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Project Title Telepresence Robot for the Elderly

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摘要

本项目致力于设计并制造一个比市面上其他类似产品更便宜的老人用远程护理机器人。该护理机器人能够被护工远程控制。它支持老人与家人之间的视频通话，并携带了只能用药分配提示的功能。

本机器人主要由四部分组成。远程控制机制通过TeamViewer实现；药品分配器主要由3D打印材料制作而成；机器人的底盘由亚克力板及部分3D打印材料制作而成；树莓派开发板被用作核心处理器。在搭建完成后，我们的机器人能够满足顾客的基本需求，并且在价格与稳定性上都有较大的优势。

关键词

远景呈现机器人，TeamViewer，树莓派Raspberry Pi，3D打印

Abstract

This project focuses on the designing and manufacturing a healthcare telepresence robot whose cost is much lower than current products in the market. Healthcare Telepresence Robots can be remotely controlled by the caregiver and supports video calls between the elderly and their family members, also it has a smart medicine dispensation function.

The robot is divided into four main parts. The remote control scheme accomplished by TeamViewer, the medicine dispenser which is mainly made by 3D printed components, the chassis made by acrylic boards and also 3D printed components, and Raspberry Pi board as the core processor. After assembly, our prototype is able to meet with the customer requirements and have advantages over other products in stableness and price.

Keywords

Telepresence Robot, TeamViewer, Raspberry Pi, 3D printing

Contents

1 Introduction

1.1 Project Motivation

With the acceleration of life pace, people usually spend more time away from home, causing more loneliness for the elderly. Under this circumstance, caregivers will be worried about physical well-being of the elderly, while the elderly may feel a loss of bond between themselves and their children. Telepresence robot is designed to cope with such scenario because caregivers can communicate and provide care for the elderly by robot when they're away. From emotion perspective, healthcare telepresence robot can play a role as an substitute of the caregivers since it can enhance connection between the elderly and their children. Healthcare telepresence robot for the elderly mainly aims at providing remote care for the elderly when their caregivers are far away from them. Indeed, the robot can provide an alternative other than in-person visits as well as a real network of care.

1.2 Customer Requirement

There have been healthcare telepresence robot products being used in Europe now, and relative research shows they indeed are able to increase feelings of happiness, self-esteem and reduced frustration level of their users. However, they're extremely expensive and difficult to operate because of a great many limitations like unstable network communication caused by firewall. Such problems remain to be solved in the future products.

1.2.1 Problems

1 **Budget**

The budget is under $1000 while current products in the market cost much more than that. The biggest challenge for us is to redesign, simplify the robot while still be able to realize essential functions under a relatively low cost.

2 **Telepresence Technology**

The core of telepresence robot is to establish a stable and simple connection, i.e. telepresence, between the operator and robot. Since firewalls and routers are often used nowadays, there are many obstacles impeding the transmission of control signals, a stable way of telepresence must be guaranteed. Moreover, in order that operator can control the robot at any time and anywhere, operating difficulty must be low enough and portable control devices must be supported.

3 **Stable Control System**

In order to realize reliable control of the robot by caregivers, core processor, actuators and sensors are essential. By giving instructions to the core processor connected to the internet, caregivers should be able to activate actuators. Then feedbacks must be obtained from sensor and notify the status of robot to caregivers. In this way, one of the main tasks of the project is to create a user interface for the robot so that caregivers and robot can interact smoothly.

4 **Functions for the elderly**

Essential functions must be realized on the robot. Mainly, healthcare telepresence robots should provide video call service between the elderly and caregivers. Video call system will also work as a way of navigation for the robot. Another essential function is medicine dispensation. According to relevant research, more than 50% of the older people are living with multiple chronic illnesses[2]. It is important to alert the elderly when it is time for medicine, and bring out what medicine to take now, in case that they become increasingly forgetful of when to take medicine and what to take. On the other hand, the elderly have respective needs and characteristics, the robot must be flexible enough to coordinate with different old people, even the elderly from different countries.

5 **Safety and Power**

Usually, the elderly will spend most time with the robot alone, safety is very important. All sharp edges must be replaced by fillets and soft cushions may become a necessity in case of collision and cutting.

For a movable robot as well as considering the safety, the nominal voltage of the power source should be acceptably low, which is no more than 24 Voltage DC. The batteries should be of high capacity so that the frequency of charging can be lowered, since it is not easy for the elderly to deal with the power shortage problem.

Therefore, the customer requirements for our project are figured out based on main problems of the current product and practical needs of potential users.

- The robot should be simple and cheap enough, which costs less than $1000 but still keeps its essential functions.

- Caregivers can have full control of the robot even when he is very far away. The remote control system should only have short lags and be free from firewall interruption. When caregivers drive the robot remotely, there should be a navigation system for him so that he can sense the environment. The robot structure should be very stable to avoid trembling.

- Caregivers and the elderly can use this robot to make video and audio calls to each other with acceptable video frame drop and clearness. They should able to see each other's face clearly and hear what they say through the screen.

- Caregivers can control the robot to dispense pills to elderly with a stable dispenser. The robot should be able to store the pills for a long time when caregivers is away and the pills won't go bad. In addition, the medicine dispenser should contain an alarm to remind the elderly of the time for medicine.

- Different customers can make minor changes to the robot (e.g. the height of the screen) for individual customization.

1.3 Competitive and Related Products or Technology

1.3.1 Giraffe Telepresence Robot

All the similar products in market right now is much more expensive than $1000, and the most representative product is **Giraffe** designed by a Europe company.

Figure 1: Overview of Giraffe

Giraffe has been put into the market for some time and it does have an effect on providing care and emotional connection to the elderly. However, it still have some problems such as firewall issues, video freezing, driving lag and so on, but it can be a reference based on which we can design and build our own healthcare telepresence robot.

In China, there is no such robot products but some smart furniture can be product for references.

2 Engineering Specifications

2.1 Information Sources

2.1.1 Medicine Dispenser

Background More than 50% of the older people are living with multiple chronic illnesses[2]. Thus, routine monitoring and assessment of the individual's adherence is crucial to improve their health outcomes. Elderly with multiple chronic conditions face the complex task of medication management that can involving multiple medications of varying doses at different times. Advances in healthcare telepresence technologies have resulted in home-based devices for medication management and health monitoring for the elderly[3]. The function of such medicine dispensers is to alert the patient when it is the date and time to take their prescribed pills[4]. When the time comes to take the medicine, the medicine dispenser automatically releases a pre-measured dose for consumption.

Medicine Dispenser Standards[5]

- Audible, visible or vibration alert support
- Lock for safety once medicine is replenished.
- Long distance connectivity to track use.
- Humidity resistant and tamper proof.
- Precise dispensation of required amount and time

2.1.2 Telepresence Robot

Telepresence Robot Standards Telepresence Robots are a very new and unique type of robot in the market nowadays, and since there are standards for collaborative industrial robots (Cobots) and AGVs (automated guided vehicles) our robot would not be included in such standards because

1. Our robot does not include a robotic arm so it is not considered an collaborative industrial robot.
2. Our telepresence robot will be a simplified version of our competitors due to our budget restriction.

We will not be adding any obstacle avoidance sensors, instead, the person controlling the robot is responsible for its movement, thus it cannot be considered and neither can AGVs. The standards we have to abide by will therefore be our electronic components such as battery and CPU, but since we will buy our batteries and CPU from third party manufacturers (already passed safety regulations and standards) we will not have to worry about any hazard as long as we use the equipment correctly according to the manufacturers.

2.2 Engineering Specifications

The custom requirements of our project are divided into the software and hardware part. They are summarized as follows:

2.2.1 Hardware Standard

1. The screen, along with its control buttons, should be large enough.
2. The speaker should be loud enough for the elderly.
3. The height of the screen should be suitable for old people who sit in a chair to watch.
4. The medicine dispenser should be located on a suitable height.
5. The medicine dispenser should have enough storage for one dose.
6. The medicine dispenser should provide dry environment to store the medicine.
7. The moving speed of the chassis should not be too fast or too slow.
8. The duration of the robot should last a long time.
9. The physical entity of the robot does not contain any sharp edges.

2.2.2 Software Standard

1. Control (both local and remote) of the robot should be easy and stable.
2. Alarm function should be added to remind the elderly to take medicine.

Besides these requirements from the two aforementioned categories, the total cost of the robot should be below $1000.

Considering the robot itself, the generated engineering specifications, along with the custom requirements are shown in Table. 1 and Fig. 2.

Item	Unit	Target Value
Budget	US Dollars	< 1000
Moving Speed	m/sec.	0.2-0.5
Speaker Loudness	dB	80
Control Lag	sec.	< 0.5
Video Lag	sec.	< 1
Robot Duration	hours	> 1 (moving)
Video Call Duration	hours	> 3
Inaccuracy of Medicine Dispenser	#Block/Round	< 1

Table 1: Engineering Specifications

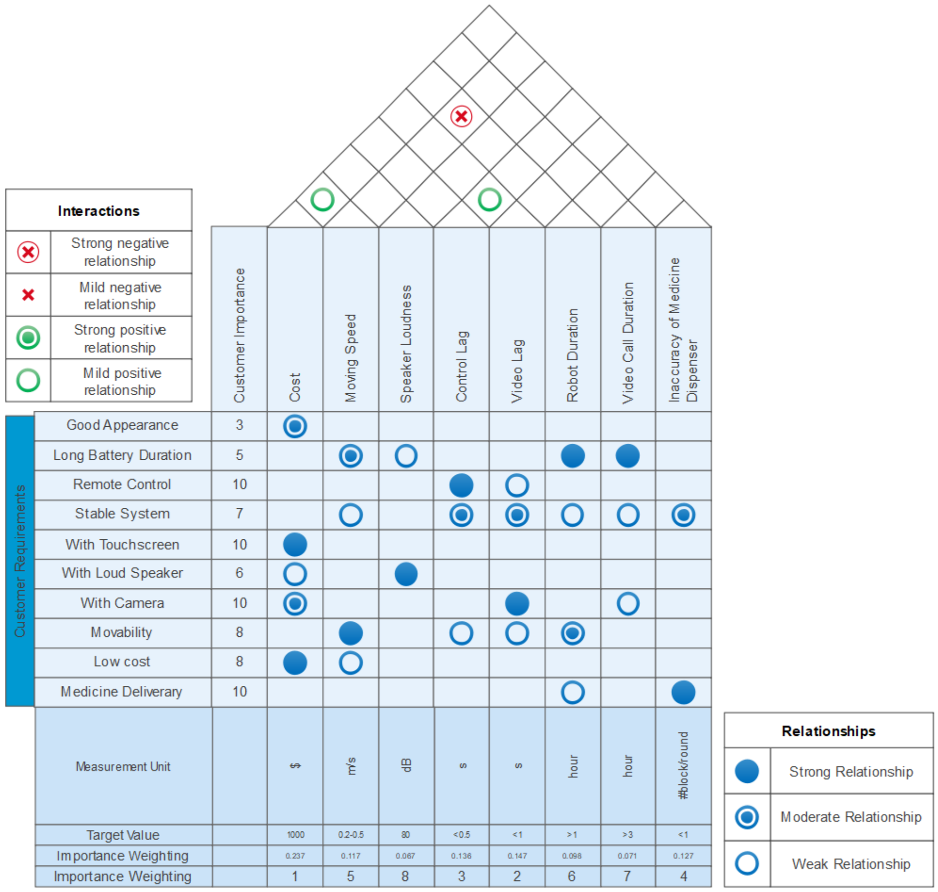

Figure 2: QFD table of our project.

In Fig. 2 above, we list 11 customer requirements and 8 engineering specifications, rate their relationships and calculate the priority. Each strong relationship symbol counts 9 points, each moderate relationship symbol is counted 3, and each weak relationship one is counted 1. Multiply by the importance points of the requirements, we can calculate the weighted average of each specification. The specification with highest weight has the highest priority. We found out that the cost is obviously the most important feature we need to consider, and the video lag and the control lag follow behind. The least important term is the video duration.

3 Selected Concept Description

3.1 Remote Control Scheme

Remote control is the core of the healthcare telepresence robots. We must find not only an easy way to develop as well as to use the function. Generally speaking, this function can be done by developing SSH. However, SSH only works well when the controller and robot is in one internal network, which is a rare case in our project. Otherwise, we need to borrow a server and build socket tunnel, which will add cost and uncertainty to the project and user. Compared to SSH, TeamViewer is a free software, agreeing with our low budget. Since it can be used all over the world, it will not be blocked by firewall. What's more TeamViewer can build connection between the robot with any electronic device, including the mobile phone or tablet, so it provides more remote-control options for our robot. The user interface provided by TeamViewer is also very friendly. For normal customers, they may hate controlling the robot by typing code to it, but with TeamViewer, they can control it by seeing the interface. In conclusion, TeamViewer is the best remote control way for our robot.

Figure 3: TeamViewer as Method for Remote Control

3.2 Medicine Dispenser

For our medicine dispenser concepts we had to keep in mind our budget restraints, our end user, and the safety standards. Which meant that the design had to operate with few electrical components (motors, servos, etc..), to be simple enough to cheaply 3D print, to be easily handled by the elderly and their caregivers and to comply with the safety standards (mainly correct dosages, tamper proof and humidity proof).

The two concepts that were generated were based on the way that the pills would be sorted and delivered to our users. In the first concept the daily medication would have to be sorted by the caregiver and the cocktail of medication would have to be put into each slot manually. The second concept would have blocks in which each block would contain one type of medication, and the system would separate them automatically depending on the demand.

3.2.1 Mixed Pill Manual Sorting

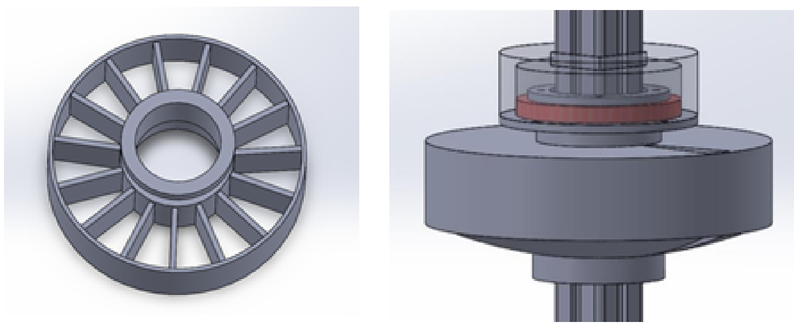

Figure 4: Mixed Pill Manual Sorting Design

The main idea for the first concept was to have the caregiver sort a days' worth of medication and load them into each slot in the dispenser, the dispenser would then rotate at the desired time so that the medication that was in the next slot would fall into a tray and be consumed by the user.

3.2.2 Pill Blocks Automatic Sorting

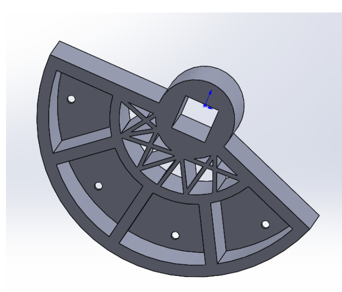

Figure 5: Pill Blocks Automatic Sorting Design

For the Pill Blocks concept the main idea was to have the caregiver load the blocks with the same type of pill, and the system would dispense into a tray the desired amount of each pill at the designated time. Each block would have its own mechanism to make sure that only a single pill would be released at a time, so that the user would have the correct dosage of medication.

3.2.3 Concept Selection Process

With both our medicine dispenser designs, the Mixed Pill Manual Sorting and the Pill Blocks Automatic Sorting being plausible choices for our needs, we will construct a scoring matrix in order to compare them with our requirements (price, user and safety) in order to ensure the best results. We will also talk more about each design's strongest and weakest points, and whether they outweigh our decision in detail.

			Concept 1 (Mixed Pill Manual Sorting)		Concept 2 (Pill Blocks Automatic Sorting)	
Selection Criteria	Rating Importance	Weight	Rating (1-10)	Score	Rating (1-10)	Score
Pill Quantity	Higher is Better	10	4	40	10	100
Ease of Use	Higher is Better	8	4	32	10	80
Manufacturing Cost	Lower is Better	5	8	40	5	25
Manufacturing Complexity	Lower is Better	5	7	35	3	15
Humidity Proof	Higher is Better	15	8	120	5	75
Tamper Proof	Higher is Better	20	8	160	8	160
Dosage Accuracy	Higher is Better	37	8	296	4	148
			Total =	723	Total =	603

Figure 6: Concept Selection Scoring Matrix

We can see from the criteria and the weights that the safety aspects of our medicine dispenser outweigh the usability and cost. Therefore since our Mixed Pill Manual Sorting concept has a higher score we have chosen to pursue this design.

The main benefit of Concept 1 (Mixed Pill Manual Sorting) is its simplicity and reliability, there is very little room for error since the caregiver is sorting the medicine dosages and the mechanism safely stores them until the predetermined time in which the dosage is dispensed using an accurate stepper motor which always knows its current position in the 360° movement. And this reliability is crucial when leading with something as important as someone's medication. Its weak point would be the refilling of medication, where the caregiver would have to manually sort the medication and insert each cocktail into the separate compartments, making it less user friendly.

For our second concept (Pill Blocks Automatic Sorting) the main benefit would be its autonomous sorting, where the caregiver would only have to pour the pills into each block and not have to sort them. The biggest downfall with the design also comes from this autonomous feature, since it is very hard to sort medication of different sizes, colors and textures, it makes the dosage accuracy (most important criteria) low. In order to ensure correct dosage, we would have to have a mechanism in each block that only lets one pill through at a time (which is very hard for different pills) and a checking system to make sure that there will not be two pills or no pills being dispensed, because an over dosage or under dosage could cause serious repercussions. Therefore an automatic sorting mechanism would be overly complicated and expensive to manufacture with our required safety specifications.

3.2.4 Overview of Selected Concept

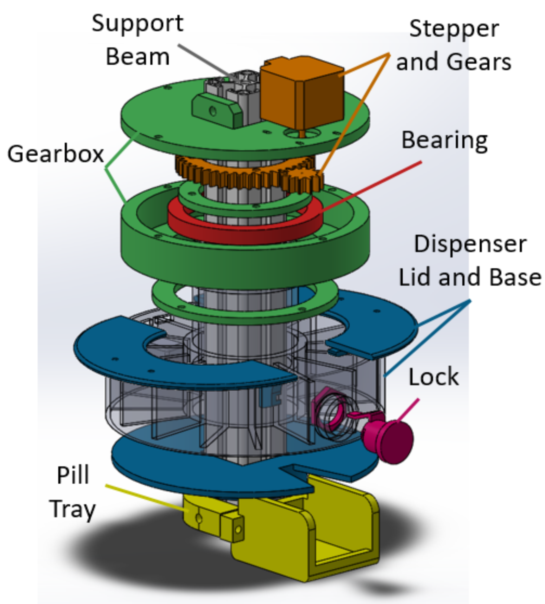

Figure 7: Explosion View of Medicine Dispenser

Our chosen concept has five sections as we can see in Fig. 4. The stepper motor, gears and bearing (orange and red) are responsible for the movement of the dispenser base. The support beam (silver) is connected to our chassis, and it supports the gearbox, bottom dispenser base and the pill tray which are all fixed to it. The gearbox (green) houses the moving parts so they are safely away from the users as well as keeps the dispenser suspended and rotating freely with the bearing. The dispenser lid and base (blue and transparent) house the pill boxes and keep them humidity proof. The lock (pink) locks the dispenser lid in place so that once the pill boxes are inside the dispenser they are tamper proof. And finally the pill tray (yellow) receives the pill boxes once they drop from the dispenser, making it easy for the user to administer the drugs.

3.2.5 Engineering Design Analysis

Medicine Dispenser Our first design iteration started with the barebones of the system:

1. Dispenser frame which would house the pills.
2. Bottom dispenser which would only allow one dosage to be administered per time.
3. Pill tray for easy access to the medicine.
4. Gearbox for our bearing and gears.

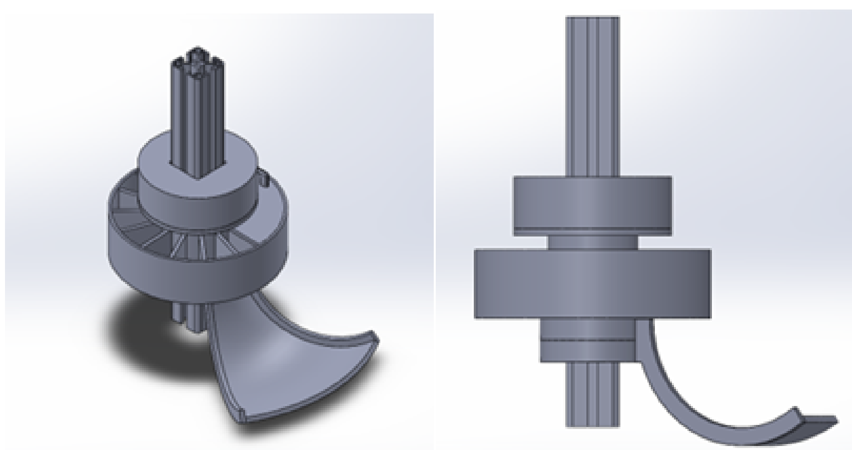

Figure 8: First Iteration of Medicine Dispenser Design

Dispenser frame Our initial design was built with 31 partitions for one month use of dosages, but the pills were to be directly deposited into each partition; this was a problem because the pills would move with the dispenser frame while they scrapped against the bottom dispenser which is fixed. This design would both cause damage towards the pills as well as make it hard for us to block humidity out of the system. There was also a clearance problem between the gearbox and the dispenser frame which was too short to comfortably deposit the pills into their partitions. The last issue with our frame was the lack of a locking mechanism to keep the pills tamper proof. Our solution to these problems was to decrease the number of partitions to 15 for two weeks of use, making each partition big enough to fit a pill box, which would simultaneously keep the pills humidity proof and prevent them from scratching against the bottom dispenser, for the clearance problem we elongated the frames connection to the bearing by 50mm which allowed comfortable user experience, and finally we adapted the frame to include a two point of contact lid and a hole for the lock in one of the 15 partitions.

Bottom Dispenser The first design of the bottom dispenser was a curved half sphere shape so that the pills would be able to slide toward the center closer to the support beam, and be able to slide easier when reaching the pill tray, but this design was quickly modified due to the difficulty of 3D printing and the introduction of our pill box.

Pill Tray In order to make it easier for the users to access their medication, a pill dispenser was designed with a slide shape to ensure the safety of the medication once it was dropped from the dispenser. The slide design was modified because of the difficulty to 3D print the design as well as the change from individual pills to the pill box, which would mean the tray would have to "catch" a little box full of pills instead of multiple individual pills.

Gearbox Our gearbox for the first design iteration was very incomplete, with only the bearing and frame fixture being designed, it was one of the sections that most needed development once the concept was chosen. For the second iteration of the design the gearbox was modified to be run by a servo motor that was connected to two helical gears, which would turn the dispenser frame. The power input for the gearbox was another item that needed multiple iterations. Since our servo motor could not be controlled with our required accuracy. We switched to a small stepper motor, which was able to control our dispenser accurately (the gears were also designed so that 48 steps would equal one iteration), but only when it was empty, for the added friction of the pill boxes would change the number of steps for each iteration. So lastly we designed the gearbox to be run by a stronger and more accurate stepper motor (400 steps per iteration), which fulfilled all our needs of accuracy and power. The three designs of the gearbox lid can be seen in Fig.5 below.

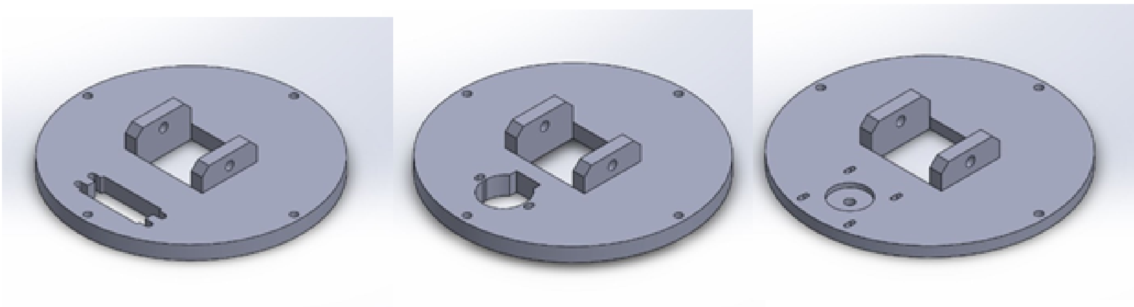

Figure 9: Gearbox Lids for Servo, Small Stepper and Large Stepper Motors

In our completed design iteration in Fig. 6 below we can see that all the necessary components are designed and bought (bearing, stepper motor and lock) or 3D printed (gearbox, gears, dispenser and pill tray) to meet our engineering specifications and requirements.

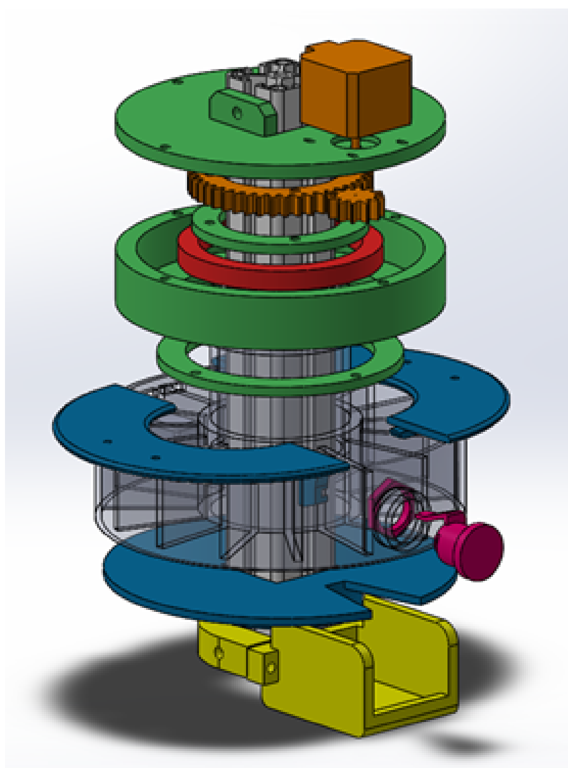

Figure 10: Completed Design of Medicine Dispenser

3.2.6 Design Description

In our component list Fig. 11 below we can see the 18 parts that compose our medicine dispenser. All parts are 3D printed except for the bearing (item 6 in Fig. 11), the stepper motor (item 4 in Fig. 11) and the lock (items 14 and 15 in Fig. 11) which were purchased. The whole assembly (without aluminum extrusion) measures in 220mm tall and 192mm x 180mm wide. The individual parts and their dimensions can be found in Appendix I. The working principal of the system starts from the stepper motor (item 4 in Fig. 11), which is fixed to the small gear (item 12 in Fig. 11) which in turn rotates the bigger gear (item 11 in Fig. 11). The bigger gear is fixed to the top dispenser (item 2 in Fig. 11), and when it rotates the programmed steps it will drop the pill box (item 13 in Fig. 11) onto the pill tray (item 17 in Fig. 11). From there the user has access to their pill dosage.

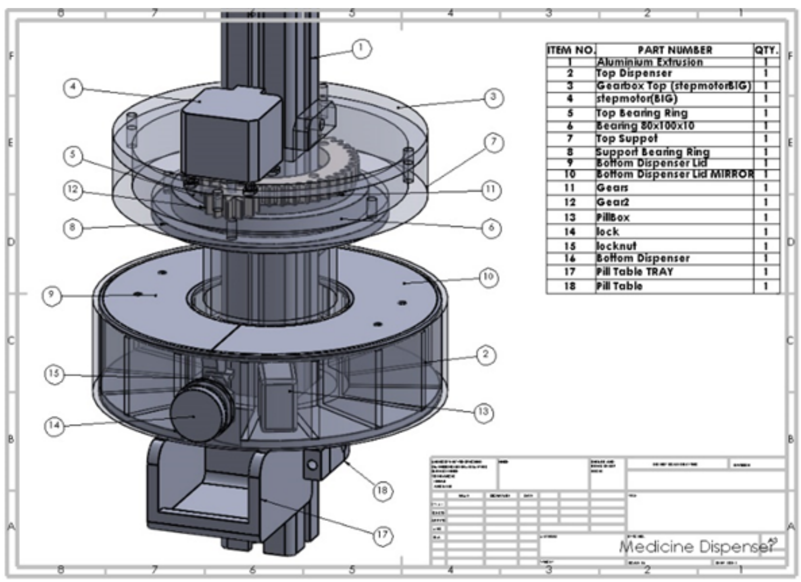

Figure 11: Medicine Dispenser Bill of Materials

3.3 Software Implementation

From the software side, the engineering specifications and custom requirements of our design indicates implementation in the following three areas:

1. The control system which control the movement of the chassis

2. The communication system that allows remote control of the robot

3. The video streaming system

3.3.1 Control System

Raspberry Pi is a microcomputer with many I/O interface. Compared to normal computers, it is much cheaper and simpler given to its ARM structure. It also has a smaller volume and energy consumption, which makes it more flexible and suitable for a robot working for a long time. However, it is much more advanced than Arduino. Thanks to its own linux operating system, we can develop and run various softwares on Raspberry Pi and control the movement of the robot freely. Another huge advantage of Raspberry Pi is that it has a user interface and Internet connection, making it more user friendly. Therefore, Raspberry Pi is the best central core for the telepresence robot.

Figure 12: Raspberry Pi Board

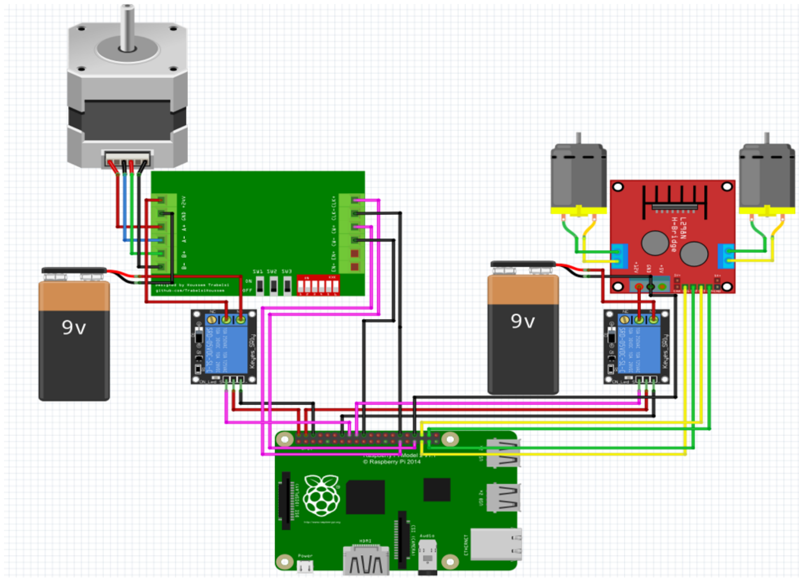

Figure 13: Circuit Design of the Control System

The Raspberry Pi board contains a set of general purposed input output (GPIO) pins. Through these IO pins, we are able to control the movement of the robot. The physical circuit is shown in Fig. 13. The control program is shown below.

```
from bottle import get, post, run, request, template
import RPi.GPIO as GPIO
import time
import sys
reload(sys)
sys.setdefaultencoding('utf8')

LeftM1 = 38
LeftM2 = 36

RightM1 = 37
RightM2 = 35

StepperStep = 33
StepperDir = 29

MovePin = 11
MDPin = 13

def setUp():
  GPIO.setmode(GPIO.BOARD)
```

```
  GPIO.setwarnings(False)
  GPIO.setup(MDPin, GPIO.OUT)
  GPIO.setup(MovePin, GPIO.OUT)
  GPIO.setup(LeftM1, GPIO.OUT)
  GPIO.setup(LeftM2, GPIO.OUT)
  GPIO.setup(RightM1, GPIO.OUT)
  GPIO.setup(RightM2, GPIO.OUT)
  GPIO.setup(StepperStep, GPIO.OUT)
  GPIO.setup(StepperDir, GPIO.OUT)
  for pin in OldStepper:
    GPIO.setup(pin, GPIO.OUT)

def forward():
  GPIO.output(LeftM1, GPIO.HIGH)
  GPIO.output(LeftM2, GPIO.LOW)
  GPIO.output(RightM1, GPIO.HIGH)
  GPIO.output(RightM2, GPIO.LOW)

def backward():
  GPIO.output(LeftM2, GPIO.HIGH)
  GPIO.output(LeftM1, GPIO.LOW)
  GPIO.output(RightM2, GPIO.HIGH)
  GPIO.output(RightM1, GPIO.LOW)

def turnLeft():
  GPIO.output(LeftM2, GPIO.HIGH)
  GPIO.output(LeftM1, GPIO.LOW)
  GPIO.output(RightM1, GPIO.HIGH)
  GPIO.output(RightM2, GPIO.LOW)

def turnRight():
  GPIO.output(LeftM1, GPIO.HIGH)
  GPIO.output(LeftM2, GPIO.LOW)
  GPIO.output(RightM2, GPIO.HIGH)
  GPIO.output(RightM1, GPIO.LOW)

def stop():
  GPIO.output(LeftM1, GPIO.LOW)
  GPIO.output(LeftM2, GPIO.LOW)
  GPIO.output(RightM2, GPIO.LOW)
  GPIO.output(RightM1, GPIO.LOW)
  GPIO.output(StepperStep, GPIO.LOW)
  GPIO.output(StepperDir, GPIO.LOW)

def stepperForward():
  GPIO.output(StepperDir, GPIO.HIGH)
```

```
  for i in range(0, 1600):
    GPIO.output(StepperStep, GPIO.HIGH)
    time.sleep(0.001)
    GPIO.output(StepperStep, GPIO.LOW)
    time.sleep(0.001)
  time.sleep(0.5)

def MoveOn():
  GPIO.output(MovePin, GPIO.HIGH)

def MoveOff():
  GPIO.output(MovePin, GPIO.LOW)

def MDOn():
  GPIO.output(MDPin, GPIO.HIGH)

def MDOff():
  GPIO.output(MDPin, GPIO.LOW)

def main(status):
  setUp()
  if status == "front":
    forward()
  elif status == "leftFront":
    turnRight()
  elif status == "rightFront":
    turnLeft()
  elif status == "rear":
    backward()
  elif status == "stop":
    stop()
  elif status == "leftRear":
    stepperForward()
  elif status == "rightRear":
    stepperBackward()
  elif status == "MoveOn":
    MoveOn()
  elif status == "MoveOff":
    MoveOff()
  elif status == "MDOn":
    MDOn();
  elif status == "MDOff":
    MDOff();

@get("/")
def index():
```

```
114   return template("index")
115
116 @post("/cmd")
117 def cmd():
118   adss = request.body.read().decode()
119   print("Button Pressed:" + adss)
120   main(adss)
121   return "OK"
122
123 run(host="0.0.0.0")
```

In the first part of the code, the pins are defined. (See Line 8 to Line 18) The initialization of the pins are done in the function setUp. (See Line 20 to 32) The following functions forward, backward, turnLeft, turnRight, and stop (see Line 34 to Line 64) is the movement control function for the chassis. As is shown in Fig. 13, the chassis is controlled by two DC motor using L298 board. To start these motors we can simply output high voltage to the corresponding pins.

The control of the stepper motor, on the other hand, is more complicated (See Line 66 to Line 73). Here we implement Pulse Width Modulation (PWM) to control the precise angle for the motor to rotate. The two function stepperForward and stepperBackward are designed to make the motor rotate clockwise and counter-clockwise respectively. However, here we wrote the implementation of PWM for two different type of steppers for test purpose. In this report, the PWM control of the new stepper motor will be explained, which is implemented in the function stepperForward. By trial and error, we ordered the PWM repeat 1600 times to make dispenser rotate for one block.

The last part of the control program is the main function and the functions to realize the listen utility provided by the bottle library in python. The main function set up all the pins and execute a function based on its input (See Line 87 to Line 110). Using decorators, we define two further functions to use the bottle library (See Line 116 to Line 121). The first function is used for request routing. The second function is used as event handler when user issued some control command via our web page interface. The detailed information of this user interface will be included on the next section. Last, we start a local server to listen to user commands (See Line 123).

3.3.2 User Interface

As mentioned before, we use TeamViewer as the remote control scheme, The inclusion of TeamViewer aligns well with our custom requirement and engineer specifications because it supports multiple platforms and offers stable connection. Also, TeamViewer offers a private communication channel due to the 256 bit AES encryption scheme it adapts. The graphic user interface of the control program is shown in Fig. 14. The website coding and the script for the website is intuitive. Every time a button is pressed on the website, the website will post a ”/cmd” request to the control program, which will then call the main function. The detailed description for the functions from the bottle library can be found through the website `https://bottlepy.org/`.

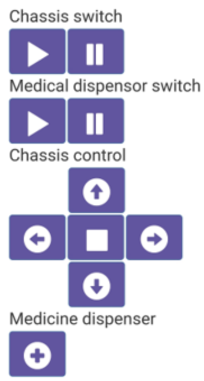

Figure 14: User Interface of the Control System

In order to remotely log in the Raspberry Pi and the pad, we need a remote control system. We decide the use a developed software called TeamViewer to realize this function.

3.3.3 Video Streaming System

To realize video communication with the elderly and provide visual guide for remote control of the movement of the robot, we need a video streaming system to give real-time information to the user. For this sub-system, we have tried two different implementations. The first approach is to write a streaming application by ourself. We bought a screen, a camera, and an audio output that is compatible with Raspberry Pi, as is shown in Fig. 15.

We managed to realize the video streaming system using the application program interface (API) provided by v4l2 drive and displayed the camera view on the same web page as in Fig. 14. However, we encountered the following problems

1. We were only able to stream the camera view on Raspberry Pi to the web page. We also needed to stream from the user’s device back to the screen.

(a) Screen (b) Audio output (c) Camera

Figure 15: The equipment initially used for the video streaming system

2. The streaming quality of our implementation was poor. There were sever video lags.

3. We only streamed the video information. To realize the video communication system, we also needed to record sounds from both sides, output them to the corresponding devices, and performed synchronization with the video streaming.

Solving these problems involves much programming in the hardware level, which is complicated and tedious. Meanwhile, we had only spent 1/5 of our budget. Therefore, we decided to buy a windows pad of which the video communication system is already implemented. With this pad, the video communication is very straightforward. We use apps such as WeChat or QQ to realize this function. Also, we can remote control the pad using TeamViewer.

Figure 16: Windows 10 Pad for Video Steaming

3.4 Chassis

Considering the end user of our product, the design of chassis requires a lot of considerations as well. First of all, it should be stable enough to support a one-meter-long aluminum rod with a bunch of components installed on it. It should have a particular traffic ability such that it can move freely in narrow places at home. Also, it should have enough space to plant electrical components and batteries, and cover them well so that no dangerous components are outside to hurt the elders. Finally, it should look well, give the users a good impression.

3.4.1 Version I

The first version of the chassis has come up at the very beginning of this project. Since the upper part of the robot had not been designed, the chassis was made as general as possible. It consists simply two round acrylic boards, with an array of holes for further assembling. It is only for temporary use, so the details are not put into consideration.

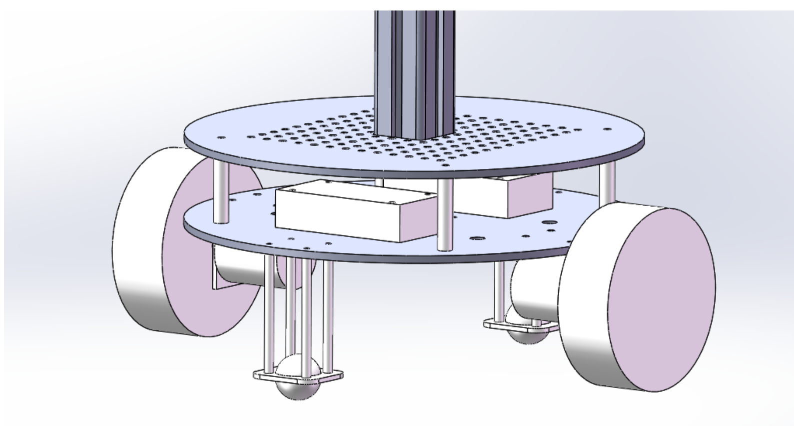

Figure 17: Chassis Design Ver.1 (old)

3.4.2 Version II

The new version was updated basing on the use experience of the old one. In the new design, we fixed the existing problems. First of all, our team found out the old one is not stable enough. Because of the usage of universal wheel, the whole robot would wobble while we control it to turn. Therefore, we lowered the chassis, and used a universal ball instead. Also, to increase the stability, we change the shape of the acrylic boards from a round into a circumscribed square of it, which increases the space to set the electrical components at the same time, while the trafficability is not changed (since the width are the same.) Another improvement is the assembling method of the aluminum rod. In the old version, there was no consideration on how to assemble the rod onto the chassis, so what we did was fixing an aluminum cross on it and screwing the rod on the cross. It was not only ugly, but also dangerous, since there were too much sharp edges exposed outsides. In the new version, we make one square hole for the rod, so it can stick inside. For the same reason, we hide the wheels inside the chassis, so it is well-packaged.

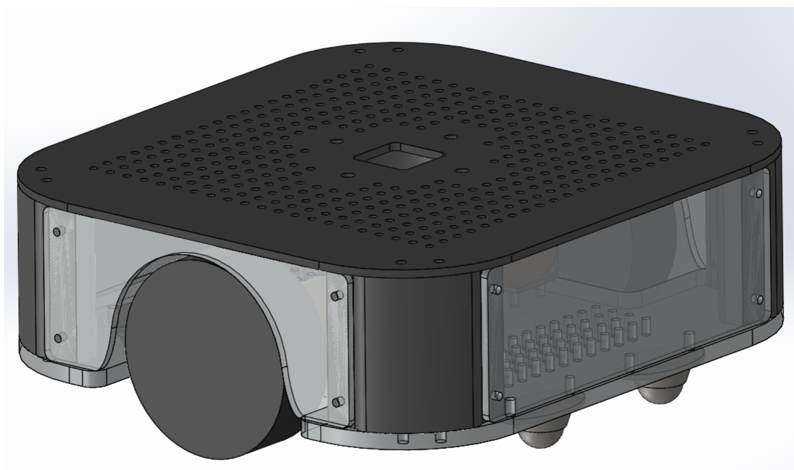

Figure 18: Chassis Design Ver.2 (new)

3.4.3 Overview of Selected Concept

The final chassis we use is shown in fig. XI. As we can see, all the components are set between the upper and lower boards, therefore, it is both stable and safe. We use the universal balls at the front and the back, so that the weight center of the robot will not change during turning process. The driving wheels are directly connected to the motors, which are controlled by a Raspberry Pi just near them. Aside of them, are batteries supplying power for both chassis and upper components. Also, a square hole is prepared for the aluminum rod, so that the connection between chassis and upper components are stable.

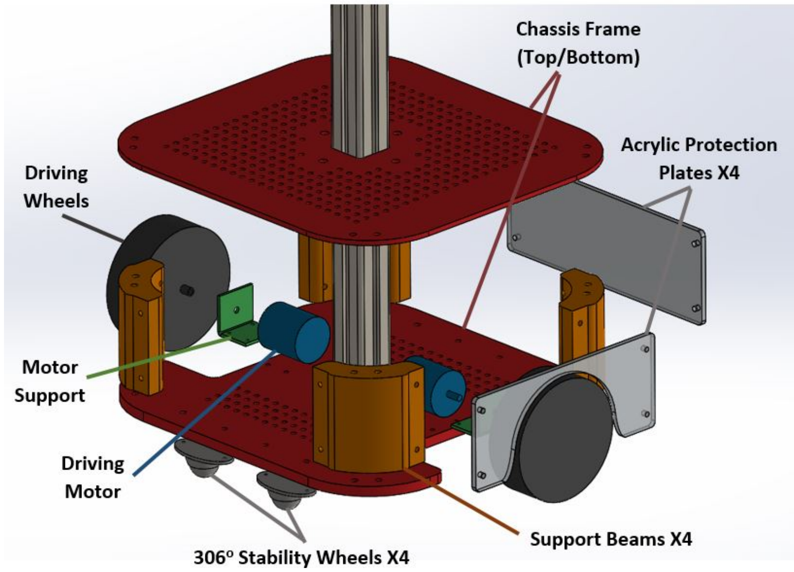

Figure 19: Explosion View for Chassis Design Ver.2

3.5 Manufacturing Plan

The list of materials and components needed to build the robot are listed in Tab. **??** in Appendix. To build the mechanical part of the robot, basic tools such as screw driver, file, hammer, saw, wrench, and electric soldering iron are needed. They are very common in a machine workshop. The assemble of all the components will take a team of 4-5 people approximately one day of time.

The acrylic boards of our chassis are designed by ourselves but manufactured by Taobao shop. The drawing of the upper and lower boards is shown below. The two motor and all wheels (including universal wheels and the driving wheels) are chosen and bought under the consideration of its specifications. The four pillars supporting the upper board were 3D printed, in order to match the shape and height, so that the out-look of the chassis would be smooth. Also, the aluminum rod should be connected with the upper board with four angles that were specially made for this rod, which were purchased along with it.

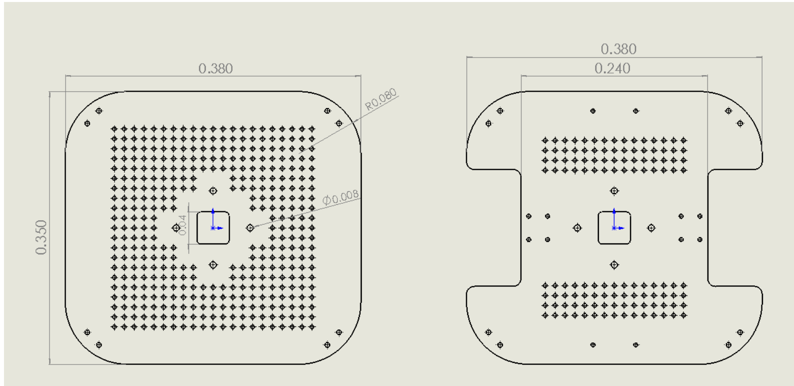

Figure 20: Layout of Chassis with Dimensions

In addition, most of our medicine dispenser parts/components (around 90%) are 3D printed using a common PLA printer. The only parts that were bought were the bearing, the stepper motor and the lock, apart from the screws and bolts. Therefore the manufacturing process was mostly designing the dispenser to the correct dimensions to house the parts that were bought accordingly. We did design the 3D parts to fit tightly, so some filing of fittings had to be done to ensure a perfect fit. Our lock bolt was also slightly modified since it as too big for its intended location, we had to bend it, cut it and file it down, having our CAD drawing as a reference for angle and size.

Our tolerances are not very rigorous, as parts that have to come together tightly are designed with the same diameter and filed down for a perfect fit, while other parts that have to fit into one another easily are designed smaller to have no interference. The gearing is also designed so that the stepper motor can be moved 2mm forward or backwards to fit perfectly. So the more important tolerances would be in the holes, having them align and be of the correct dimension so that screws can be accurately inserted and secure the system. And less tolerance in the parts that fit in one another such as the dispenser lids and the bottom dispenser, since they work as intended even if manufactured with less tolerance.

3.6 Validation Plan

There are three major criteria to evaluate the quality of the product: the chassis movement, the medicine dispenser, and the remote video communication. Here we will present experimental set up to test their corresponding engineering specifications. For other engineering specifications such as the loudness of the speaker, the volume of the battery, the height of the screen, and the screen resolution, they can be directly measured or validated by reading the manual for each component used.

3.6.1 Robot Movement

To set up this experiment, a clear field is needed with a line of length 5 meters measured. The robot is placed at one end of the line. At the other end, a chair with person sit on it should be placed in a different direction with the robot. Through remote control, the robot should be able to forward in a straight line for the 5 meters, and then turn to the person. The user that control the robot cannot see the situation in the field directly. He or she can only move the robot using the view provided by the camera on the robot.

In this experiment, we will validate the moving speed of the robot and the video streaming specification.

3.6.2 Medicine dispenser

The experiment is set up in 10 rounds. In each round, we fill in the medicine dispenser with pills. Then we rotate the dispenser 14 times and see if the pills can be correctly dispensed. The number of failures are recorded. In each round, pills with different weights should be applied.

In this experiment, we will validate the functionality of the medicine dispenser, as is required by the engineering specification.

3.6.3 Remote Video Communication

To perform this experiment, we need another stable video communication tool as a reference. We turn on the video communication utility of the robot and the reference tool at the same time. Then a third person will shoot the video conference using a camera. By analysing the time delay between the streaming of these two tools, we are able to get the delay of the video communication utility of the robot.

In this experiment, we will validate the engineering specification for the video communication lag.

4 Project Timeline and Plan

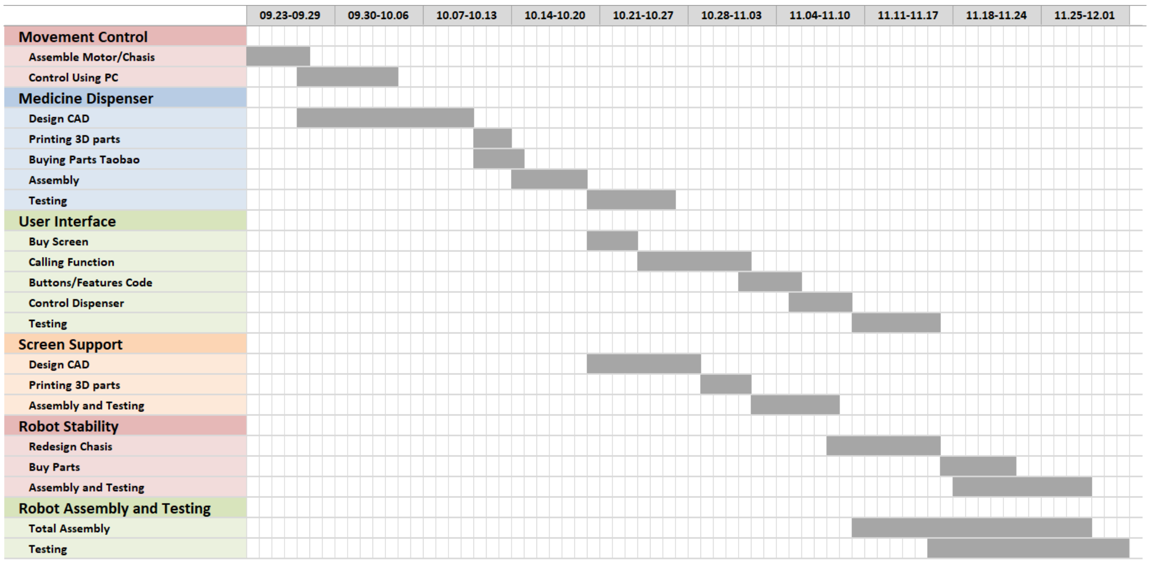

Figure 21: Gantt Chart

Up to now, we have completed all parts of the manufacturing and testing for the robot. From Design Review 3, following parts have been improved:

1. We have changed the lower chassis plate from 5mm thick to 8mm thick, which will definitely more difficult to bend. Also the upper plate and the lower plate have been linked together by long screws and supporting pillars to be kept parallel.

2. We have added relays (switches) to DC motors for robot moving and stepper motors for medicine dispenser's rotation. Since stepper motor will be self-locked when powered but not triggered. We use signals to control the power. This increases stepper motor's duration to a great extent. The degree of safety will also increase.

3. We have made the robot fancier and more appealing, all electrical structure has been hidden between two plates of chassis, and shields on the four sides are installed to make the structure unreachable.

4. We have added medicine taking alarm to alert the elderly to take the pills. It will also notice the caregiver when it is time for the elderly to take pills.

5 Analysis of Problems

Due to the limit of time, our prototype still have many shortcomings and can be improved in the future as follows:

1. The inaccuracy of the medicine dispenser is still too large, the inaccuracy should be further reduced. A stronger stepper motor that can deal with friction should be installed.

2. The storage of the medicine dispenser is still too small. 14 blocks can only meet the need of 7 days if twice a day (and only 4 days if three times a day). Moreover, current pill box can only contain small pills but cannot deal with medicine such as oral liquid. A better medicine dispenser should be designed and manufactured.

3. Collision avoidance and advanced navigation scheme should be applied. Currently there is no distance sensor in the lower chassis, which may cause safety issues. And the only navigation is from the windows pad on the top. More cameras must be installed to ensure more angles of navigation.

4. Tremble when the robot starts to move exists so that the robot may not move in the right direction, also the robot cannot move in a very straight line (severely affected by the quality of the ground). From straight move problem we may replace the current DC motors with more advanced motors with encoder so that we can keep the speed of rotation the same. We are not able to find ways for the tremble problem right now. We may further try to stand the main structure on an AGV with better movement system to avoid this problem.

5. Power supply should be integrated to one. Currently the power sources are separated and are placed in different places. Doing the integration means easier way for wire connection and re-charging.

6. The customization should be more free for the elderly. Currently the height of medicine dispenser and the screen, as well as the angle of the screen is locked as soon as they are settled. The structure should be further improved to be both stable and adjustable.

7. The privacy protection scheme should be improved. Currently the elderly can only passively accept the healthcare. In the future prototype, we need to enable the elderly to control the robot and have the authority to choose the service from the robot.

6 Conclusions

Telepresence robot is still a relatively new technology in which a person can transmit his ”presence” by controlling a robot with his projection on a screen, the idea is that someone can be ”present” in the room even though they are located anywhere in the world. Telepresence robots can be particularly useful for elderly care, where family members can control the robot and give attention to the elderly on a more regular basis, with additional functions such as being able to monitor the medication intake and being alerted when a fall has been detected. Thus the elderly do not necessarily have to move to elderly care homes, instead they can remain in the comfort of their homes while still receiving the proper attention and care necessary.

However, current telepresence robots for the elderly are expensive according to the users[6] , around 5 to 15 thousand dollars for a model, the persistent connectivity issues also make it hard to operate and control, causing a negative feedback from the elderly and caretakers alike[7].

We took about 2 months to finish the design, manufacture and assemble the entire robot, with the cost of only 3000 RMB. It successfully fulfilled all the requirements. However, due to time limit, we are not able to take every circumstance into consideration and have a better design.

In general, we think our project delivery is quite successful. Future group that is going to work on similar project can definitely obtain experience from ours and we are looking forward to the project being put into market in the future.

7 References

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8 Appendix

8.1 Detailed Design for Components of Medicine Dispenser

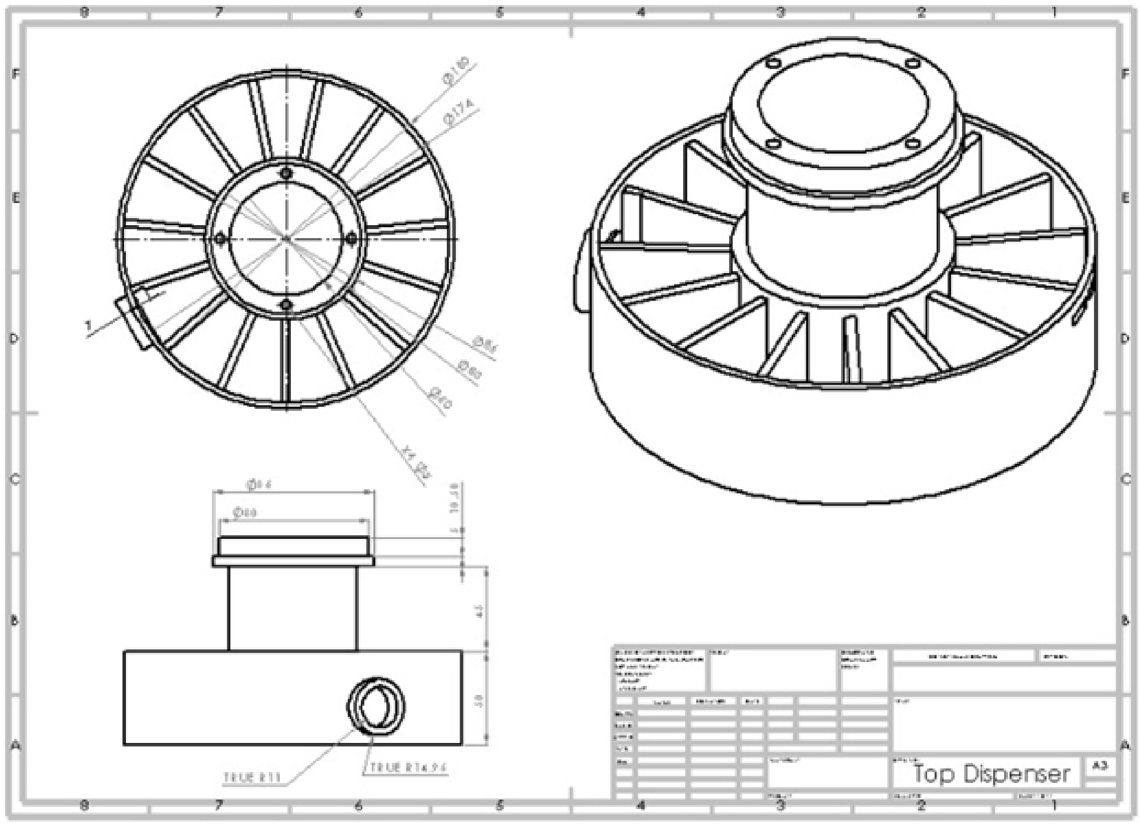

Figure 22: Top Dispenser Drawing

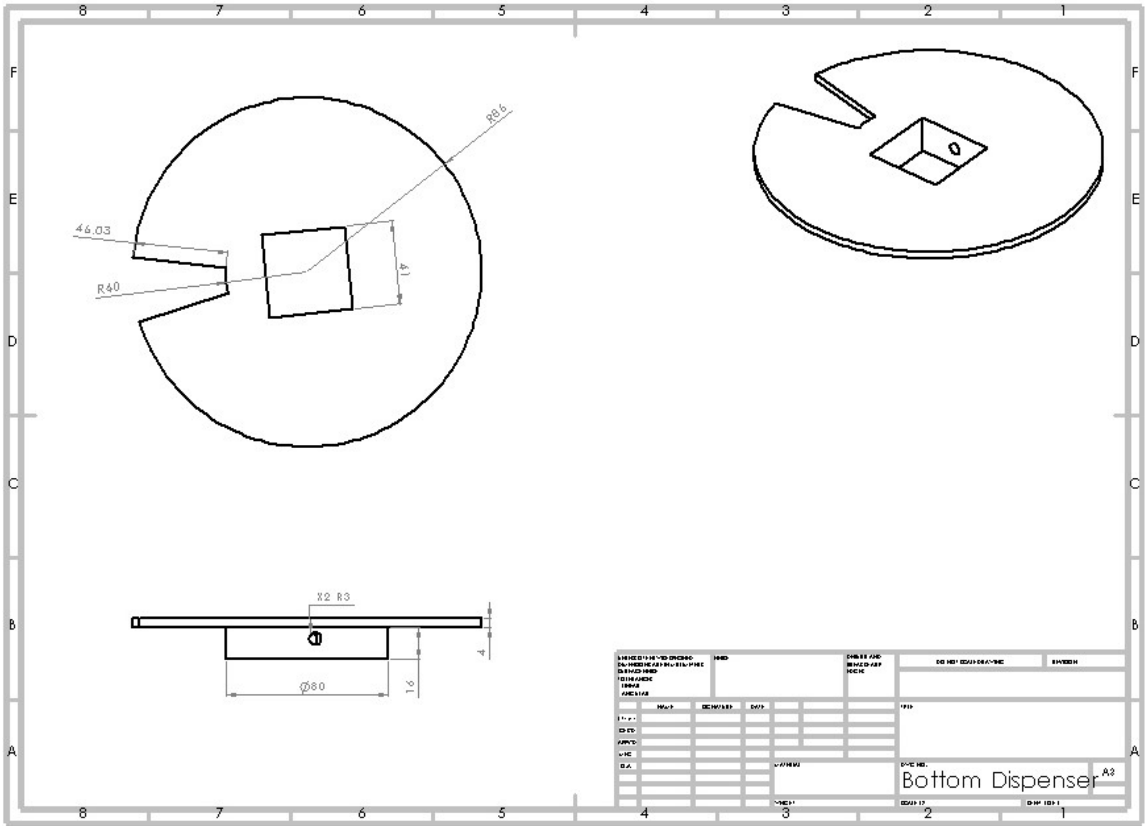

Figure 23: Bottom Dispenser Drawing

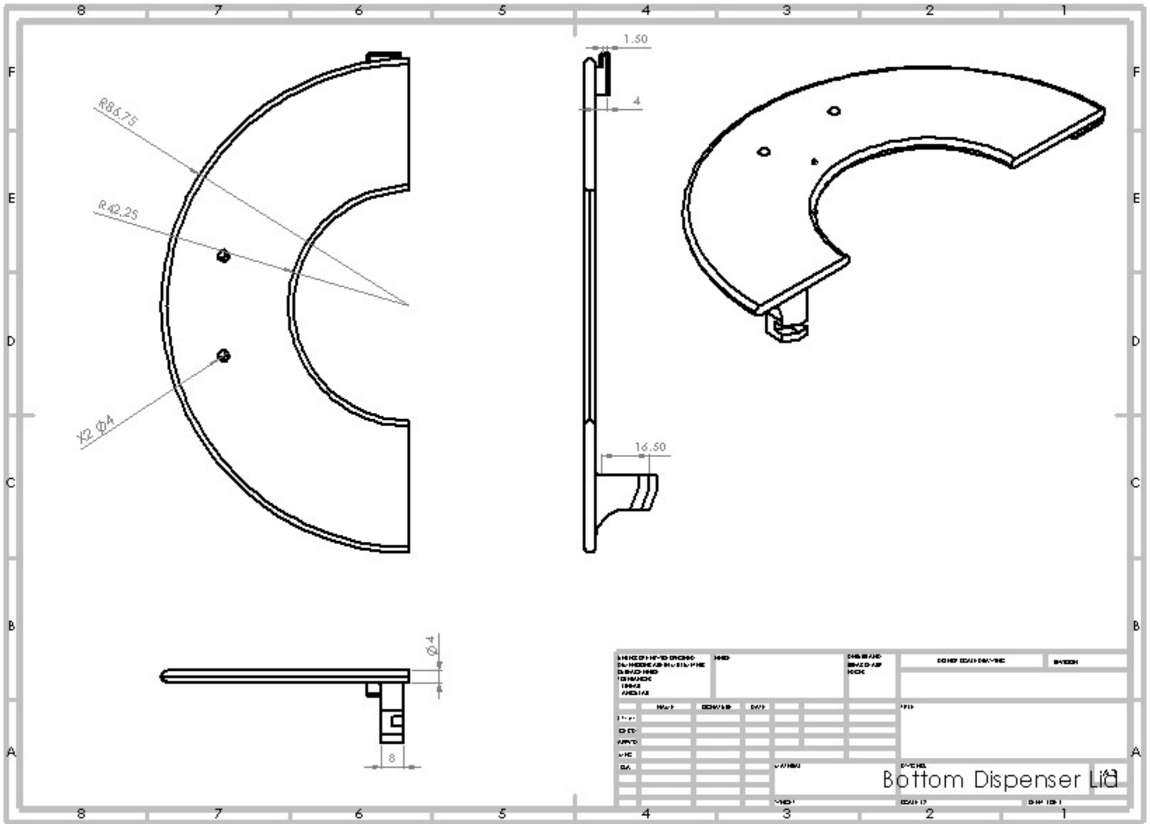

Figure 24: Bottom Dispenser Lid Drawing

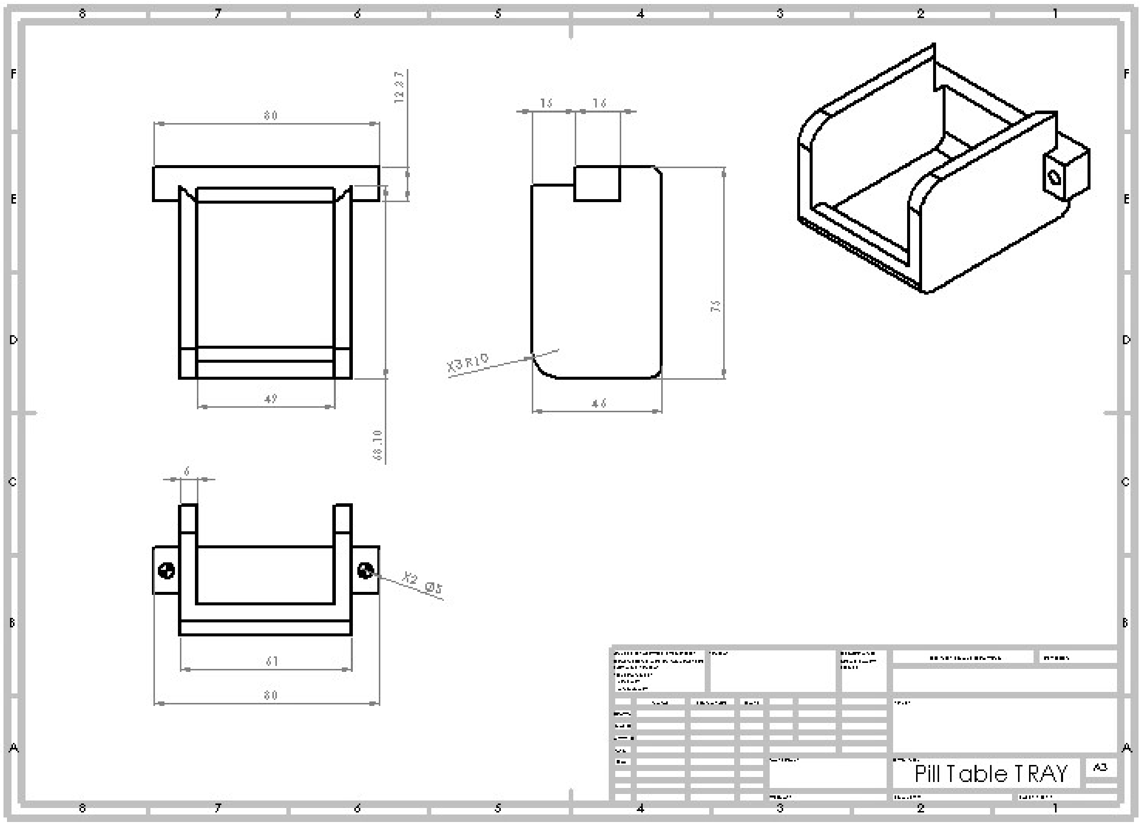

Figure 25: Pill Table Tray Drawing

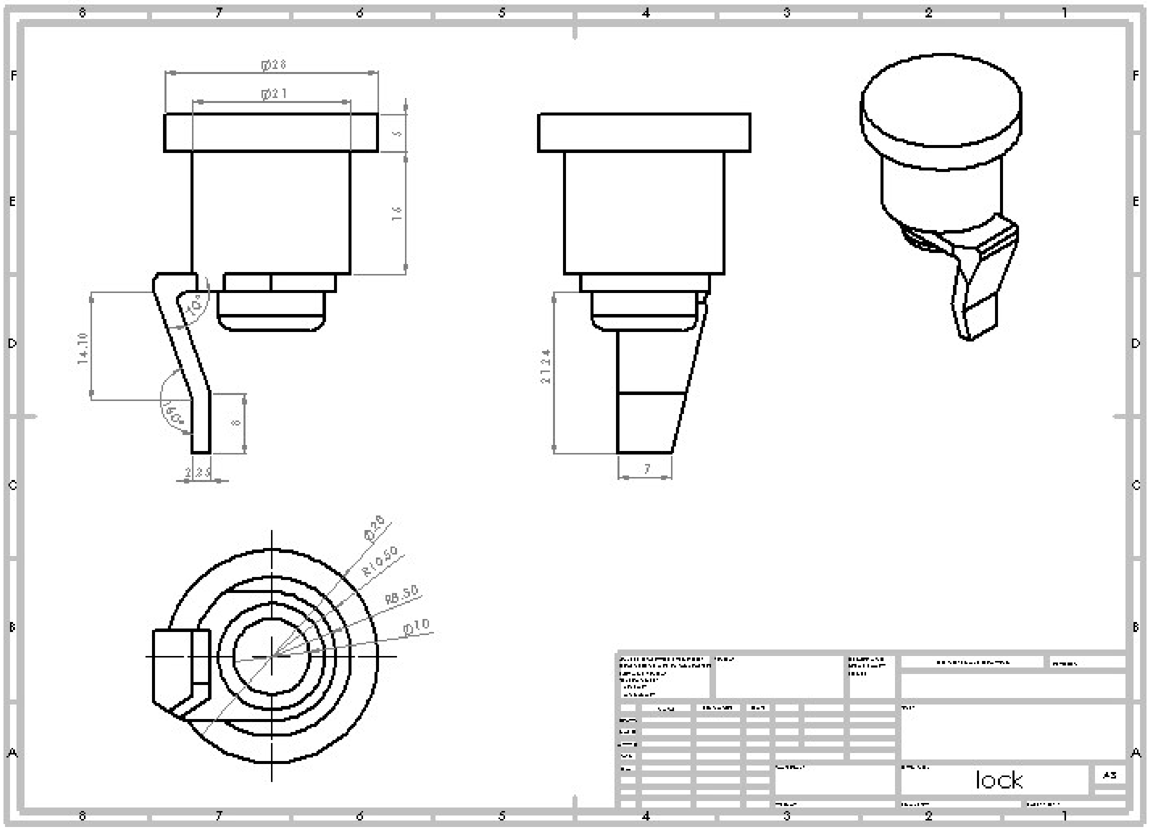

Figure 26: Lock Drawing

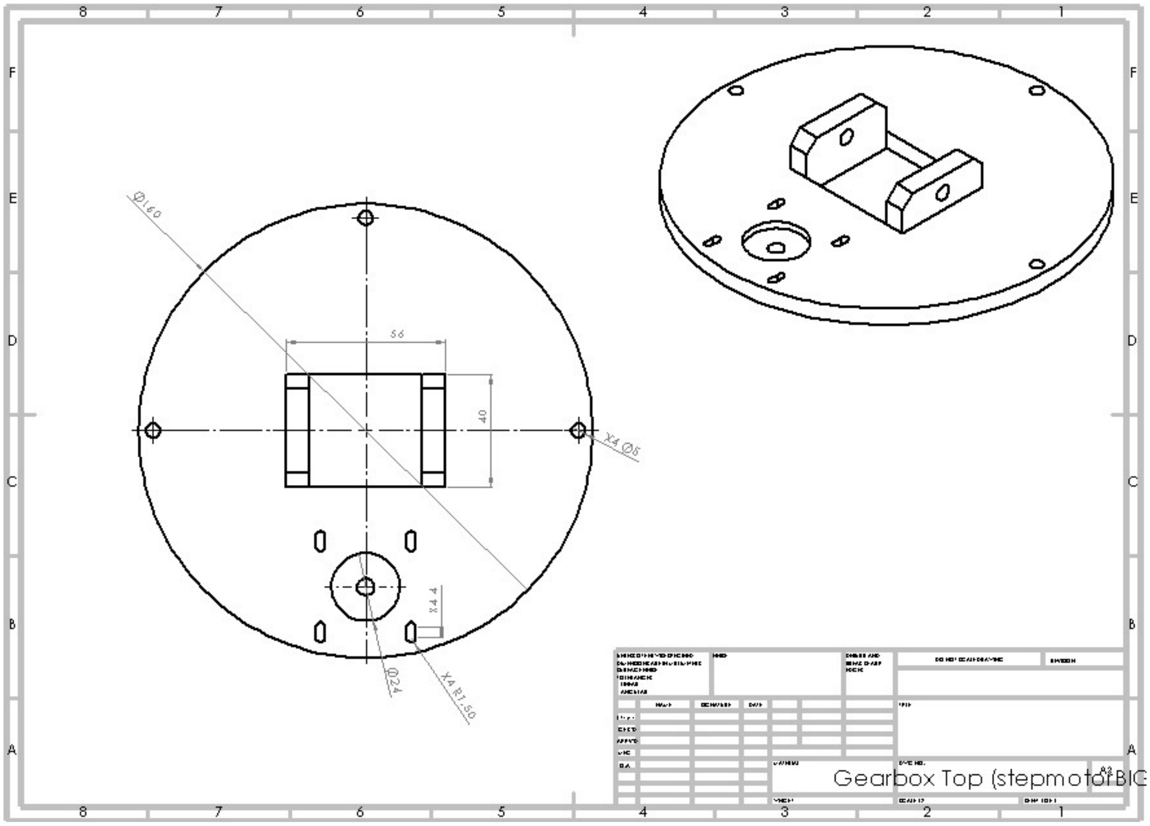

Figure 27: Gearbox Top (steppermotor BIG) Drawing

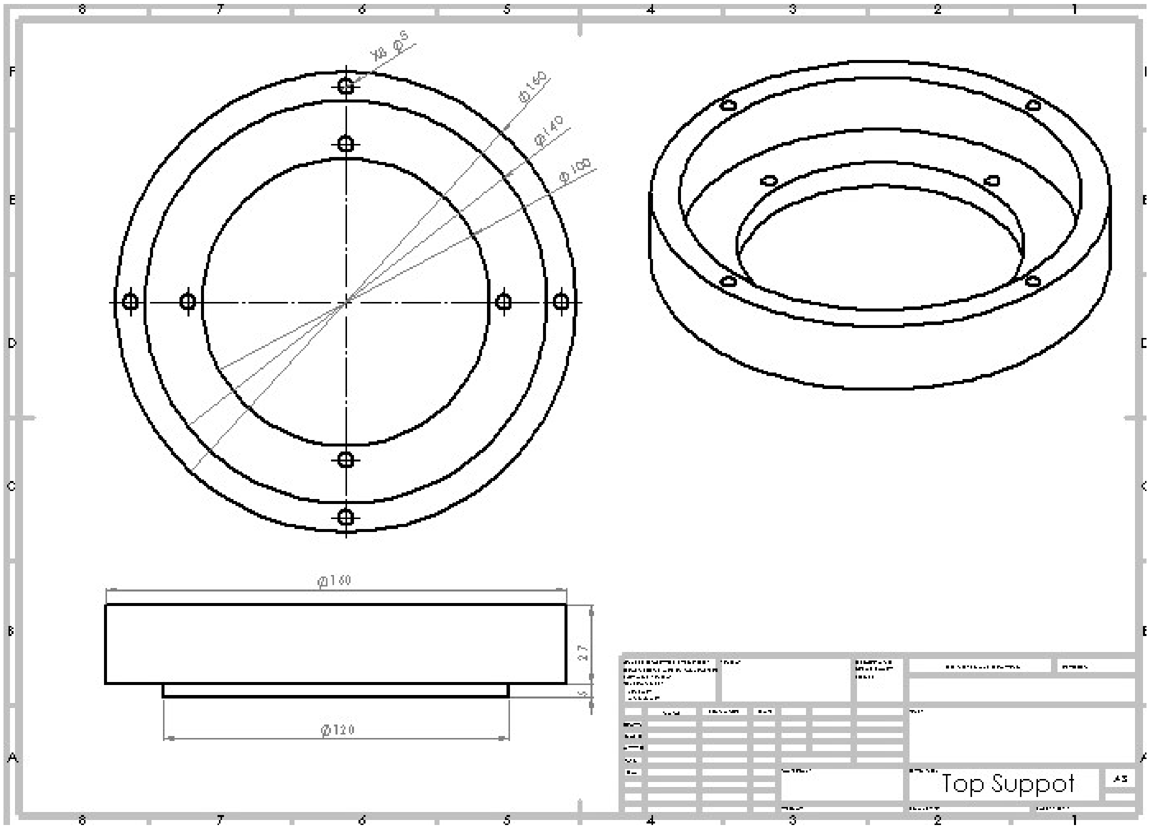

Figure 28: Top Support Drawing

8.2 Bill of Materials

	Item	Description	Quantity	Price (￥)	Remark
Chassis	Aluminum Beam	40*40*1000	1	33.00	
	DC Motors & Driving Board	DC Motors	2	87.00	
	Wheels	Wheels	2	104.80	
	Batteries	2200mAh, 11.1VDC	2	98.00	
	Relays	5VDC	2	5.78	
	Omni-Balls	Omni-Balls	4	20.00	
	Acrylic Board	5mm, 8mm in thickness	/	170.00	
	Power Bank	5000mAh	1	50.00	
	Supporting Pillar	3D print	4	0.00	print in innovation center
Pad	Jumper Win10 Pad	Jumper Ezpad	1	1599.00	
	Supporting Handle	3D print	1	0.00	print in innovation center
Medicine Dispenser	Bearing	Inner d 80, outer d 100	1	43.91	
	Stepper Motor & Driving Board	42Stepper Motor	1	81.69	
	Lock & Key	Triangle lock	1	13.00	
	Pill Box Collection	Small pill boxes	1	39.90	
	Medicine Dispenser Structure	3D print	/	0.00	print in innovation center
Other	Screws & Nuts	m4,m5,m6,m8	/	0.00	get from JI Lab
	Tools	screw drivers...	/	0.00	get from JI Lab
	Wires	wires & dupont lines	/	0.00	get from JI Lab
	TeamViewer	Free Software for remote control	/	0.00	
	Tecent QQ	Free Software for Video calls	/	0.00	
Total				2346.08	

Figure 29: Bill of Materials

9 Acknowledgements

We sincerely thank our sponsor, Prof. Pradeep Ray and our instructor, Prof Guo Yunlong for their patient instructions and great help.

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