Introduction to Engineering Design with Professional Development 1

Final Report for Automatic Pill Dispenser

Team: Pillgrims

Section 4

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Executive Summary

The Automatic Pill Dispenser (APD) is a device meant to help people remember and take their medication. The APD is shaped like a cube to allow the user to easily pick it up and place it. The APD comes with multiple dispensers using a compliant foam wheel for different types of pills and can allow multiple users to interact and use it. The APD uses a fingerprint scanner to verify users and let them access their medicine through a touch screen. The user interface is built to require minimal user input to operate. The APD is significantly cheaper than alternatives and is an all-in-one system that does not require users to make any additional purchases.

The APD is broken down into six subsystems: the housing unit, the dispenser, the Arduino integration, the user interface, the alarm, and the security system. The user interface, alarm, and security system are software subsystems and the Arduino integration connects together into a cohesive unit. This is connected to the fingerprint scanner, which identifies users, the touchscreen, which allows them to interact with the device, and the dispensers, to control when to drop pills. All of the components are mounted together to a housing unit, which provides a compact fit for everything. The mechanical systems were developed using plywood, 3D filament, and acrylic. These materials were strong enough to not break under at least 5 pounds of force. They were manufactured through laser cutters and 3D printers. This was because of the specific shapes and dimensions they had to be which made it too hard to make by hand.

This report discusses the process and final product of the APD. From concept to final design is discussed. Decisions were made using concept selection matrices and grading concepts against each other. Mechanical models were made using Siemens NX while electrical models were made using Visual Studio Code, Arduino IDE, and LT spice.The final product is considered successful as it met all of the target specifications. Most notably, it can dispense up to six different types of pills, each one at a time, only takes one user input, has an injury rate of 0%, and is less than twenty pounds. It also achieves one of its fundamental goals, which is to be cheaper than alternatives. The APD costs $199 to make while competitors charge their models at either more than $1000, or rely on a continuous subscription which will exceed the APD cost over time.

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0 Revision History

Table 0.1: Revision History

Version	Date	Name	Reason For Changes
0.0	4/27/2022	Final Report for Automatic Pill Dispenser	Initial Document.

1 Introduction

Consistently and correctly taking medication is an ongoing problem for many people worldwide. A study by Georgetown (Georgetown University, 2022) indicates that 66% of all US adults, at 91% of those over 80, take medication for some chronic condition. However, some have issues correctly taking their prescribed dosage. According to a study by Clinical Toxicology (Hodges, 2017) adults in the US are severely injured at a rate of 1.73 per 100,000, as a result of incorrectly taking medication, and this rate is increasing. Because of this danger, designing a device to aid those who chronically take medication, by making it easier to take pills, serves to greatly and positively impact the lives of those taking medication, and those who care for those taking medication, who share in the burden of incorrectly providing pills. An automatic pill dispenser, that intakes multiple types of pills and dispenses the correct medication at the correct time fulfills this purpose.

In creating such a product, initial customer outreach stressed the importance of two parameters: safety and ease of use. As the intended customer base for this product is the elderly, who take medication at the highest rate, not only was the product to be completely safe to use, having a near-zero failure rate in dispensing pills, but it was also to be simple, catering to those who have trouble using technology. A detailed description of customer requirements can be found in Appendix B.

2 Project Objectives and Scope

The scope of the project is to design, create and test an automatic pill dispensing device. Over the course of the time allotted, the entire engineering design process will be used to create six subsystems and integrate them to form one cohesive unit, to be tested. Testing of the integrated system consists of loading pills into the device to be dispensed and calculating the failure rate. Due to time constraints, testing will be minimal, and if production were to be executed, further testing on not only failure rate, but material interaction with the medication, usability, and more would need to be done. This testing will not be executed in this project.

2.1 Mission Statement

Medicine management is a challenge that plagues those who rely on it to go about their daily lives, as situations may arise which can prompt individuals to not correctly take their prescribed dosage. Creating a device that can easily and affordably aid those who have troubles with medicating will alleviate these issues, and could shoulder some of the burdens of those caring for those who need medication. The proposed design seeks to safely and accurately dispense required medication according to schedule, and make doing so as easy as possible for all involved.

2.2 Customer Requirements

The target customers of the proposed product are those who are taking medication, particularly the elderly, who may have issues keeping to strict regimens or schedules. Expected target customers were Baby boomers and the X generation who generally start to take many pills, therefore, feel the inconvenience of taking pills. Those caring for the elderly may also be target customers. Secondary customers may include any who want a more centralized and automated medicine management system. Overall, the proposed Automatic Pill Dispenser would improve the quality of life of all target customers.

Table 2.2.1: Ranking customer needs by importance

No.	**Customer Needs**	**Importance (1-5)**
1	Reliability	*****
2	Safety	****
3	Storage	**
4	Cost	*
5	Easy to Use	***

Table 2.2.1 shows the customer needs ranked by importance. Since dispensing a proper and exact number of pills is important to the health of pill takers, reliability becomes the priority of customer needs. Primary customers are usually people who suffer from dementia, Alzheimer's, and other similar conditions. Therefore, safety and use without difficulty become the next focus of the project. Storage and price can be good properties for the final project design but will be pushed back to fulfill the customer requirements.

2.3 Technical Specifications

Table 2.3.1: Customer Requirements and Technical Specifications

Customer Requirements and Benchmarking		
Customer Requirements	Technical Specifications	Target Value / Range
Must take multiple pills	Number of Slots For Pills	<=6
Must be easy to use	Minimal Interaction	1 user input
Must be small	Dimensions	24”x36”x36”
Must be lightweight	Weight	<20 lbs
Must Dispense right pill	Failure rate	>1000 pills
Must be Safe	Injury rate	0%

Table 2.3.1 shows the customer requirements and benchmarking of the Automatic Pill Dispenser. The dispenser can take up to 6 different types of pills and should be very simple to use considering the customer. The failure rate should be minuscule since it dictates a proper dosage and any discrepancy in what is dispensed could be potentially life-threatening to the consumer.

3 Assessment of Relevant Existing Technologies

The concept of an automated method of dispensing pills has been implemented by several companies to varying degrees of success. With improvements in computer technology, more features can be implemented without increasing manufacturing costs such as BlueTooth integration. The group has researched products and patents pertaining to design and discovered common features.

Table 3.2: Competitive Benchmarking

Competitive Product	**Title / Description**	**Relation to this project**
MedaCube	Automatic electronic locking pill dispenser with wi-fi and optional cellular	Used to benchmark for security system subsystem
Hero	Smart pill dispenser designed for households with wi-fi	Used to benchmark for general features
Livi	Smart home pill dispenser designed for households	Used to benchmark for price

The main pill dispensers on the market are the Medacube, Hero, and Livi pill dispenser. The Medacube has the ability to dispense up to 16 different medications, alarms, and email notifications. However, this product comes with a cost of $1849.99, which is difficult for the average family to afford. The Hero and Livi are cheaper options with an upfront cost of below $150 dollars. However, these dispensers have a subscription-based model, where the pills dispensed have to be bought from the dispenser company to work. This not only increases the long-term cost of the dispenser but also limits the pill options to only the ones that the company provides.

Table 3.3 - Patent Research for Related Technologies

Patent Number	**Title / Description**	**Relation to this project**
US20130110283A1	“Pill Dispenser”	Used to benchmark dispenser module designs and integration

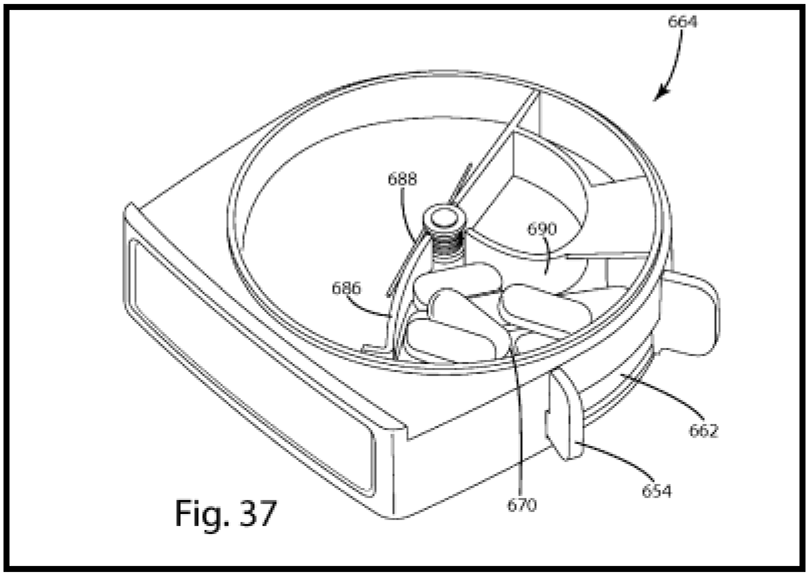


Figure 3.4: Dispensing unit (Baarman & et al, 2012)

On April 25, 2012, Baarman et al filed US Patent US20130110283A1 for the “Pill Dispenser” [2]. This patent showcased a prototype of a pill dispenser and aimed to be simple to produce. The design also had several different dispensing modules that were considered by the group. This specific design in figure 3.4 was the primary dispensing module that was used for the design proposed. The restricting element of this design is that it is prone to jamming. The project team has taken inspiration from this design to dispense pills one at a time.

4 Professional and Societal Considerations

Table 4.1: Engineering Solutions Impact

Area of Impact	Positive Impact?	Description of Impact
Public Health / Safety	Y	The pill dispenser automatically and accurately dispenses pills at preset times. This dramatically decreases user error, especially for the older population. The device is also extremely easy to use, so most of the general population benefits from it. The built-in fingerprint sensor ensures that only the user can access the pills. This lessens the chance of theft or toddlers accessing it.
Global	–	The device has no major global impact. People who do not understand English may not utilize the system, but that is a direct and active impact of the device globally.
Cultural	–	The simple interface of the pill dispenser does not negatively or positively impact any cultures. People who have had no experience with touch screens may experience difficulties, but this is the very edge case.
Societal	–	The device is easy to use and targeted towards older customers. This makes it so that most of the general population can easily understand and use the device. Thus, the device has no significant societal impact.
Environmental	Y	The dispenser is stationary and has a robust outer housing. It has few moving parts and the device microcontrollers have electronic failsafe. This makes the device extremely durable and mechanically sound. The dispenser can easily last the user years, and the few moving parts are generic and easy to repair. This makes the device very environmentally sustainable because it can last users years and disposal due to dysfunctional will be extremely rare.
Economic	–	The device is made out of cheap, generic, and accessible parts. They have already been repeatedly tested and proven to be durable. The usage of these parts has no significant economic impact.

Our team applied the engineering design process to produce solutions that meet the specified needs with consideration for the topics found in Table 4.1 - Engineering Solutions Impact.

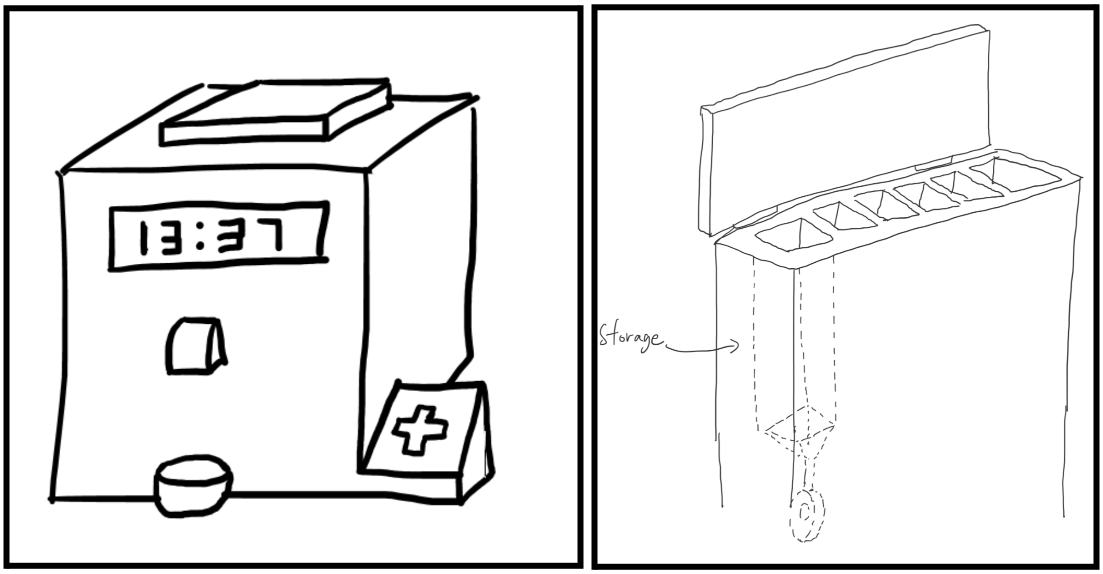
5 System Concept Development and Selection

Deciding on a system concept was relatively easy, as only one feasible idea revealed itself among group discussion: an automatic pill dispensing robot. Compared to other ideas, the pill dispenser seemed to be a feasible idea within the scope of abilities of student engineers.

Table 5.1: System Concept Selection

Scores are -1, 0, 1	Concepts				
	Automatic Pill Dispenser	Guide Robot	Face tracking rig	Automatic ping pong launcher	Solar cooker
Affordable	0	-1	-1	-1	1
Practicality	1	0	-1	0	-1
Feasibility	0	-1	0	1	0
Difficulty	0	-1	-1	0	0
Net Score	1	-3	-3	0	0
Continued	Yes	No	No	No	No

The final concept developed for the automatic pill dispensing robot was that the device would take pills from a funnel and dispense the correct amount of the correct type of pill at the correct time of day, based on an alarm. After brief discussion, the concept was defined as a medical tool to be used for people that have trouble with taking medication rigidly, with the target customer base being the elderly. The goal of the product was to make taking pills as easy as possible so that there was a simple user interface, which would work through a touch screen. Figures 5.1 and 5.2 are simple prototype sketches of the pill dispenser as a whole, which served as a basis for the design.



Figures 5.1 and 5.2: Initial System Concept Sketches

After a system concept was created and thoroughly discussed, Each group member separated to work on each respective subsystem. The analysis of the engineering design process and discussion of testing of each subsystem are in the Subsystem Analysis and Design section to follow.

6 Subsystem Analysis and Design

6.1 Subsystem 1: Housing Unit

The housing unit of the APD is shaped like a box (shown in figure 6.1.1). The base of the housing unit is a funnel (shown in figure 6.1.2) which causes pills dispensed from the dispenser to fall towards the front and allow the user to easily reach inside and take the pills out. The walls of the APD provide structural support for all of the components by using brackets (shown in figure 6.1.3) to mount the dispensers and electronics to the wall. The front wall features holes for the touch screen and fingerprint sensor to fit in and secure (shown in figure 6.1.4). It also features a raised base in order to prevent dispensed pills from falling out of the APD. The roof acts as a lid for users to open in order to pour pills into the dispensers.

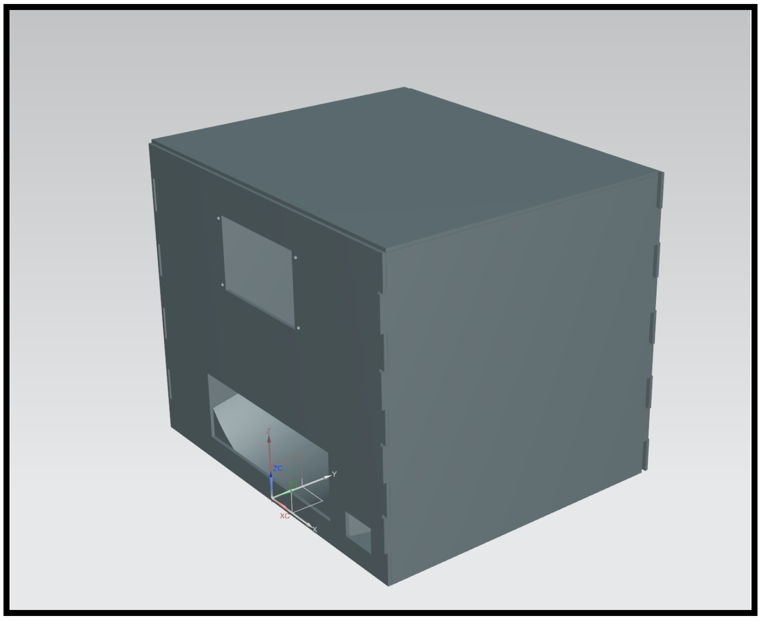


Figure 6.1.1: CAD model of housing unit

The housing unit design was relatively simple. Since most of the other components had already been designed with a known quantity. The size was simply the volume that they all took up. This made the housing unit a compact fit for the parts. The placement of components was decided based on what limitations each component had in terms of placement. For example, the touch screen and fingerprint scanner were required to be on the front so the wiring and Arduinos had to be next to it. This meant that the dispensers had to be lined up against the back of the housing unit. From this information, the funnel was made such that it was wider in the back and thinner towards the front. This allowed for all of the dispensers to drop into the funnel and left extra room in the front for more components. This also created room in the front of the housing unit, where the funnel was narrower, for components such as the speaker to be placed. The roof of the housing unit was designed to be a simple lid with a hinge for the user to open and pour pills into the dispensers.

The roof was initially designed to have a locking mechanism so that other people, such as children, could not access the medication easily. However, this idea was not implemented since it would take up too much time with respect to how far along the project has come so far.

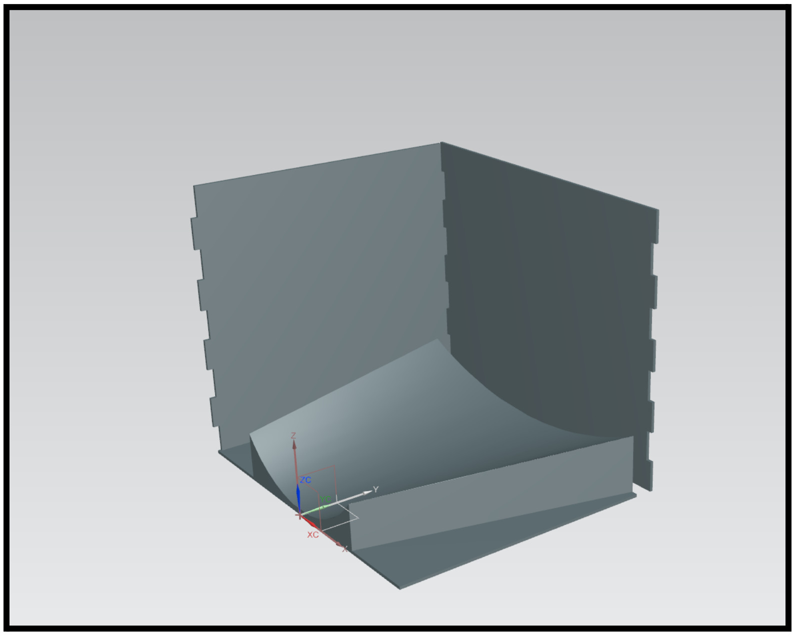


Figure 6.1.2: CAD model of interior

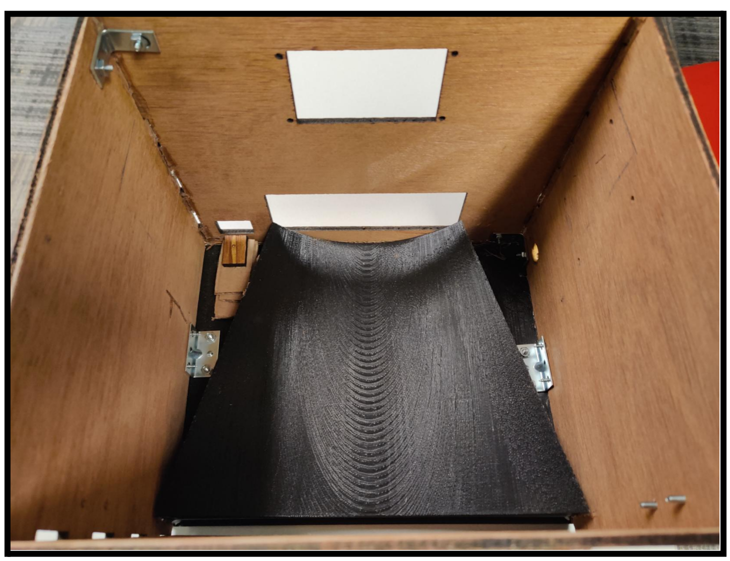


Figure 6.1.3: Birds-eye view of interior of housing unit

Figure 6.1.4: Front view of housing unit

When the housing unit was made, the base was made out of 3D printer filament while the rest was made out of laser-cut plywood. The base was 3D printed because of the funnel shape which would not be easy to make using machines. The plywood was chosen as the material because it is strong enough and was in high abundance. The walls had a pattern on the end which made them fit together better like puzzle pieces.

For the initial prototype, the walls and base were connected by hot glue while the roof was taped on. In the initial prototype (shown in figure 6.1.5), the roof was made out of cardboard as it made the whole unit lighter and easier to manufacture. However, when testing, it was shown that the roof was not strong enough to meet target specifications. It collapsed upon itself which meant that it had to be made stronger. Along with the roof, the walls were also weaker than desired even though they still met target specifications, they could have been improved.

In the final design, the walls were attached to the base using metal brackets, these were much stronger and proved to be significantly better than hot glue. For the roof (shown in figure 6.1.6), it was remade out of laser-cut plywood to match the rest of the unit and used a metal hinge to keep it stable. Along with these changes, the walls had to be adjusted to account for other subsystems changing. For example, the Arduino Integration subsystem changing from two Arduinos to one meant that the mounting holes had to be remade. All of these changes allowed for the housing unit to meet target specifications and even made it stronger than necessary in the case of the walls.

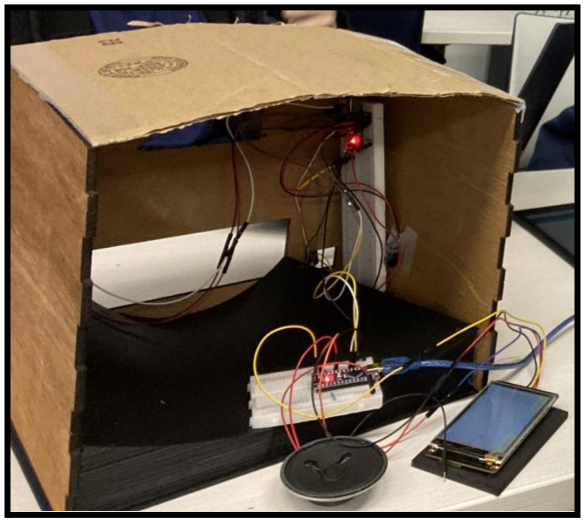


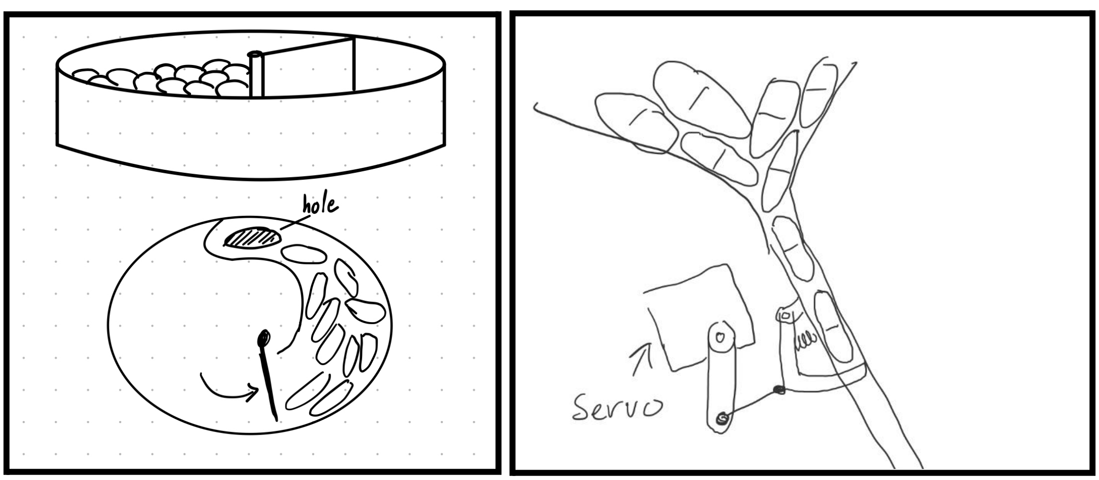
Figure 6.1.5: View of initial housing unit with components

Figure 6.1.6: View of exterior of final design

6.2 Subsystem 2: Dispenser Modules

The pills themselves are dispensed using the compliant wheel design, which eliminates the size and shape of the pill being dispensed as a constraint. In designing such a system, safety in the number and type of pills being dispensed was of utmost importance, as giving the end user the wrong type of pill or the wrong amount could be deadly.

The dispenser system design started as a set of possible designs, namely the pill chamber design, pill scythe design, and the compliant wheel design. In the pill chamber design (shown in figure 6.2.1), pills are loaded into a puck-shaped module, within which a sweeping arm pushes the pills into a horizontal funnel, and then into a hole where the end-user would pick them up. In the pill scythe design (shown in figure 6.2.2), pills would be funneled from storage into a tube, where a spring-loaded stopper would keep pills from sliding until a servo motor moves the scythe to let one pill pass, after which the spring would keep more than one pill from being dispensed at a time. In the compliant wheel mechanism (shown in figure 6.2.3), pills would be dispensed by sliding past a soft foam wheel, which would grab the pills by molding them to their shape, and dispense them below, making use of an infrared break-beam sensor to detect a successfully dispensed pill, stopping the motor driving the wheel.



Figures 6.2.1 and 6.2.2: Initial Sketches for Pill Chamber Design and Pill Scythe Design

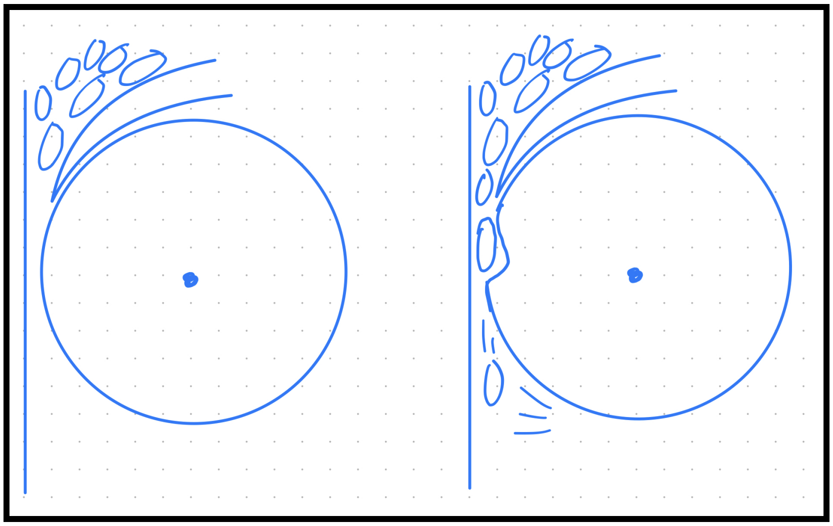


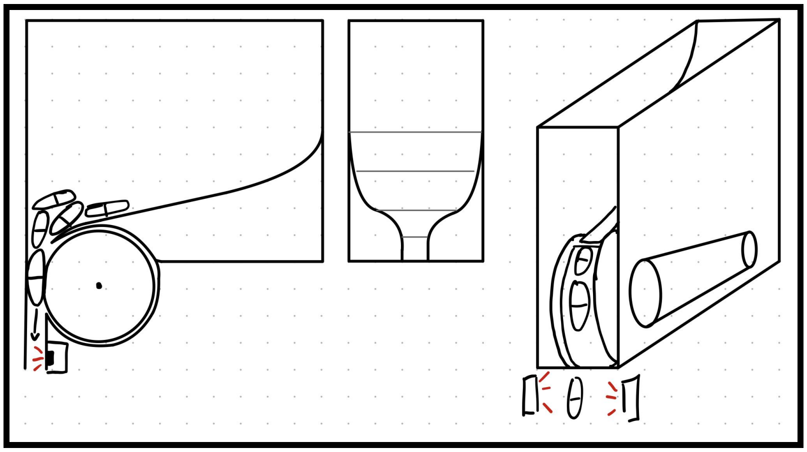
Figure 6.2.3: Initial Sketches for Compliant Wheel Design

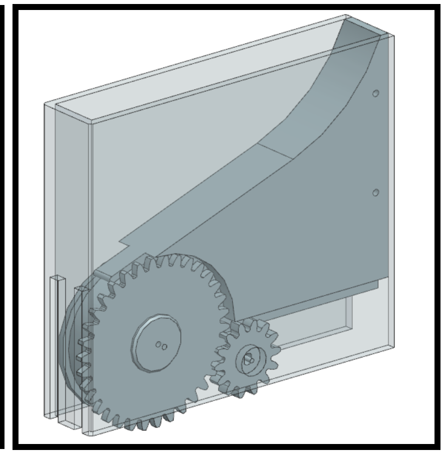
To compare designs the initial technical specifications were considered. Of greatest importance was safety, meaning tight control of the number and types of pills dispensed. Anything other than perfect was unacceptable. Secondarily, the ability to dispense any kind of pill was considered, as that would differentiate the proposed pill dispenser from competitors. Considering these and other parameters, each design was compared and put into a decision matrix (table 6.2.1), where it was found the compliant wheel mechanism would be the best design to move forward with.

Table 6.2.1: Decision Matrix of Pill Dispensing Solutions

	Concepts			
Selection Criteria	Foam Fly Wheel	Scythe Controlled	Chamber	Horizontal dispenser
Cost	1	1	1	1
Difficulty of Implementation	1	-1	0	-1
Creativity	0	1	0	0
Efficiency	1	0	1	0
Performance	0	0	0	1
Consistency	1	1	0	-1
Accuracy	0	0	0	1
Practicality	1	0	1	0
Safety	1	1	1	1
Durability with Average Usage	0	0	1	0
Sum of +1's	6	4	4	4
Sum of 0's	3	4	5	3
Sum of -1's	0	1	0	2
Net Score	6	3	4	2
Rank	1	3	2	4
Continue?	Y	N	Y	N

The design of the compliant wheel mechanism is simple, combining the pill storage and dispenser systems into one. In the final concept sketches shown (figure 6.2.4), the pills funnel down the slant towards the wheel, where they are dispensed. Completed CAD models (figure 6.2.5) and CAD drawings (figures 6.2.6 and 6.2.7) reflect the concept sketches well, implementing an almost identical design. The final design problem facing the dispensing mechanism was how to drive the wheel itself. Originally designed using a pulley system, it was found that the slipping of a rudimentary pulley could compromise the safe orderly dispensing of pills, and so a rigid gear train was implemented. The gears were made using NX's GC Toolkits, based on parameters retrieved from geargenerator.com (Vincze, 2014). The comparison between the online render and final CAD models is shown in figures 6.2.8, 6.2.9, and 6.2.10.





Figures 6.2.4 and 6.2.5: Final Concept Sketches of Wheel Mechanism and Completed CAD

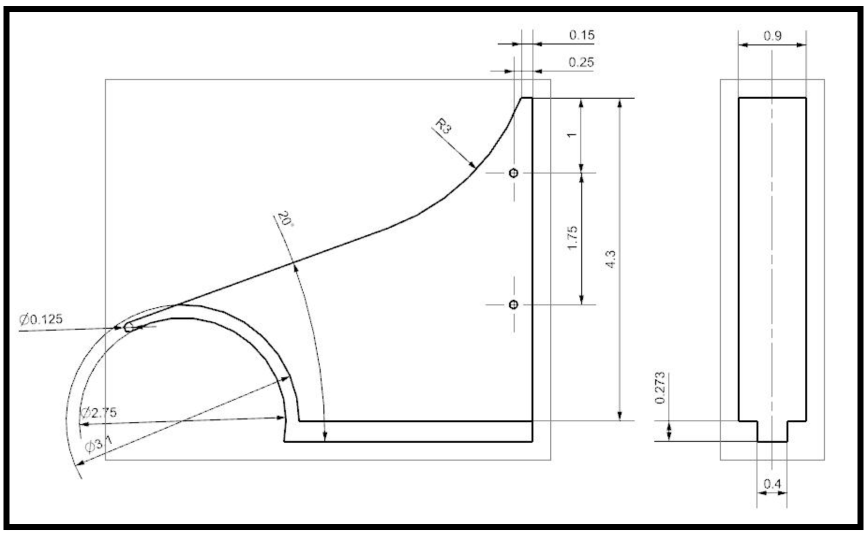


Figure 6.2.6: CAD Drawing of Dispenser “Core”

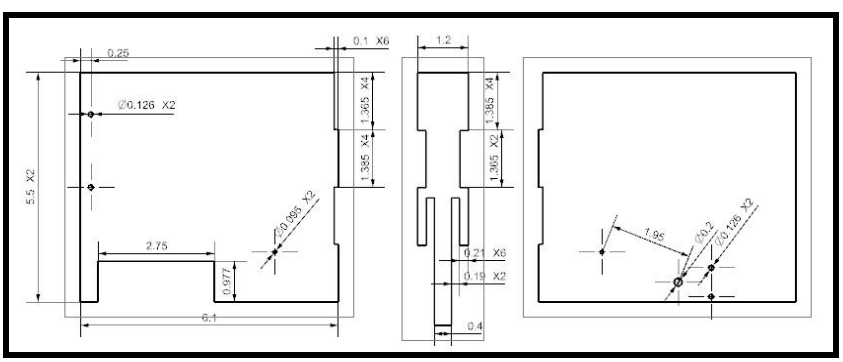


Figure 6.2.7: CAD Drawing of Dispenser Side Walls

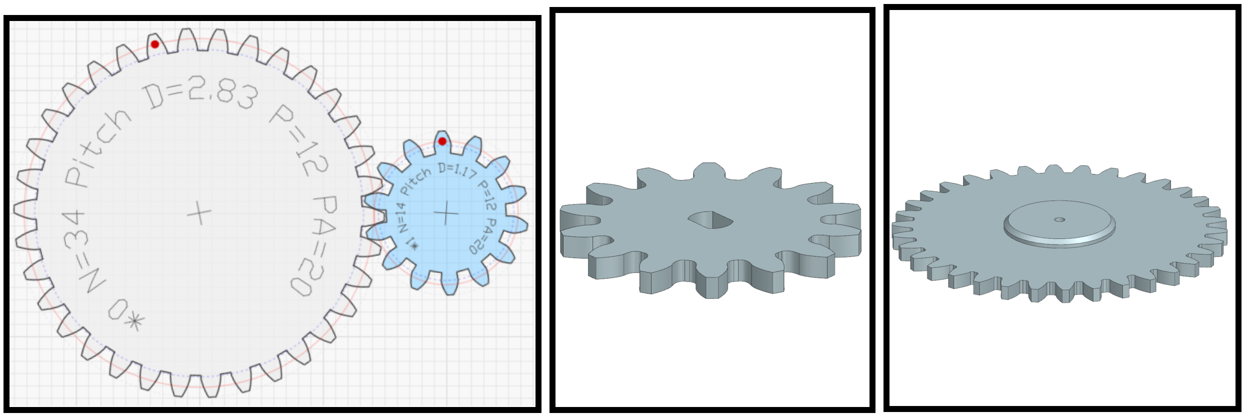
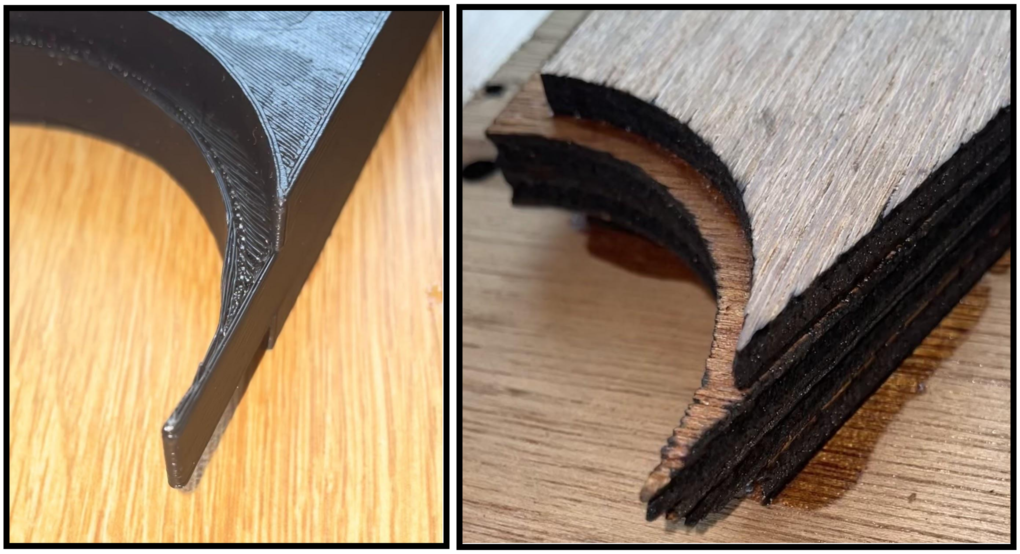


Figure 6.2.8, 6.2.9, and 6.2.10: Gear Generator Render of the Gears Meshing, and Final Gear CAD Models

Testing was done with multiple prototypes using different fabrication techniques. First, a cardboard test module was created, showcasing the functionality of the foam wheel mechanism. Tests were promising, and the wheel worked well given how crude the test module was. Production of real prototypes soon started, with multiple 3D-printed models, and moving quickly to laser cut acrylic for the module walls. Laser-cut acrylic, and laser-cut plywood, was more ideal for the side walls, as each piece was flat and could be easily glued together and held in place with the jigsaw pattern on each piece, which provided a better, tighter fit between the sidewalls and front face plate than was seen in the 3-D printed prototypes. This can be clearly seen on the CAD drawings in figure 6.2.7.

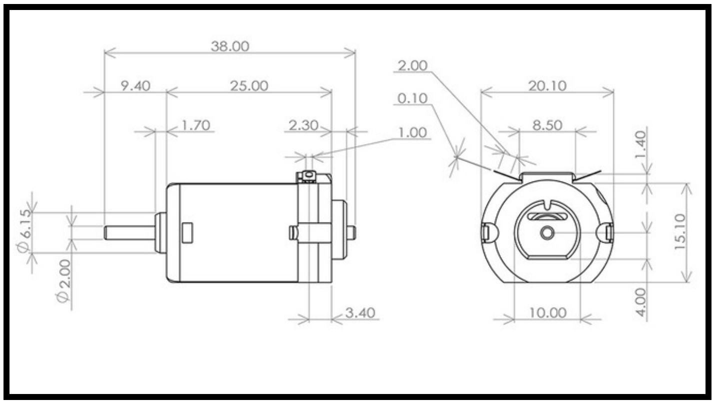
However, due to time constraints that made 3-D printing infeasible, the “core” of the dispenser module had to be switched to layered and glued laser-cut plywood sheets. This was not ideal for many reasons. The precision and tolerances of laser-cut plywood were very different from 3-D printing, and the thin slants of the core piece were initially designed for printing, and when cut out of wood, the plywood burned and became more brittle, eventually breaking (figures 6.2.12 and 6.2.13). A comparison of all module prototypes created and tested can be found in figure 6.2.11.

Figure 6.2.11: Comparison of all prototypes created for testing



Figures 6.2.12 and 6.2.13: Comparison between 3-D Printed and Laser Cut Parts

Aside from problems with manufacturing, problems quickly arose when integrating the dispenser with the rest of the subsystems. The original motors (Gikfun miniature DC motors) could provide neither the power nor the precision movement required to adequately dispense the pills, and so new motors (AEDIKO TT DC gearbox and motors) were found. The new motor features an integrated gearbox which lowered its top speed and increased its torque, better meeting specifications. However, due to the very different size and shape of the new motors (shown in the dimensional diagrams in figures 6.2.14 and 6.2.15), the redesign of the mechanism with these new motors proved timely, and set the project back greatly. Other than the motors, integration with the Arduino and break-beam sensor was flawed, and the pills being dispensed by the modules were not caught by the sensor, and so an incorrect number of pills were dispensed. In testing, pill detection by the break beam was inconsistent, catching pills less than 50% of the time, and no further testing was performed.



Figures 6.2.14: Initial Motor Dimensions

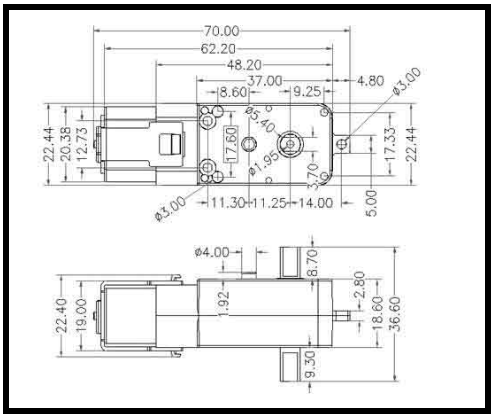


Figure 6.2.15: Final Motor Dimensions

6.3 Subsystem 3: Arduino Integration

The final dispenser unit is controlled with an Arduino Mega that interfaces with the screen to display and retrieve information about the time, alarms, and, the fingerprint sensor to retrieve user information, the speaker to sound the alarm, the motors to dispense the pills, and lastly the break beam sensors that will detect when one pill is dispensed. As seen below in figure 6.3.1, the circuit schematic shows all of the components of the APD wired together. The Mega was chosen for this project due to its high storage capacity to hold large amounts of the users' information, the relevant technical specifications are: 256kB of program memory and 8kB of dynamic memory [8].

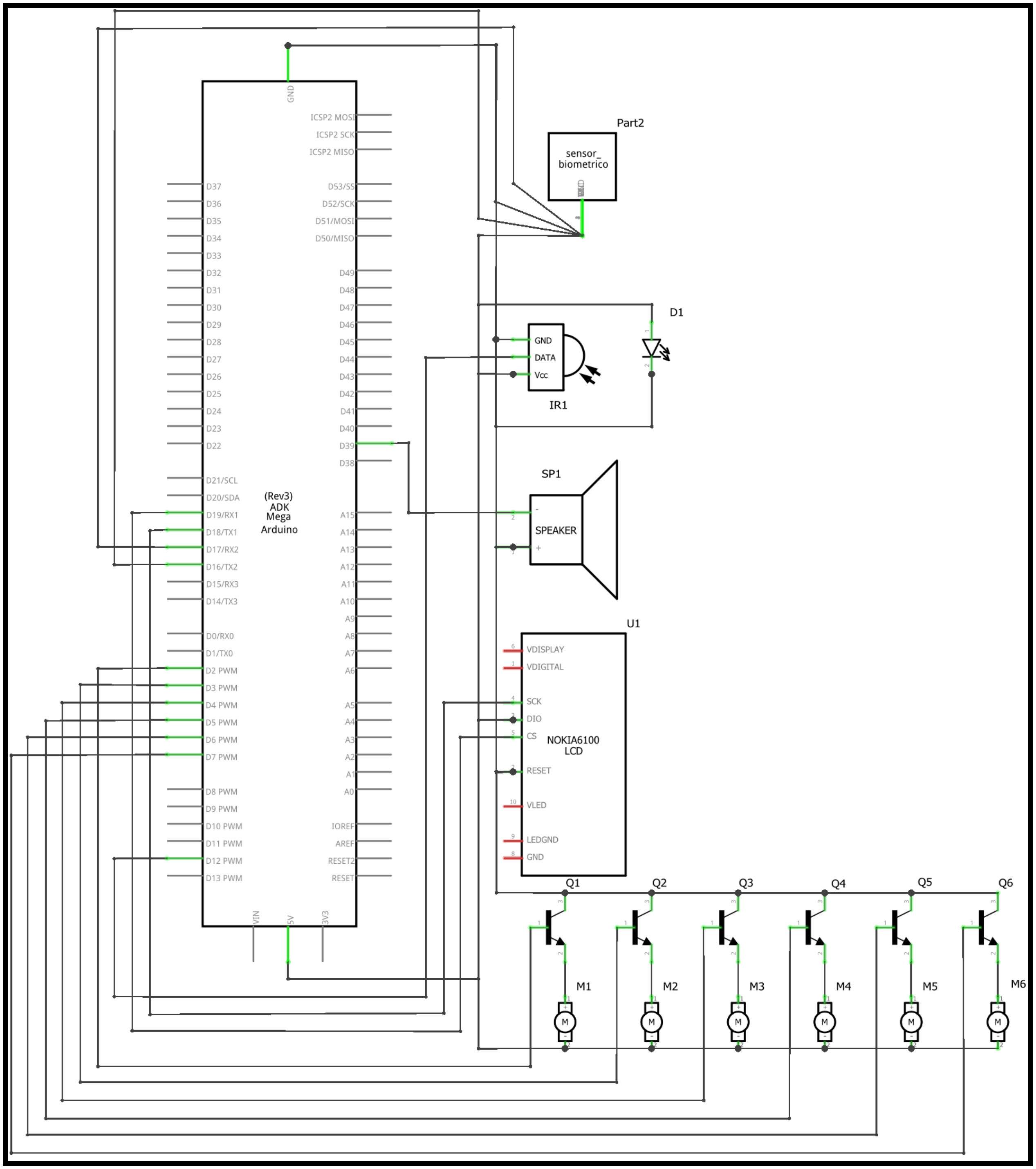


Figure 6.3.1: Schematic of APD

The APD follows two algorithms that had to be coded and programmed into the Arduino. The first algorithm is the initial setup of the APD shown in flowchart in figure 6.3.2. The user first has to input the time since the APD is not connected to the internet and cannot update the time on its own. Next, the user has to input a name and register a fingerprint to their profile. The name and fingerprint id that is returned from the fingerprint sensor is stored in the user's profile object. The maximum number of profiles that can be created is 10 profiles (i.e. 10 names and 10 fingerprints). After the fingerprint has been registered, the user now has to enter the number of pills for each dispenser and the dispenser name. Likewise, the name and the number of pills are also stored in their respective dispenser objects. The next step is to set any alarms for the selected dispenser. Each alarm has the hour and minute and days of the week that the alarm will ring on. Each profile can have 10 alarms associated with it. This means that the Arduino can store a total of 100 alarms.

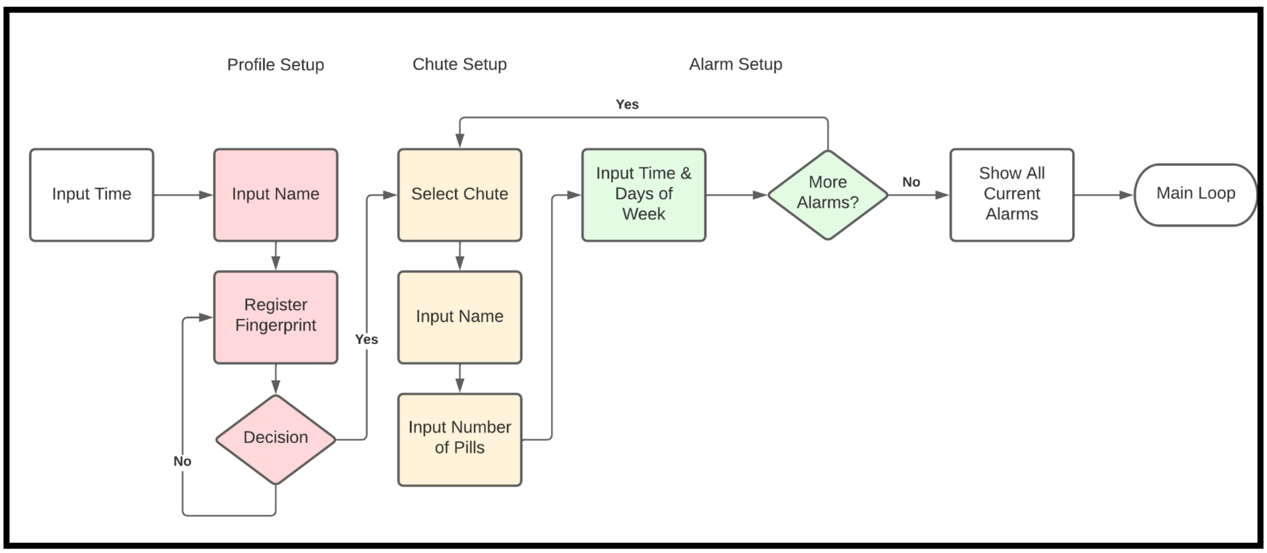


Figure 6.3.2: Flowchart for the Setup of the APD

After the initial setup, the APD goes into the second algorithm, the main loop (as seen in the flowchart in figure 6.3.3. In the main loop, the touch screen will send the current time every minute to the Arduino in order to keep the two synced. After the Arduino receives one of these updates, the Arduino will check to see if any of the alarms are at the current time. If an alarm needs to be rung, the Arduino will send signals to the touchscreen to display the relevant screen, signals to the speaker to play sounds, and signals to the fingerprint to wait for a finger of the user of the specific alarm. Once the fingerprint has been verified to be the user, the Arduino sends signals to the motor of the specific pill to start dispensing a pill. Once the pill breaks the IR beam below the dispensing units, it will send a signal to the Arduino and the Arduino will stop turning the motor.

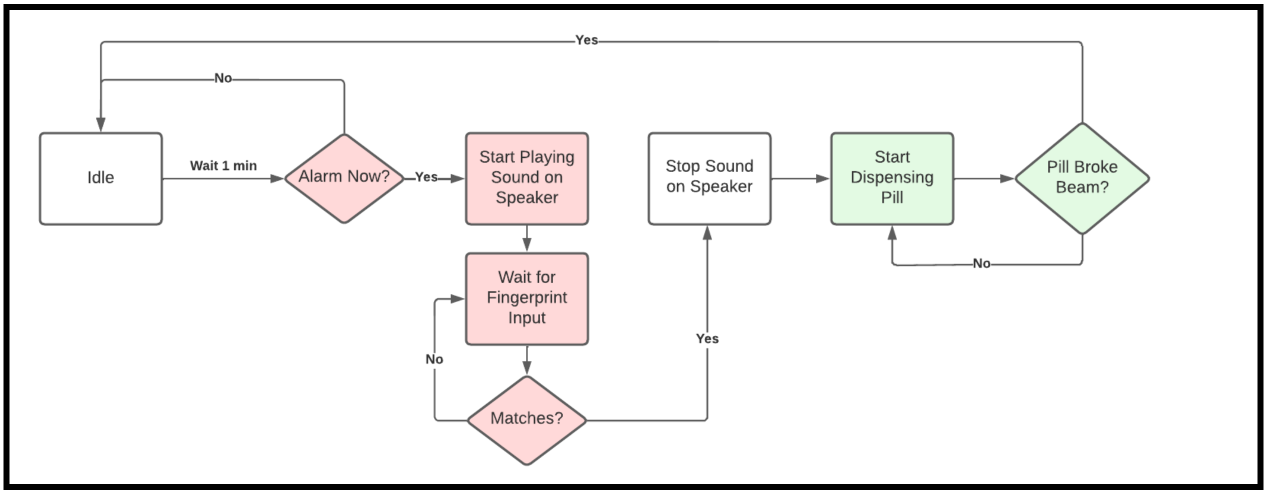


Figure 6.3.3: Flowchart for the Main Loop of the APD

The microcontroller used at the start of the project was an Arduino Nano which has a 30kB of program memory, and 2kB of dynamic memory [9]. It was thought that this amount of memory would be able to store all 100 alarms at the start of the project but as the project progressed, the group came to the conclusion that a Nano was not sufficient enough.

During the beginning of the project, the Nano was enough to start testing the interaction between the touchscreen display, fingerprint scanner, and the Nano itself. However, a problem arose as the program grew larger and the amount of memory became more limited, bugs started to appear that corrupted profile and alarm data (figure 6.3.4). As more alarms were added, more memory was overwritten and the Nano became more inconsistent with its behavior. In order to alleviate the memory issue, another Nano was used specifically for controlling the fingerprint sensor and motors. A UART communication protocol was then developed for communicating between the two Nanos: whenever a user was prompted to use the fingerprint sensor, the master Nano would send a commands to the slave Nano to activate the fingerprint sensor and it would send any information back after the fingerprint sensor was done. This new configuration can be seen in figure 6.3.5.

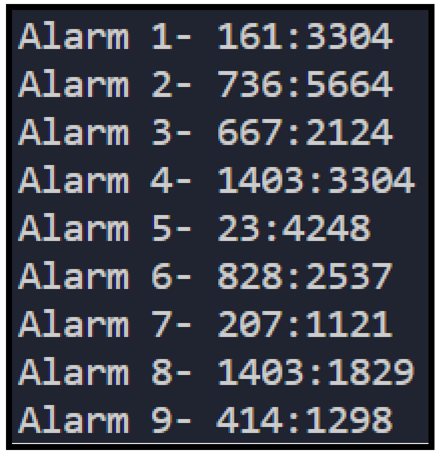


Figure 6.3.4: Nine Alarms With Corruptions

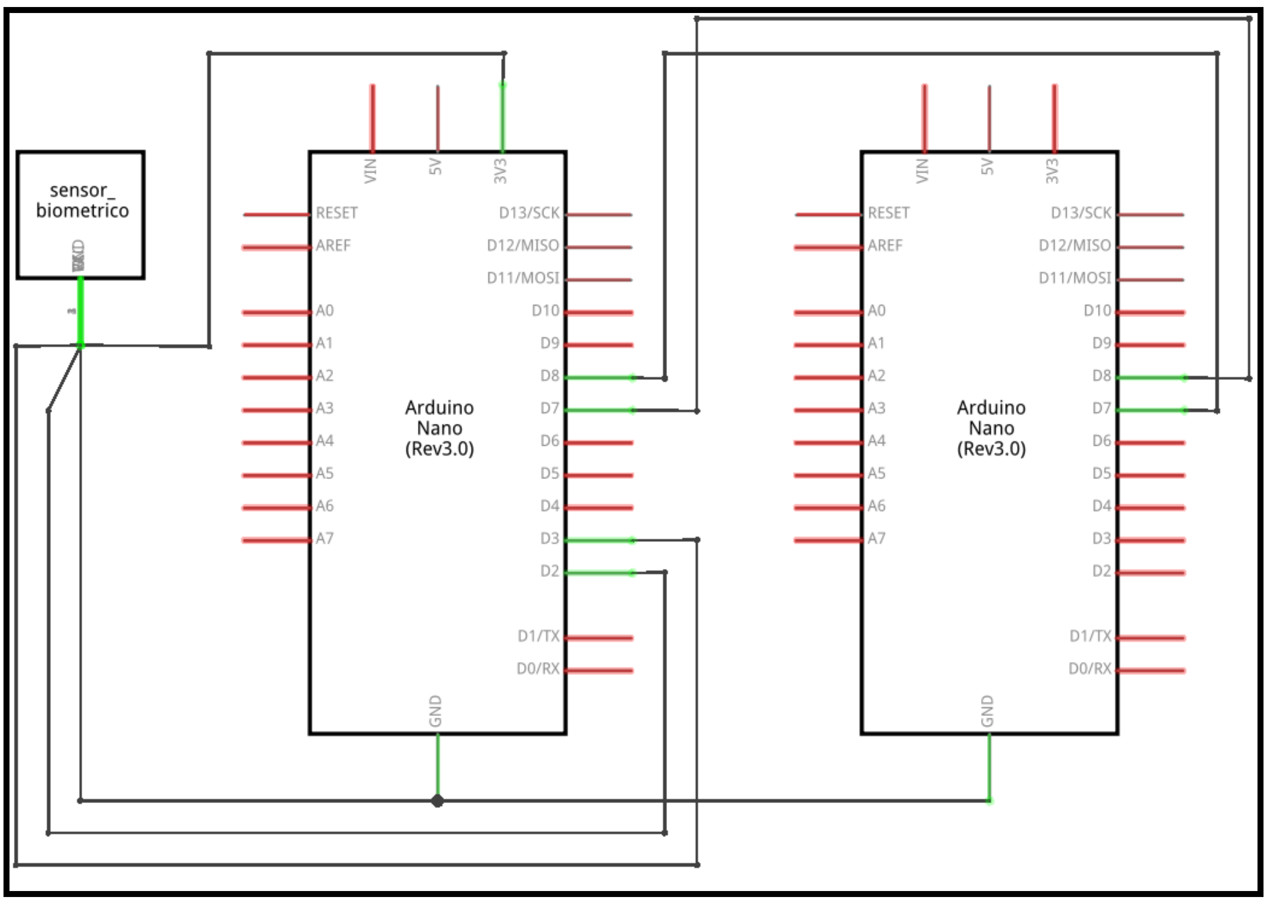


Figure 6.3.5: Schematic of the Two Nano Configuration

The double Nano solution worked for the MS2 presentation for demonstrations on subsystems, but the system still was not able to store all 100 alarms in the master Nano still due to memory constraints. The last solution was to upgrade to an Arduino Mega that has 8 times the program memory and 4 times the dynamic memory.

Upgrading to the Mega and initializing 10 profiles with 10 alarms each (as seen in figure 6.3.6) showed that there were no problems with memory management: no bugs appeared after setting all alarms.

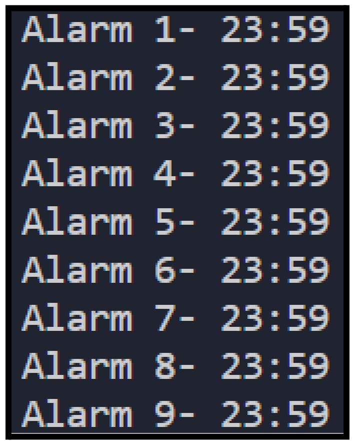


Figure 6.3.6: Nine Alarms With No Corruptions

6.4 Subsystem 4: User Interface

For easy interaction between the user and the dispenser, making a system that connects those was an inevitable sequence. Using the software, Arduino, creating a touchscreen-based user interface was the best fit for the goal.

The user interface is built up based on two loops of flowcharts: the initial setup loop and the main loop. In the initial setup loop, time setting, name input, and fingerprint registration are performed with scheduling. In the main loop started with the Idle page (Figure 6.4.1), a customer can create a new profile including name input and fingerprint registration which follows the initial setup loop and access to the existing profile. If a customer successfully accesses the existing profile through the security system, the customer can edit schedules and profile information. Every input is performed through inner keyboard touchscreens.

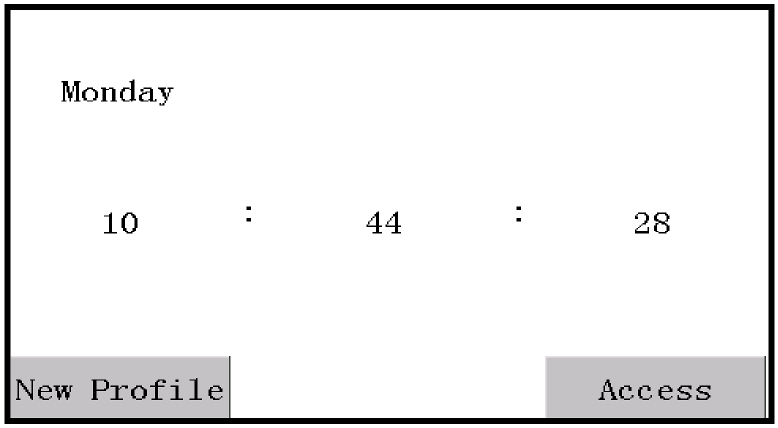


Figure 6.4.1: Idle page

Because main targets are baby boomers and X generation who are suffering from poor eyesight due to aging issues, large icons with large text are used. Also, because those generations are not familiar with electronic devices, intuitive and simple design with minimizing user inputs is pursued.

At the beginning stage of design, the initial setup loop was divided into two sections: profile input and schedule input. This division of steps made awkwardness in coding and form of design. Moreover, it could bring confusion if the user was not familiar with electric devices. Therefore, those steps were compressed to one linear step. (Figure 6.4.2)

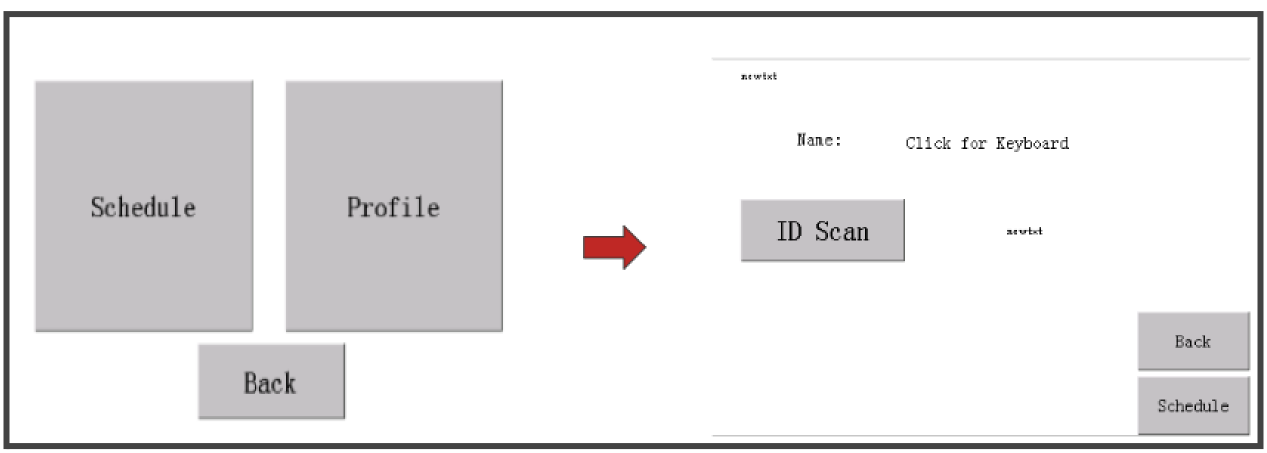


Figure 6.4.2: initial step before and after

In the first prototype of the main loop, a customer needed to select a personal profile in the profile lists and verify it through fingerprint scanner. Although large icons with large text were pursued, a small touchscreen compared to ideal one has been used. Due to this limitation, target customers who are baby boomers and X generations could feel inconvenience of reading profiles in the selection step. At first, using larger text with implementation of scroll was suggested. It was a comfortable solution for designers, but it forced users to motion one more - scrolling down. Through several considerations, collaboration with the security system was decided. The solution was deleting the profile selection stage and making the verification system automatically directing users to their profiles. (Figure 6.4.3)

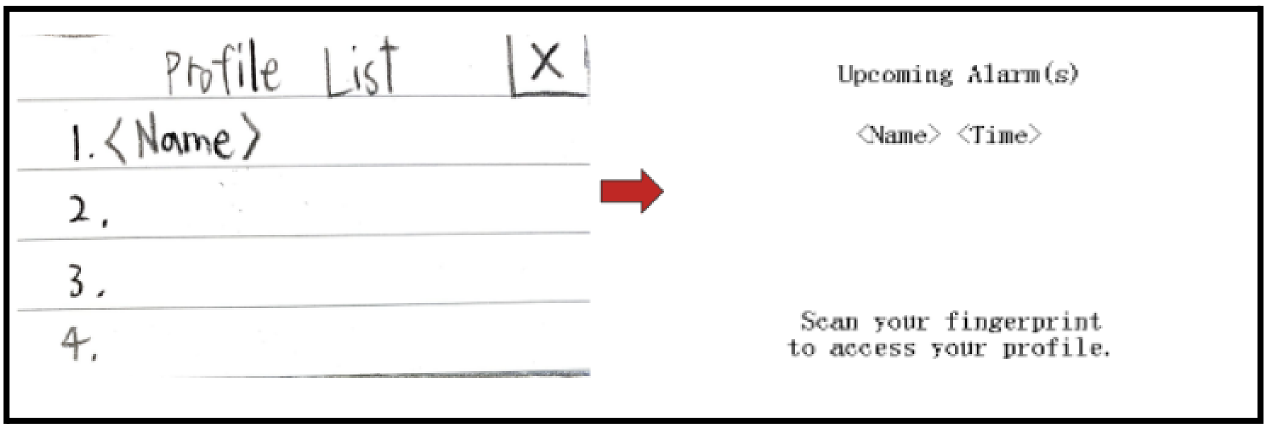


Figure 6.4.3: profile list before and after

In the final stage, time input and default input sentence were added. Because every test was done under internet connection, time setting automatically followed local time. This situation could not happen because the final prototype would not be connected to the internet or Wifi. Therefore, an inner time input setting was made. (Figure 6.4.4) Because the default setting was empty space, a customer could not know exactly where to touch to input by keyboard. Input of default sentences solved the problem by directing the customer where to touch. (Figure 6.4.5)

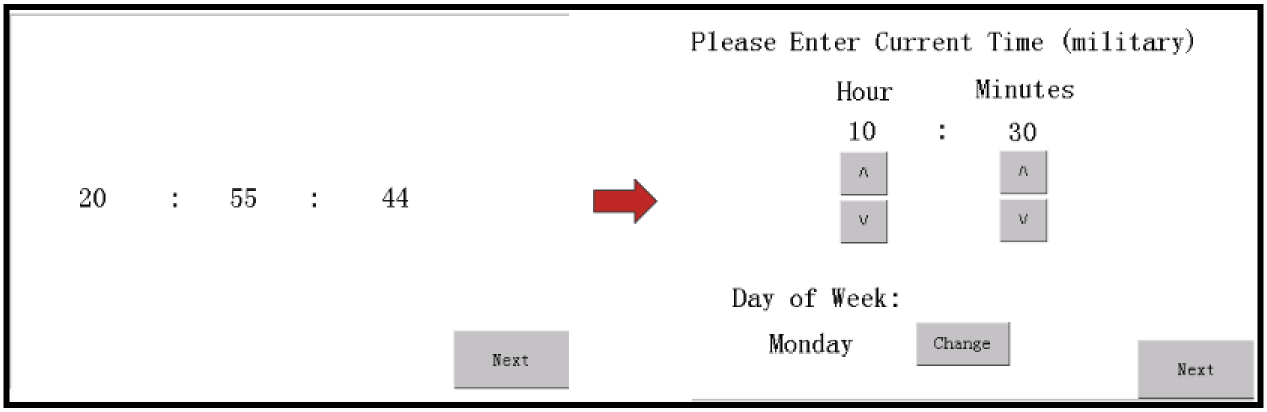


Figure 6.4.4: time setting before and after

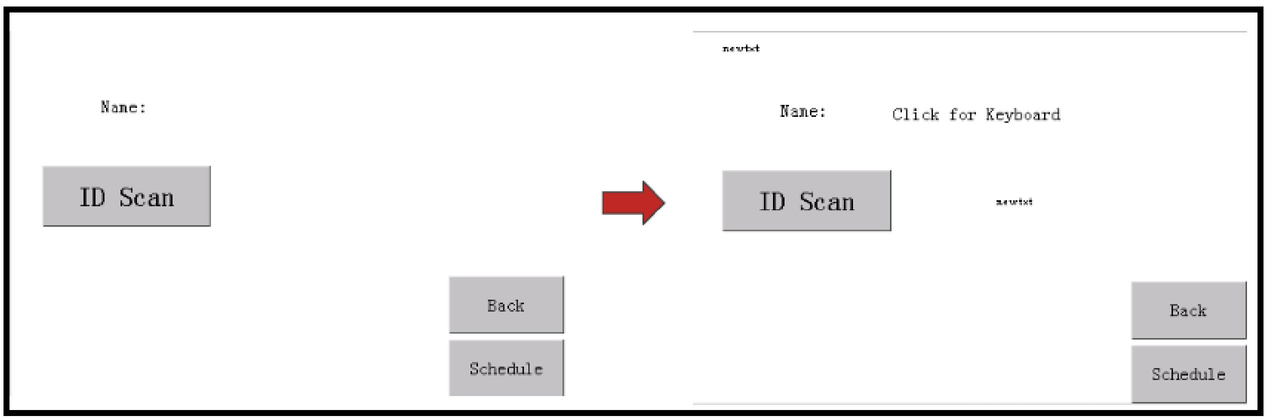


Figure 6.4.5: default view before and after

6.5 Subsystem 5: Alarm

The alarm is interfaced through the touch screen display. Its main function is to alert users when the preset alarms are triggered. It does this through startup config and settings of the pill dispenser. The device is able to set alarms for up to 10 users, and each profile has the ability to save 10 alarms. The basic circuitry for the alarm can be seen below (Figure 6.5.1) with the Arduino Mega R3, the 3W speaker, and a TFT touchscreen display.

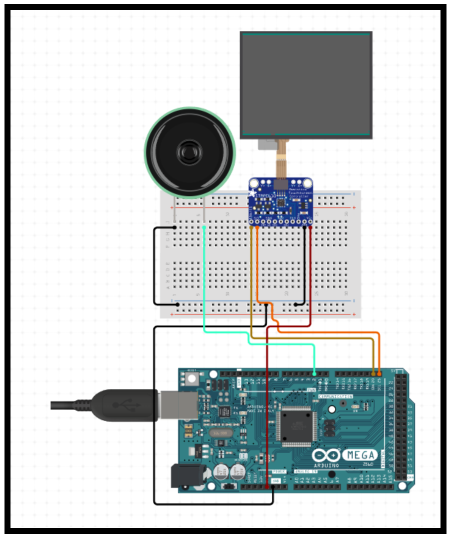


Figure 6.5.1: Alarm Circuitry

First at the startup of the system, it prompts the user to input the current time of day as well as the day of week. This display is shown by Figure 6.5.2. This gives the dispenser input about the current time, so that it may alarm at the correct time. After calibrating the dispenser for the current time, the built-in clock will correctly keep the time. As long as the pill dispenser is plugged in, the clock will only have an error of one minute after around four months of usage. This is determined to be adequate, as the such little time difference over long periods will have negligible effect on the function of the alarm system. After four years of use, the clock will only deviate twelve minutes from the current time. This is virtually non-effectual towards taking the medicine at the correct time, as it is generally advised that doses can be taken after two hours from the prescribed time (Owen, 2021).

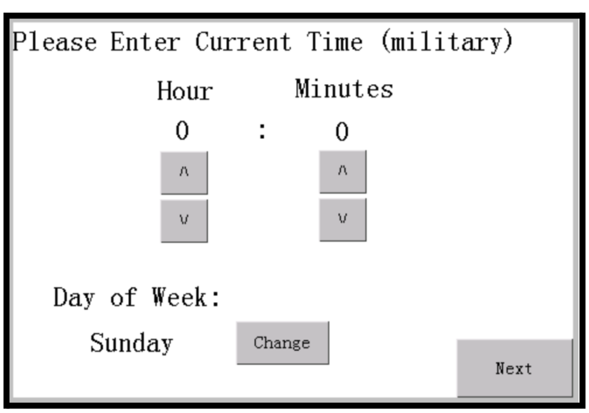


Figure 6.5.2: User Time Config

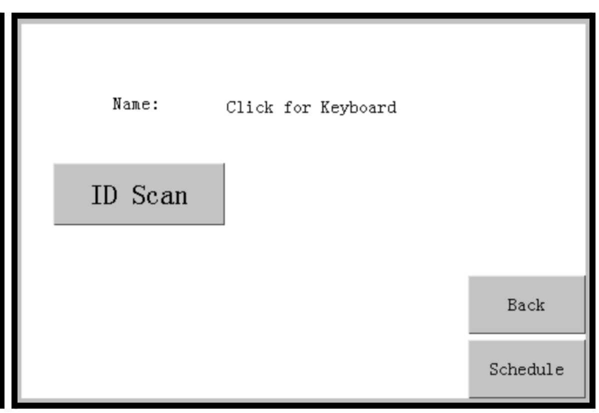


Figure 6.5.3: Profile Config

After inputting the user's name and fingerprint through the security system on the Profile Config page (Figure 6.5.3), they will encounter the storage unit page as seen in Figure 6.5.4. The user can touch click any of the storage buttons to configure the storage. This can be seen in Figure 6.5.5. On this page, the user inputs the medicine name as well as the amount of medicine they put into the storage unit. This way makes it so that users can make alarms for each storage unit. Different medicines can have different alarms.

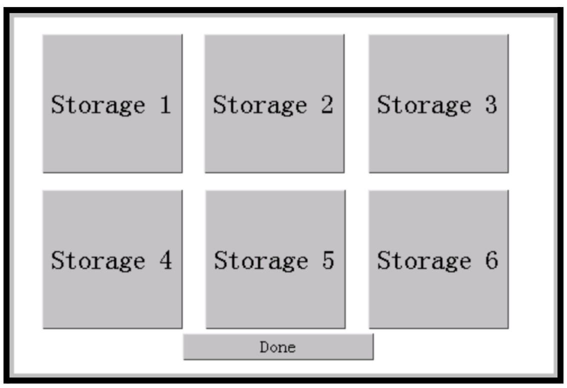


Figure 6.5.4: Storage Page

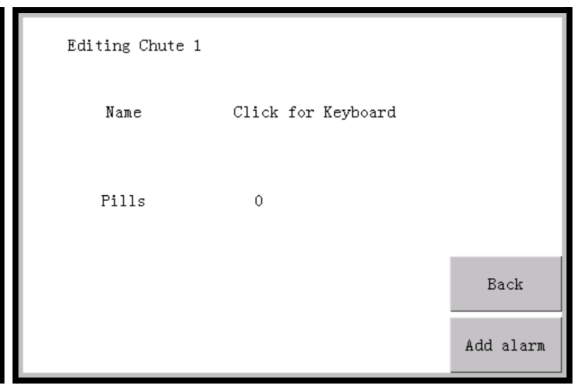


Figure 6.5.5: Storage Config

After configuring the storage units, users can click the "Add Alarm" button on the bottom right corner of the page seen in Figure 6.5.5. This proceeds to the page seen in Figure 6.5.6. This is the alarm setup page, where the user can input the time as well as the days of the week that this alarm should ring. The user can either click the up and down arrow touchscreen buttons, or click on the hour and minute number digits to bring up a number pad touchscreen keyboard. These two methods are used to input the time. The up and down arrows buttons are used for small adjustments to the time, while the number pad keyboard is used for fast input to the time. The hour is limited to numbers 0 through 23 and the minutes are limited to numbers 0 through 59. If the user inputs numbers above or below the limited values, the dispenser automatically corrects the number to either the upper or lower bound of the limits. This ensures that the user inputs valid values and is easily understandable.

After this alarm is fully configured, the user can click either the "New Time" button to add more alarms, or the "Finished" button to finish configuring alarms. The "New Time" button will lead the user back to a refreshed page shown in figure 6.5.6, where all the values are set back to initial. Adding values to this page will add more alarms for the storage unit selected at first. Otherwise, if the "Finished" button is clicked, then the profile alarm setup is finished and the dispenser's display is taken to the idle screen shown in figure 6.5.7.

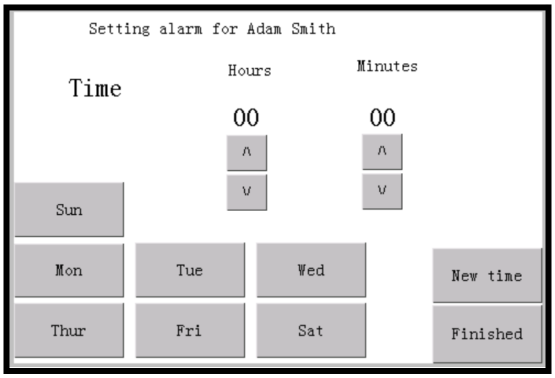


Figure 6.5.6: Alarm Configure Page

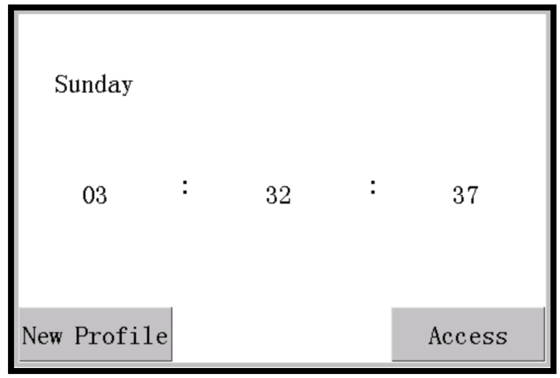


Figure 6.5.7: Idle Page

The idle page will be shown while the dispenser is not in use and if none of the alarms are triggered. It will display the time and the day of the week. The "New Profile" button on the bottom left corner of the Idle Page (Figure 6.5.7) will direct the user to set up a new profile and go through the alarm setup process again. The "Access" button on the bottom right corner of Idle Page (Figure 6.5.7) will direct users to the Profile Verification Page (Figure 6.5.8) allowing users to access their profile through their fingerprint. After access is granted, they are taken to the Edit Profile Page (Figure 6.5.9). Clicking the "Reschedule" button on the Edit Profile Page (Figure 6.5.9) will direct users to the Storage Page (Figure 6.5.4) and allow the users to edit the Alarms. Clicking the "Edit Profile" Button on the Edit Profile Page (Figure 6.5.9) will take users to the Profile Config page (Figure 6.5.3), where users can edit their name or fingerprint. Clicking the "Exit" Button on the Edit Profile Page (Figure 6.5.9) will take the user back to the Idle Page (Figure 6.5.8).

Figure 6.5.8: Profile Verification Page

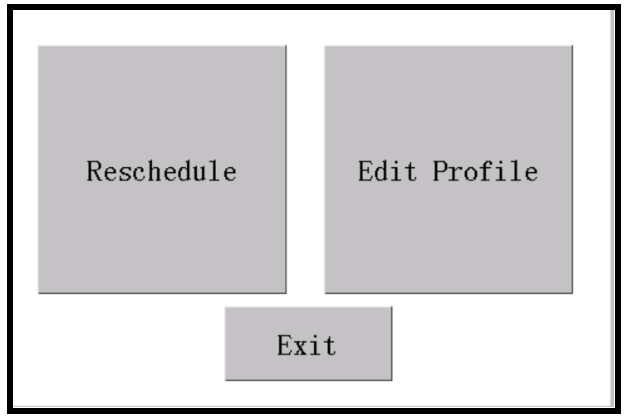


Figure 6.5.9: Edit Profile Page

When an alarm is triggered, the display transitions from the Idle Page (Figure 6.5.8) to the Confirm User Page (Figure 6.5.10). The dispenser will play a repeated buzzing sound at 567Hz with a decibel level of 73. This sound is at the middle of the human hearing range, so most people will have no trouble detecting it. The buzz sound is used because it is a conventional alarm sound, so people from most cultures will be able to recognize the sound as an alarm. The sound level of 73 decibels does not exceed 85 decibels, so it does not harm hearing. However, the sound is not so low that people cannot hear it. Once the user passes the security system, the system will transition back to the Idle Page (Figure 6.5.7).

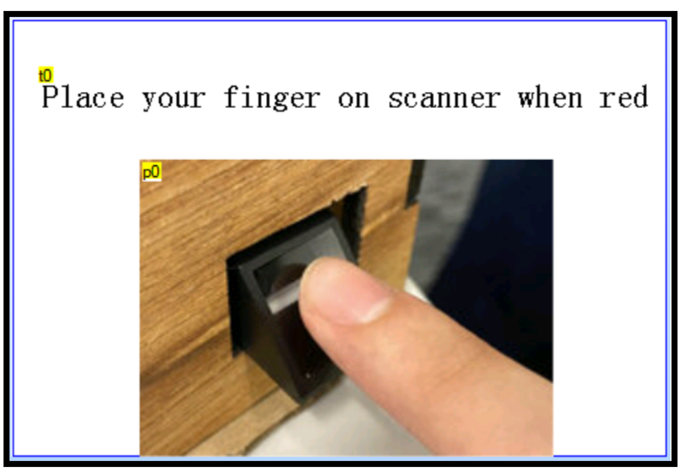


Figure 6.5.10: Confirm User Page

6.6 Subsystem 6: Security System

Table 6.6.1 : Security Concept Selection Matrix

	Concepts		
Selection Criteria	PIN	Facial Recognition	Fingerprint Scanner
Cost	1	-1	0
Difficulty of Implementation	1	-1	0
Efficiency	1	0	1
User-friendly	0	1	-1
Consistency	1	1	0
Accuracy	-1	-1	1
Safety	-1	0	1
Net Score	1	-1	3
Rank	2	3	1
Continue?	N	N	Y

The security system started out with several design concepts consisting of personal identification numbers, fingerprint scanners, and facial recognition. After some consideration, the fingerprint scanner was the most advantageous as shown by the concept selection matrix(table 6.6.1). The fingerprint scanner offers a fast, secure way to verify a person's identity that is more robust than other methods shown above.

The security system consists primarily of a fingerprint scanner that is being controlled by Arduino Mega. This model of the scanner was chosen instead of its competitors due to several advantages it has. The appeal of this model was its innate flash memory and the high refresh rate. The innate flash memory helped instead of storing the fingerprint image onto the Arduino, which would consume a significant portion of memory and would interfere with other subsystems. In addition, the high refresh rate on the fingerprint scanner allows for rapid response times from the finger touching the scanner to retrieving an image of said finger.

The technical specifications initially were quite simple and only focused on speed and capacity, however, upon consideration, accuracy was also added. The most significant specification was accuracy since it ties with the safety of the system. Since if an incorrect fingerprint was successful, it would lead to the consumption of a wrong prescription if the end-user wasn't the intended target.

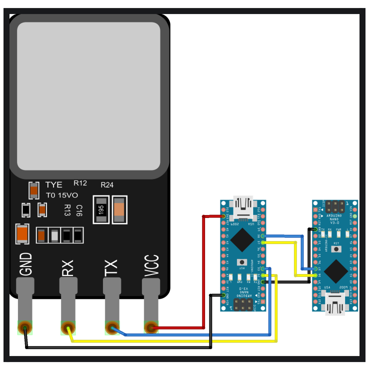


Figure 6.6.2: Dual Arduino Setup

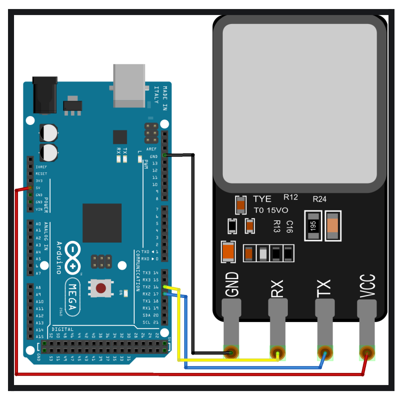


Figure 6.6.3: Arduino Mega Setup

```
.
.
Fingerprint Detected
.
.
Fingerprint error, please try again
.
.
.
.
Fingerprint Detected
Successful fingerprint with a confidence level of 241
```

Figure 6.6.4: Debugging

Testing was performed when the fingerprint scanner was not integrated with the other subsystems. In this isolated testing environment, the scanner was successful and did its function properly, however, it was discovered that for a fingerprint to match the database, it had to be in the same position as when the fingerprint was used to create the profile. As shown by Figure 6.6.4, there is a confidence level associated with each fingerprint scan. The confidence level can range between 0 and 400, in which 0 being that the fingerprint is completely wrong and 400 being exact. The software is programmed such that it would allow for a 85% tolerance, which means that if the fingerprint is around 85% correct, it would be a successful input. This is to allow some leniency and improve the quality of life of the end-user.

Problems arose when integrating it with other subsystems. With the original Arduino nano setup, it was unable to handle all the functionality, therefore a solution was devised by offloading the fingerprint functionality to another Arduino nano as seen in figure 6.6.2. With this solution, the original problems were solved, however, new problems arose in its place. To remedy these new problems, an Arduino mega replaced the dual Arduino nano setup as shown in figure 6.6.3. This new Arduino corrected all of the previous issues and allowed for more storage for fingerprints.

Within the initial setup of the system, the fingerprint scanner serves one purpose which is to initialize a profile in order to continue with the setup of the chutes and alarms. The fingerprint scanner would constantly be active until a proper fingerprint has been stored within the memory displayed on figure 6.6.6.

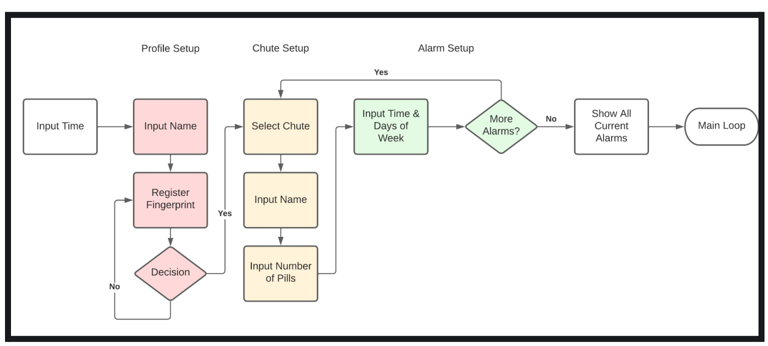


Figure 6.6.6: Setup Flowchart

After the setup, the fingerprint scanner is responsible for the proper dispensing of the prescription. The fingerprint scanner activates when the alarm is being played which would prompt the end-user to input a finger as shown in figure 6.6.7. If the fingerprint matches the fingerprint used to set up the end-users profile, the system would start dispensing the pills.

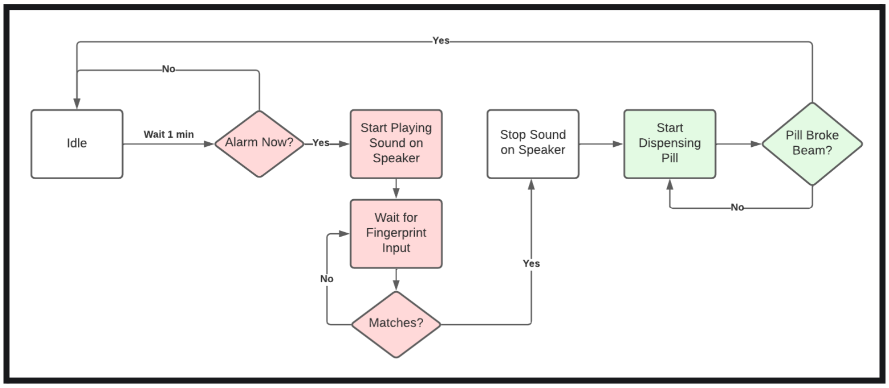


Figure 6.6.7: Main Flowchart

7 Results and Discussion

7.1 Results

The design prototype presented for the MS2 project demo was unfinished in many respects. Some of the major problems were that only two dispensers were made and mounted onto the housing unit, the roof of the housing unit was shown to be too weak, and the dual Arduino setup required two external power sources which looked very cumbersome, and the alarm was not fully debugged. Each of these issues were minor on their own, but combined made the APD a shell of what it could have been. Overall, the demonstration was still a success as even though there were only two dispensers, it showed that the foam wheel design was successful in that it could dispense one pill at a time, even if the pills are different shapes. The demonstration showed that conceptually, the APD was a successful prototype. The touchscreen user interface and fingerprint scanner were successful and apart from the roof, the housing unit was strong. The alarm had minor bugs but still worked when demonstrated. These results showed that the APD has solid conceptual proof and could go further with more time.

The final design after the MS2 demo was the result of this. The mega Arduino was tested and shown to be successful, the roof was remodeled to be stronger, and more debugging was done to make the software run smoothly. This made the APD become what it was designed to do and allowed it to work.

7.2 Significant Accomplishments

The team members could develop skills with many different software and hardware tools such as Arduino tools, touchscreen, fingerprint scanner, and 3D printer. The team members could learn technical writing, presentation skills, time management, planning, and team collaboration with Johari Window and Kilmann Conflict Styles valuable not only in the field of engineering but also in societal activities. Because the project forced teams to develop a product that contained an automatic mechanism and plausibility of public, societal, and environmental contribution, the team members also learned about the mindset of engineers in product development.

Collaboration of people in different engineering majors which could happen in the future workplace was a good experience for one aiming to be an engineer. The field of computer science and field CAD modeling collaborate frequently for product development in the current industry. Conceiving as a prior learning, the team members could go one step toward good engineers.

8 Conclusions

In conclusion, the Automatic Pill Dispenser helps those who struggle to remember to take their medication. This helps them lead a healthier life and in general make society safer. The main advantage of the APD is the affordable price it has over competitors while still keeping modern features such as a touchscreen and fingerprint scanners.

The development of the APD was done through a variety of methods, ranging from concept selection matrices to ranking customer needs to choose which features should be prioritized. Since reliability was the most prioritized metric of the APD, the slow and precise dispenser combined with the break-beam sensors allowed for minimal error in terms of the correct amount of pills being dispensed.

When manufacturing the APD, parts were made on site using laser cutters or 3D printers, while electronics were ordered online to reduce manufacturing error. Prototypes of some subsystems, such as the dispenser, were much earlier than others since those were key to making others. These prototypes gave information that allowed for other subsystems, such as the housing unit, to begin being worked on.

The testing has shown that while some parts were successful, others were not. This meant that they had to be remodeled in order for the APD to work. Testing was very important as it revealed flaws that may have snuck into the final design.

Throughout all of the phases of design, the team learned valuable lessons including time management and how to work as a team. This has shown how difficult it can be to manufacture a prototype of a complex project and some of the issues that may occur when doing so. Some of these issues led to increased costs from realizing that initial designs did not work and new components had to be bought. In the end, all target specifications were met from the final design. Being able to hold at least 20 or 6 different types of pills, an integrated user interface with Arduinos, and an alarm, all in a compact unit. This design was the product of weeks of development, manufacturing, and testing to make the product in time.

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10 Appendices

10.1 Appendix A: Selection of Team Project

Table 10.1.1: Selection Matrix

Scores are -1, 0, 1	Concepts				
	Automatic Pill Dispenser	Guide Robot	Face tracking rig	Automatic ping pong launcher	Solar cooker
Affordable	0	-1	-1	-1	1
Practicality	1	0	-1	0	-1
Feasibility	0	-1	0	1	0
Difficulty	0	-1	-1	0	0
Net Score	1	-3	-3	0	0
Continued	Yes	No	No	No	No

Within the selection matrix, the Automatic Pill Dispenser was chosen since the group was able to discover corresponding subsystems that each member of the team can fulfill. Also, upon us in-depth benchmarking research, there were already existing products however there was a way to improve upon the existing products. To that end, the group has decided to choose the Automatic Pill Dispenser for the team project.

10.2 Appendix B: Customer Requirements and Technical Specifications

In gathering data to create customer requirements, two people were primarily interviewed, Julianne Heckert and Myra Endler. Heckert, the mother of group member Henry

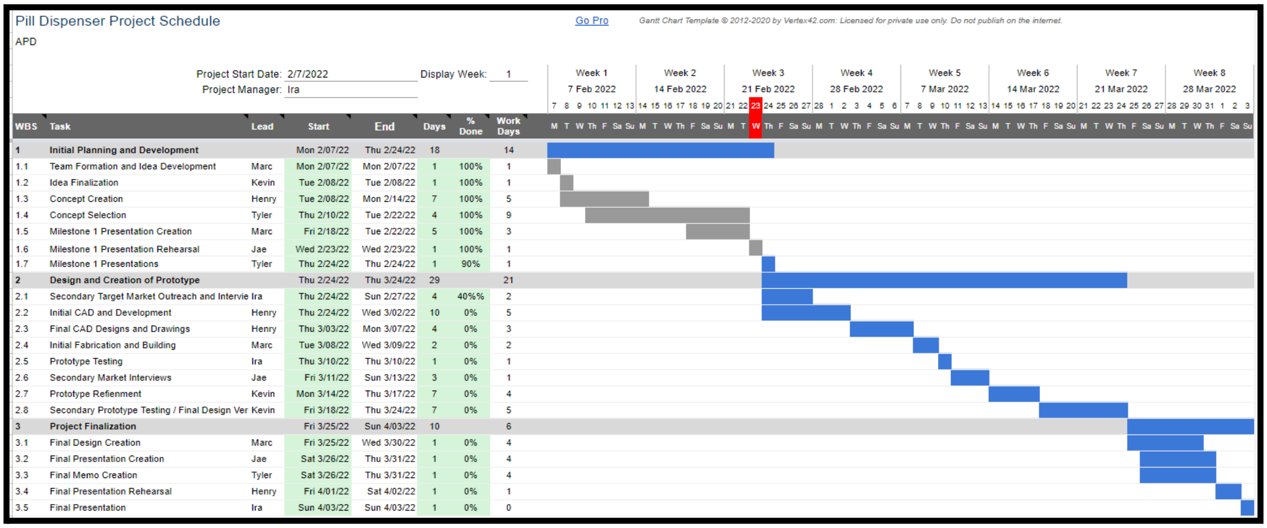
Heckert, both takes medication for chronic conditions, and takes care of Endler, who has significant difficulty taking medication. Heckert gave invaluable data, allowing us to create our requirements. In speaking to her, two things were stressed above all others: safety and ease of use. Heckert said that if she were to purchase such a product, she would need to know that it would operate without fail, and that it would be simple to use, for her and for Endler. Safety is an obvious priority, as preserving the health of those using the product is paramount dispensing an incorrect pill, or the incorrect number of pills, could potentially be deadly. As the product is to be designed for the elderly, who take medication at the highest proportion, ease of use is critical, not only for the comfort of the end-user but to minimize the chance of the user misusing the product.

In gathering information, Heckert also stressed the importance that the product should store a large amount of different types of pills, saying that in her opinion five or more different types of pills would be enough to justify her purchasing the product. After speaking with Heckert and Endler, table 10.2.1 was created, detailing the customer requirements and corresponding technical specifications.

Table 10.2.1: Customer Requirements and Technical Specifications

Customer Requirements and Benchmarking		
Customer Requirements	Technical Specifications	Target Value / Range
Must take multiple Pills	Number of Slots For Pills	<=6
Must be easy to use	Minimal Interaction	1 user input
Must be small	Dimensions	24”x36”x36”
Must be lightweight	Weight	<20 lbs
Must Dispense right pill	Failure rate	>1000 pills
Must be Safe	Injury rate	0%

10.3 Appendix C: Gantt Chart



WBS	Task	Lead	Start	End	Days	% Done	Work Days
1	**Initial Planning and Development**		Mon 2/07/22	Thu 2/24/22	18		14
1.1	Team Formation and Idea Development	Marc	Mon 2/07/22	Mon 2/07/22	1	100%	1
1.2	Idea Finalization	Kevin	Tue 2/08/22	Tue 2/08/22	1	100%	1
1.3	Concept Creation	Henry	Tue 2/08/22	Mon 2/14/22	7	100%	5
1.4	Concept Selection	Tyler	Thu 2/10/22	Tue 2/22/22	4	100%	9
1.5	Milestone 1 Presentation Creation	Marc	Fri 2/18/22	Tue 2/22/22	5	100%	3
1.6	Milestone 1 Presentation Rehearsal	Jae	Wed 2/23/22	Wed 2/23/22	1	100%	1
1.7	Milestone 1 Presentations	Tyler	Thu 2/24/22	Thu 2/24/22	1	90%	1
2	**Design and Creation of Prototype**		Thu 2/24/22	Thu 3/24/22	29		21
2.1	Secondary Target Market Outreach and Intervie	Ira	Thu 2/24/22	Sun 2/27/22	4	40%%	2
2.2	Initial CAD and Development	Henry	Thu 2/24/22	Wed 3/02/22	10	0%	5
2.3	Final CAD Designs and Drawings	Henry	Thu 3/03/22	Mon 3/07/22	4	0%	3
2.4	Initial Fabrication and Building	Marc	Tue 3/08/22	Wed 3/09/22	2	0%	2
2.5	Prototype Testing	Ira	Thu 3/10/22	Thu 3/10/22	1	0%	1
2.6	Secondary Market Interviews	Jae	Fri 3/11/22	Sun 3/13/22	3	0%	1
2.7	Prototype Refienment	Kevin	Mon 3/14/22	Thu 3/17/22	7	0%	4
2.8	Secondary Prototype Testing / Final Design Ver	Kevin	Fri 3/18/22	Thu 3/24/22	7	0%	5
3	**Project Finalization**		Fri 3/25/22	Sun 4/03/22	10		6
3.1	Final Design Creation	Marc	Fri 3/25/22	Wed 3/30/22	1	0%	4
3.2	Final Presentation Creation	Jae	Sat 3/26/22	Thu 3/31/22	1	0%	4
3.3	Final Memo Creation	Tyler	Sat 3/26/22	Thu 3/31/22	1	0%	4
3.4	Final Presentation Rehearsal	Henry	Fri 4/01/22	Sat 4/02/22	1	0%	1
3.5	Final Presentation	Ira	Sun 4/03/22	Sun 4/03/22	1	0%	0

Figure 10.3.1: Image Linked to Gantt Chart Excel Sheet

10.4 Appendix D: Expense Report

The manufacturing costs of the APD can be broken down into two subsets: the electrical/software and the mechanical side shown in Table 10.4.1. A significant portion of the cost came from electrical components to ensure that the APD follows the customer requirement for safety. If cheaper components were used, then the safety of the end-user could be put at risk. For example: if an Arduino Nano over an Arduino Mega, the user's alarms could be saved incorrectly and the APD would dispense at the wrong time.

Table 10.4.2 breaks down the cost of the APD into individual components. Expenses could have been reduced through the use of bulk sellers and the use of lower-quality materials. The cost of the printer filament, sensors, and motors would have been significantly reduced if purchased in bulk. For example, all components were bought from retail sellers however, if purchased from wholesalers, components such as the fingerprint scanner. The price from the wholesaler would be $7.08 per unit, which is a price reduction of 60%. Similar price reductions can be applied to other components within this project. An escalation of manufacturing procedures to injection molding for the housing and dispensing units would help to minimize the cost from buying materials for 3D printing and laser cutting.

Table 10.4.1: Expenses Broken Down by Subsets

Subset	**Cost of Subset**
Electrical/Software	$131.75
Mechanical	$67.25

Table 10.4.2: Expenses Broken Down into Individual Components

Need/Function	**Part Type**	**Part Name**	**Price**	**Price/Unit**	**Retailer**
Dispensing Singular Pills	Compliant Foam Wheel	Foam	$15	$2.30	Amazon
Housing Unit	Enclosure	Printer filament	$25	$10	Amazon
Housing Unit	Enclosure	Tempered Hardwood	$7	$45	Home Depot
Housing Unit	Enclosure	Acrylic	$40	$5.20	Home Depot
Turning the Wheel	Motor	6V DC Motor	$13	$9.75	Amazon
Scanning for Number of Pills Dispensed	Sensor	Break Beam Sensor	$10	$10	Amazon
Security System	Fingerprint Sensor	AS608 Fingerprint Reader Sensor	$18	$18	Amazon
Alarm	Speaker	3” Diameter	$8	$8	Amazon
User Interface	Touch Display	Nextion Display	$51	$51	Amazon
User interface	UI	Arduino	$35	$35	Amazon
Mounting	Mounts	Brackets	$10	$4.75	Ace Hardware
TOTAL:				$199	

10.5 Appendix E: Team Members and Their Contributions

10.5.1 Team Member 1: Henry

Throughout the team project I contributed to my subsystem, the dispenser modules, and writing and editing different parts of the memo. For my subsystem, most of the time spent on the project was in manufacturing, in the Forge makerspace. I extensively used the forge’s laser cutter, coming to a total cut time over the course of the semester of 4.3 hours, in designing, redesigning, fabricating and testing the dispensers.

For the technical memo, I wrote the introduction section, the section regarding the dispenser modules, the appendix section regarding customer requirements and technical specifications, and the section for system concept development and selection.

10.5.2 Team Member 2: Tyler

For the team project, I mainly worked on the electrical and software side of the APD: helping to write code that interfaced with the Nextion display, the motors, and the break-beam sensor, and for the MS2 presentation helped to learn about UART communication and setup the communication protocol between the two Nanos. I also wired all the electrical components together and helped other team members debug code when.

For the technical memo, I wrote about my subsystem, the expense report, added additional sections to appendix G, and proof-read the document to make sure that formatting was consistent.

10.5.3 Team Member 3: Marc

For the project I mainly worked on my respective subsystem, the housing unit. The housing unit required me to be at the Forge makerspace and IED shop for many hours to make my parts and edit them. Apart from technical design, I also wrote and edited multiple parts of each memo. For this memo, I wrote the executive summary, results, conclusion, and my subsystem analysis. I also did the conclusion and subsystem analysis of the housing unit for the presentation.

I also facilitated a lot of communication throughout the team, from some of the arranging meetings to keeping members updated with what we have worked on. I kept track of team members who may need more time on their parts and planned accordingly. I feel that I contributed a lot to making the team run smoothly and efficiently.

10.5.4 Team Member 4: Ira

My contribution to this project was the development of the security system subsystem of the Automatic Pill Dispenser. I have spent time improving the software that was pertaining to the subsystem and eventually lowered its memory usage of it.

Initially, I have also given insights into every subsystem and how the final product should be. I have assisted with integrating the integration of the whole system. When problems arose from insufficient memory, I aided in the development of solutions to fix this problem. I was in charge of writing Appendix A, Appendix H, and Appendix I and aided in proofreading other sections.

10.5.5 Team Member 5: Jaeyoung

I contributed to idea suggestions of subsystems and plausible mechanisms. I designed the concept of storage units and house units. I also contributed to making the initial setup loop, main loop, and their flowcharts. Because I was not skillful enough to contribute coding and CAD, I spent time on user interface design. I suggested coders give feedback for project collaboration and organizing code to fit my and their purposes. Therefore, I could successfully finish my subsystem. Before I was sick, I suggested meeting schedules, created Gantt Chart, and made shareable google documents.

In this technical memo, I wrote user interface subsystem analysis, significant accomplishment and Appendix C.

10.5.6 Team Member 6: Kaiwen

I contributed mainly to the software and user interface (UI) development portion of the project. First, I collaborated with members to design a flowchart for navigating the UI, and making it user-friendly especially to the older population. I also wrote the whole alarm section of the Arduino code. This included design, implementation, integration, and testing of the alarm system. I wired the circuit for the speaker, and I programmed the pulse width modulation to play the speaker at a certain sound level and frequency. I also contributed to writing the alarm subsystem, professional and societal considerations, and assessment of relevant technologies sections of the memo.

10.6 Appendix F: Statement of Work

Statement of Work (v2/14/22) - Automatic Pill Dispenser (APD)

Team

Mark Kuo, Henry Heckert, Tyler Chan, Ira Cheng, Jaeyoung Nam, Kaiwen Yang

Semester Objectives

- To design a pill dispensing device, that simply and without much intervention gives the correct number of pills at the correct time of day.
- Engage in design analysis to create the optimal design for the dispenser.
- To design a working prototype by the end of 10 weeks.
- Integrate subsystems in order to provide a better user experience

Approach

The team will design and manufacture a prototype of an Automatic Pill Dispenser that would allow for storage and dispensing of several pill types while simultaneously providing a simple user experience. Each team member would be responsible for the development of their respective subsystem, while keeping in mind the overarching integration of the product. The team will strive to refine a prototype that is more versatile and cost effective than other products that can be mass produced.

Deliverables and Dates

1. MS1 Presentation (2/24)
2. Milestone 1 Memos – Due Wednesday, Week 8, 11:59PM
3. Initial Prototype (3/15)
4. Research and Engineering analysis of initial prototype (3/22)
5. Milestone 2 Forms – Due Monday Week 13, 8:00AM
6. Milestone 2 Templates Filled Out Due – Wednesday, Week 13, 11:59PM
7. Final Prototype (4/11)
8. MS2 Project Demo (4/18)
9. MS3 Final Project Presentation (4/25)

10.7 Appendix G: Lessons Learned

The project team overall developed significantly on technical skills throughout the duration of the project. Just as the team has been struggling on skills, there were just as many setbacks and challenges that the team had to manage. In this section, there are several key points that have been exemplified that can aid future teams who have a similar project design.

Problem: Hardware Limitations

As described in the Arduino Subsystem, the Arduino Nano that was first used had only 2 kilobytes of dynamic memory. Since the alarm program seemed easy to implement and runs completely fine on the laptop, we overlooked that the Arduino Nano might not have enough memory to contain the whole program. The night before the demonstration, we finally implemented the program onto the Arduino. However, the program took over 340% of the Arduino memory. After reducing the number of profiles to 2 and the number of alarms to 3, the program still took 170% of the memory. To solve this, the programming team had to learn how to serially connect two arduino on the spot. This took many hours, and the transfer of data between them is known to be somewhat inaccurate. Although the Arduinos did functionally communicate on demonstration day, it was far from a good implementation. The lesson learned from this problem is to research all aspects of the project before buying the parts. The team needs to build in delay time for unanticipated problems so that the deadline can be met.

Keep: Team Meetings

Keeping track of what each member was doing and when parts were going to be made became less clear as time moved on. The team would meet during class and try to coordinate everything however it proved less effective as time moved and deadlines were closer. In order to bring everyone together, the team decided to have long team meetings, not just to catch up on what each member did in between the time, but to do a large chunk of work. The team held in-person meetings where the members would all meet up and work on the project. This let members hold each other accountable and created a period of highly productive time. Even when not every member could be at the meeting, those that could kept each other focused on the task at hand. This became especially crucial before major deadlines such as the MS2 presentation and demo, where the team needed to get a lot of work done together. Team meetings were where members were most productive and should be kept for future projects.

Keep: Resource Center

All of the project's subsystems are related to each other, and one does not function without the other. This made designing and implementing each subsystem very hard, as one subsystem's design needed the working model of another subsystem. This delayed timelines and made individual work very inefficient. To solve this, the group established a resource center on Discord. This is where all the current files and metrics for each subsystem are kept. For example, the mechanical engineers put their CAD files in the resource center every time they updated something to the file. A change log file is uploaded along with it to explain the work done to it. This allowed for a more parallel working dynamic, where individuals can work on their subsystems without excessive waiting times. The software/electrical team could then design the wiring based off of the mechanical model, making communication among the discipline more streamlined.

Problem: Gantt Chart Deadlines

When the Gantt Chart was created for an in-class activity, there was an issue with following the specified deadlines. In addition, most of the time allocated on the Gantt Chart was for developing the mechanical subsystems where in reality, the software subsystems took the most time to develop.

Try: Github

Some team members have used Github in order to work on the project at the same time and found it introduced additional problems. At some point in time when merging changes from different team members, an old version of the code was merged into a newer version. This caused the code to malfunction and was very hard to diagnose since the code was over 600 lines long. So the best solution was to revert to a working version of the code. This caused a setback of about one day due to the reverting of code. In the future, Github may be helpful in collaborating when the group does not all work on the project at the same time so that versions are more easily separated from each other.

Keep: Google Docs

Google Docs offers a seamless way to cooperate with other team members on technical writing assignments. The ability that Google Docs offers real-time editing and viewing has improved productivity and reduces the time spent on accessing documents by using other software such as Word Doc. The team members who aren't as comfortable with writing can be edited remotely by another team member. This feature became vital due to circumstances that prohibited certain team members from convening in person.

Problem: Shipping and Prototyping Times

Despite leaving ample lead time for part delivery, unforeseen hiccups still caused the team delays in subsystem construction and testing. A source of these delays was that the Forge was often too crowded and the machines were constantly being used so that the mechanical team were not able to manufacture parts. Another source of delays was that the IED shop was closed on weekends, which was when the team often met up to do work. This led to major delays that slowed down overall production and made it much more difficult to meet deadlines. This effect grew until there was near no time for testing, which showed during the MS2 demonstration, when some parts of the APD failed.

10.8 Appendix H: Software / Technology Used

Collaboration Among Team Members:

- Cisco WebEx Teams and Meetings
- Google Docs
- Google Drive
- Discord
- Github

Subsystem Design:

- Siemens NX
- Fritzing

Programming:

- Visual Studio Code - Integrated Development Environment
- Arduino IDE
- Nextion Editor

Subsystem Testing/Simulation/Emulation:

- Siemens NX
- Nextion Editor
- Arduino IDE
- Visual Studio Code - Integrated Development Environment

10.9 Appendix I: User Manual

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Setup:

Connect the USB cable that is located on the left side of the product to a 5V power supply. The recommended power supply to use would be a laptop but others alternatives can suffice.

The Automatic Pill Dispenser is ready to use

Operation:

1. Find a suitable location to put the APD, preferable in a location that is not inconvenient to reach.
2. Open the lid of the unit to reveal the internal components of the APD, there should be 6 chutes. From left to right, the chutes are labeled from 1-6, and at this time, place the different types of pills in its individual chute. Remember what pills are being placed in which chutes.
3. Follow the instructions given on each page on the touchscreen in order to set up the user profile

Safety Precaution:

- The APD's internal components and wiring aren't rated for water exposure. Keep the Unit away from wet conditions. In case of water exposure, quickly unplug the APD and
- Do not store it outside. May cause warping of wooden side panels
- Do not store in damp, moist conditions. May cause unwanted bacteria growth within the unit.

- Do not use a modified USB cable or a 3.3 to 5V adapter. May short circuit the internal components and start a fire.

Troubleshooting:

Problem	**Possible Solutions**
Touchscreen does not turn on	● Check if the USB cable is properly connected ● Check if the power supply is suitable/is not damaged
Pill is stuck at dispensing	Open the lid of the APD, and use a small tool to dislodge the pill
Fingerprint Scanner doesn’t accept fingerprint	● Ensure that the fingerprint was in the exact same position as first used ● Ensure that the scanner is not dirty in use
Alarm doesn't ring	● Ensure that the speaker is properly socketed onto the breadboard ● Verify that the speaker is outputting sound