Smart Medicine Dispenser

Contents

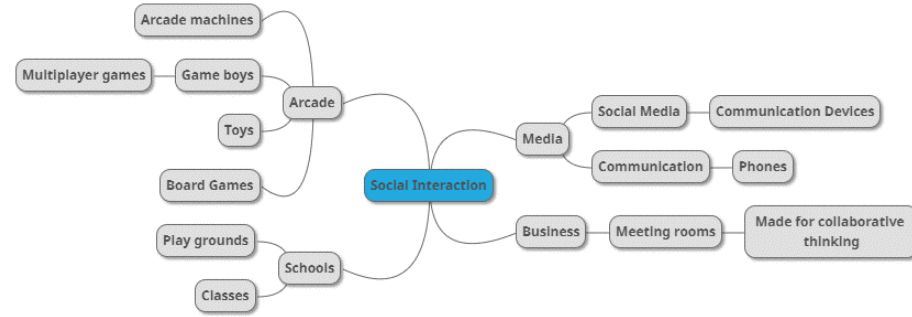
Context Research & Potential Ideas

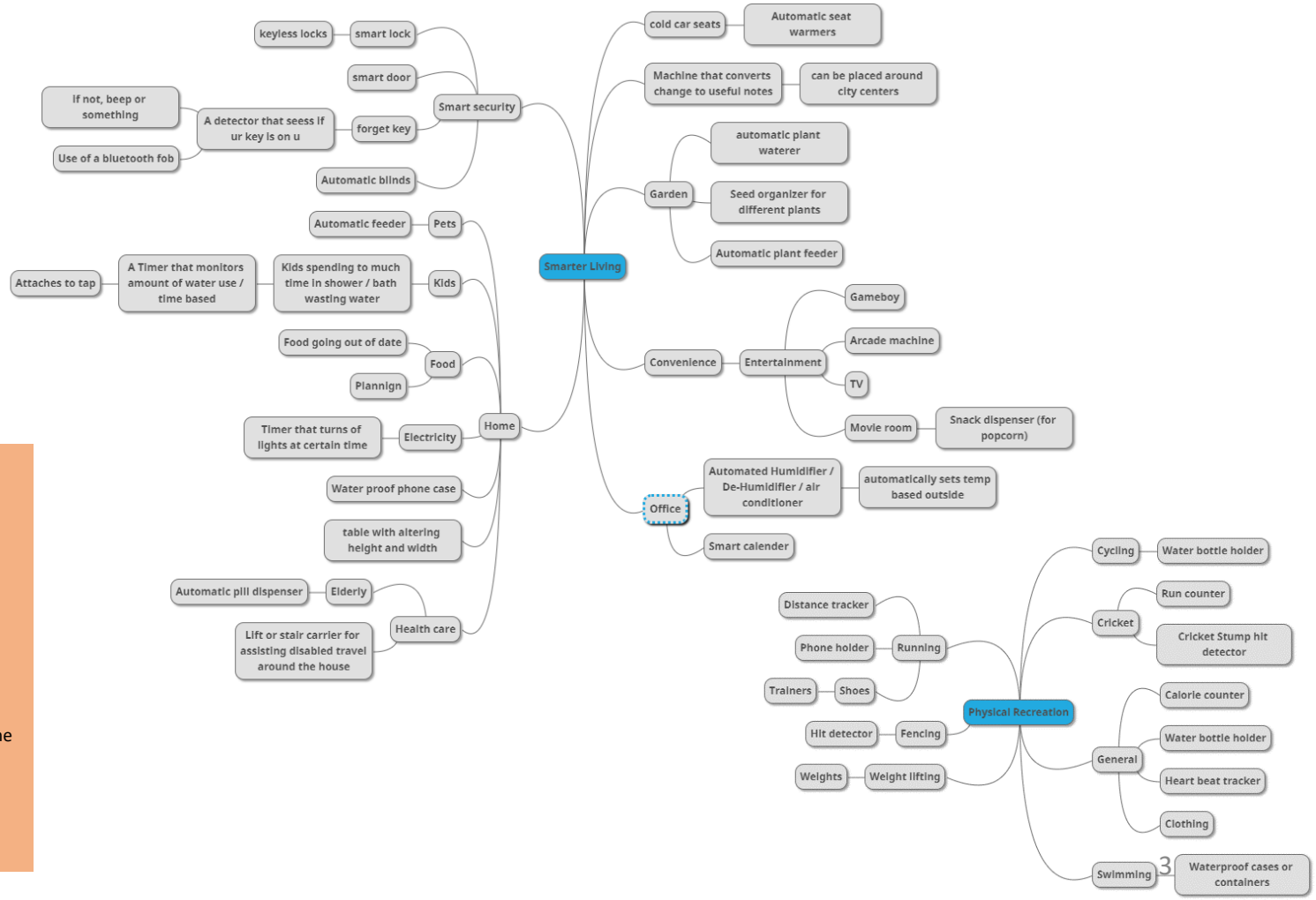
There were three contexts to choose from (Smarter Living, Physical Recreation and Social Interaction), so I started my project by researching each context looking at the potential problems with each area. I concluded each mind map by listing potential ideas, problems and starting points that I could come up with.

For Smarter Living, I found multiple ideas that could be done to help with improving quality of life. I was quite attached to the idea of automation, such as automating daily activities that may hinder a person's productivity. For example, coin sorting and automatic pet feeders. As quite the forgetful person myself, I also found myself drawn towards organisation products such as a smart calendar which would help with reminding people of events and the automatic pill dispenser which would remind people when to take their medication.

With Physical Recreation, I tried to focus on the different sport activities, such as running, cricket, cycling etc… I quite liked the idea of some form of data tracker for the various sport activities which could give data on distance travelled, heart beat, calories and more.

Social Interaction, was a harder context as I was not quite sure on what products would have a large social impact, and as a whole I wasn't quite interested with the ideas that I had come up with.





Potential Brief Ideas:

Smarter Living:

- Pill dispenser => Remind user when to take dose of medication
- Smart Calendar => Help people with general organisation
- Automatic pet feeder => Assist people with pets whilst they are on holiday etc…
- Automatic plant monitoring and watering => Assist people whilst they are on holiday etc…

Physical Recreation:

- Running data collector => track distance ran, calories lost, speed, heartbeat etc…
  => could provide useful information to the user

Social Interaction:

- Game boy => Multiplayer game to play with friends and family
- Board game => Fun game to play with friends and family

In the end I decided to go with ***Health Care*** and the pill dispenser from smarter living, as in my family my mum often forgets to take her medication during the day and so I want to design something that could assist with this.

Because of this I decided to do some quick initial research on the topic:

Poll Shows That Almost 50% Of People Forget To Take Their Medication At Least Once A Month

Posted Jun 20 2017 in Anti-epileptic drugs / Living with epilepsy

Patient adherence to medication regimes is a large problem across the world. Across all medicines, it has been estimated that up to 75% of people do not take their medicines properly. This could be a problem in epilepsy as a lowering of the medication in the bloodstream could lead to breakthrough seizures. We wanted to know how often people who receive our e-newsletter felt that they adhered to their medication regimes. The results were interesting. Please bear in mind that this was a self-selecting poll of 125 people and so any results must be read in that way. They were also asked to estimate for themselves how many times in the last month that they had forgotten to take their medication altogether or had taken it at a different time to that which had been recommended.

1. Of the 125 respondents, **almost 90% were responsible for their own epilepsy medication** while just 9% were responsible for someone else's medicine (as a carer or parent).
2. **90% of the respondents had to take their medications two or more times a day** with the majority having to take medication twice a day.
3. Half of our respondents were taking just one medication while 28% took two

https://www.epilepsyresearch.org.uk/poll-shows-that-almost-50-of-people-forget-to-take-their-medication-at-least-once-a-month/

This article is about a poll that showed how nearly 50% of people forget to take their medication at least once a month. I decided to take note of the important information that the poll revealed:

- Out of all the respondents, 90% of them had to take their medication 2 or more times a day.
- 54% had forgotten to take their medication at the right time in the past month
- 15% had said that they had taken their medication at the wrong time once in the last month
- Over a quarter said that they had taken their medication at the wrong time twice or more in the last month.

8 Creative Ways to Remember to Take Your Medicine Every Day

Medically reviewed on Aug 3, 2014 by L. Anderson, PharmD.

Do you feel like you already have enough to juggle each day?

And now you have to remember to take one, two or maybe more medications each day?

It's a fact - keeping up with your prescription, over-the-counter, and vitamin treatments can be a daunting task. But never fear – there are tried and true methods to help you to remember to take your daily meds on time without fail.

A Pharmacokinetic Primer: Half-life and Steady State

https://www.drugs.com/article/taking-your-medicine.html

This article gives a lot of potential ideas that could be used to help remind someone to take their medication, and so I decided to take some of their ideas that I could implement into my product:

- ***Use of a pill box*** can really help with remembering to take medication and are incredibly useful as they can be brought along in a bag with the user anywhere.
- ***Electronic Applications / Pill reminders*** can be helpful as apps can send alerts to remind a user and can track pill usage to remind the user when they need to buy a new prescription.
- ***Calendar Alerts*** can be set up similarly to electronic applications to send a reminder to the user.

Design Brief

Design a product that helps to remind people when to take their medication.
It should be suitable for a broad range of people who are on medication for long periods of time.

Primary User:

- Irene Tan (Another senior in her late 70s who is on permanent medication)
- Lisa (A diabetic on permanent medication)

Stakeholders:

- Hospitals (may want to invest)
- NHS
- Health Insuruances
- Doctors (may want to use them for patients)
- Families who have members that are on medication
- Schools (may want to invest for students who are on medication)

To help with my research I decided to bullet point a list of things that I needed to do:

- Primary User Needs
    - Interview
- Stakeholder Needs
    - Hospitals – NHS / Medical Insurance
    - Schools
        - In contact with School Nurse
- Survey
- Existing Products
- Dispensing Methods
- Reminder Methods

Moving on I started researching existing products!

Research on Existing Products

Pivotell Automatic Pill Dispenser
A small container designed for keeping what pills you need to take per day.

Pro:
You have all the pills you need to take on a day in one section – you won't need to worry about forgetting.
You won't have to worry about forgetting to take a pill in the day if you take multiple pills per day.
Has an alarm that can alert you every so many hours to tell you when to take your next set of medication

Con:
No labels, hard to tell what day your on.
Several segments, hard to operate having to refill each segment once all medication has been used.
Segments are small, hard to remove the pills to take.

Medca Weekly pill organiser
A small container designed for keeping pills needed for a week

Pro:
Simple, and allows the user to take the pills from one day.
The slot for each day moves up like a conveyer belt meaning that it keeps track of what day it is as the slots move up in the container

Con:
Seniors who struggle with picking up or sliding the slots out due to a condition will struggle with handling this.

Strengths to include:

- At least 1 week of slots for medication.
- At least 3 slots per day for 3 doses. (morning, afternoon and evening)
- Some form of alerting system to tell the user when to take their medication.
- Easy to remove pills for the given day.
- It needs to be simplistic, for easier use.

Weekly medic pill box divider
A small container designed for keeping what pills you need to take per day.

Pro:
Simple – very easy to work out what everything does.
You have all the pills you need to take on a day in one section – you won't need to worry about forgetting.
You won't have to worry about forgetting to take a pill in the day if you take multiple pills per day.
Labelled sections so you know what day you need to take the pills.

Con:
No labels, hard to tell what day your on.
Several segments, hard to operate having to refill each segment once all medication has been used.
Segments are small, hard to remove a single pill to take. (For multiple doses, per day)

MedMinder
A small container designed for keeping what pills you need to take per day.

Pro:
Has multiple sections per day for multiple doses for different periods of the day
Is connected to a watch which can alert you for when to take the pill.

Con:
May be hard to remove pills from the mini plastic containers due to human condition or illness such as arthritis.

To get additional information, I contacted my primary uses along with doing a survey.

Fit Fresh 7 Day Am/Pm pill dispenser
A small container designed for keeping pills needed during the day

Pro:
Allows for does in the morning and evening of each day in a week.

Con:
Can be easy to get the Am and Pm sections mixed up, maybe would work better if it was colour coded.

A small container designed for organising different pills

Pro:
Pills that look similar wont get mixed up

Con:
No labels, hard to tell which pills do what.
No tracking of which pills you have already taken
No tracking of how long since when you last taken a pill

Talk with potential Stakeholder (School Nurse)

I contacted my school's nursing team on their thoughts and ideas for what I am making. I have summed the main points we had discussed below:

Deliver medication as many times a day:
The school nurses though that it would be more beneficial if it could deliver medication as many times a day as necessary for a patient. They mentioned how on average, it is around 3-4 times a day.

Ease of access for people with dexterity issues:
They had also mentioned how it should by easy to remove the pills and medication for people with dexterity issues such as arthritis. They also mentioned that it should be easy for people who also suffer from visual problems such as cataracts.

Simple and Straight forward:
The nurses also stated how it should be easy for someone to use even with extreme memory problems or learning difficulties.

Older Generation:
They also mentioned how the older generation would not be so up to date with new technology and that I should keep that in mind with my design.

Survey (https://www.surveymonkey.co.uk/r/3YQT2R8)

I preformed a survey using survey monkey, that I sent to various people who take medication to gather information to help with my product. Below is a summary of the responses I managed to gather:

Questions Asked:
How many times in a day do you take your medication?
According to the results I got, the average amount of times a day a person takes their medication is 3, but some people only required 1 or 2, 1 being the minority.

How many different types of medication do you take?
This number varied a lot between 2 – 5 the most common being 5 which means I would need to make my design able to factor in this high number of different pills.

How long are you, on average, on medication for?
Most people where on medication permanently, with only a few being on for a select few months which means my design has to last long and be easy to integrate into a persons daily routine.

How often do you forget to take your medication for?
A lot of people bellow the age of 40 do not for get their pills very often, but above that, people where being slightly forgetful, but as shown on this graph from my data, sadly, not many people do forget to take their pills that often.

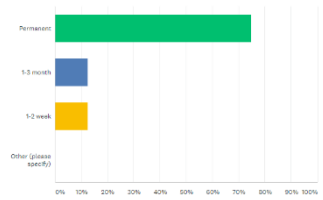
When you do forget to take your medication its because…
This was a very straightforward answer with the majority just having forgotten to take it, but there where quite a few who forgot due to other reasons such as being out of the house or that they had forgot to buy a new prescription, the former being the least frequent

Would you like some way of alerting you when to take your medication?
This was straightforward as the majority of people wanted a way of alerting them for convenience sake.

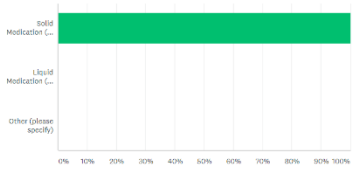
Are you on solid medication (E.g Pills) or liquid medication (E.g Calpol)?
All the people that had done my survey where on solid medication such as pills which means I don't need to factor in a method for liquid medication which would cause a whole other set of problems.

How big would you like the pill dispenser to be?
This answer was very close between 15cmx15cmx15cm and 20cmx20cmx20cm, with 15cm cube space just about coming on top. The latter option of over 20cmx20cmx20cm was not touched upon very much, meaning that people probably wanted my product to be small and not overly large and cumbersome.

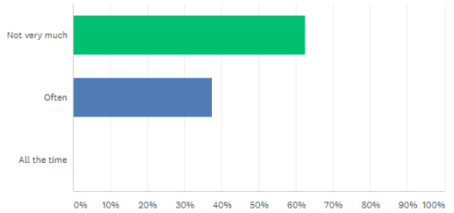
How long are you, on average, on medication for?



Are you on solid medication (E.g Pills) or liquid medication (E.g Calpol)?



How often do you forget to take your medication?



Interview with Primary Users (Irene Tan, Madam Lay and my Mum)

I talked with three potential primary users about what they thought of a design to help with their organisation for their medication and what useful systems would help in their day to day life.

Summary of what we discussed:

Quality of Life and Peace of Mind:
Irene had mentioned that it is very important to focus on quality of life, and that my design should help with improving the users quality of life so that they do not have to constantly worry about whether they had taken their medication. If my design did not reassure them that they can concentrate on other activities without forgetting to take their medication, then it isn't really helpful. In other words, my design needs to put the user at ease so that they can get along with daily life normally.

Portability:
With my mum, we discussed about that since she is always out and about, she sometimes forgets to take her medication with her so she often forgets to take her daily dose when she is outside of the house. If she does remember to take her medication with her, she doesn't want it to be cumbersome to her, so I should keep this in mind with my design.

Overdosing:
My mum and Irene also discussed how they would often accidently overdose as they forget whether they had already taken their medication or not, and so it would be beneficial to have some form of system that could prevent a user from coming back twice if they do not remember taking their medication previously.

Running out of medication:
Madam Lay has a care taker who assists her with taking her medication and her care taker mentioned to me that the biggest problem is that since Madam Lay is at the age where moving about is limited, they often stay at home a lot and as a result often forget when they need to buy a new prescription. We discussed how it would be useful to implement some form of system to help keep track of when the user might need to get a new prescription.

Conclusion, Things that I should include in my design

Below is a list of things that I need to include in my final design:

- The design must give the user insurance that they will remember to take their medication so that they can have a better quality of life.
- The design must prevent the user from taking multiple doses by accident.
- The design must be easily portable to help when being taken out and about.
    - If possible, maybe some method of reminding the user to take their medication with them.
    - However this point can be omitted if the Dispenser is designed to be used at home / in a hospital.
- The design must hold 3-4 doses of medication per day.
- The design must be easily used by the older generation who may not be so up to date with new technology.
- The design must be able to remind the user when their prescription is about to expire.

I then compiled all this research into a list of Stake Holder Needs and Primary User Needs:

Stake Holder Needs:

1) ***The pill dispenser must remind the user when to take their medication***
2) The pill dispenser must be able to alert the user when to take their medication
3) The pill dispenser should tell the user if they are about to overdose or prevent the user from overdosing
4) The pill dispenser must be able to tell the user when to get a new prescription
5) ***The pill dispenser must be simple***
6) The pill dispenser should be easily used by seniors who may not be up to date with technology or would only need to be setup once by a doctor or home carer
7) ***The pill dispenser should be able to supply for long period of time***
8) The pill dispenser must be able to hold at least 1 week worth of medication
9) The pill dispenser must have at least 3 doses of medication per day
10) ***The pill dispenser must be able to be easily used by all ages***
11) The pill dispenser must easily dispense medication for people who have dexterity issues
12) The pill dispenser should be safe around children (for within a family setting)

Primary User Needs:

1) ***The pill dispenser must be easy to use*** – For general ease of use
2) ***The pill dispenser should remind the user when to get a new prescription*** – So that the user doesn't need to remind themselves when to buy a new prescription
3) ***The pill dispenser should put the user at ease*** – So that the user can get on with their own activities without stressing about forgetting to take their medication

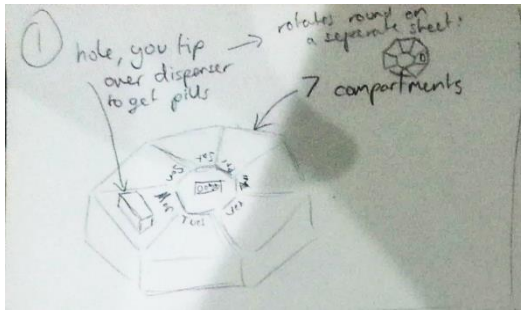
Following this I then created a simple table to show what my design had to do

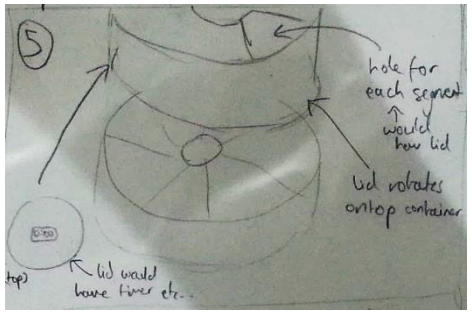
	Specification point	Justification and link to Research
Aesthetics	It needs to look simple.	Most medicine dispensers on the market are very simple to make it easier on the user.
	It should look exactly how it would act. (Intuitive aesthetics)	By having the pill dispenser look the way that it will act makes it much easier for the user to use as they can just work it out at first glance.
Cost	Under £50	Most pill dispensers I found where under £50
Customers	Mostly Elderly who are on medication, but can be used for younger people who have permanent medication.	Most people on medication would like an easy way to keep track of when to take their medication to improve their quality of life.
	Primary User => Irene Tan, Lisa	
Environment	The product should be made from biodegradable and recycled materials where ever possible	This should help with the environmental impact of the product
Safety	The material of the medicine dispenser must not react / interact in anyway with the medication placed inside.	This is so that medicine does not become contaminated while in the medicine dispenser
Size	It should be large enough to be easy to handle, but not so large that it's cumbersome to use, about (15cmx15cmx15cm)	Seniors prefer something that would be easier to handle due to the effects of aging on the body.
	It should be moderately light	This is to not cause harm when being moved around
Function	The design must be intuitive to use	This is so that a user can figure out how to use it just by first glance
	Must be able to give different doses during the day, such as morning, evening and afternoon	Most medication is not only taken once a day, but is also taken multiple times a day.
	Must be able to give the correct dose of medication each day	This is to prevent the user from taking their medication twice in a day if they forgot that they had already taken medication before.
	Must alert the user when to take their medication	This is to prevent a user from completely forgetting to take their medication.
	It must easily dispense the pills	This is to help with seniors who struggle physically due to a condition / illness such as arthritis.
	It must hold atleast a week worth of pills	Most pill dispensers on the market hold up to a weeks worth of medication.
Materials / Manufacture	Plastic	Plastic does not interact with pills and other solid forms of medication and so is a cheap and viable material to use

From this point on, I sketched out a few initial ideas that could be used and ranked them on a scale of 1-10 accordingly for which is better suited for the intended purpose.

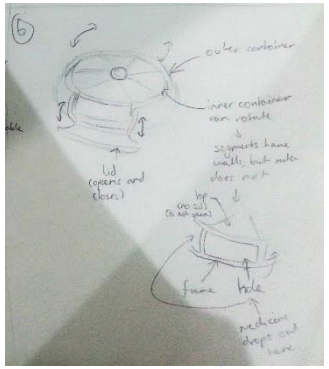
Because design 1 and 5 are very similar in concept I shall group them together. In these designs I was aiming for a easy way to dispense the pills, of which I decided to go with tilting so that the user could just tip the box over and a pill will fall out. I really liked this idea as it solves multiple issues, such as people who have visual problems (as they just tip the box over, they do not need to worry about taking from the wrong segment etc…), but I do not think that this design is very suitable for seniors. This is because I want my pill dispenser to be able to at least dispense medication 3 times a day, which in a week means 21 slots (3 x 7). This number of slots in a circular fashion would make it quite tedious and difficult to add pills at the end of every week, to make it worse, the more slots that the dispenser has, the less space each slot as to hold a pill. This also means that people with dexterity issues will find it very hard.

I shall rate these designs ***5/10 (with design 1 being slightly better than design 5).***



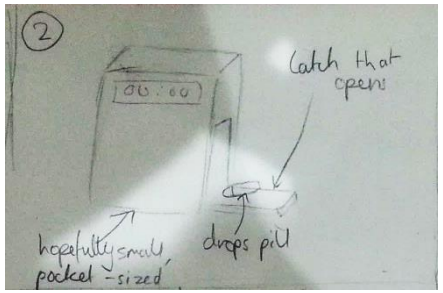


Design 6 offers a much simpler version of designs 1 and 5, however I think that this design fails in a lot more aspects than designs 1 and 5, for example as it has a lid that opens and closes it can be hard for people with dexterity issues and so I will rate this lower than the other 2 at ***3/10***.



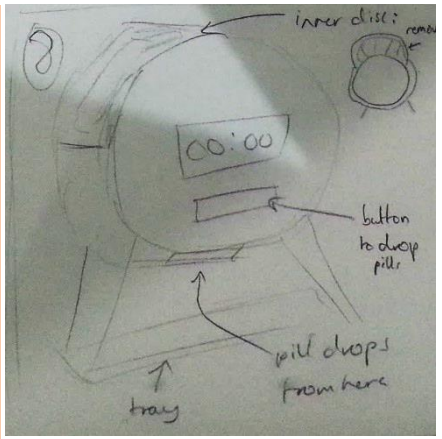
For design 2, I was aiming for portability to allow people who are not at home to still be able to take their medication. I like the idea of having a sort of mini alarm clock inside of it but due to portability I am not sure on how this alarm clock could be configured as with a small size, an interface is not very viable. This design is also not very generalised as it will most likely only be helpful to those who travel / are away from home a lot making it less effective for doctors / seniors to use.

From this I will rate this design ***3/10.***



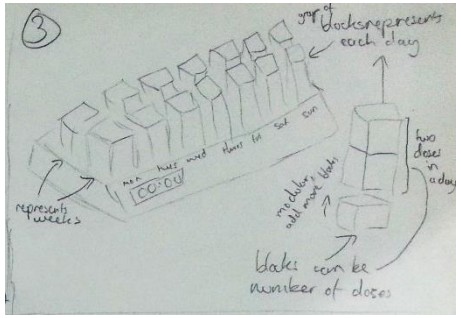
I am very happy with design 8 as it solves multiple problems. Due to it dropping the pill at the bottom and by doing so when the user moves their hand under (motion detector is used to detect this) it helps with people who have visual and dexterity issues as visually impaired people can just put their hand in front and feel the pill drop, whilst dexterity issues aren't a problem as a user does not need to preform precise or complex actions. The inner disc that keeps the pills can be easily removed from the rest of the pill dispenser as the pill dispenser could just be tipped upside down and the disk will fall out form the top. However, due the system using a disk with segments as storage for the pills, it suffers from the some of the same problems of design 1, 5 and 6.

Due to its more forgiving design for seniors and ease of use in general I think this design is a ***8/10.***



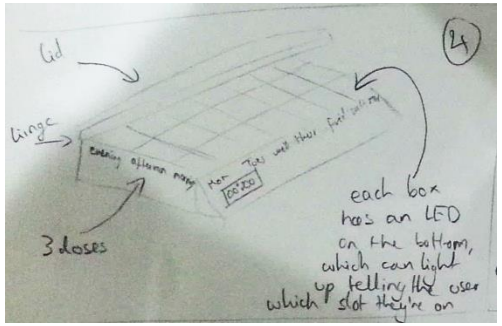
Design 3 was aimed to be a lot more flexible with doses during the day by having a modular system where if you had more / less medication to take during a day you would add / remove a part of the dispenser. This is useful for doctors as it would be much easier for them to manage lots of medication in a day. However, due to its complexity I do not think that this is useful for people in general. Modules could also be lost / dropped which would be much more of a hassle.

Because this design creates more problems than solutions I will give it a ***2/10.***

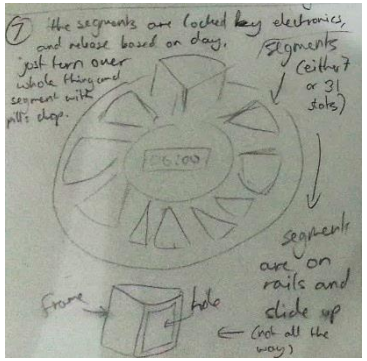


For design 4 I tried aiming for a much more simpler design that is more intuitive to use, and so I went with a much simpler grid, similar to the grid boxes used for packaging chocolate. This allows this pill dispenser to be a lot more portable as it is basically just a simple container with an alarm clock. An issue with it is that it can be confusing trying to find which container is the right one, which I tried to solve by adding an LED back light that will shine the correct section a pill should be taken from. However this means that people with visual problems won't be able to use this very well.

I shall rate this ***6/10***.

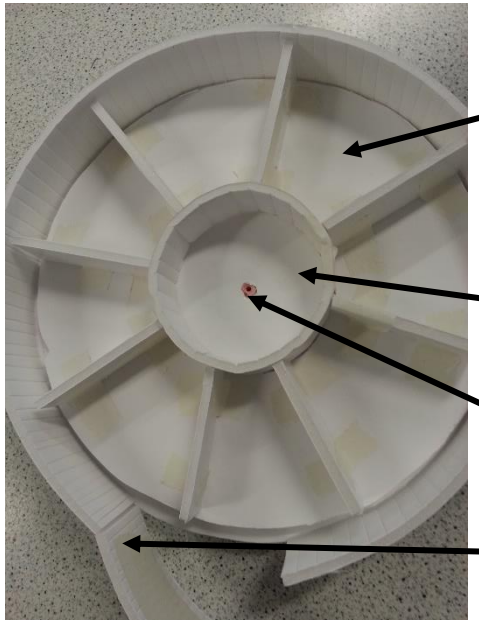


I'm actually not quite sure what I was aiming for with design 7, but I can say that it is probably the worst design. An issue that instantly comes up is the fact that since each segment can't be removed completely, it will be a *huge* hassle to restock the dispenser with more pills. To make matters worse, is that due to it working with segments it falls under the same problems as design 1, 5 and 6. Because of this I will rate it a ***1/10***.



From these ideas I decided to start modelling to help grasp the general idea of how I want the dispenser to work.

Foam board modelling of Pill Dispenser

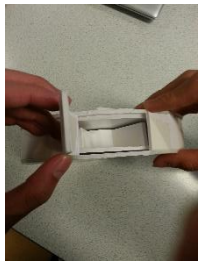


Segmented areas of which pills could be placed. This is not glued in place and can rotate freely around the central segment Currently there are 8 slots, I plan of creating 21, but I created 8 first to make things slightly simpler in this prototype.

This *middle section* is where I plan for the rotation mechanism of the outer ring to be.

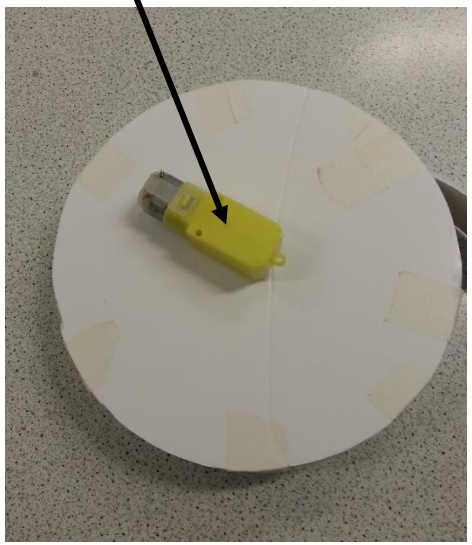
Motor axel can be seen poking out here.

Latch that will open for the pills to fall out of the dispenser



Latch opening to a segment of the pill dispenser

Motor that will drive the rotation of the inner segment will be placed in a small box with other electronics here

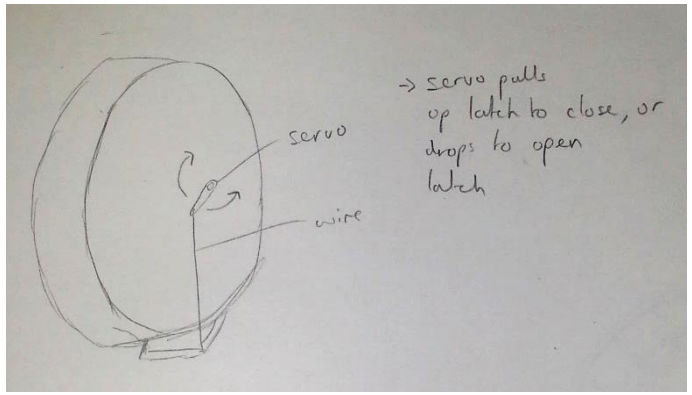


Currently the latch is loose, and has not mechanism to open or close it. This is a problem I'll have to address as I develop this on.

My Thoughts on the design:

Whilst this prototype has all the main features I found many issues with the overall design. Firstly, the central *middle section* is just way to small to fit any electronics and I would prefer for the motor to be housed inside the design. The space given in each segment is also rather large for only a few pills and so there is room to expand the middle section:

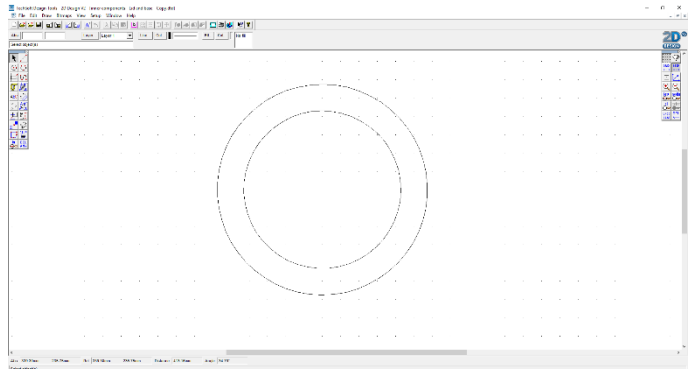
For the issue with the latch opening I thought of using a servo with a wire joint to control the opening and closing, but I found that to be chunky as it would have to be placed on the back causing it to stick out, as it couldn't be attached to the *middle section* because it would have to pass through the segmented areas:



To prevent this I decided to go for an approach that uses gravity. This would work by not using a hatch and just leaving a gap, and as the dispenser will sit upright, the pills should just fall straight out when the segmented section rotates to reveal the next set of pills.

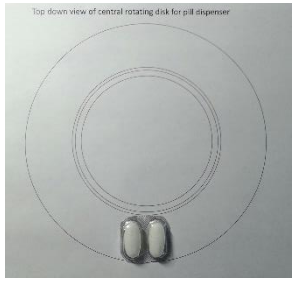
Developing my design

With these new ideas I began re designing this prototype using 2D design to plan out the layout for this new iteration:

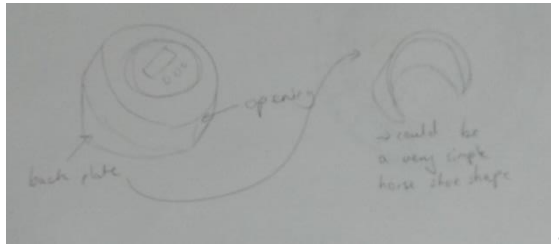


I then printed this out to scale so that I could check the dimensions with a set of pills: (The set of pills you see in the picture are 1000mg)

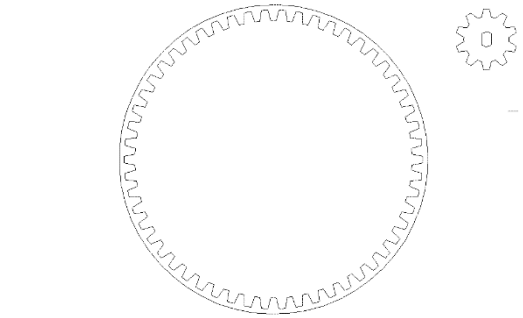
From this I managed to work out that a good difference between the outer circle and inner circle is at around 15mm.



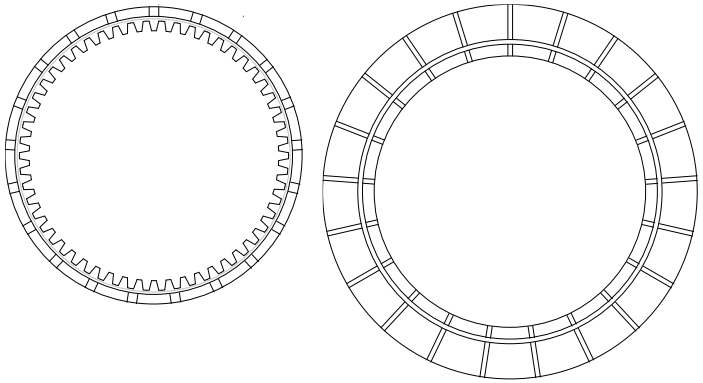
Another Issue I thought about whilst prototyping was how I will mount the dispenser upright. At first, originally I wanted to use a simple wire frame stand with a try at the bottom as shown in the original sketch of *Design 8* however, this would be easily knocked over and could be unsafe. Because of this I decided to go with a slanted mount so the dispenser sits at a angle rather than straight up:



After getting the general shape I started to work on the mechanism. For the inner ring I first thought of using a simple planetary gear attached to the segmented section to rotate it. This is the gear I produced in 2D:

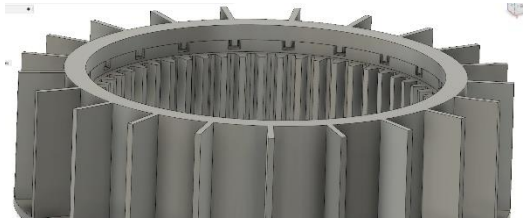


However I found that this mechanism wouldn't allow for easy removal and replacement of the segmented area as interlocking gears can be quite fiddly at times. The reason why I wanted the user to be able to change the segmented area is to allow the design to have any number of segments. My solution was to make a main rotating ring that would have the segmented area lock on top of it allowing it to rotate with the main ring:

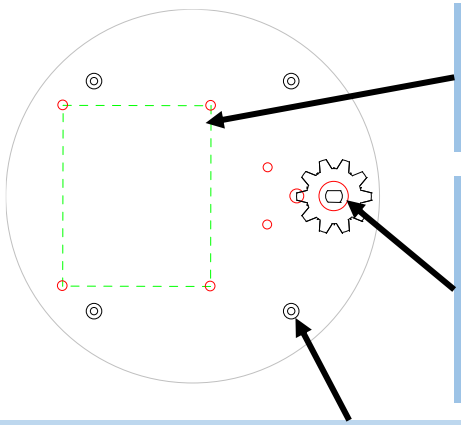


The piece on the left represents the main rotating ring and the piece on the right represents the segmented ring that can lock onto the inner ring. The locking works simply by using upward facing teeth the interlock with each other.

To help visualise how this would work I converted my 2D design templates into .dxf files and imported them into fusion 360 allowing me to extrude them and produce a 3D model. This model below shows how the segmented ring will lock into place with the main rotating ring using teeth.



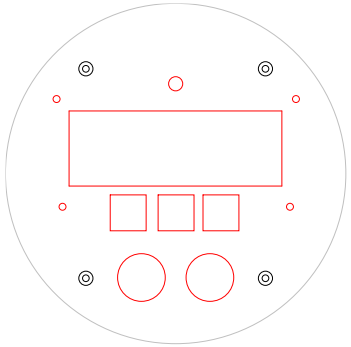
Next I configured how the internal parts will be placed in the dispenser. The 2D layout below shows some of the components that will be housed inside the central area:



Red holes indicate M3 screw holes that will be used to fasten the Micro controller I will be using to the base

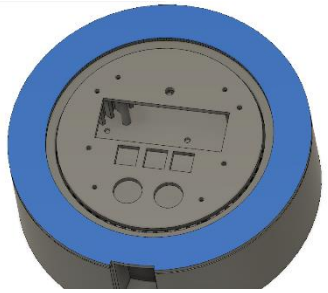
Red holes indicate M3 screw holes and space for where the DC motor will be placed. The Motor is attached to the gear shown and is what will drive the rotating inner ring.

These Poles are what will be used to hold the lid on top of the whole design. This is because the lid will cover only this central unit and contain other components such as the LCD display, LED and buttons that I will be using to display information and control the format of the dispenser.



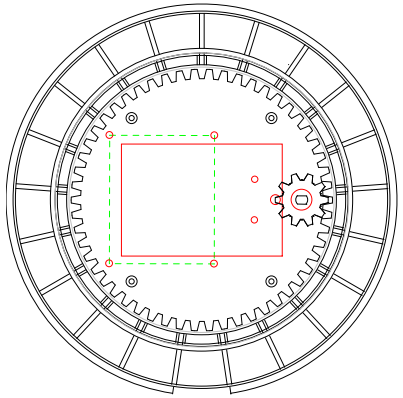
The lid, as shown on the left, has holes for where the components previously mentioned will be placed. For a better Idea of how this will work I modelled it in Fusion 360 as shown on the right.

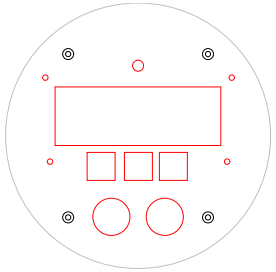
The lid is attached to the poles via M3 screws. Mounted onto the lid is a LCD display for displaying the time and other information that it will need to show such as settings. 3 Buttons will be used to control the dispenser, 2 buttons to operate selection (next and back) and the last to act as a select button (like pressing OK). There will also be a motion detector, this is for helping people with dexterity issues so that they just have to wave their hand in front of it for the dispenser to dispense the next set of pills. A Piezo will also be housed internally to act as a alarm that will go off to remind the user when to take their medication along with a LED that will blink for those who are deaf.



For a cover that will fit over the segmented ring I went for a simple ring that would cover it and I plan on using a hinge on the back to allow for it to open and close

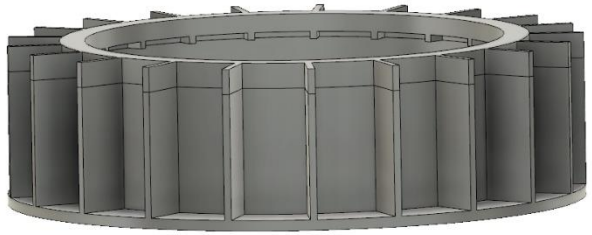
This is the final 2D design layout that I created to make this model:



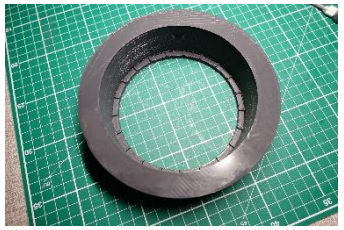


3D Printing of Pill Dispenser

With all the parts modelled I decided to produce the dispenser by 3D printing it. However to prevent scaffolding from being needed I separated all the pieces with overhangs so that I could glue them together after both had been printed:



As you can see above I separated the top overhang of the segmented ring so that it could be printed separately.

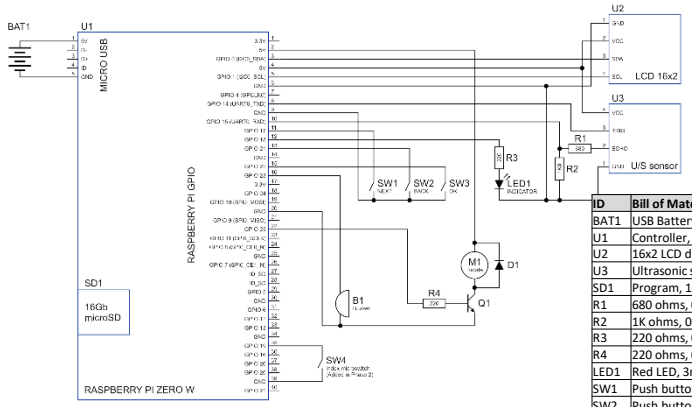


The left image is the under side of the printed inner rotating ring and you can see the notches that will inter lock with the main rotating drum of which is shown below

Electronics of the Pill Dispenser

Once I had all the main components printed out, I then moved on to creating the electronics. To start things of I chose to use the Raspberry Pi Zero W for my micro controller. The reason why I chose to use a Raspberry Pi rather than Genie or Pickaxe is mainly just because I am a lot more familiar with how to use the Pi over Pickaxe and Genie chips

To start things of I created a quick schematic:



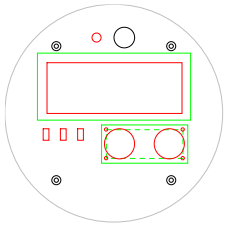
ID	Bill of Materials needed
BAT1	USB Battery Pack, 5V 10,000mAh
U1	Controller, Raspberry Pi Zero W
U2	16x2 LCD display, HD44780 I2C
U3	Ultrasonic sensor, HC-SR04
SD1	Program, 16Gb microSD
R1	680 ohms, 0.25W
R2	1K ohms, 0.25W
R3	220 ohms, 0.25W
R4	220 ohms, 0.25W
LED1	Red LED, 3mm
SW1	Push button switch, AD1459
SW2	Push button switch, AD1459
SW3	Push button switch, AD1459
SW4	Microswitch, Omron Ss-5gl2
M1	TT DC gearbox motor, 3-6V/0.15-1A stall
D1	Diode, 1N4002
Q1	NPN transistor, 2N2222
B1	Buzzer, ADA1536

As the motor required a relatively high current of 150mA-1A, I considered 3 options:

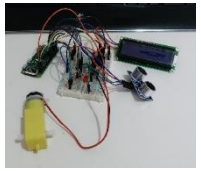
1) motor driver board
2) logic level MOSFET
3) bipolar transistor.

The motor driver board would have required more space and expense, and the MOSFET may not turn fully on for driving the motor. The simplest option in this case was to use a bipolar transistor and to drive the base with a large input current via a 220ohm resistor (12mA when GPIO pin is on) so the transistor is in saturation (current gain 100, so could theoretically drive 1.2A which is more than sufficient for the motor).

As the buttons I used were smaller than the ones I originally planned to use and so I had to redo the placement of components on the lid piece and then laser cut it out of 3mm acrylic:



After designing the circuit I moved on to breadboarding the components:

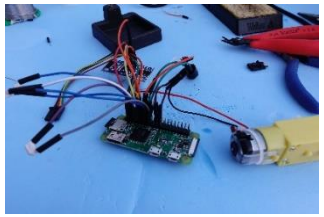


Whilst bread boarding I found that I did not have a 660 ohm resistor for the ultrasonic distance finder on the echo pin. Because of this I settled for 3x 220 ohm resistors.

Soldering and finalising the circuit

Once I had tested all the components and had them working I proceeded to solder them to the raspberry pi using heat shrink to cover connections:

This is me soldering the components onto the pi. For safety I wore gloves as the solder I used contained lead.



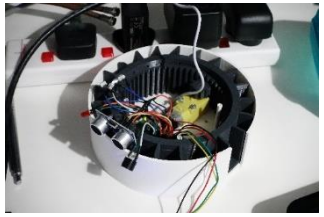
Raspberry Pi with all components soldered on!

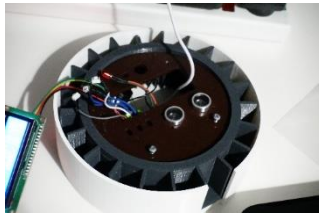
Testing all the components to check that they all work using a small python script!

Once I had all the wiring done I moved on to mounting them onto the 3D printed parts from earlier.

However I found that the gearbox motor's case was a bit too large for the design. Because of this I used a saw to trim down the edge of the case so that it fits within the central area

Soldering and finalising the circuit





Mounting of lid components using a test lid piece!

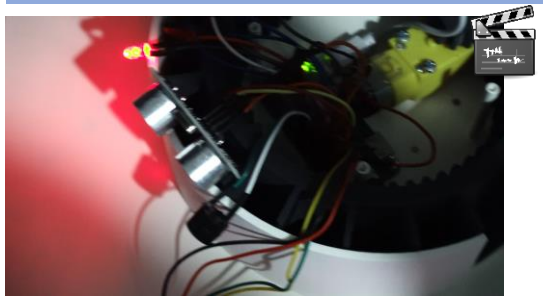
Programming of Pill Dispenser – Basic functionality

Once I had all the pieces mounted and in place I moved on to programming the software for the microcontroller. However before doing so I spoke with my primary users in depth about how the program would work to interact with the user.

Together we came up with a set of rules that the program must follow:

- Must prevent overdosing through rejecting a double take.
- Must alert the user of when to take their medication
    - Must not continuously alert (alert must turn off after 30 minutes) similar to an alarm clock
- Must be customizable, such as different timings and different dates
- Easy to use UI

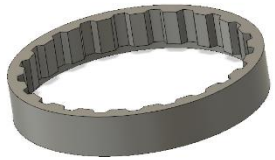
From this I had a basic idea of how the software would work, and from this point I first started writing code for the basic functionality of the Pill Dispenser adding simple interactions such as the wave of the hand over the ultrasonic sensor to trigger the motion of dispensing the pills as shown in this clip:

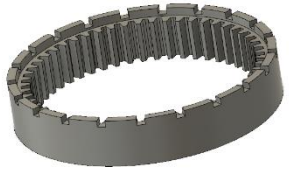


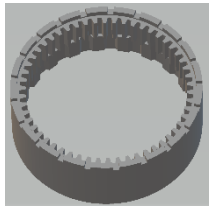
As you can see from the clip, after multiple rotations, the dispensing segments become mis aligned with the dropping hole. This can especially be seen on the third rotation.

To solve this I went back to redesign a much more reliable gear mechanism.

This time I created the inner rotating gear from 2 halves, the first having the teeth of the gear for the actual rotation, along with the notches along the top to catch onto the segmented rotating part. The lower half is designed with 21 notches that are rafted to allow for a lever switch to run over them. I would then have my program count the number of notches passed and use this to decide when to stop the rotation. The reason for choosing 21 notches is because the most times a user will take medication per day is and so the number of segments is 3 x 7.

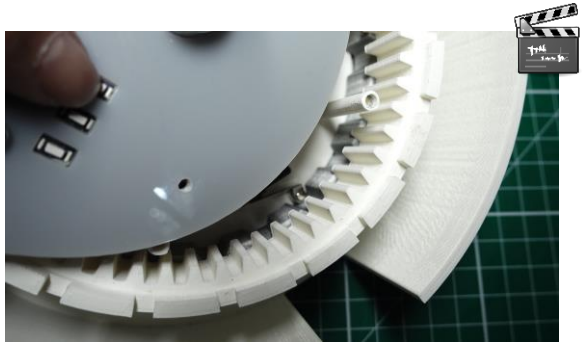






Above shows the two halves and how they are placed together to form the main rotating drum

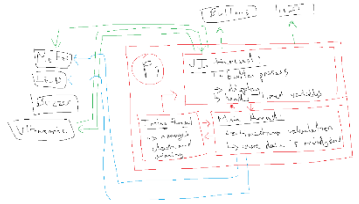
This clip below shows this mechanism in action!



At this point I had completed the programming for:

- Detection of hand wave
- Accurately dropping pills
- Buzzer and LED actions
- Handling of Button Presses

From this point I then proceeded with the main bulk of the software, starting by creating a *quick* layout for all my required scripts and code blocks:



As shown in the diagram I planned on using multiple threads rather than a single threaded program as many of the components require time breaks and pauses. For example, the Ultrasonic range finder is rated to require a 100 millisecond pause between readings to allow it to reset. This can make the Pill Dispenser feel unresponsive at times and this can be seen in the very first clip on the left as it takes some time to detect my hand.

Because of this I separated timed based components to run along side the main UI thread which handles displaying items as well and runs at a much slower tick or frame rate, whilst running the main program on the Main Thread. However threads turned out to run much slower than a single thread so rather than threads I ran them on different processors and used python's multiprocessing library

You may also notice that I had put the motor on the timed UI thread. This is because the TT Gear box motor I used is rated at 200rpm which is really fast for what I need it do and I do not have a pwm pin to control the speed due to using a transistor. The momentum generated by the high speeds can also cause the rotating drum to rotate past a notch as the momentum keeps it spinning. Because of this I had the motor *"Waddle"* and just sent short pulses every 500ms to the motor. This created overall jerky movement, but made the motion much slower and much more manageable. This can be seen in both clips to the left.

```
def Waddle(Self): #Slowly increment motor
    Self.State(GPIO.HIGH)
    Time = 0
    Self.Update()
    time.sleep(0.01)
    Self.State(GPIO.LOW)
    time.sleep(0.1)
```

Here's a small snippet of my code which shows how I waddled the motor simply by turning the motor for 0.01 seconds and then waiting 0.1 seconds before continuing. The waiting from time.sleep halts the thread hence why it is on the UI thread.

```
#Rotate motor one switch notch
while (ContinuousSysUpdates.S1.GetInput()):
    Motor.Waddle()
while (not(ContinuousSysUpdates.S1.GetInput())):
    Motor.Waddle()
while (ContinuousSysUpdates.S1.GetInput()):
    Motor.Waddle()
```

This bit of code is how I would rotate the segmented area by 1 simply by *"waddling"* the motor until the switch is triggered, and then continue *"waddling"* until the switch is no longer triggered.

Here is a clip of the program working !

With the working program I went back to my primary user, Lisa and Irene, and we played around with it.

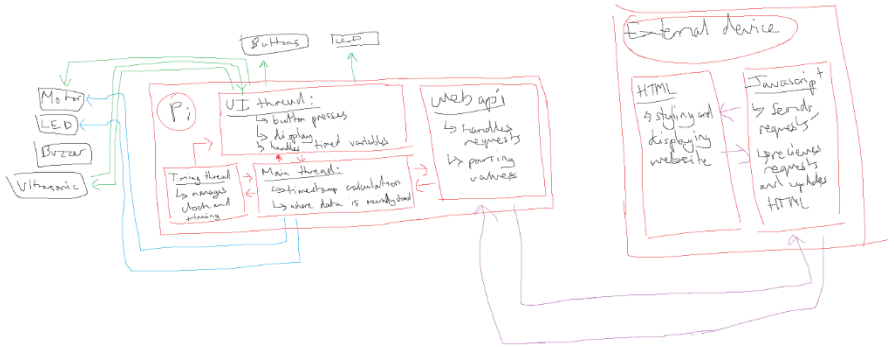
One of the tasks I asked Lisa and Irene to do was to try and use the pill dispenser without me telling her anything. For the most part everything was intuitive and easy to work out via trial and error. This was a good sign, however when it came to setting up any values in the Pill Dispenser, such as shown in the video as try to set the time, Lisa said that it was "way to cumbersome" and that "it takes way to much time".

Together, we also found that the buttons were incredibly shallow and difficult to press. To fix this I could add caps to the buttons allowing them to stick out and be much easier to click. Another helpful thing would be to label the buttons as well, however this didn't solve the main problem of setting up being a really big pain.

However, whilst brainstorming for a solution I remembered that Irene uses an iPad a lot. Because of this, I thought why don't I just allow the user to setup the Pill Dispenser through their tablet / phone. This may seem contradictory as most elderly do not know how to use technology, however it is possible to design the UI in a way that its easy for an elderly person to learn and pick up within a couple of minutes. Because of this I decided to create a secondary interface for the Pill Dispenser. Using an app would not be a viable solution as this would vary over different tablets and phones, and computers wont be able to access them. Because of this I settled on creating a website for the Pill Dispenser as the microcontroller I used, the raspberry pi zero w, comes with Wi-Fi, meaning that I can create a very simple hotspot from the Pi that would host a local web page.

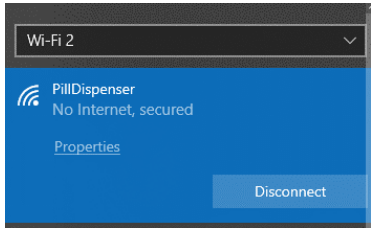
Programming of Pill Dispenser – Web server

Before starting to setup the raspberry Pi for the web server I updated my programming diagram to help me visualize how it will work:



From this I determined that the Javascript and HTML running locally on the external device should only be handling displaying of values along side of sending and receiving requests. This is to prevent people being able to used F12 developer settings on chrome or internet explorer to access important code blocks and changing them locally to send unauthorised requests to the Pill Dispenser which is good for security. I also planned the Web API on the Pi to only access the main thread as the other threads are unresponsive at times due to pauses on components which will cause requests to be handled a lot slower.

From this point I then setup the basic Web API and local hosting on the Pi using Python libraries, of which can be accessed simply by connecting to its Wi-Fi:



With Wi-Fi setup (password for the network being password) I then moved on to design the UI. However I do not have that much experience in creating UI's and so I proceeded to preform research on a few existing apps with a similar purpose.

UI – Research on Existing products

Lady Pill Reminder

This app really caught my eye as it shows your typical tablet packet with the pills in it. Because it visually represents what you are interacting with, it makes it a lot more intuitive and I think I might do something similar with my web UI!

Another thing that I liked is how minimalistic it is. I don't think I'll be able to achieve this with what I want my UI to show, but it could be useful to have a minimalistic UI as then there isn't much a user will have to learn in order to use it, as it would be extremely simple to approach.

This UI design is a lot more on the modern side of aesthetics which works really well with a younger demographic of people, however what I really like about this UI is how easy everything is to access. The UI elements such as buttons or different tabs are either very large such as the "Add Activity" button or in a contrasting colour such as the icons shown on the left side of the image.

This UI also shows and tracks various statistics which I think would be really important to have so that a user can track how they are doing.

Points taken from "8 Characteristics of Successful User Interfaces" - *http://usabilitypost.com/2009/04/15/8-characteristics-of-successful-user-interfaces/*

From this website I learned about the general specifics of making a UI. The main points where on:

- Clarity
- Concise
- Familiar
- Responsive
- Consistent
- Attractive
- Efficient
- Forgiving

The most interesting points that I will have to include in my UI is making it forgiving and efficient. Making a UI forgiving is a very new concept for me but the website stated how a good UI will always allow a user to take back an action. However, only for actions with very high consequences such as deleting a message on your mail. This is something I will have to implement in case a user accidently deletes a time stamp from the Pill Dispenser (A time stamp being the time during the day that a pill needs to be dispensed). Efficiency was another interesting point where the website states how a UI should make the user exert as little effort as possible to get to their desired result. For this I think I'll have to add options for default settings that will setup most of the Pill Dispenser functions for the user. Finally I would have to make the UI be similar to most other UI's out there. This is because, as explained by the site, "when you're familiar with something, you know how it behaves – you know what to expect" which allows for a much more intuitive design.

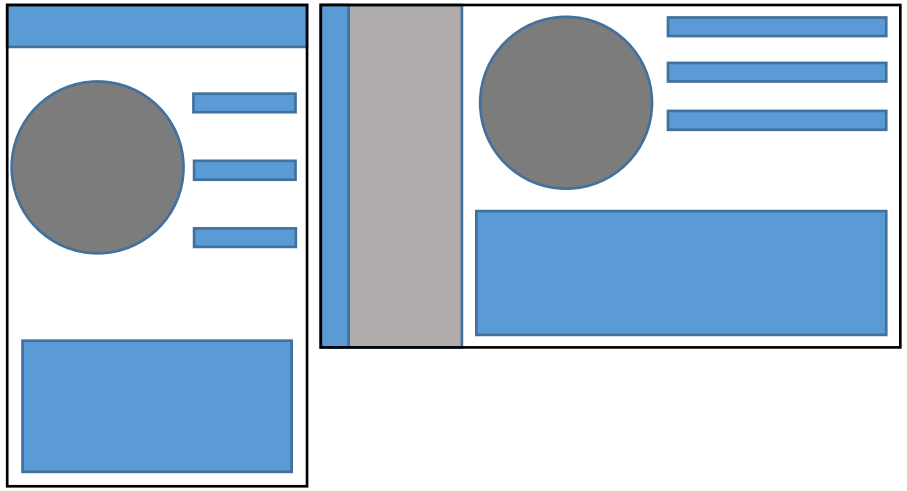
Ideas to take forward

- I really liked the idea of showing a visual representation of the pills from "Lady Pill Reminder" and so I think I'll do something similar but with the rotating segments on the Pill Dispenser instead.
- I also would like the UI to show various statistics such as days a user had missed their medication, along with when to take more pills and even when to buy a new prescription when a user's current one is about to run out.
- Multiple UI's for multiple platforms, this was not taken from my current research but rather from experience. For example the YouTube website is setup different to the YouTube mobile website, this could be something that I'll have to consider on my UI

Next I moved on to designing and creating a basic layout for my UI!

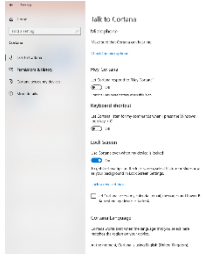
Programming of Pill Dispenser – Website UI

As per usual, I started off with a basic layout planned and drawn in PowerPoint before getting stuck in with the programming:



The layout on the left represents a simple design for mobile users, whilst the UI on the represents the design for laptop users. The general idea was that the main circle you see is going to be a real life representation of the Pill Dispenser's rotating segmented circle to give a visual representation of what's happening. Next to that, shown as three rectangles to the right of the circle, I want to show some statistics such as *time till next pill*. Possibly I would like it to also show when a new prescription needs to be bought, or when the Dispenser needs refilling. Below the circle, in the large blue rectangle, I want to show all the upcoming medication that needs to be taken.

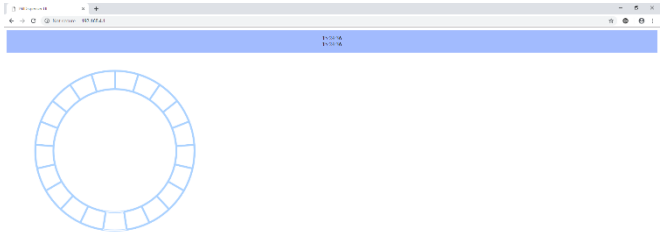
For accessing other functionality such as settings or re arranging time stamps I decided to go with something similar to windows settings for familiarity:



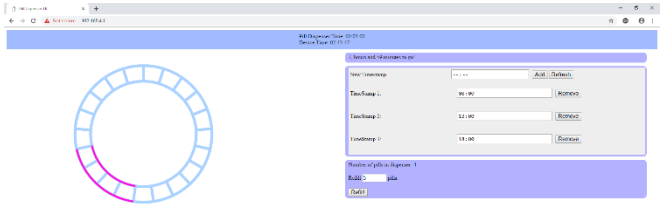
So for the computer / laptop users, they will have a UI similar to their laptop settings making it a lot more intuitive to use. All the options for changing time arrangements etc can be placed on the left grey bar.

For mobile users I planned on doing something similar but by having a button on the top left corner that opens this settings panel from the left. This is similar to how most mobile apps work.

Here I have generated a page with the rotating dial to represent the rotating segments. I have also got a simple request system that gets the time stored on Pill Dispenser and displays it on top of your system time, this will be removed in the future, but its there to show that the web page and Pi are communicating.

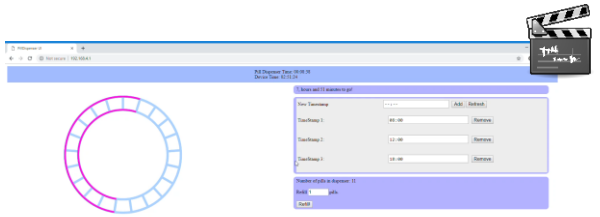


From this point I started to work on programming functionality into the segmented piece with the pi adding rotation and then creating the buttons required to set the different time stamps for when to drop pills:

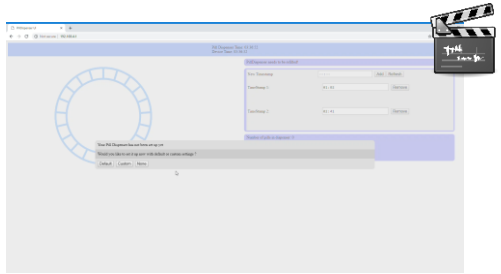


The purple highlighted segments represents the segments that have pills in them. The Pill Dispenser itself cannot detect this, but the user can input how many they added to the dispenser through the UI elements.

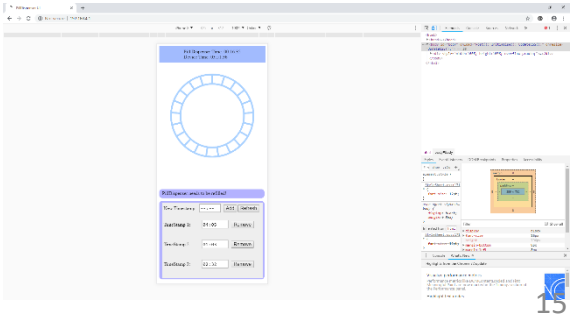
I then went back to my primary user, this time Lisa, to discuss my UI, and we came across quite a few issues. Firstly, the UI was fairly unresponsive at times and sometimes glitched when refilling pills as shown in the clip below. This is mainly due to the communication between the web api and the Pill Dispenser being very slow and there isn't much I can do about that.



So a *half-simplified* solution I had was to create a separate "Alert" UI element that let the user set everything they wanted to in a fast responsive, client side UI, and then send all that data in one large heap to the Pill Dispenser. This turned out to work great and you can see the difference between them in the clip below:



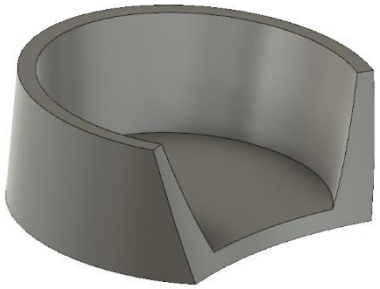
Using F12 developer settings I also made sure the web page was fit for use on various different mobile devices as shown in the image below. To finish things of I obfuscated my files and compressed them to speed up load times



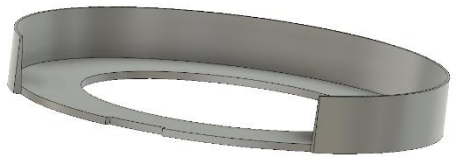
Quick Evaluation and Testing

With everything completed I went back to both my primary users to get some feed back and we tested the design. Here is a clip of the design working (I had the buzzer disabled as the noise was getting incredibly annoying with testing :P):

Whilst testing Irene, pointed out that its rather hard to get the pills of the table once they drop out, and so to fix this I modelled a small try that slots in next to the pill dispenser so that the pills drop into the tray and the user can just easily take out the tray and take the pills directly from it, drop them into their hand etc…



Finally I also modelled a lid to finish of the design completely. With the lid I made sure not to make it a fiddly design by making it easy fall onto the dispenser and then be spun round to slot into place. This way a senior with dexterous issues should have no problem removing and attaching the lid.



Are Stakeholder and Primary User requirements met ? (From slide 7)

Stake Holder Needs:

1) [✔] ***The pill dispenser must remind the user when to take their medication***
2) [✔] The pill dispenser must be able to alert the user when to take their medication
3) [✔] The pill dispenser should tell the user if they are about to overdose or prevent the user from overdosing
4) [✔] The pill dispenser must be able to tell the user when to get a new prescription
5) **[✔ ✕] *The pill dispenser must be simple***
6) [✔] The pill dispenser should be easily used by seniors who may not be up to date with technology or would only need to be setup once by a doctor or home carer
7) **[✔] *The pill dispenser should be able to supply for long period of time***
8) [✔] The pill dispenser must be able to hold at least 1 week worth of medication
9) [✔] The pill dispenser must have at least 3 doses of medication per day
10) **[✔] *The pill dispenser must be able to be easily used by all ages***
11) [✔] The pill dispenser must easily dispense medication for people who have dexterity issues
12) [✕] The pill dispenser should be safe around children (for within a family setting)

Primary User Needs:

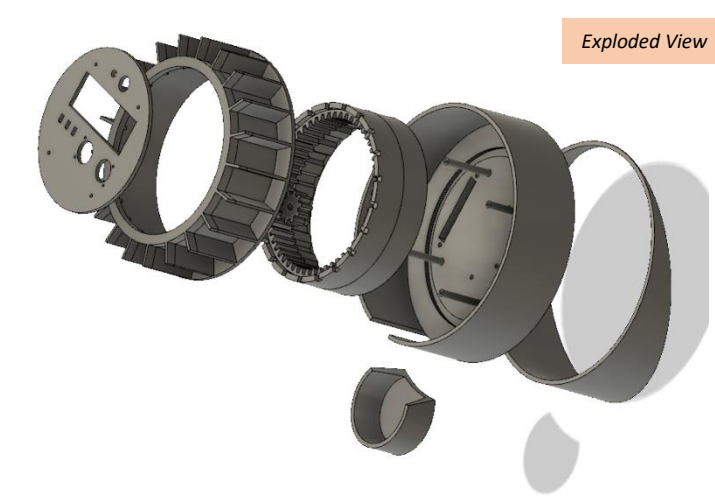
1) [✔] ***The pill dispenser must be easy to use*** – For general ease of use
2) [✔] ***The pill dispenser should remind the user when to get a new prescription*** – So that the user doesn't need to remind themselves when to buy a new prescription
3) [✔] ***The pill dispenser should put the user at ease*** – So that the user can get on with their own activities without stressing about forgetting to take their medication

Extra Notes:

I am really happy with how this design turned out, it manages to fulfil most of the requirements, however it falls short when it comes to being safe around kids. This is because of how easy it is to access the pills by just waving your hand over and by kids just taking out the pills. Another weakness to my design is that it's not very simple to setup. As shown above for *The pill dispenser must be simple* I put both a tick and a cross as it's really simple to use, but can be quite complex to setup and get going. The website does help with this, but when it comes to seniors without knowledge of technology its quite the hassle. Especially since connection to the website is made through an IP which is rather hard to remember. This of course can be fixed by adding it to favourites, or setting up a host name.

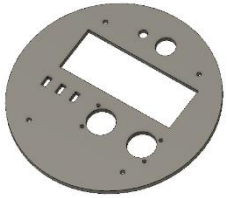
Full Dimension drawings and CAD

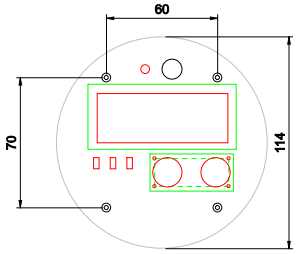
Here are the full drawings and schematics for the pill dispenser!



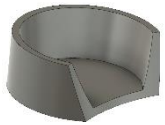
Exploded View

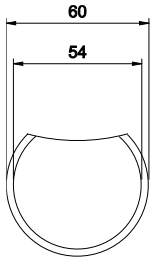
Part	Material	Method
Lid	3mm Acrylic	Laser Cut
Base	PLA Filament	3D Printed
Stand	PLA Filament	3D Printed
cover	PLA Filament	3D Printed
Inner rotating segments	PLA Filament	3D Printed
Planetary Gear	PLA Filament	3D Printed
Inner button notches	PLA Filament	3D Printed
Driver Gear	PLA Filament	3D Printed
Tray	PLA Filament	3D Printed



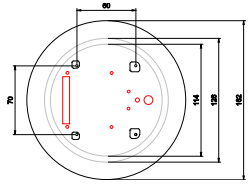


Lid

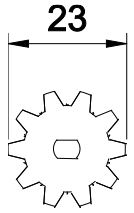




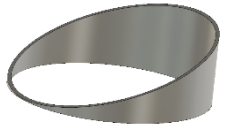
Tray

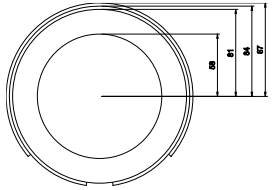


Base

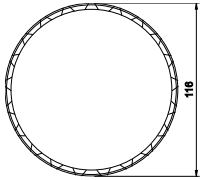


Driver gear



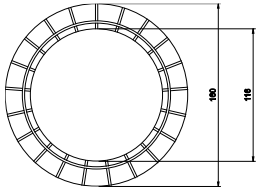


Stand and cover

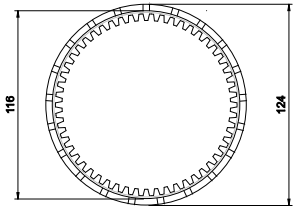


Inner button notches

Both parts for inner rotating segments



Planetary gear



CAD parts with their 2D drawing counterparts.
All attachment points are made with m3 screws.

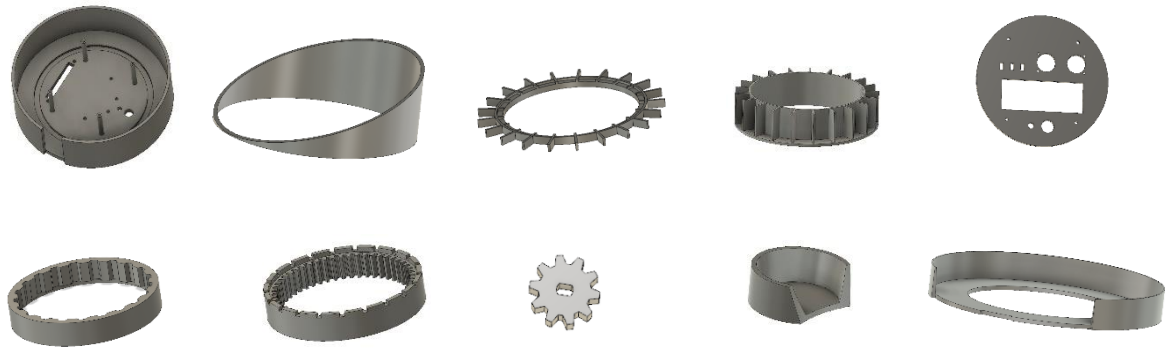
List of Requirements

Identified Requirement	When it was Identified	Why it was considered important	Has it been considered in the final design solution ?
The pill dispenser must remind the user when to take their medication	Technical – Slide 7		
The pill dispenser must be able to alert the user when to take their medication	Technical – Slide 7		
The pill dispenser should tell the user if they are about to overdose or prevent the user from overdosing	Technical – Slide 7		
The pill dispenser must be simple	Technical – Slide 7		
The pill dispenser should be easily used by seniors who may not be up to date with technology or would only need to be setup once by a doctor or home carer	Technical – Slide 7		
The pill dispenser should be able to supply for long period of time	Technical – Slide 7		
The pill dispenser must be able to hold at least 1 week worth of medication	Technical – Slide 7		
The pill dispenser must have at least 3 doses of medication per day	Technical – Slide 7		
The pill dispenser must be able to be easily used by all ages	Technical – Slide 8		
The pill dispenser must easily dispense medication for people who have dexterity issues	Technical – Slide 8		
The pill dispenser should be safe around children (for within a family setting)	Technical – Slide 8		This has not been considered in the final design solution because I needed to sacrifice it for a much more user friendly interaction with the dispenser. For example, adding a key and lock mechanism to the lid would make it harder for seniors to open to refill their dose etc and so I sacrificed this point to make quality of life for the user easier in another area.
The pill dispenser should put the user at ease so that the user can get on with their own activities without stressing about forgetting to take their medication	Technical – Slide 8		

Producing final design

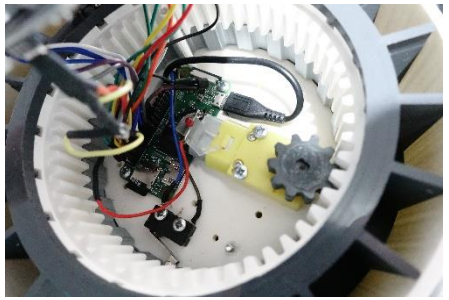
As I had produced my final design by modifying my prototype, swapping and re-making different pieces, I don't really need to create a new final product, however I have compiled all the steps to producing the final product:

First is the 3D printing of the Base, Stand, Rotating Segments (2 separate parts to prevent large scaffolding), Lid, Inner Rotating Gear (2 separate parts to prevent large scaffolding), Gear, Dropping Tray and finally the lid cover:

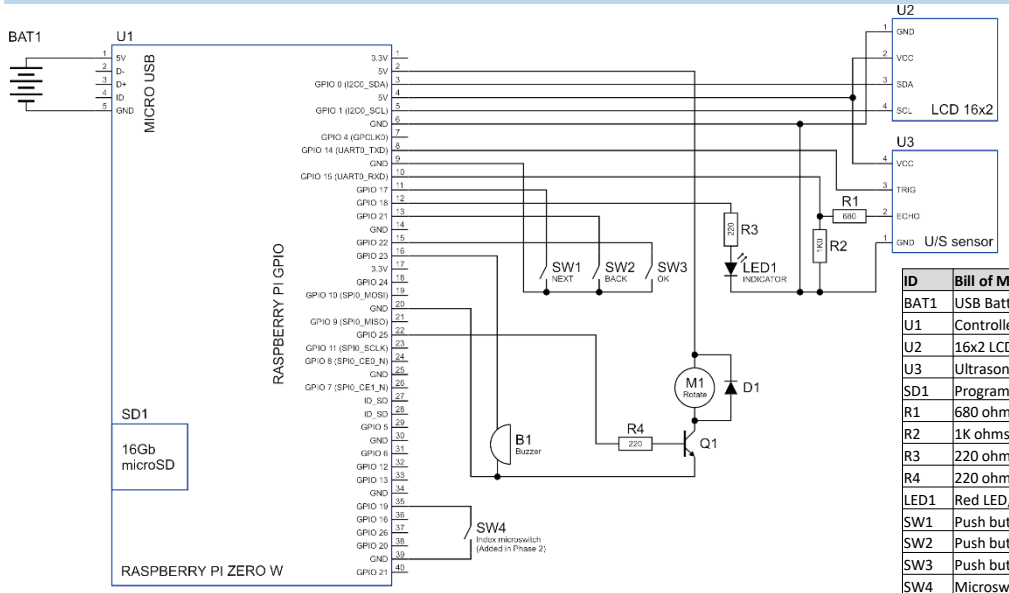


Assembling is simply done by gluing necessary segmented parts together using super glue (in my case serious glue):

Finally the components simply fall into place, with only the lid and electronics which requires M3 screws to be mounted onto the Base



Below is the schematic I used previously for the wiring of the electronics



ID	Bill of Materials needed
BAT1	USB Battery Pack, 5V 10,000mAh
U1	Controller, Raspberry Pi Zero W
U2	16x2 LCD display, HD44780 I2C
U3	Ultrasonic sensor, HC-SR04
SD1	Program, 16Gb microSD
R1	680 ohms, 0.25W
R2	1K ohms, 0.25W
R3	220 ohms, 0.25W
R4	220 ohms, 0.25W
LED1	Red LED, 3mm
SW1	Push button switch, AD1459
SW2	Push button switch, AD1459
SW3	Push button switch, AD1459
SW4	Microswitch, Omron Ss-5gl2
M1	TT DC gearbox motor, 3-6V/0.15-1A stall
D1	Diode, 1N4002
Q1	NPN transistor, 2N2222
B1	Buzzer, ADA1536

Once everything is wired up, the raspberry pi needs to be setup to produce a Wi-Fi hotspot. This was done through firstly downloading python web api library using:

```
sudo pip install web.py
```

Then proceed to setup the WAP (wireless access point) using the very helpful raspberry pi documentation:
https://www.raspberrypi.org/documentation/configuration/wireless/access-point.md
However, we do not want to create masquerade or routing, so the steps beyond that point can be ignored.

Finally we can use a file transfer protocol such as filezilla to upload my PillDispenser code and necessary files to the pi, and then setup the pi to auto run this code using:

```
sudo nano /etc/profile
```

And adding at the bottom:

```
cd /home/pi/web
sudo python program.py 80
```

Viability of final design - Testing

Here is a clip of the full testing of the design (using ball bearings to act as pills)

So does it actually work ?

Yes! It works like a charm, however there are a few bugs with code communication between the web app and Pill Dispenser which can cause some data to glitch, but this can be fixed by just refreshing and overall it works really well!

Viability of final design – Stakeholder opinions

Lisa

- Looks very fancy
- “I would like to take this home with me now to use!”
- Buttons are rather small, maybe caps added would make it better
- Button labels as well
- Would like different variants of buzzer noises, just preference though

Irene

- Web app is very nice, works on all devices
- Maybe add rubber feet to the stand ? Design slips when pushing on buttons
- Maybe add some way to message the user when to take their pills as well ?

Evaluation

Strengths of my design:

- Web app – This allows for a much simpler interactable UI rather than having to struggle pressing the limited buttons and reading off the small 16x2 character display
    - Web app also allows for automatic setup using device information such as system time
- All removeable parts slot together easily with no issue – Allows for easy customizable parts that can be swapped out, such as segmented area for different sizes
- Very customizable to fit users needs – User can change all timings to fit their schedule, and due to the Web app, can access the settings from anywhere as long as they are in range of the Wi-Fi
- Ultrasonic Finder – No need to fiddle about, just a simple wave or hand gesture over it

Weaknesses of my design:

- Slow response time of Web app – Can be frustrating at times as the UI can be laggy due to the limitations of the raspberry pi
- Slippery Stand – When using the buttons on the Pill Dispenser, the Pill Dispenser can slip and slide due to not having any rubber grip on the stand
- Very easy for children to access – Not a good design in a family setting
- No battery pack – Has to be placed near a plug for power

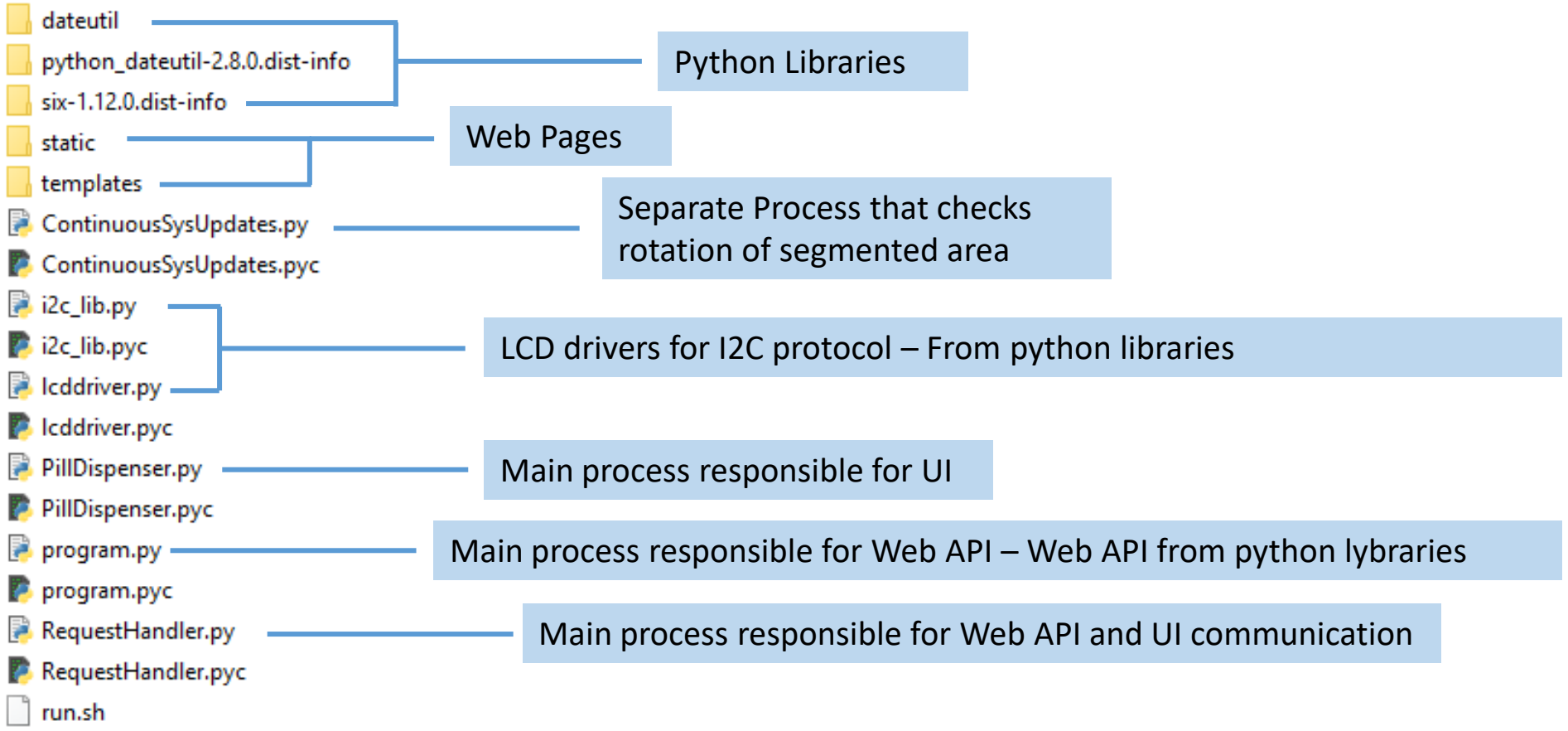
Design Optimization

As most of my design is 3D printed it is incredibly easy to produce, however the electronics are most of the hassle if soldered by hand.

Possible Modifications

- Rubber grip on support – To simply prevent Pill Dispenser from slipping
- Button Caps – Allow for easier use of buttons
- Replace lever switch with motor encoder – Quieter rotation of segmented circle as the mechanical mechanism clicks every rotation
- Some form of logging for missed pills, currently I have variables setup for this in the software but I did not have time to fully implement them into the final design
- Battery pack – Currently the device is powered through a USB (can be plugged into any android charging port, computer USB port etc) a batter pack could add more versatility to the Pill Dispenser allowing for it to be placed anywhere around your house
- Language support on web app – Allow for wider use

Extras – Source Code



Source code can be downloaded from my git hub: https://github.com/randomuserhi/Smart-Pill-Dispenser