July 12, 2020

Dr. Andrew H. Rawicz and Dr. Craig W. Scratchley

School of Engineering Science

Simon Fraser University

Burnaby. BC, V5A 1S6

Auto-Pharm Tech.

Re: ENSC 405W/440 Design Specification for Auto-Pharm

Dear Dr. Andrew H. Rawicz and Dr. Craig Scratchley,

The enclosed document attached with this letter is our design specification document for our Auto-Pharm, the automatic medicine supplier. Our goal is to create a pill storage machine that, for the guardian who needs to take care of the elderly in the family use, can provide multiple kinds of medicine and set the time to alarm the elder to take them through the website. Meanwhile, the elderly are not required to remember the instrument's operation, preventing medicine errors about taking the wrong drugs or overeating when the children are not able to supervise them.

The following functional specification document will outline the design details and determine the method to assemble components into subsystems and achieve their tasks in the Auto-Pharm. To explain more, this document will start from a high-level system overview, then delve into the separate modular sections, such as Basic Operation System, Feedback System with self-check, Remote system, and Power System. At the end of specifications, the Test Plan and User Interface design will be attached as appendices.

Auto-Pharm consists of five creative senior engineering students, Yu (Hazel) Yang, Yixuan (Tony) Wang, Yuyan (Richard) Dong, Yimin (Amy) Long, Tao You, coming from three different engineering majors. Our team has extensive Co-op working experience in software and hardware to aid us in realizing this proposition.

Thank you for taking the time to review our design specifications. If you have any questions, advice, or comments regarding the document, please contact our Chief Communications Officer Yu (Hazel) Yang at yya168@sfu.ca.

Sincerely,

Richard Dong

Chief Executive Office

Design Specification for Auto-Pharm

Automatic Medicine Supplier

Team 6

Project Members: Yu Yang (CCO, yya168@sfu.ca)
Yixuan Wang (COO, yixuanw@sfu.ca)
Yuyan Dong (CEO, yuyand@sfu.ca)
Yimin Long (CTO, yla468@sfu.ca)
Tao You (CFO, tyou@sfu.ca)

Contact Person: Yu Yang
yya168@sfu.ca

Submitted to: Dr. Craig William Scratchley (ENSC 405W)
Dr. Andrew Rawicz (ENSC 440)
School of Engineering Science
Simon Fraser University

Issue Date: July 12, 2020

Abstract

Increasingly, the elderly are required to take multiple prescription pills or over-the-counter drugs to maintain their health. In America, the ambulatory elderly need to fill between 9-13 prescriptions a year, and the average elderly patient is taking more than five prescription medications [1]. Therefore, the medical accidents on taking wrong drugs or overeating drugs become severe issues for the elderly's guardians when they are not able to supervise the elderly, especially the seniors who are suffering from vision and memory impairment. The project: Auto-Pharm was found to protect the elderly from daily medical problems efficiently, preventing the occurrence of medical errors as the elderly need to take the pills only without remembering additional instrument's operation. The children of the elderly can use Auto-Pharm to help set up the schedule, such as dosage and time for their parents and this can lower the probability of medical errors caused by the negligence of the elderly, and avoid the occurrence of tragedy.

The following document addresses the detailed design with specifications to the automatic medicine supplier: Auto-Pharm. First, this document will outline the high-level descriptions of the entire system. Each of Auto-Pharm's independent subsystems is listed with detailed specifications on software, hardware, and mechanical sections. From a rudimentary level, Auto-Pharm contains a website that the guardians of the elderly can set the alarm and the dosage of pills, giving the order to the machinery. In general, the user needs to refill the medication once a week. Meanwhile, the instrument will remind the user of the lack of medicine.

Auto-Pharm Technology split this project into three stages: the proof-of-concept (Alpha), prototype (Beta), and the final product. For this document, the primary focus is on the proof-of-concept design. The details of Auto-Pharm functionalities and components are given into the Basic Operation System, Feedback System with self-check, Power System and Remote system, providing the User Interface (UI) and test plans as Appendices at the end of this document. The proof-of-concept will be delivered by August 2020. The prototype/final product will be further optimized for consumers and will be delivered by December 2020.

Table of Contents

List of Figures

List of Tables

Glossary

UI	User Interface
PWM	Pulse-Width Modulation
GPIO	General-Purpose Input/Output
LED	Light-Emitting Diode
DC	Direct Current
PCB	Printed Circuit Board
3D	Three-Dimensionality
RAM	Random Access Memory

1. Introduction

1.1 Background

In this developing society, an increased number of the aging population appears in people's sigh. The World Population Prospects published in 2019 state that there is one person over age 65 within 11 people, and the data is expected to grow into one within six people by 2050 [2]. Over time, the elderly ends up on a growing list of medications. According to the article from the Canadian Institute for Health Information in 2016, nearly 65.7% of seniors in Canada are required to take five or more different drug classes to maintain their health [3]. Many old people are suffering from memory impairment and vision issues, this implies various problems such as overeating and taking the wrong medicine, which causes medical accidents. Therefore, it becomes a problem for the elderly's guardians to prevent the elderly from medical errors and provide drugs to them, especially when the caregivers are not able to supervise the elderly.

Several relevant pills dispensers have appeared on the market to reduce the possibility of medication errors for the above concerns. Take the Philips Medication Dispenser as an example, it can "accommodate complex regimens, dispensing up to 60 cups of medicine, and up to six doses per day." [4]. It also provides the alter notification and up to 18 hours of backup power during an outage [4]. However, this dispenser also has some defects: First, it requires the elderly to press the button to get the medicine, which means the elderly have to wait for the machine to load the drugs, to be more specific, the products are not good enough for seniors with memory impairment because they may leave once they pressed the button. Second, the dispenser requires the user to pay $59.95 every month to get the full service of the device, and unfortunately, this price can not be accepted by lots of low-income and middle-income families, this means the potential audience for this product will be limited by the high price. All of these concerns indicate that there is still a large room for improvement in the home supply of smart medicines, which is what Auto-Pharm Technology can help.

1.2 Basic information about the Auto-Pharm

The automatic medicine supplement device: Auto-Pharm, is designed to prevent the elderly from taking the wrong pills and overeating. Meanwhile, the entire instrument will be automatic so that the old adults do not need to remember the dosage of each drug and the instrument's operation. Auto-Pharm will remind the elderly users to take their medicine on time and interact with their caregivers in real-time.

Auto-Pharm provides a medicine storage box that contains multiple kinds of pills, and the caregivers of the elderly can set up the time for taking medicine through the user interface, a website. The device will download the schedule from the database of the website and use an alarm clock to remind the elderly to take their medication at the specified time. At the same time, the medicine that the elderly need will be given by Auto-Pharm directly. Furthermore, Auto-Pharm will send an emergency message to the guardians if it keeps alarming for 30 minutes.

Auto-Pharm aims to protect the elderly who need to take many types of medicines every day while their caregivers are out at work, reducing medical error accidents as much as possible, including the consideration of error operations on the device.

1.3 Scope

This document intends to provide the design specifications of Auto-Pharm and identify the individual choices addressed by Auto-Pharm Technology for the prototype. Meanwhile, this document will outline the appendix for specifications of the User Interface Design to support the instrument's operations for the guardians of the old adults. Another appendix details the test plans to address each achievement of the subsystem and component.

1.4 Intended Audience

This design specification document is intended for the project members of Auto-Pharm Technology for the development and implementation of Auto-Pharm. With Dr. Craig Scratchley, Dr. Andrew Rawicz, the teaching assistants Mohammad Akbari and Chakaveh Ahmadizadeh supporting in the ENSC 405/440, this document will be the fundamental guideline for the proof-of-concept demo. As a reminder: the future revisions and other related documents will draw on the framework detailed in this document, some of the design decisions may change as the project develops forward.

1.5 Design Specification Classification

To maintain the clarification and read convenience, all the design specifications are listed in this document will follow the format:

{<Des>.<Section>.<Subsection>.<Design Number>.<Stage of Development>}

The short-writing for each stage of development will list the scheme in Table 1.4:

Table 1.4: Short-Writing Code for development stage

Short-Writing	Stage of Development
C	Proof-of-Concept
P	Prototype
F	Final Product

As an example of the format, the first design specification of the third section's first subsection as the proof-of-concept will be presented as

Des 3.1.1 - C.

"Des" is an abbreviation of design. To explain more, Auto-Pharm Technology. will develop the proof-of-concept (Alpha) stage of Auto-Pharm at the end of ENSC 405W and the prototype (Beta) stage will be demoed in ENSC 440. For the Final Product stage's requirements, it lists all the requirements that must be satisfied when the device is in production in the market.

2. System Overview

Auto-pharm is an age-friendly, easy-to-use device that helps seniors take their medications safely and promptly. This device is designed for people who have memory problems and cannot remember to take their medication on time but are able to take care of themselves in their daily lives. The ideal final product will be simple in configuration, low-price, and easy to use, which can assist the daily life of the elderly, and reduce stress for the elderly's families.

For the appearance of the product, the device is a prismatic triangle with sides length approximately 30 cm and 35 cm for the height. The user only needs to follow a few basic steps to launch and set it up: First, the caregivers of the elderly will set medicine type and dosages for the elderly through a clear user interface website; then the Auto-Pharm will be ready to release the drugs after matching the medicine storage boxes and the amount of the medicines. In addition, it includes an alarm function that alerts the elderly if they should take their medicine, and once the alarm is activated for a long time, for example, over 30 minutes; the notification email will be sent to the elderly's children or other contacts stored in the database. In Figure 2.1, it graphically listed the Auto-Pharm hardware's block diagram which intuitively displays the hardware design strategies.

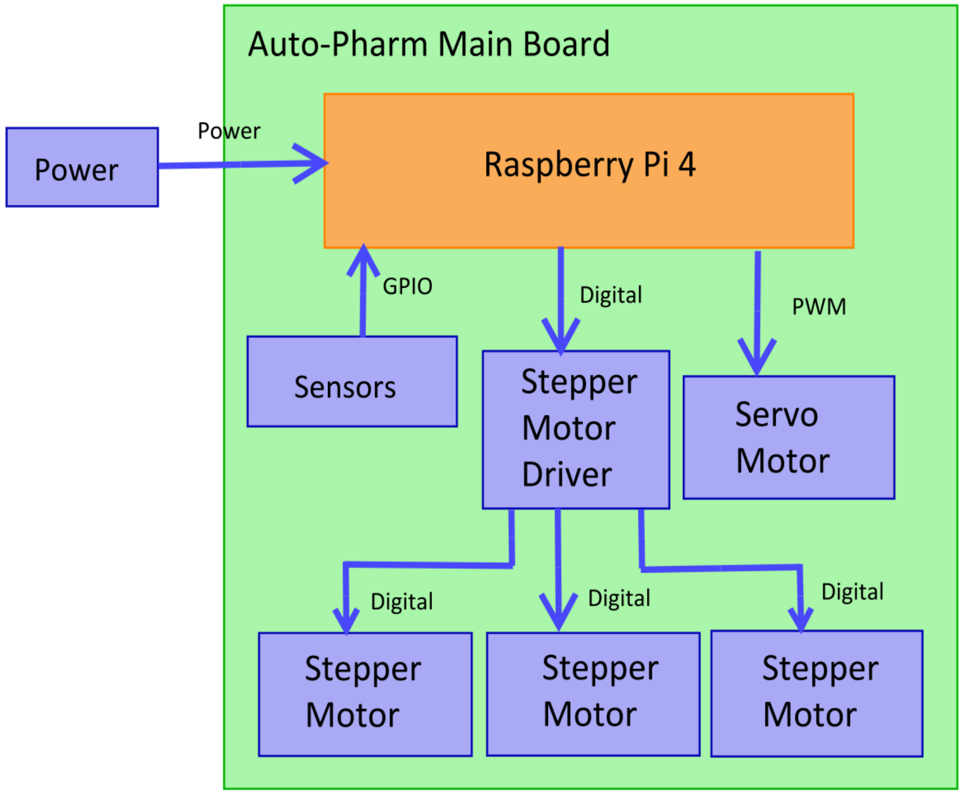

Figure 2.1: Auto-Pharm Hardware Block Diagram

Based on Figure 2.1, the Auto-Pharm's hardware will be chosen to perform as a feedback system. Due to the limitation of Raspberry Pi 4, the 5V-3A power charger will be used as the power connector to avoid burning out. By using the stepper motor driver boards, the rotation degree can be controlled, the drivers will apply digital pinout to continuously receive and enlarge the control signal to make the information of their rotation direction and number of steps legible. The amount of stepper motor will be three due to the device can contain three types of medicine in total, and will be commanded by drivers respectively, the stepper motor aims to rotate the storage boxes. The servo motor block shown in the middle of Figure 2.1 will be used to open and close the door for medication, it will use pulse-width modulation (PWM) signal to control the rotation direction and angle. The power cord will be directly connected to the Raspberry Pi, and the sensor connected with the Raspberry Pi will need general-purpose input/output (GPIO) pinout to transfer data with Pi 4.

Besides the figure shown. The Raspberry Pi also will be helpful to achieve functions such as: alarming for taking medicine, checking the scheduled time, or warning for refillings. and two buttons with light-emitting diodes (LEDs) will be used to show the signal and the status of the machine.

Again, the aim of the automatic medicine supplement device: Auto-Pharm is to provide the elderly with a better life by decreasing their life inconvenience, improving their living conditions, and reducing the burden on their family.

3. Basic Operation System

Auto-Pharm is an automatic medicine supplier device, and the motion system design is the core step for the essential operation. The motion system's expected functionalities are based on motors, to be specific, each motor will drive a turntable separately, representing different types of drugs. The turntable will contain individual spaces to store pills in it. Then the drugs will be dropped into a soft tube before the two minutes of the scheduled time, the guardians of the elderly set the alarm time through the website—the sections below elaborate in detail the individual subsystems and components' specifications.

3.1 Stepper Motor System for Rotation

Based on the requirement document, Auto-Pharm Technology members decided to add another fundamental requirement, which is the operating system is configured with motors for rotating motion. Applications of the stepper motor are suggested by the hardware team to satisfy the rotation requirement of the system. The hardware team provided the specific explanation that: for the general direct current (DC) motor, it rotates irregularly with high speed, which is hard to control the rotation angle, and the servo motor can only rotate with large different fixed angles such as 60 degrees, 45 degrees, but it can not provide degree such as 17, 23, etc. Stepper motors will not have this concern; hence it provides more accurate angles that can satisfy any rotation angle of the turntable [5]. Moreover, the related design specifications about the stepper motor are listed in Table 3.1.

Table 3.1: Stepper Motor Specification

Design Code	Description
Des 3.1.1-C	Auto-Pharm contains three 5V DC Stepper motors to achieve the rotation of the turntable
Des 3.1.2-C	4-Phase Stepper Motor Driver Printed Circuit Board (PCB) will be utilized to supply 5-volt Voltage to the motors [6]
Des 3.1.3-C	Plastic Gear with 5mm center hole to match the motors' rotor

Table 3.1 also presents the required components in the motion system, which indicates that the dimension and weight of the motor are the main reason for choosing the 5V DC stepper motor. Although the 5V DC stepper motor is not ultimate accuracy at 1.8 degrees for one step, the 30 grams weight and round 34 mm edge diameter as one unit will not become a burden for Auto-Pharm [7]. In addition, the motor's rotor dimension is 5mm, which has to be matched by the gear, and the gear should be made of plastic to prevent rust

Furthermore, the hardware team members informed that stepper motors' accuracy comes from the motor driver, which is programmable in microcomputers and supports power to the motors. The PCB board is usually bundled with the 5V DC stepper motor and contains connectors heads, which are not easy to break, serving the required power voltage to motors.

3.2 The Turntable Which Stores the Medicine

Besides the requirements mentioned in requirement specifications, the mechanical team members indicated that there should be another requirement to complete the Auto-Pharm, which is the turntable that will serve as the supporting surface of the drug and achieve the drug drive function. To be more specific, pills are deposited one by one in the turntable and are separated from each other by a baffle. Referring to the mechanical team's suggestion, each compartment size will be chosen to fit one pill to save the user's time from setting up the containing amount for each compartment through the website. According to the data from Capsule Connection Limited Liability Company, the largest body size is 22.2mm for capsule [8], the compartment should be able to fit the maximum size. In other words, each compartment should reserve enough space such as the height and length of the single block, even if the drugs can be placed with an angle. Therefore, the design specifications of the turntable are informed in Table 3.2:

Table 3.2: Turntable Specifications

Design Code	Description
Des 3.2.1-C	The turntables should be designed as a circular surface in order to apply better rotate motion
Des 3.2.2-C	The turntables will be handmade(at stage "C"), and each one will have 20 compartments to store pills
Des 3.2.3-C	The diameter of the turntable is designed as 12cm to cover the stepper motors
Des 3.2.4-C	The height of the compartment will be 3cm in order to prevent medicines from falling out during rotation
Des 3.2.5-P	The entire turntable will be 3D printed to meet long service life

The mechanical team decided to use 18 degrees as a compartment interval, which are partitioned into 20 pieces to deal with the general drugs' dosage of the elderly for about one week. The main reason to handmade the turntables during the proof of concept stage is, the members can quickly compensate and improve the problem of compartments' baffle and space size error when they find, this also can effectively reduce the cost of materials in the development stage. After determining the details of space size, the Auto-Pharm will utilize the three-dimensionality (3D) printer to print the entire module of the turntable for the final product to increase the speed of assembly and meet the long service life purpose. A handmade sample is given as Figure 3.2 shows:

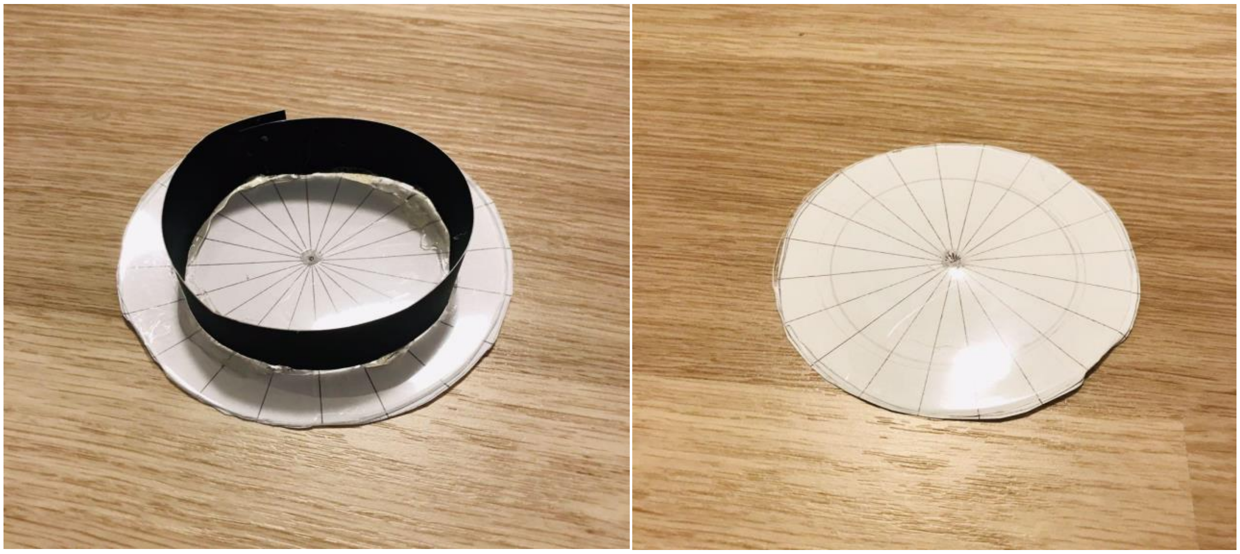

Figure 3.2: Handmade Sample of the Turntable

As Figure 3.2 shows, the right part of Figure 3.2 is the clear bottom surface of the left part. On the bottom plane, the angle between the two solid lines is set to 18 degrees to ensure that the turntable is evenly divided into 20 parts. Moreover, the mechanical team defines the placement of the black strap as the left of Figure 3.2 shows and will make sure the space between the black strap and the outermost edge of the turntables match the specification: Des 3.2.2-C to store the pills(space larger than 22.2mm in length). The space of each compartment can be adjusted by changing the length of the black strap and the plane distance between the center of the turntable and strap, this is the main strategy to ensure the adequate storage space.

3.3 Pill-Dropping System

The essential requirement of Auto-Pharm's function is to deliver medicine to the elderly from the inside of the machine. The mechanical team decided to make some changes to the turntables to develop the pill-dropping system which can satisfy this requirement. Firstly, the black strap with baffle will not connect with the turntables' bottom plate, which means the base plate will stay still when the baffle is rotating. One of the compartments will be hollowed out and a door with an open/close function will be installed under it. The baffle will drive the drugs to the door's position, and then the door opens once the setting time arrives. Furthermore, under the door, there will be a funnel interface and soft tube that can catch the drugs which fell from the door and will deliver the pills to a small box for the elderly to take. As the same before, the mechanical group lists the details of this part in Table 3.3:

Table 3.3: Pill-Dropping System Specifications

Design Code	Description
Des 3.3.1-C	The bottom plate of turntables is designed as non-rotatable and include a plastic door to drop drugs
Des 3.3.2-C	The pill-dropping system will contain a servo motor to open and close the door horizontally
Des 3.3.3-C	The diameter for the top of the funnel will be 3cm to make sure the medicine will not leak
Des 3.3.4-P	There will be a 2cm length soft tube that allows the pills to fall into the small box for elderly
Des 3.3.5-P	The size of the small box for dispensing medicine will be at least 3cm x 3cm x 3cm to store more than 3 pills

As mentioned in section 3.1: Stepper Motor System for Rotation, the servo motor can rotate 180 degrees or 90^{o}, which is enough for the opening and closing movement of the door. The pills will eventually be given to the elderly, so some delivery structure is required from the turntable to the drug delivery box. The mechanical team members decided to add the funnel interface and soft tube to achieve this job and to prevent dropping into other places in the Auto-Pharm during progress. Moreover, we provide the servo motor model as the below figure shows:

Figure 3.3: The Full Picture of SG90 Servo Motor

The 23mm x 11.5mm x 24mm cabinet dimensions for this servo motor is the most important reason for being selected [9], and the white plastic gear as Figure 3.3 shows, is disassembled and replaceable. The microcomputer can control the angle of rotation by programming to operate the opening and closing movement.

4. Feedback System

The feedback system in this section will contain three main parts: the self-checking system, the refilling feedback system, and the alarming system. The following subsections describe the designs for each system, including the implication LEDs and strain gauge sensors which the development group use to sense the weight of the pills.

4.1 Self-checking System

Based on the requirement specifications, the self-checking system will be triggered by a momentum button with a LED inside. When the user presses the button, the LED will light up and the Raspberry Pi will receive a signal to start the check-up process. Then the Pi will send a signal to the stepper motors to rotate the turntable storage boxes. While it is checking, the strain gauge sensor will sense the weight and it will check whether there is load inside each small box. When the checking is done, the self-checking LED will be turned off and the feedback result will be transferred to the database. The self-checking system mainly focuses on ensuring there are medications inside the boxes. Table 4.1 lists the design description of the self-checking system.

Table 4.1: Self-Check System Design List

Design Code	Description
Des 4.1.1-C	Button with LED will be the trigger of the self-checking system
Des 4.1.2-C	Strain gauge sensors will be used to sense the existence of the medication in the turntable storage boxes
Des 4.1.3-C	Board HX711 will be used to amplify the signal from the strain gauge and transfer to the Raspberry Pi 4

Des 4.1.4-C	Load cells will be used to assist the strain gauge sensor to make it less flexible and support the shape change

Table 4.1 presents the required components in the feedback system and their usage. The button is necessary to trigger the self-checking function and the LED will be an obvious signal to the user. Moreover, considering the weight of the medications is small, the strain gauge sensor will be a better choice due to its accuracy. The board HX711 and the load cell are essential while using strain gauge sensors because the sensors are very soft and flexible. The Load cells ensure the sensors can stick to a stable surface and change shape only if the surface is exposed to a force. The board will amplify the data from the strain gauge sensor and transfer the serial data to Raspberry Pi, otherwise, the raw data from the sensor will be too slight to modify.

4.2 Refilling Feedback System

The refilling system is the intermediate system between the database and the user interface. The achievement of this system will rely on a variable in the database. Every time the self-checking system succeeds, the variable will be reset to “20”. With the storage box release the pills, the number stored in this variable will decrease, the standard is: Once the variable number decreased to “5”, which means the pills number inside the storage box is five; the database will send a warning signal to the interface which will notify the user that some medications inside the storage boxes are low. At the same time, Raspberry Pi 4 will light up a LED. After the user refills the medication boxes and the machine finishes self-checking, the LED will be turned off if there are enough medications filled in(self-checking succeeds). Table 4.2 shows the needed component and variable for the refilling system:

Table 4.2: Refilling Feedback System Design

Design Code	Description
Des 4.2.1-C	A LED will be used to show the low medication signal

Des 4.2.2-C	A variable needs to be created in the database to achieve the counting remaining pills function

As table 4.2 shows, a single LED will be necessary to complete this task because it will be used as an obvious notification for the users, it will only be activated when the refilling function is triggered. The variable will be created in the database development stage.

4.3 Alarming System

The alarming system will focus on reminding the user to take medications as scheduled. When the clock reaches the scheduled time, the medications will be spilled to the tray at the taking area, the underneath of the taking area will include a sensor to detect whether the tray has the medications. Meanwhile, the buzzer will be triggered to remind the user to take the medicine. The buzzer will produce a sound with a lower volume within 15 minutes after the scheduled time is reached, the volume of the buzzer will increase after 15 minutes of the scheduled time. If the medicines are not taken within 30 minutes from the designated time, the sensor will send a signal back to Raspberry Pi to notify the caregivers of the senior. Table 4.3 below shows the design components for the alarming system.

Table 4.3: Alarming System Design

Design Code	Description
Des 4.3.1-C	LED will be used to notify the seniors while the alarm is ringing
Des 4.3.2-C	The buzzer will be used as an alarm to notify elderly
Des 4.3.3-C	The strain gauge sensor will be used to sense the existence of the medication under the tray
Des 4.3.4-C	Board HX711 will be used to amplify the signal from the strain gauge and transfer signal to Raspberry Pi 4

Des 4.3.5-C	Load cells will be used to assist the strain gauge sensor to make it less flexible and support the shape change

As table 4.3 lists, the LED will be needed to show the alarming system is on and give the elderly a visual notification. The buzzer will keep alarming when the scheduled time comes and will be muted until the strain gauge cannot detect any medications in the tray. The strain gauge, load cell, and HX711 board are used for the same reason as the self-checking system, to detect the weight of the tray to judge whether it contains the medications or not.

5. Remote System

In this document, the alarm clock setting has been mentioned many times, and the document also indicated that the old adults' guardians will carry out this motion through the user website, which means the remote system settings are part of the Auto-Pharm. More specifically, remote systems are controlled through a connection between a microcomputer and an online database to help caregivers supervise the number of pills and set the alarm as long as they have the internet.

5.1 Microcomputer

In the Basic Operation System section of this document, it mentioned the requirement for motors to operate rotation. Therefore, the hardware team members informed the company that it required a program in the microcomputer to give movement signals to the motors, communicate with components including gauge sensors and LED, and connect with the command client which is the website. The document also mentioned that the team would utilize the Raspberry Pi to control the components. To be more specific, the hardware team listed Table 5.1 as our microcomputer:

Table 5.1: Microcomputer Specifications

Design Code	Description
Des 5.1.1-C	Raspberry Pi 4 Model B 2GB random access memory (RAM) will be used to control the components

Des 5.1.2-C	Auto-Pharm will use the 400 Holes Breadboard to connect one Raspberry Pi with three motors and other components

Referring back to the part of the fifth requirement in section 3.2 of the requirement specifications (Res 3.2.5), the system will be controlled by the Raspberry Pi for Auto-Pharm. The hardware team members disagree to utilize Arduino due to Arduino is a simple controller that can run one program repeatedly only, which can not respond well after guardians of the elderly change the time [10]. The memory storage and operating speed are not enough for Arduino which compared with Raspberry Pi. Moreover, as for the communication function, Arduino needs to have an ethernet shield, but the Raspberry Pi does not require it.

Although the Raspberry Pi has 40 GPIO pins including pins of voltage input and ground, which is also one of its advantages, Auto-Pharm still requires a breadboard to connect components such as switches, LEDs and motor drivers. Most of them need to be connected to the ground pin to protect the circuit when the Raspberry Pi controls the electronic components. Meanwhile, the 54mm x 83mm dimensions are more in line with the company expectations for size, which does not occupy much space [11].

5.2 Command Client: The User Website

To achieve remotely controlling, the team sought out a development tool that has already completed built-in libraries and functions. In the proof-of-concept stage of Auto-Pharm, the software team decided to satisfy the specifications in the software section of requirement documents, especially Req 4.1.1-C, through a website. The reason given by the software team is that the web page could be better to determine the frame and establish the database. However, considering that the mobile application will be more convenient, the company treats launching the exclusive mobile app for Auto-Pharm as an optional development in the market stage. Base on section 4 of the requirement document, the software team modified the design specifications in Table 5.2:

Table 5.2: User Website Specification

Design Code	Description
Des 5.2.1-C	The development of the website will be hosted by google's firebase
Des 5.2.2-C	Auto-Pharm will utilize email to achieve the login of the website and the emergency notification
Des 5.2.3-C	The website will be designed to contain multiple choices section that the customer can set the type of pills and the time slot to alarm the elderly to take the medicine
Des 5.2.4-C	The website will include the database to bound users' account with the instrument
Des 5.2.4-P	Users will be able to control multiple machines through their own mailbox
Des 5.2.5-F	The web page will provide a summary of a time schedule to do opportune double-checking for the users
Des 5.2.6-F	All applications of the website will be ported into the phone, making the client more convenient to carry for customers (optional choice)

In the proof-of-concept stage, based on Table 5.2, Auto-Pharm utilizes the email as the tool to send notification messages because the team wants to achieve part of the convenience in the development process, and save costs for both the company and customers: The customer will incur additional charges if the messages are sent through a mobile phone. With more detail, the guardians of the elderly will need to register their email account on the website. Then the Auto-Pharm will be bound to this email to receive notification messages later. The development of mobile applications will be treated as an optional final product function after all the other systems are developed. The software team posted a picture: Figure 5.2.1 to give a clear display of the login page of the website.

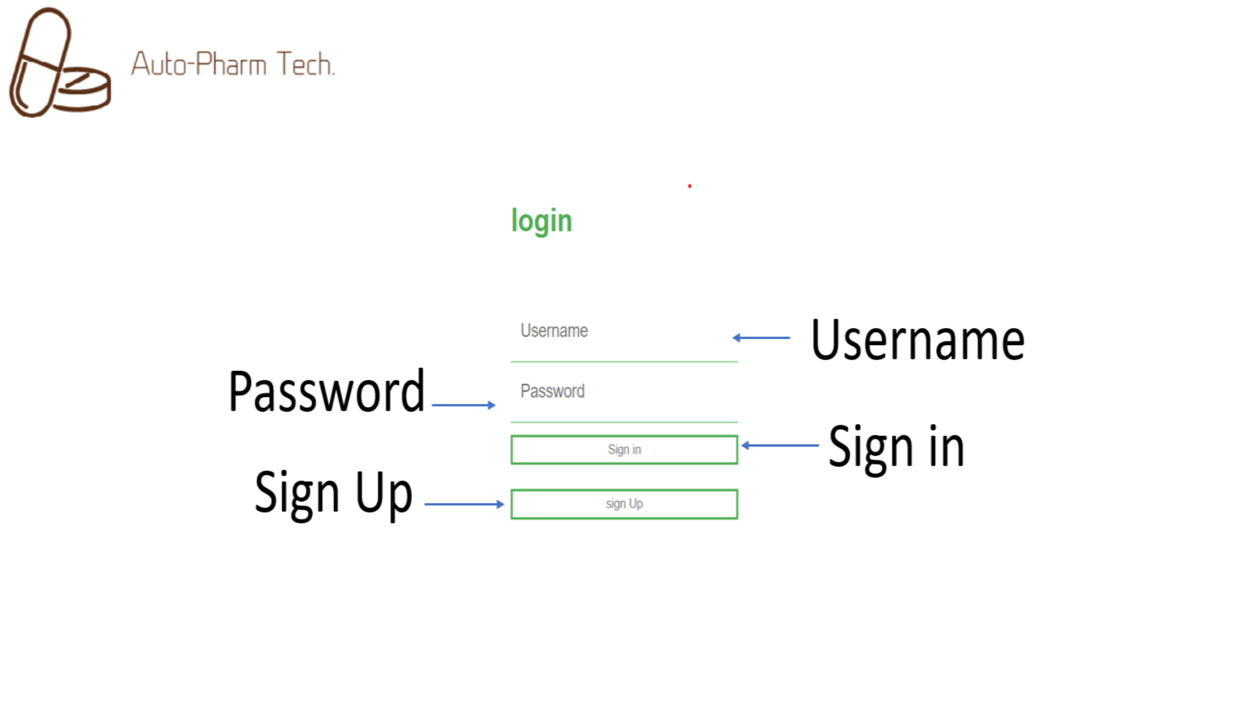

Figure 5.2.1: The Login Web Page of Auto-Pharm

As the figures 5.2.1 shows, the caregivers can click the “sign up” button to register their email as their account name, then they will need to enter the machine code to bind the machine to the account.

Firebase belongs to the Google platform for web application development that can provide fast and secure hosting. Meanwhile, Firebase can ensure real-time data transmission between the Auto-pharm machine and the website. As for the programming, the software team can utilize the firebase library, which contains various javascript functions to develop Auto-Pharm's website. The communication between website and users will be based on the multiple options function that guardians can select different choices to make the information more detailed, especially, the alarming time. The schedule will be developed also to allow the guardians to do better check about the details of dosage and time. To be more clear about the choices section, the software team provided Figure 5.2.2:

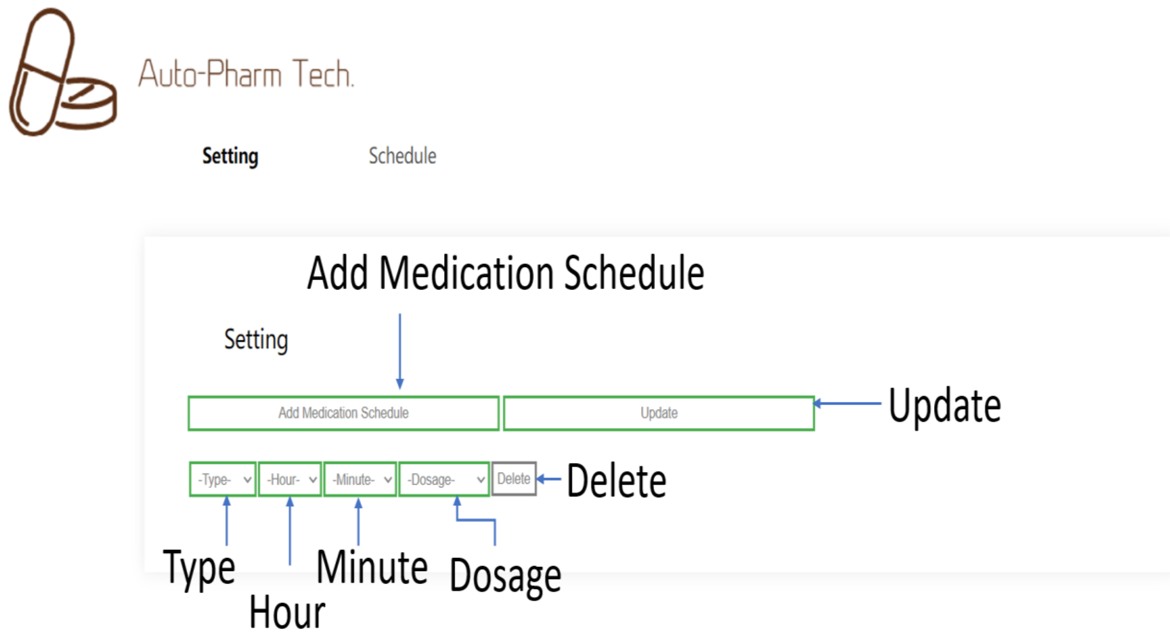

Figure 5.2.2: Setting Choices of Auto-Pharm

Figure 5.2.2 shows that the caregivers can add the schedule of medication and then set the type of pills, the time to alarm as well as the dosage. After that, there will be a time schedule to help the caregivers to do double-check when they click the “Update”. More details will be mentioned in the UI appendix.

6. Power System and Data Transfer System

The power system is needed to drive the Raspberry Pi 4 and all the components, such as motors and driver boards. For the data transfer system, it needs jumper wires. Table 6.1 shows the details about the power supply, cables and wires the development team used in this project:

Table 6.1: Power and Data Transfer System Specifications

Design Code	Description
Des 6.1.1-C	26-awg jumper wires to connect the raspberry pi to the breadboard
Des 6.1.2-C	USB 3.0 (A type) to USB 3.0 (C type) cable to transfer power
Des 6.1.3-C	5V 3A USB 3.0 power supply with switch to achieve open/close function

As Table 6.1 lists, 5V 3A power supply and the USB 3.0 type A to type C will be needed in the project to power Raspberry Pi 4. The jumper wires will be needed to transfer data between Pi and other components, such as motors and sensors. By using 26-awg jumper wires, the maximum current the wires can hold is over 2A, which is enough to power small electronic components up.

7. Conclusion

This design specification document encompasses the detailed development of proof-of-concept and engineering prototype for Auto-Pharm as a whole and each of its subsystems. Auto-Pharm is an automatic medicine supplement device for protecting the elderly from taking wrong medicine and overeating. The instrument will provide the pills and contain an alarm. At the same time, Auto-Pharm has a supporting website where caregivers of the elderly can set a specific time to remind the elderly. The system design consist of 4 major sections:

- Basic Operation System: It is aim to specifies the design about how Auto-Pharm will operate as a medicine dispenser including pill-dropping with details.
- Feedback System: The purpose is to describe the Auto-Pharm's self-checking design and how to achieve the application about reminding the elderly.
- Remote System: The specifications informed that Auto-Pharm will contain a website and microcomputer to control the components and communicate with caregivers
- Power System: It analyzes the consideration about the power supply and wires to detail the development of Auto-Pharm.

This design specification document will serve as a technical guideline for Auto-Pharm Tech.

as the team enters the prototyping stage of the project. These designs may be subjected to change as the device goes through the development and engineering iterations.

Auto-Pharm Technology is committed to providing users with more concise and practical products. The engineering team of Auto-Pharm Technology will provide customers with excellent, reasonably priced products that meet all the requirements of this document, and will ensure that the product can be borne by most families.

Reference

[1] "*How Many Pills Do Your Elderly Patients Take Each Day*", October 04, 2010. [Online], Available: https://www.mdmag.com/conference-coverage/aafp_2010/how-many-pills-do-your-elderly-patients-take-each-day [Accessed July 9, 2020]
[2] United Nations, *Ageing*, United Nations. [Online], Available: https://www.un.org/en/sections/issues-depth/ageing/ [Accessed July 9, 2020]
[3] Canadian Institute for Health Information, *Drug Use Among Seniors in Canada, 2016*, Canadian Institute for Health Information, Ottawa, 2016. [Online], Available: https://www.cihi.ca/sites/default/files/document/drug-use-among-seniors-2016-en-web.pdf [Accessed July 9, 2020]
[4] "*Philips Medication Dispenser*". [Online], Available: https://www.lifeline.philips.com/pill-dispenser/health-mdp.html [Accessed July 9, 2020]
[5] "*What Is The Difference Between DC Motor, Servo Motor And Stepper Motor?*", EL-PRO-CUS, [Online], Available: https://www.elprocus.com/difference-dc-motor-servo-motor-stepper-motor/ [Accessed July 9, 2020]
[6] "*4 Phase ULN2003 Stepper Motor Driver PCB*", electronic scales, [Online], Available: https://www.electronicoscaldas.com/datasheet/ULN2003A-PCB.pdf [Accessed July 9, 2020]
[7] Stan, "*28BYJ-48 Stepper Motor with ULN2003 driver and Arduino Uno*", 42 Bots, March 1, 2014, [Online], Available: https://42bots.com/tutorials/28byj-48-stepper-motor-with-uln2003-driver-and-arduino-uno/ [Accessed July 9, 2020]
[8] "*Capsule Sizing Information*", Capsule Connection, [Online], Available: https://capsuleconnection.com/capsule-sizing-info/#:~:text=Capsule%20Sizes-,Capsule%20Sizes,the%20powder%20you%20are%20using. [Accessed July 9, 2020]
[9] "*SG90 Micro Servo Motor*", JSUMO, [Online], Available: https://www.jsumo.com/sg90-micro-servo-motor [Accessed July 9, 2020]
[10] "*Raspberry Pi or Arduino Uno? One Simple Rule to Choose the Right Board*", Make: Community, [Online], Available: https://makezine.com/2015/12/04/admittedly-simplistic-guide-raspberry-pi-vs-arduino/ [Accessed July 9, 2020]
[11] "*Breadboard, 400 Holes, 54x83mm – White*", Circuit- Test Electronic, , [Online], Available: https://www.circuittest.com/mb-400-breadboard-white.html [Accessed July 9, 2020]

[12] ISO/IEC 24786: 2009, "Information technology -- User interfaces -- Accessible user interface for accessibility settings", Standards Council of Canada, [Online], Available: https://www.scc.ca/en/standardsdb/iec/16695 [Accessed July 11, 2020]

[13] IEEE 1621-2004, "IEEE Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments", IEEE Standards Association, [Online], Available: https://standards.ieee.org/standard/1621-2004.html [Accessed July 11, 2020]

[14] IEEE 1872-2015, "IEEE Standard Ontologies for Robotics and Automation", IEEE Standards Association, [Online], Available: https://standards.ieee.org/standard/1872-2015.html [Accessed July 11, 2020]

[15] ISO 9241-11: 2018, "Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts", ISO, [Online], Available: https://www.iso.org/standard/63500.html [Accessed July 11, 2020]

[16] ISO 9241-161: 2016, "Ergonomics of human-system interaction — Part 161: Guidance on visual user-interface elements", ISO, [Online], Available: https://www.iso.org/standard/60476.html [Accessed July 11, 2020]

[17] IEC 61508-2: 2010, "Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems", IEC Webstore, [Online], Available: https://webstore.iec.ch/publication/5516 [Accessed July 11, 2020]

[18] CAN/CSA-C22.1-18, "Canadian Electrical Code, Part I (24th edition), Safety Standard for Electrical Installations", CSA Group, [Online], Available: https://store.csagroup.org/ccrz__ProductDetails?viewState=DetailView&cartID=&sku=C22.1-18&cclcl=zh_CN [Accessed July 11, 2020]

[19] ISO 13854: 2017, " Safety of machinery — Minimum gaps to avoid crushing of parts of the human body", ISO, [Online], Available: https://www.iso.org/standard/66459.html [Accessed July 11, 2020]

Appendix A: Test Plan

A.1. Unit Test

Table 8.1 shows the Unit test processes of Hardware and Software part. In the hardware part, the development team is planning to test the 3 main motors which are Stepper Motor, Servo Motor, and Load Cell to make sure their function works properly. In the software part, the development team is planning to test the authentication functions and setting functions to make sure the web application operator properly without crashing. The testing result will be Pass and Fail.

Table A.1: Hardware & Software Test Specification

Hardware Test			
Component	**Test Case**	**Excepted Result**	**Result (Pass/Fail)**
Stepper Motor	Set action time at 10:30 am in the user interface. Set 30, 60, 90 rotation degree in python script	Stepper motor is able to rotate at 30, 60, 90 rotation degrees at 10:30 am	
Servo Motor	Set action time at 10:30 am in the user interface. Set 90 rotation degree in python script	Servo motor rotated 90 degrees at 10:30 am	
Load Cell	Put the 500 mg pill above the load cell	Sensors catch weight differences and send responses to Raspberry Pi	

Software Test			
Component	**Test Case**	**Excepted Result**	**Result (Pass/Fail)**
Signup	Enter a valid email address and an at least 6-digit password. Click on the Signup button	New user account is updated in the database. Users stay in the Login Page	
Login	Enter the registered email and password. Click on the Login button	Jump to the machine code page if the password is matched	
Logout	Manually Click on Logout button	User logout successfully. Back to Login page	
Setting	Choose the type, time, dosage. Click on the update button	Setting data is updated in the database properly	
Schedule Display	Click on Schedule section on website	Medication schedules and dosage are shown in the timeline properly	

A.2. Integration Test

Table 8.2 shows the Integration test processes. In the integration test, the team combines the software and hardware part to measure if the overall system works properly. The team will use black box test, giving an input and observing if the output is expected. Same result statement as A.1

Table A.2: Integration Test Specification

Component	Test Case	Excepted Result	Result (Pass/Fail)
Overall System	*Turn on Auto-Pharm device *Login in website *Link with machine code Choose Type A, 10:30, 3pills/time *Click on "Update" button	Device drop 3 pills from Type A storage at 10:30 am	
Self-check System	*Turn on Auto-Pharm machine *Fill in all slots in Type A, B, C storage *Press the "Self-Check" button	No exception come up No warning email sent	
Self-check System	*Turn on Auto-Pharm machine *Leave all slots in Type A, B, C storage empty *Press the "Self-Check" button	Warning LED light is on Warning email is sent	

A.3 User Test

Table 8.3 shows the User test processes. In the user test, the team will observe the caregiver and senior user to use the product. The team measures the web application by observing if the website crashes during the caregiver using the website and the team will measure the machine by observing if it can drop the pills and send warning signals properly. Same result statement as A.1.

Table A.3: User Test Specification

User	**Test**	**Excepted Result**	**Result (Pass/Fail)**
Caregiver	Observe caregiver user setting up and using the web application	Web application does not crash and data is updated in real-time Users can receive warning email if there are any exceptions	
Senior	Observe senior user using the Auto-Pharm machine to receive the medication	Users are able to be reminded to take the pills at specific times User is able to get a warning sound if he didn't take the pills after 30 minutes	

Appendix B: User Interface

B.1 Introduction

Auto-Pharm Tech. strives to create a medicine dispenser, namely Auto-Pharm, that automatically provides the correct dosage of pills at a specific time to the elderly and reminds them to take medicine, meanwhile the elderly do not need to remember Auto-Pharm's operation. This automation gives rise to a User Interface (UI) that is easy to use: It allows the caregivers to input the time to alarm the elderly only through the Auto-Pharm's website. This appendix will first start with introducing the target users. Secondly, this appendix will inform a detailed UI design about the proof-of-concept stage and engineering prototype, following with the discussion about the engineering standards and the tests. Auto-Pharms prototype iteration will contain the following main UI elements:

1. Power Switch

   Once Auto-Pharm is positioned properly, the caregiver of the elderly can turn on and off of the Auto-Pharm.

2. Self-checking Button

   Once the caregiver fills the medicine into the machine, this switch allows the Auto-Pharm to check the existence of drugs immediately. Once pushed, the turntables will be operated to do a rotation in order to check whether each compartment has pills.

3. Remote Controller

   By making selections on the website, the caregivers can provide the information about time alarm schedule to the microcomputer in the Auto-Pharm through the website. All the hardware components in the Auto-Pharm will complete its own work remotely.

4. Buzzer

   If the pills are dropped into the dispenser box, the buzzer will be sound to remind the elderly to take medicine.

B.1.1 Purpose

This appendix aims to assist potential & current customers to understand Auto-Pharm's main features and how to utilize the device through its simple UI design. It will contain diagrams to illustrate the main UI design related to the concepts and components including the explanations.

B.1.2 Scope

Since Auto-pharm is in the early design stages, this document will mostly focus on testing the basic functionalities.

1. B.2 User Analysis:

   Look into the requirement knowledge for users to operate the device, for caregivers to set up the device and for the environment to support the settings and functionalities.

2. B.3 Technical Analysis:

   Present the details about “Seven Elements of UI Interaction” by Don Norman and make a comparison to our designs.

3. B.4 Engineering Standards:

   List the engineering/ safety standards that Auto-Pharm must follow.

4. B.5 Analytical Usability Testing:

   This section is mainly based on functionalities tests using engineering perspectives to test the feasibility of the design.

5. B.6 Empirical Usability Testing:

   This section is mainly based on functionalities tests by a users’ and caregivers’ perspectives to test the feasibility of the design.

B.2 User Analysis

In order to provide acceptable user experience, Auto-Pharm Tech. did a user analysis for the product. The analysis covers the UI of the Website Application and the interface port of the Auto-Pharm machine. The following is a list of necessary user requirements:

- Users should be able to access the internet.
- Caregivers should be able to sign up with a valid email address and an at least 6-digits password.
- Caregivers should accurately fill the pills into the slots of each section.
- Caregivers should be able to read and tell all the warning emails sent by the machine when any exception occurs

- Users/Patients should be able to understand the purposes from different LEDs.
- Users/Patients should be able to understand the functions of different buttons.
- Users/Patients should be able to hear a buzzer with range roughly between 40-80 dB.
- Users/Patients should consciously extract the pills and take it when the alarm sounds.

Users and caregivers are expected to have most of the capabilities listed above. Any user lacking in two or more should use the product with the assistance of others.

B.3 Technical Analysis

This section will illustrate how the "Seven Element of UI Interaction" by Don Norman is incorporated into the product UI design. These elements will be based on the users' point of view, and they will improve the quality and usability of the product in Proof of Concept (PoC) and Prototype.

B.3.1 Discoverability

Discoverability also is known as learnability. It specifies the degree of difficulty for users to find the User Interface elements when they first see a product. A simple design has been used to minimize User Interface elements required for operation to provide higher discoverability for the users.

Auto-Pharm's control panel will consist of two buttons and four LED lights. The two buttons are an on/off button and a self-check button (Shown on Fig.B.3.1.1.(a)). By pressing the on/off button, users are able to turn on/off the machine. The machine can also do a self-check when reloading the drugs by pressing the self-check button. The on/off button will be located on the back surface and the self-check button will be placed on the front surface of the machine. There are four LED lights (Shown on Fig.B.3.1.1.(b)) on the front surface of Auto-Pharm, which are a power light, a self-check light, a medicine refilling light, and an alarm light. This document will also enclose other aspects of Auto-Pharm that the company does not want the user to discover.

(a) (b)

Figure B.3.1.1: (a)Momentary Switch with 3V LED (b)3V Red LED

B.3.2 Feedback

When the machine is operating normally, it should give corresponding feedback according to the different actions users did. There are two parts of feedback in the Auto-Pharm product that will be given to caregivers and senior users. For the caregiver, the main feedback is a warning email. Waring email will be sent when users misplace the pills, medicine does not drop at the expected time, or patients forget taking medicine for a while. For the senior user, the red LED, and a gentle audible is on to remind the user that it is time to take medicine. If the user forgot to take the pills after 30 minutes, the prompt sound would become sharp to catch the user's attention.

B.3.3 Conceptual Model

With a good design of Auto-Pharm, it should naturally portray the information required to understand the conceptual model of Auto-Pharm. The medicine storage and delivering parts of Auto-Pharm are designed to imitate how a vending machine works, which is specialized to give medicine automatically. The design of the product is simple and direct, which makes it easy for users to get started without bothering to study.

B.3.4 Affordances

To provide friendly user experience, the UI is committed to be made as simple, clear, and easy to understand. In the web application, to avoid the user being misled and filling information incorrectly, each filling clearly states what information the user should fill in. Also, there is a timeline displaying the schedule and the dosage set by the user, which is convenient for users to check the data by themselves. For the machine, the triangular arrangement of the three turntables can save space for users, each turntable will clearly label the medicine type name(“A”, “B”, “C”).

B.3.5 Signifiers

The LED lights will show bright twinkle light to notify the caregivers when needed. The power-on LED will be on continuously when the device is powered. The self-checking button will light up while checking, and the LED will turn off when the checking is done. The power supply power button and buzzer are designed at the back of the device where they are usually to be placed.

B.3.6 Mapping

In the following section, the report reviews the front panel and back panel structures. As figure B3.6.1 shows, the power switch and buzzer are designed at the back of the device in order to make the front panel easy and neat. As the figure 3.6.2 shows, the front panel only contains 1 switch (with LED) and 3 LEDs.

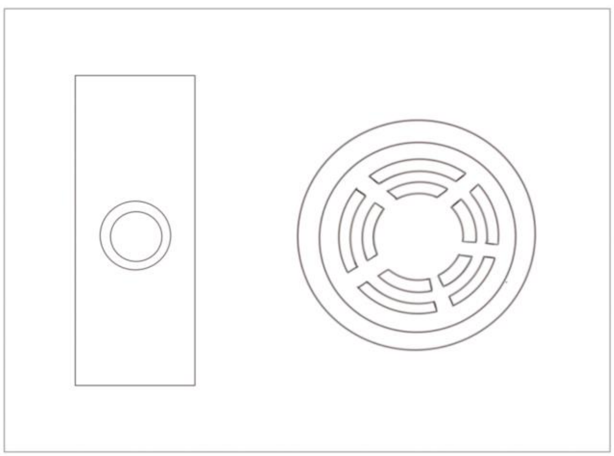

Figure B3.6.1: Back Panel (Left: Power Switch, Right: Buzzer)

Seen figure 3.6.1, the power switch is a push switch, which can be easily triggered by pressing. The buzzer is on the right-hand side of the switch. In order to make the front panel neat, the team hid the power switch and the buzzer at the back panel。

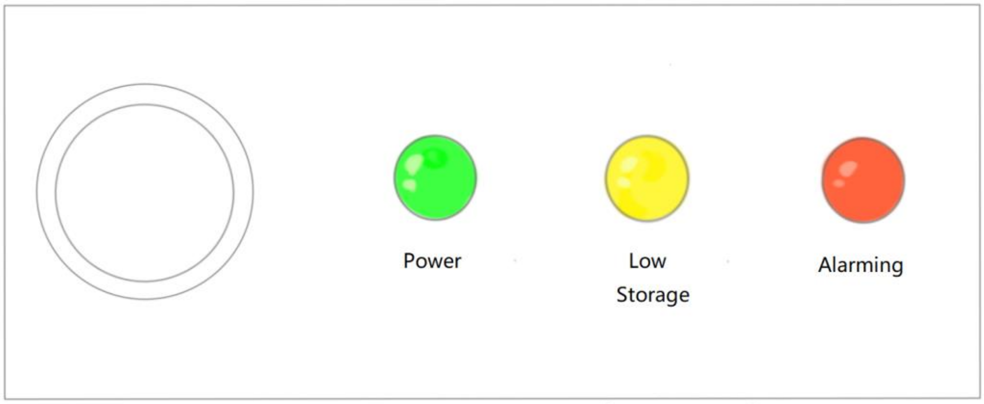

Figure B3.6.2: Front Panel (Left to Right: Self-Checking Button with White LED, Green Power LED, Yellow Low Storage LED, Red Alarming LED)

Figure B3.6.2 presents the appearance of the front panel, the switch with the white LED is at the left-most location because, after the refilling, the button needs to be pushed for self-checking. So, it should be obvious using a big white button. The other 3 LEDs are power light, low storage light, and alarming light respectively. It shows different states of the device. To make it user-friendly, distinct colored LEDs are applied and the labels are stuck to the LEDs.

B.3.7 Constraints

Constraints in UI are the limitations that restrict the interaction between Auto-Pharm and the caregivers of the elderly to prevent a product from being used incorrectly. For Auto-Pharm's users (the elderly), they are not required to remember the operation. The constraints are on the guardian. This UI control client: the website is designed as simple as possible for the caregivers. It contains the schedule that allows them to do double-checking to avoid any accidental action being performed. Furthermore, all the components such as LED and switches on the panel should need exactly matched ports and properly connected wire.

B.4 Engineering Standards

UI design directly involves the interaction between the instrument and the caregivers (customers), therefore Auto-Pharm UI design will be built by following the engineering standards:

1. ISO/IEC 24786: 2009

   Information technology -- User interfaces -- Accessible user interface for accessibility settings [12]

2. IEEE 1621-2004

   IEEE Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments [13]

3. IEEE 1872-2015

   IEEE Standard Ontologies for Robotics and Automation [14]

4. ISO 9241-112:2017

   Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts [15]

5. ISO 9241-161:2016

   Ergonomics of human-system interaction — Part 161: Guidance on visual user-interface elements [16]

B.4.1 Safety Considerations

Safety is the most important aspect of any product UI design. The team members at Auto-Pharm Tech. have considered various potential hazards that may damage the elderly to maximize the safety of the elderly (users). Auto-Pharm design stages shall meet the following standards:

1. IEC 61508-2: 2010

   Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems [17]

2. CAN/CSA-C22.1-18

   Canadian Electrical Code, Part I (24th edition), Safety Standard for Electrical Installations [18]

3. ISO 13854: 2017

   Safety of machinery — Minimum gaps to avoid crushing of parts of the human body [19]

B.5 Analytical Usability Testing

In this part, analytical usability testing will be applied. The testing time will be approximately 1 week. The following section will list the testing components for the user interface.

Power switch

1. The device has an easy-to-use inline switch.
2. The on/off is properly shown with a physical height.
3. The power on/off will physically connect/disconnect the power supply circuit.
4. The power on/off switch is at the back of the device.

Self-checking switch

1. The device has an easy-to-use inline switch.
2. The switch is momentary which can be triggered when pushed once.
3. The switch on/off will physically connect/disconnect the data wire which can be monitored by the Raspberry Pi 4.
4. The self-checking switch is at the front of the device.

LED signal light

1. The green LED turns on when the power is on.
2. The yellow LED turns on when medication is in low storage.
3. The red LED turns on when the alarm is on.
4. The white LED on the switch turns on when the device is self-checking.
5. All the LED lights are at the front of the device in order to make the lights easier to check.

Alarm

1. The alarm makes loud enough noise to make it noticeable.
2. The alarm is at the back of the device, next to the power switch.

Refilling

1. The device cover is at the top of the device and it is also the place where the medications go in.
2. The cover has a mechanical switch which can be locked/opened.

B.6 Empirical Usability Testing

In order to ensure the high quality and high performance of the product, corresponding user tests are required during the product development stage.In proof of concept stage, user tests are limited as the product is not completed. The test cases in this stage would be more specific and users with professional backgrounds would be invited because the errors of functions or designs would likely to be found by other SFU engineers. This can make sure the specific functions of the product work properly. In this case, the user test does not reflect the market situation.

The following table shows the test cases designed for the caregivers and senior users:

Table. B.6.1 Empirical Usability Test Cases

User	Test (Process)	Excepted Result	Result (Pass/Fail)
Caregiver	Sign up with a valid email and an at least 6-digit password	Account created successfully and user data showed in the database	
	Log in with the registered account and bind with the machine code	Log in successfully and jump to the machine code page. Jump to the settings page if the machine code is matched with the user account	
	Click on the “setting” section, choose “Type”, “Time”, “Dosage” and click the “Update” button	Data update successfully in database	
	Click on the “Schedule” section and check the timeline	Data set by user display properly in the timeline	
	Log out	Users can log out properly	

Senior	Users take the pills once the user hears the general reminding sound (within 15 minutes)	The red LED light until the medications are not in the tray Sound stopped once the user takes the pills	
	Users have not taken medicine for over 15 minutes	The reminding sound becomes sharp Reminding sound stops and the red LED is off once the user took the pills	
	Users have not taken medicine for over 30 minutes	A warning email is sent to the corresponding email	

Once the user test is done by the specific user, the product would be upgraded based on the user feedback and usage status.

B.7 Conclusion

This appendix outlines the user interface considerations, including the seven elements of UI interaction to provide better user experience to the elderly and the caregivers. The development team will follow the mentioned engineering and safety standards, such as the "Safety Standard for Electrical Installations" to develop the product. For the Auto-Pharm's proof-of-concept stage, the UI design will mainly focus on the button and switch placement as well as the supporting website development. As for Auto-Pharm's prototype stage, the development team will use this appendix as the guideline to implement Auto-Pharm's UI. Further details and improvement on the UI design will be updated in later documents in ENSC 440.