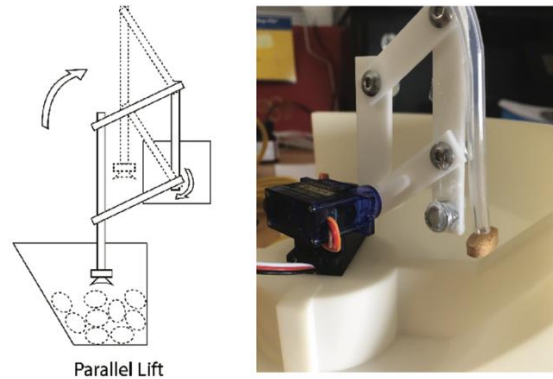


Fig. 3: Prototype Arm Design.

5 Pneumatic Suction System

The pneumatic suction system is the proprietary technology of the entire system. Through research and years of experience, we have concluded that any traditional robotic grabber arm that includes a physical motion (closing and opening a robotic claw) because it doesn't adjust to the infinite sizes, shapes, and textures of all the different pills. This is the core technology of this project that differentiates it from other products.

The pneumatic suction system is at the core of the design, and this is a very dynamic design. By using a system similar to a vacuum system, the air flow allows the intaking system to collect pills regardless of their shapes, sizes, textures and weights.

A system using 12V diaphragm pump was developed, but the power and the overall system was no effective. The size profile was simply too big and therefore undesirable, and the noise factor also played a big role in us shifting into a new design.

The improved system involves a DC motors that spins at a high RPM with a miniature rotor on top. The rotor has 2 propellers that are tilted such that air will be produced to provide the suction force for the pill dispenser.

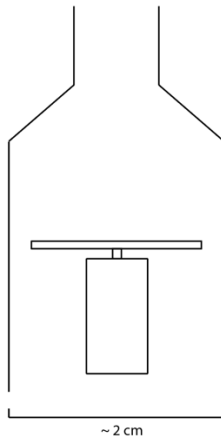


Fig. 4: Internal chamber containing motor and propeller

A simplified drawing of the core of the device where the motor sits in the middle and a propeller is attached to the top. The suction tube will be connected from the upper side.

This design is extremely effective because the vacuum technology is indiscriminate regarding size and shape. Cost is a big factor in this design as well as the whole core package can be designed from ~\$10 USD.

This entire mechanism sits beneath in the upper level of the device along with the Arduino microcontroller and the main device battery.

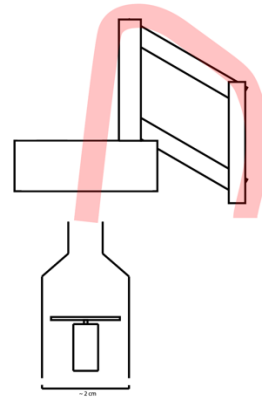


Fig. 5: Combination of chamber and lift design. Red represents pneumatic tubing.

This design allows for a smaller profile compared to the original diaphragm pump, which produces less noise and overall more efficiency in terms of motor power and suction force.

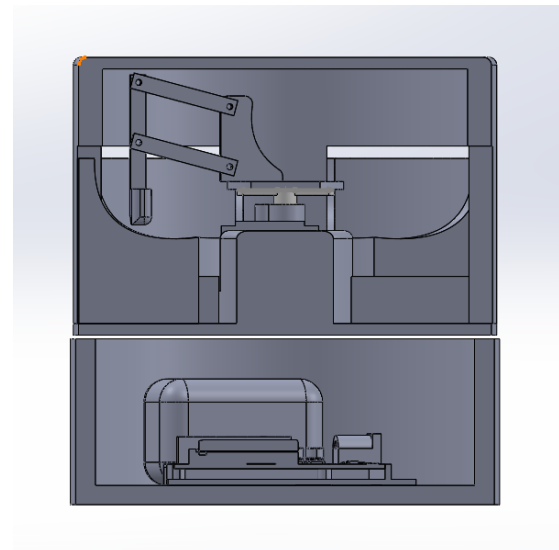


Fig. 6: Overall cross-sectional view in Solid works.

6 Digital System

This section provides plans for expansion of a digital system related to the automatic pill dispenser. The system is currently Arduino

based because of its accessibility. This is the flow chart of the programming that we have done in the Arduino interface.

Users first enter their information into the LCD screen using knobs and a button, and then it will dispense the pills on time. We plan on improving the system so that in the future it is one touchscreen display.

There are 2 main systems that we considered. The first system being more of a menu-select system where there is a main screen and you can access different portals, kind of like smartphone home screens. Another system is a more straight-forward step-by-step system where the user is guided through different steps to complete the information needed to dispense the pills. We decided that it was better to use the step-by-step system because it is both easier to implement and easier for the users, especially the elderly.

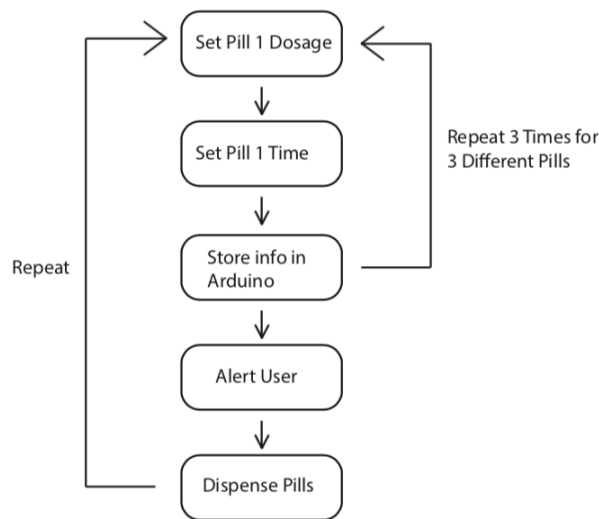


Fig. 7. Diagram for programming logic.

7 Future planning

From the software perspective, there is an intend to build an Android and iOS application to accompany the product. This platform will allow medical centers and patients to connect digitally. Users will be able to message doctors and track their daily progress, while doctors can monitor patients and track their patients' progress as well.

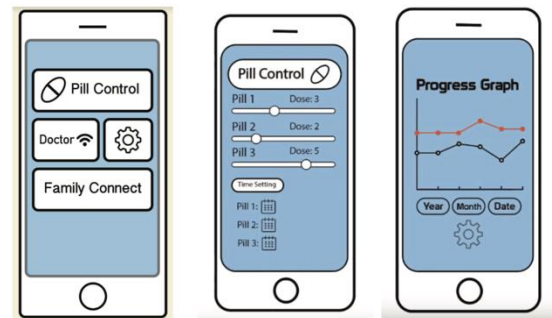


Fig. 8: App layout for digital control system

Pneumatic Suction system upgrade:

A more advanced system is proposed involving cameras and machine learning technology. Essentially, a camera will be pointed downward from inside the robot pointing at the pills. Using image recognition and segmentation technology, it will optimally decide which pill on the top or more easily to be picked up.

Instead of using a parallel lift design, an alternative design could be using a linear slider using simple rack and pinion so that the suction head can travel straight down. Weight sensors can be implemented on the bottom of pill collection cups in order to detect the presence of pills.

8 Conclusion

By implementing a pneumatic system and a digital control system, issues for automatic pill dispensers regarding collecting pills of multiple sizes, shapes and weights are solved while drastically reducing the production cost of the device itself. While

9 Acknowledgment

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Exhibit A: Pill Dispenser



Source: https://www.123rf.com/photo_28755539_daily-pill-dispenser-with-assorted-pills-on-blue.html (Accessed July 5, 2018)

Physical Properties and Components:

Rectangular, plastic. The device is composed of a plastic shell with 7 different compartments that can be opened by the users with hand.

Analysis:

This device requires users to compartmentalize pills before and after they take the pills for a one week cycle. A common problem that is encountered with these device is that the users often forget to compartmentalize at the end of the week, and even sometimes, users, especially the elderly, will forget if they have taken the medication on that day or not, resulting in double the confusion.

Exhibit B: Pill Dispenser Type B with Alerting Functionalities.



Source: <https://www.amazon.com/LiveFine-Automatic-Dispenser-Electronic-Medication/dp/B00FL620B0> (Accessed July 5, 2018)

Physical Properties and Components:

This type of device usually comes in either circular shaped or rectangular shaped with many different compartments on the outer side indicating date and time (morning, noon, eve).

Analysis:

This type of device offers another level of sophistication because it has the alerting function through a digital display. It also allows more compartmentalization because it divides each day into 3 different segments.

These are some of the problems with the device itself. First, it requires users to put in pills prior to taking them. When the users do not need to take the pills at a specific time period, the slot will be left empty, wasting unnecessary space. The physical shape of this type of device is also extremely unfriendly because it occupies a large horizontal space, making it hard to set on a tabletop or counter. Users will continue to forget to put in a new set of pills after the initial week.

Price point: \$60-80

Exhibit C: Pill Dispenser Type C with full functionalities



Source: <https://herohealth.com/> (Accessed Aug 10, 2018)

Physical Properties and Components:

Plastic cylindrical structure about 1 feet in height. The device includes all the necessary functionalities of an appropriate automatic pill dispenser. On the front, a LCD and control panel sits such that users can choose the appropriate settings of their choice.

Analysis:

The device has all the capabilities that an automatic pill dispenser should have such as alert function, different times settings in one day, and picking up pills regardless of size. The biggest problem of this device is the mechanical complication on the inside that leads to the unnecessary pricing, which doesn't allow it to be marketable. Because of the price point, this device has not been mass produced on the market and is being crowdfunded.

Price: \$699