Harvard Soft Robotic Design Competition 2023

1. Introduction

a) Title:

SOFT ROBOTIC DESIGN FOR ADVANCING KITCHEN INDEPENDENCE AMONG INDIVIDUALS WITH FINE MOTOR DISABILITIES

b) Abstract

Preparing and cooking food can be a significant challenge for many individuals who face difficulties with fine motor control, despite accessible cooking options on the market. A healthy and nutritious diet requires a level of independence in cooking healthy meals at home, often involves the delicate slicing of various ingredients to prepare. Hence, individuals with limited fine motor skills due to a disability and those with limb amputations often encounter obstacles that hinders their ability to prepare food in a similar manner to able-bodied individuals. The soft robotic device developed in this project solves this problem by providing a device capable of 'clamping' vegetables to slice them in half and a separate "PneuNet" device designed for holding flat, softer vegetables while they are more finely chopped. The device therefore contributes to the soft robotic field by adding further application of soft robotic grippers to work in conjunction with people with a disability. The dual actuator design of the device also offers a point of comparison between pneumatic rigid systems and soft robotic systems, demonstrating how both systems can work together to deliver safe and effective independent living.

c) Background Knowledge

When referring to the gripper having a 'PneuNet' bending actuator design, I am referring to the class of actuators developed by the Whitesides Research Group at Harvard. They are a single moulded/joined piece of silicon elastomer with channels and chambers inside the actuator that inflate when pressurised to create motion and provide force.
The force and pressure sensors used in the project operate by provide an analog output to the voltage supplied.
The microcontroller which runs the control algorithm is based on the Arduino Uno platform and is programmed through the Arduino IDE Software, the programming language is C++.
The feedback control or feedback loop system monitors and adjusts the system's behaviour to respond to changing conditions or disturbances. The pressure/force sensors measure the device's current parameters, comparing them to a defined value then adjusting the device to maintain the desired outcome (known as a feedback loop)

2. Authors

Tim Wilson

3. Design

a) Component Overview

The project is comprised of two central components/systems which perform the two central functions necessary when chopping/slicing vegetables. The first is a system for holding more delicate vegetables to be sliced and is completely compliant. It is based on the Harvard PneuNet design and imitates the function of a claw style grip when chopping vegetables. The second is a mostly rigid pneumatic system which has some soft robotic elements to provide compliance and mirrors the function of a clamp grip (ie. Holding both sides of a vegetable to chop in half). The control system is a 3d printed box with a screen and accessible rotary knob for both rotary and press input. Inside the box are the two pumps (vacuum and compressor), the microcontroller, the pressure sensors (receiving data from the air tubing), and valves which are used to select the device and whether to vacuum/pump.

Figure 1: Final device: See rigid clamp design on left and soft robotic actuator on right.

The manufacture and required tools are further detailed in the Fabrication/Design Process section, but the production of the device requires a 3D printer, a precise scale for measuring amounts of elastomer, cups and stirring tools for mixing, soldering tools, wires etc. and tools for pneumatic tubing such as tube cutters.

System 1: Soft Robotic PneuNet Gripper (biomimetic of finger)

The material that the PneuNet device is made from is silicon elastomer. Silicon elastomer is sold in varying degrees of hardness and is usually food grade. About 150g of elastomer is necessary to manufacture the device. The bending actuator is inside of a 3d printed mount which holds it in position and is slotted into a keyhole mechanism that allows the actuator to move in one axis (forward and back). This allows for securing mounting but also so that the actuator can be removed for cleaning easily and changed position for different shapes and sizes of fresh produce. The mount is 3D printed in PLA filament. The chopping board that the mount sits on can be either 3d printed (with grooves to hold vegetable in place) or can be made from a wooden chopping board. The device is supplied air pressure through silicon or polyurethane tubing. The actuator is embedded with a flexible force sensitive resistor (measuring compression force acting on sensor). The base of the actuator was designed to limit the slipping of the fruit through adding bumps and a textured base which meant that the fruit slips less when it is being cut.

The parameters for the size and design of the PneuNet actuator was determined through testing and prototyping various sizes of actuator. This allowed me to evaluate the weaknesses in the actuators and design custom 3d printed moulds to produce better results.

Figure 2: Testing of larger sized actuator (compared to smaller, final design)

Silicon Elastomer Properties: Elongation at break: 600%; Colour: translucent; Shore Hardness A: 28; Tear Strength: 20kN/m; Tensile Strength 7.5 MPa; Mix Ratio 10:1

Figure 3: Top Section of PneuNet Actuator (pre-joining)

Figure 4: Final 'finger' PneuNet actuator on 3DP mount

System 2: Mostly rigid ‘clamp’ with compliant cushioning

The clamp system is made from small syringes which act as pneumatic cylinders to provide uniform and controlled linear motion. The syringes have 10mL capacity and can be bought from some pharmacies or online. The two pneumatic cylinders (syringes) are clipped into a 3d printed bracket, which is screwed into the chopping board that holds them at a constant position with minimal/no play. The pneumatics are then attached to a 3d printed ‘jaw’ which is coated with silicon elastomer for easier cleaning and some compliance. The jaw holds both the cylinders at the same axis, so that they both extend the same amount and are not lop-sided. The other ‘jaw’ is mounted with a bracket to the chopping board and has a variation on a silicon PneuNet actuator (made in a similar method to the gripper in System 1) that adjusts the amount of compliance to not bruise the fruit and to increase the system’s safety. The jaws of the clamp also have embedded force sensitive resistors for an understanding of the forces acting on the fruit. The device’s purpose is to allow the user to cut vegetables accurately and easily in half (especially vegetables that are hard or slippery) with one hand, or without posing any risk of cutting themselves that might ordinarily occur. While fully soft robotic linear extension actuators were tested such as origami extending actuators, the devices were unsuccessful at providing sufficient force and were not as useful for this project.

Figure 5: Final clamp device (using syringes, 3DP mount). Note wires for force sensors

System 3: Control System

The housing of the control system is a 3D printed box, around the size of a piece of a piece of printer paper. The box was 3d printed so that custom additions to fit certain electronic components such as the screen and encoder in the lid could be easily made. The power is supplied through a singular DC in power transformer from mains which supplies 12V 1A electricity in a singular pin on the box's exterior. There are also ports for debugging and software updating the Arduino. Along the side of the box there are two output connectors for the finger and clamp air tubes to be quickly connected and disconnected. As previously mentioned, the control of the device is done through a singular Arduino microcontroller. A breadboard is used to connect the pressure sensor, force sensors and screen to the Arduino. The small LCD screen on the box's exterior has a GUI interface of a scrolling menu, controlled through the large and accessible rotary encoder knob. The GUI can display pressure values, force values, switch to manual vs preset mode, set the preset value and power off/on the device. This interface has been tested with individuals with limited fine motor and with individuals with an intellectual disability.

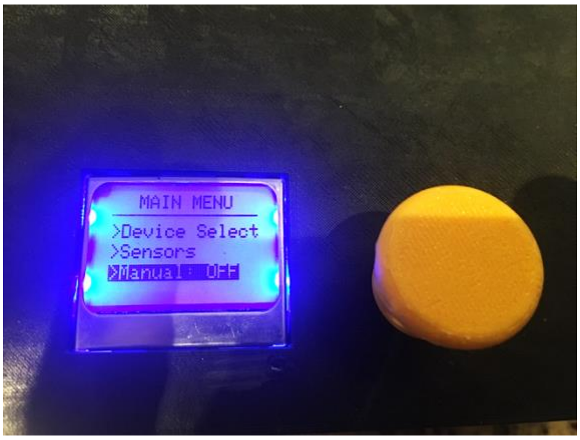


Figure 6: Control box LCD Screen and rotary knob, top view

b) Material Selection

How were the materials decided on for the project? Are there alternate material solutions that would be adequate, but simplify the design, cost, etc.?

The choice of materials for the PneuNet and soft robotics elements of the design came as a result of research into research papers and designs for industrial pneumatic grippers that used a silicon elastomer for a similar purpose. This is because it is stretchable and compliant, food safe and durable. If there was a similar elastomer which had a Shore Hardness A between 25 and 40, and a value of >500% elongation at break, it would also work for this project. The silicon elastomer was bought from Australian supplier 'Barnes' and has the product number 'RTV3428'. After buying 500g of the silicon, I tested and proved the effectiveness of this material choice. There would be limited other options aside from silicon elastomer which shared these properties and was effective for this application.

The project relied heavily on 3D printed parts (printed in PLA filament), but the parts and moulds could all be produced in other filaments such as ABS. PLA was chosen because it is food safe, stable and cheap. It would be very difficult to reproduce or make the PneuNet designs without 3D printing technology, but some parts could easily be made out of wood or other materials (such as the chopping board). The cost of PLA filament is low and accessible for most.

The microcontroller can be changed for other similar or custom microcontrollers, but the Arduino platform is fairly cost-effective and easy to prototype. The LCD screen can be changed for another other screen tech such as OLED or a different size of LCD (or without backlight). The control of the system can be achieved through just using a laptop for prototyping or altering the code. The use of pressure sensors are necessary, and any IC pressure sensor can be used. The force sensors are non-essential and offer only a little more control. The material of pneumatic tubing can be anything that fits into 3/8" quick connect fittings, or other joinery. The transformer/power supply can be any specifications of 12V 0.5A or above DC power.

c) Design Optimisation and Experimentation

There were multiple stages of experimentation with the design in the forms of analysis of motion and methods of gripping/chopping vegetables, prototyping, analysis of primary case studies, manual testing of device function and re-performing experiments with user group to evaluate effectiveness.

Movement Analysis (of chopping vegetables) with user group

The first stage of research to optimise the device's function was analysing the motion and movements required for gripping/chopping fresh produce and what someone with a fine motor disability struggles with. This included video analysis, determining the most popular ways to chop vegetables and testing with user group (as a case study). The vegetables and types of chopping that I investigated included an onion, carrot, pumpkin and potato. I gathered quantitative data on the movements and the most importance of certain motions.

Results

Vegetable	*Motion*	*Grip*	*Comments of User Group Performance*
Onion (diced)	1: halving (cutting lengthwise).	Holding both sides of onion	Fairly safe motion, knife had tendency to slip
	2: Cutting/slicing into slivers	Claw grip or fingertip grip on top of onion	Confident with 75% of onion. Very difficult last 25% (fingers slipped because not enough strength to grip.
	3: Dicing/second direction	Not holding at all or flat palm	Easy with long knife on board, thumb stuck out (safety concern)
Carrot (cut in sticks, diced)	1: Halves (cutting lengthwise x2)	Clamp/pincer grip on both sides	Determined too dangerous for user group to test (knife can easily slip off carrot) Difficulties with strength
	2: Cutting into chunks	Hold flat, flat hand on board	Easy to hold, no safety issues. Found sizing difficult
Pumpkin (diced)	" (same process as carrot)	"	Easy to hold, stiff, well-shaped with a less slippery texture
Potato (diced)	"	"	Large size, easy to cut in half and dice (strength/pressure) was difficult for user group

Conclusion

After analysing grip techniques required for chopping some of the most common vegetables, I have shown that there are two key movements to cutting most vegetables, no matter shape or hardness. These are:

1. Chopping the vegetable in half (using a clamp or over knife grip)

2. Slicing/dicing the vegetable in a second direction

Therefore, my design should be optimised for the above two movements.
The hardest movement was slicing the onion - especially the end of the onion (as there was little space to grip) and required much more precision. Additionally, the halving of harder vegetables like carrots and pumpkins was challenging due to strength issues and the tendency of the knife to 'slip off' the centre. Hence, I will try to design a device which can assist with these tasks as they are the most limiting.

Prototyping, force tests with prototypes

System 1: Soft robotic PneuNet Actuator

First prototype was made with information from the *Soft Robotics Toolkit*'s website, made of silicon elastomer and some nylon pneumatic tubing. I 3D printed two different sized moulds downloaded from the internet and tested the breaking pressure and forces generated from the two differently sized actuators. I found that for the smaller actuator, I was able to produce approx. 1.96N down (measured with a scale) and this was at 7PSI (relative). At 8PSI, the force would remain constant, and the finger would bulge outward without producing any more force. This is evidenced in the image below.

The larger actuator had a similar problem but at a higher pressure of 9PSI before it did not produce any additional force. At this peak, it produced approx. 2.75N of force down which was an improvement for my application. While testing this design, one of the actuators 'bulged' out as shown above and ruptured meaning that the prototype was no longer functional.

Design optimisation decisions:

- Reinforce the sides of the modules that inflate by increasing wall width.
- Programming: consider a 'max pressure' loop so that the actuator cannot burst at a high pressure
- Less length means that the actuator curls less and therefore produces a greater downward force (for this application)

System 2 Prototype: Soft Robotic Linear Origami Extending Actuator

Considering a method of linear extension that used soft robotics, I researched the possibilities of origami-based actuators which were based on cylindrical patterns encased in silicon. I used the principles and method from the paper "Elastomeric Origami:

Programmable Paper- Elastomer Composites as Pneumatic Actuators” by Ramses Martinez et al. which included the Yoshimura origami pattern. I attempted this pattern, but found that I could not pore a mould which covered the whole paper in silicon, and the thick silicon impaired the bending of the folds and therefore caused the sides to cave in. If I chose to pursue this idea, I could investigate using a different type of paper and a thinner mould. Overall, however, this experiment led to me moving away from a soft robotic linear expansion to a hybrid pneumatic option, which has similar outcomes, but is much easier to manufacture and has great reliability.
See moulds and prototype actuator below:

Fruit/Vegetable Testing (force to break)

By testing the limits of certain common fruit/vegetables I determined some of the parameters for the max force that could be applied to a piece of fresh produce that is being cut before it deforms/bruises. This was tested by hand on a scale and force was derived from the mass readout. The data is to one significant figure.

Results

Fresh Produce	Max Force Applied Before Deformation/Bruising (N)
Apple	700
Banana	30
Onion	200
Carrot	800
Pumpkin	200
Potato	200
Strawberry	10

Durability Experimentation

To optimise the durability of the device, I did a repetitive trial of the soft robotic ‘finger’ actuator. A program was used that counted cycles from 6PSI to 1PSI (relative) as this is about the working pressure of the device. I recorded 45 cycles for the larger device (first prototype) until a small air leak came from an air bubble in the silicon. Aside from the minor leakage, which was fixed with tape, there was some shape deformation over time which caused its rest position to be more inclined.

Factors to improve durability:

- Minimise air bubbles in manufacture of device

- Shape deformation -> vacuum feature of device to make actuator rigid and straight upright

Final product durability evaluation

The test was repeated for the final design, and 100 cycles (@1-6PSI) were recorded without any leaks (due to improved fabrication quality). There was some shape deformation, but it was still usable due to the vacuum feature which pulled device to horizontal. The pressure sensor had .8 PSI of offset which could be addressed by adding a reset button for the offset to the menu, but this amount is within the functional range of the device.

The clamp part of the device survived with no change for >100 cycles, likely because of its rigid design and limited complexity. The pump and motor also remained healthy, with no variation.

Results

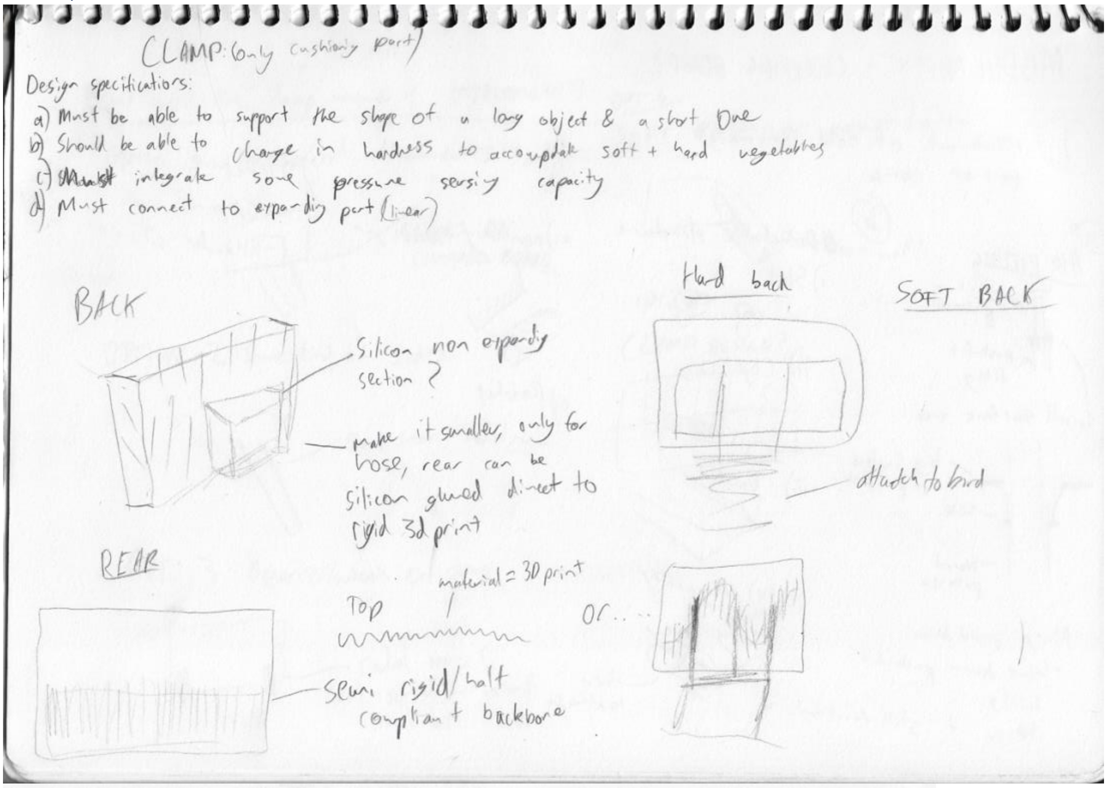
Devices	Cycles before issue or significant deformation (@6 PSI to 1 PSI)
Prototype (1st iteration) soft 'finger' actuator	45
Prototype (2nd iteration) soft 'finger' actuator	60
Final soft robotic 'finger' actuator	>100
Clamp device (rigid)	>100
Pressure Sensor	100
Pump	>100

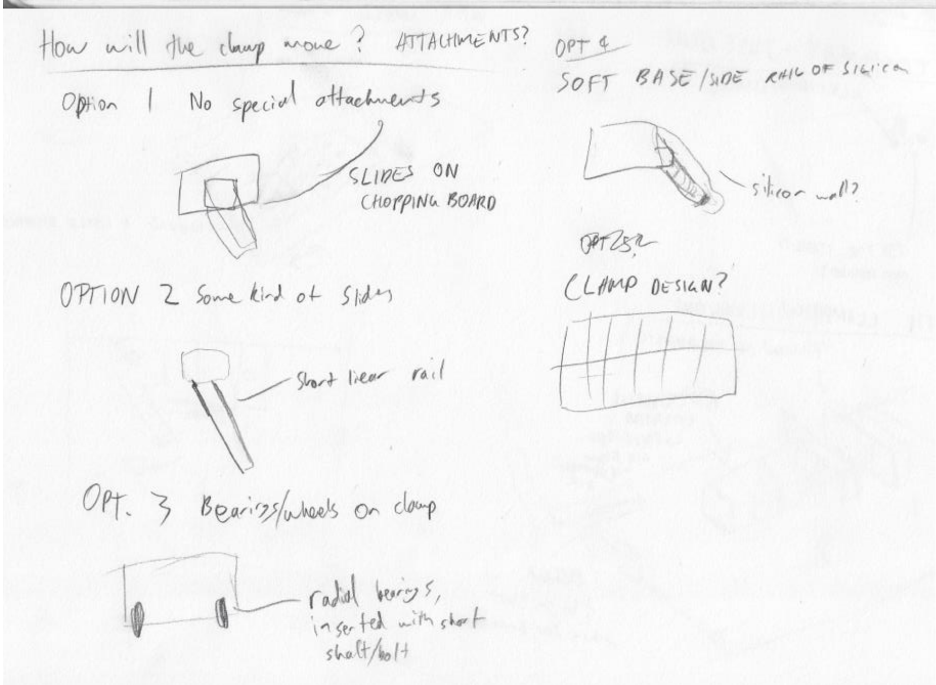
Configuration of device for durability test:

4. Fabrication: Design Process

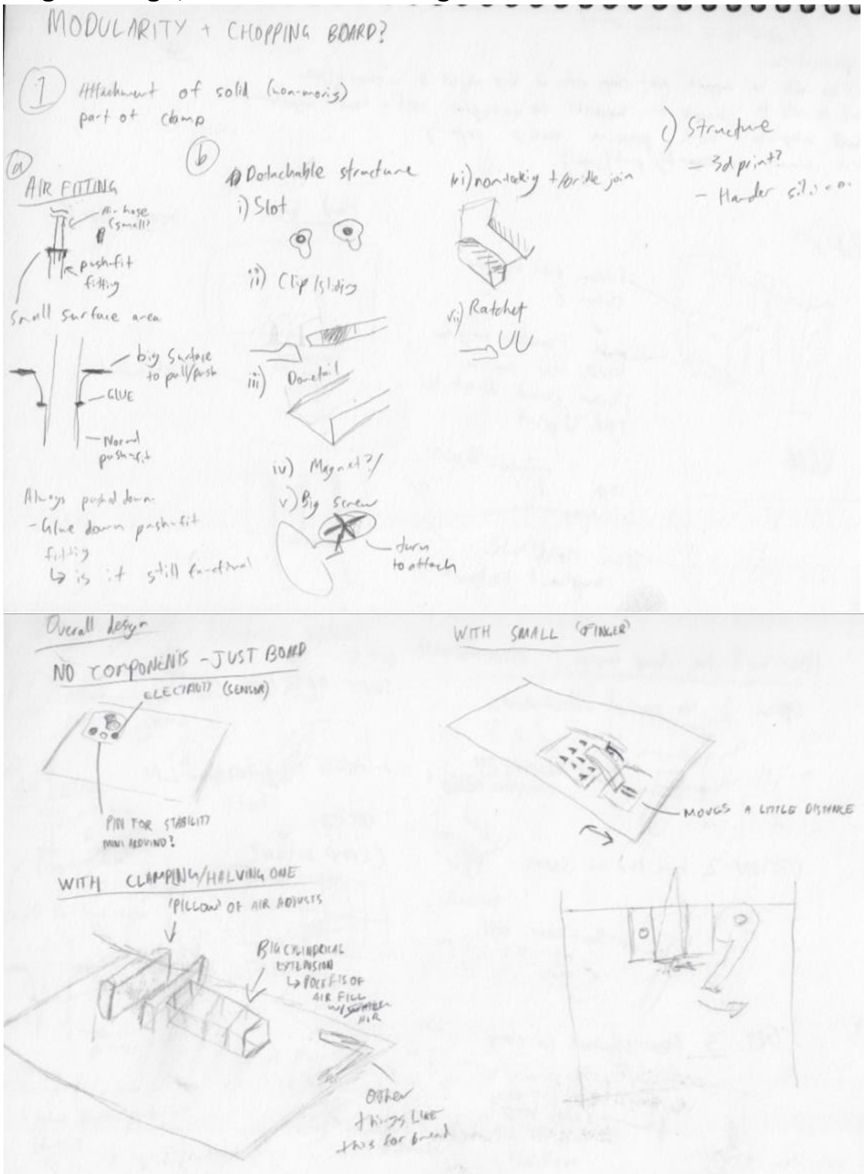
Sketches of design, mechanisms (hand-drawn by designer)

Clamp:





Finger Design, holistic device design:

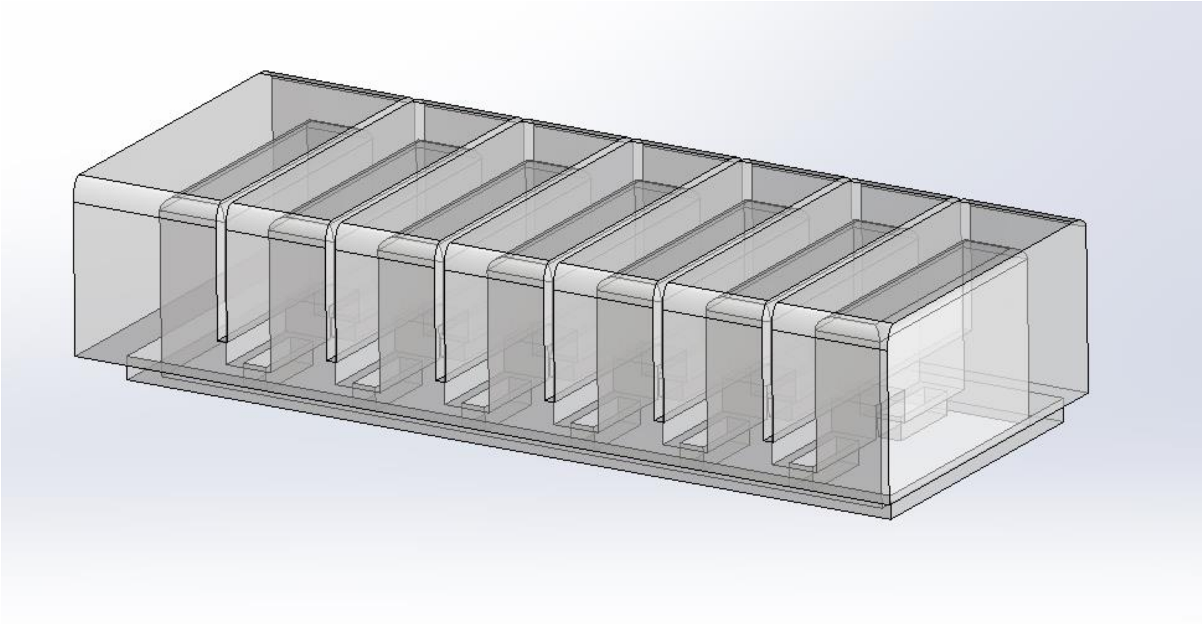


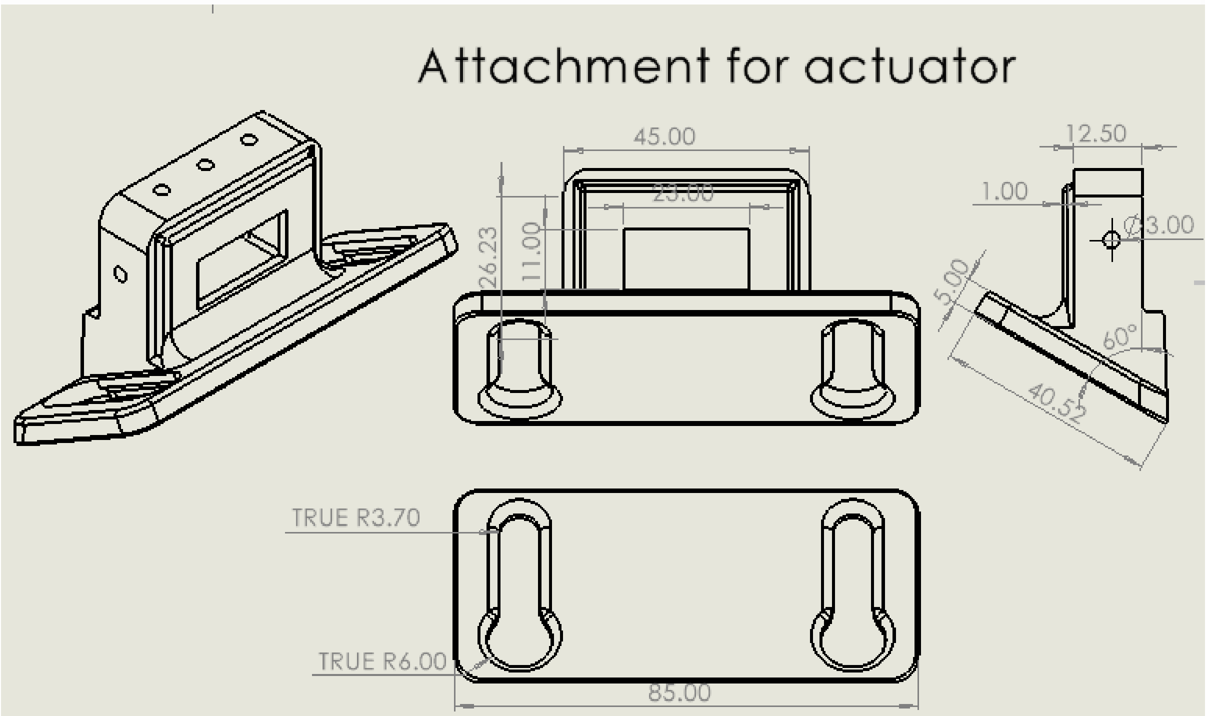
CAD modelling (mould parts, base printable)

https://github.com/timo-wilson24/Soft-robot-kitchen-assistant/tree/1f0e81280b5753aea2adc9df44ec5698dffbd508/Solidworks%20CAD%20files

Once sketches of design were complete, I used Computer Aided Design (CAD) modelling to make the mould and design the board and mount, which could then be printed.

For the mould of the finger, I first made each compartment which was patterned, added air channels to make the positive of the mould. Extruding around this shape and adding tabs for mould removal completed the CAD process. By changing the dimensions of the compartments or air channels, the characteristics of the device could be altered, which was effective for prototyping. See dimensions in engineering drawing at the bottom of this portfolio.





Manufacture Process:

1. 3D printing of parts, assembly of mould

https://github.com/timo-wilson24/Soft-robot-kitchen-assistant/tree/1f0e81280b5753aea2adc9df44ec5698dffbd508/Printable%20files%20(STL)

All my prototypes and final design utilise the process of 3D printing to create customisable and highly detailed moulds for silicon. The 3D printing process involves 3 steps: slice the 3D model in a slicer software (Ultimaker Cura 5.2) using settings which make the best print quality; transfer GCODE file to a printer (Anycubic Vyper) and press print; wait for print to complete then remove 3D print from print bed with a scraper and clean model of any support material.

Once the mould is printed, the top and bottom part can be placed together, ready for silicon to be poured.

Figure 7: Mould for finger actuator (3D printed, PLA) see top and bottom part assembled, rear is base with traction marks

2. Mixing of silicon elastomer, pouring of part 1 of mould

Mix the two parts of silicon elastomer according to the mass and the ratio given. Mix slowly and let to rest for 10 minutes to reduces air bubbles. If applicable, use a vacuum chamber to remove bubbles for mix. Pour the silicon generously into the mould.

Figure 8: Application of mixed silicon elastomer to base of actuator

3. Insertion of Strain-Limiting Material, Curing

So that the soft robotic actuator can bend, a material (fabric or paper) must be put inside the silicon to limit its flexibility on that surface. I determined that the best durability material for this application is fabric, as paper tends to fold and crack under repetitive and high loads. Paper can, however, be used as an alternative.
Cut a piece of non-elastic fabric to place on the base (flat part) of actuator. Place on the base/flat mould once the first layer (~2mm of silicon) along with a thin flexible force sensor. Ensure the wires are accessible (either have connections or easy solder points).

4. Demolding

Use a screwdriver or other prying tool to separate the top from bottom mould. The silicon can bend and stretch without snapping, just ensure not to puncture the walls or roof of the actuator. Once demolded, and the strain-limiting material is inserted, the top and flat part of the mould can be fused together (with more silicon), taking care as to not seal the air channels.

5. Curing

Leave parts on a flat surface for curing. Curing will take approx.. 15h. A faster curing can be achieved by leaving parts in an oven at about 50˚-70℃.

6. Electronics and general assembly

Once the mechanical/soft robotic subsystems are finished, the electrical and pneumatic subsystems must be connected to the soft robotic parts. A tube must be glued into a hole punctuated in the soft robotic PneuNet device. This tube can attach to the quick connect fitting in the outside of the control box.
The pumps and solenoids (if necessary) need to be soldered so that they can be permanently tethered inside the box without reliability issues. The other side of the wires should be plugged into the MOSFET bank.

Connect all relevant pins to the Arduino, including the sensors. Connect the other end of the pins to the breadboard or relevant device. Solder any resistors onto the perforated circuit board.

Screw electrical components into enclosure so that they are secured.

Attach tubing to solenoids and pressure sensors. Attach tubing/anything else from the exterior (including the force sensor).

7. Programming of Arduino

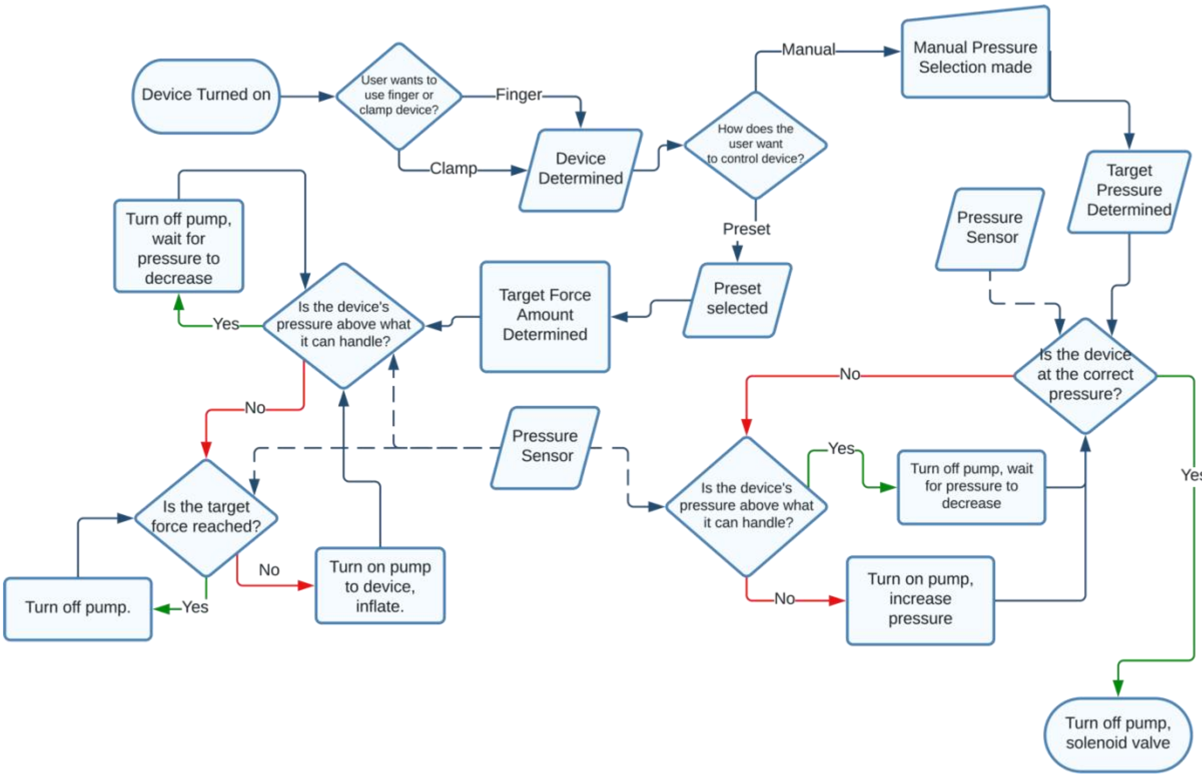


Figure 9: Flow chart of programming, feedback loops on Arduino microcontroller

https://github.com/timo-wilson24/Soft-robot-kitchen-assistant/blob/1f0e81280b5753aea2adc9df44ec5698dffbd508/Menu-screen-and-control-code.ino

5. Contribution Significance

The development of this project contributes valuable insights and practical applications to the field of soft robotics, particularly in the context of assistive technology.
The integration of rigid and compliant systems, particularly in the mounting of the soft 'finger' actuator and the 'jaws' of the clamp are effective demonstrations of how soft robotics can be used to enhance rigid and more conventional robotic systems. It also offers a point of comparison between pneumatic rigid systems and compliant systems, demonstrating how both systems can be used concurrently in a solution to deliver safe independent living. In doing so, the device will meaningfully encourage other research into more modular/movable mounting for the commercial application of soft robotics.
The research and development to the PneuNet 'finger' actuator and rigid clamp are now open sourced, so anyone looking to prototype similar solutions or looking into optimise the PneuNet model for similar or different applications have a knowledge base and CAD files which can be used to reproduce the project.

6. References

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7. Case Study

a) Grace Case Study

The case study was performed with 'Grace' who has Downs Syndrome and so has decreased fine motor control in her fingers and an intellectual disability. I observed her cutting some vegetables to prepare a healthy pasta, including onion, carrot and potato. This revealed the difficulties faced by people with motor disabilities in preparing food (see full results in Section 3c), especially relating to safety issues around the knife slipping into fingers and potentially causing injury.

After the product was fabricated, I conducted another observation experiment with Grace to test her improvements in using the device. I explained to Grace how to use the product and she seemed to understand how to operate the screen well and increase, decrease pressure. In using the clamp system, she attempted to prepare the same vegetables tried previously without the device. While using the clamp system, her grip and cutting was much more stable than previously. She had better control over her cuts because she could focus more on the movement hand that was cutting (rather than holding the vegetable). The only issue with the clamp device was that she instinctively felt that she had to hold the chopping board or hold the clamp to secure the device, so some suction cups should be added to the base to make it more stable.

The device held the carrot very securely and had no movement of the carrot when slicing horizontally to slice it into pieces. It was noted that having a very high pressure on the device made it difficult for the user to chop the vegetable as it compressed the vegetable onto the knife. A lower pressure was preferred for vegetables that could be held at a high force even though it might create some minimal movement. The clamp was also good for slicing perpendicular to the carrot to dice the carrot (if necessary). The prototype used for this test was mounted on a small chopping board which made the use of the device a little clumsy, and a larger chopping board was used for the final prototype.

The slicing of the onion in the clamp device was effective and easy for the user. The removal of the vegetable to chop it into quarters was simple as all it required was the turning of the accessible knob. Similarly, to the carrot, a higher pressure made it difficult to chop the onion in half, so a moderate pressure was preferred. It was still sometimes difficult for Grace to cut directly down the middle, so a moving guide might be considered for another prototype/future improvement.

The finger device was used to finely chop the onion and it was mostly effective. It had a less secure hold on the onion, largely because the actuator was curling in a direction not exactly perpendicular to the board. This pulled the onion towards the actuator base and reduced the force holding the onion in place. The finger had to be used at close to its max operating pressure to generate enough force to hold the onion securely. Grace was able to chop most of the way through the onion without issue, but towards the last third, the actuator was prone to slipping off the onion.

The cutting of a more delicate fruit – a tomato – was performed to test the device's effectiveness at all types of fresh produce. The clamp device worked fine on a low pressure and did not squash the tomato. As the tomato was easy to slice into, it was not hard to use in this setting. There were no safety concerns. Cutting the tomato with the soft actuator was effective as the device was more effective at a lower pressure. This allowed Grace to finely slice the tomato for a healthy meal!

Most of the testing in the case study is showcased in the video:
https://youtu.be/luMKAHcBeGc?t=9

b) Other use cases of design

The device can be used for plenty other user groups in the kitchen – for example it could make the chopping of vegetables in a professional kitchen more efficient or safer. For fast food restaurants where efficiency and safety of (often) not highly skilled workers is key, this device could be used to minimise risks of injury. It could also help with allowing the employment of people with a fine motor disability in the hospitality industry, making a big difference financially on their lives.
In other applications aside from the clear kitchen application, the device could be used in the workshop setting for automating the holding of fine parts. This could be for electronics, where clamps and soft holders are often needed to allow for steady soldering and the attachment of parts. Additionally, the device could be scaled up to a larger workshop setting and be used as an automated clamp and holder for woodworking for people with a motor disability.

The impact of the device on individuals with a fine motor disability is extensive and will enable many to live and function independently. Diet is an essential aspect of all wellbeing and is often the result of the choices of food that a person makes at home. The process of preparing healthy food is often very difficult for people with a fine motor disability, so enabling this process to be simpler and easier will make it easier for these people to have a more nutritious diet. A healthier diet affects long term physical and mental health and is an important part of a person's wellbeing. At present, in Australia, "around half of people aged 2 and over with disabilities eat less than the recommended serves of fruit and less than the recommended serves of vegetables each day," (ABS, 2018).
Greater independence that allows someone with a disability to not require a carer is empowering for the individual and values their role in society (Social Role Valorisation - SRV). Independence in the kitchen can lead to further independence in one's life in other aspects (where they don't have to rely on carers) so that they can exercise autonomy and control over their relationships, environments, and daily activities. This overall achieves greater health outcomes and fosters a greater sense of purpose and fulfilment.

The impact of the device on society is multifaceted, promoting inclusivity by increasing the independence and ability of people with fine motor difficulties. Generally, improving the health of a disadvantaged group is integral to the betterment of social welfare. A functional societal should care for and assist those most vulnerable, so when fine motors disabilities significantly affect the diet of this group of people, something must be done to address this. As the device makes it easy for people with a fine motor difficulty to prepare healthy meal options, widespread use of the device will improve public health and therefore better society. At present, limited solutions address the challenge of preparing fresh produce and accessibility remains a significant concern. These devices often fall short in effectively accommodating the diverse array of culinary tasks and the wide range of fruits and vegetables encountered in daily meal preparation. The need for an innovative and comprehensive solution that caters to a broader spectrum of disabilities and culinary needs becomes apparent in this context.

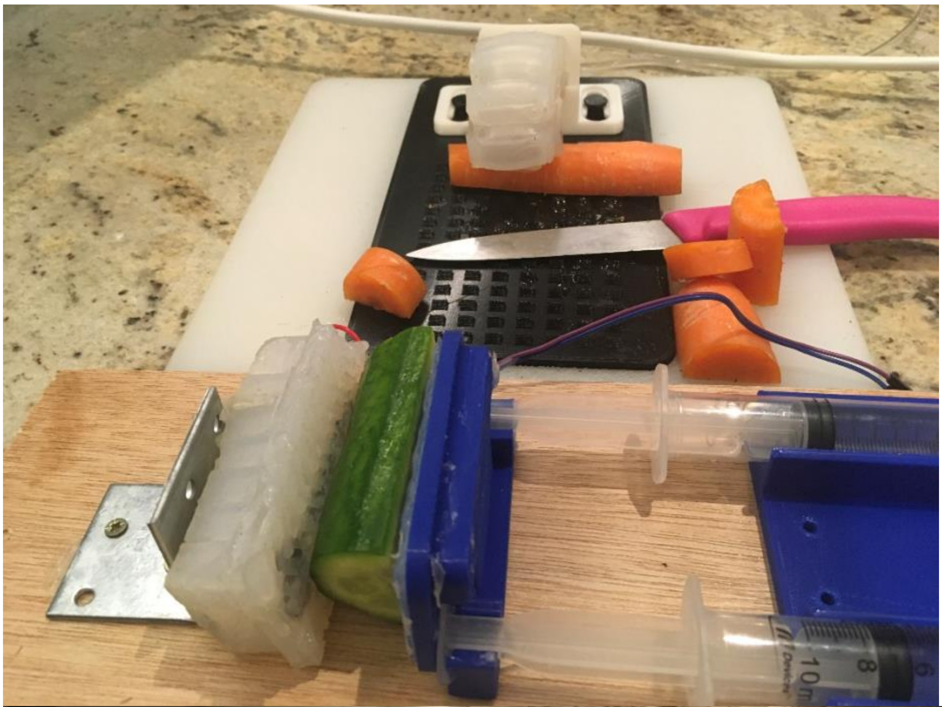
The impact of the device on a community would be in making the community more inclusive and accessible for people with a disability. This would hopefully make certain communities more welcoming and inhabitable for people with a disability and overall empower the disadvantaged individuals who struggle to be independent due to meal preparation. The independence of people with a disability in communities leads to social role valorisation which means that everyone is enabled and established as valued in the community. In a much broader context, a movement towards healthier diets in a community (encouraged through the device) can lead to reduced emissions, and a healthier climate.

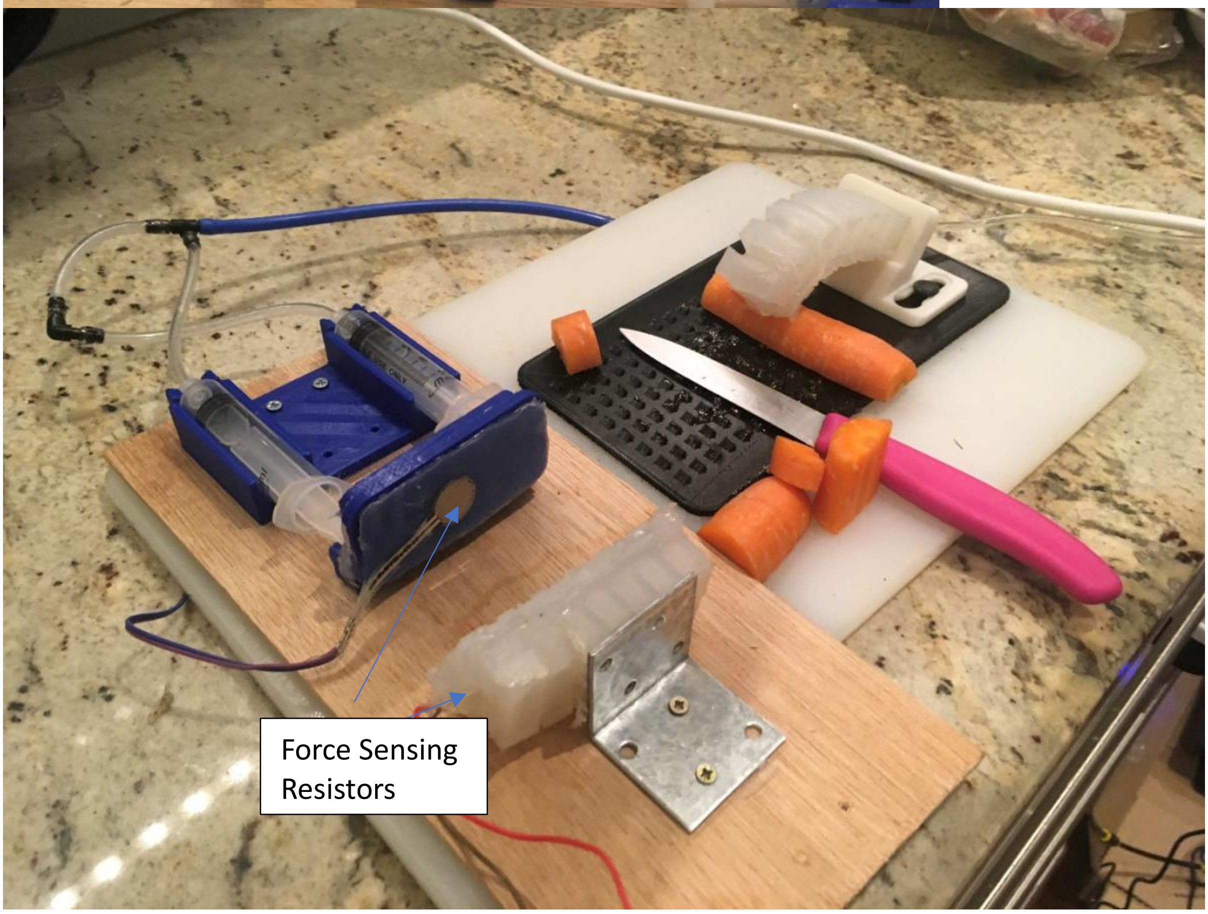
8. Evidence/Media of Project

a) Demonstration Video

[Soft Robotic Chopping Board Assistant - SRT Comp Submission - YouTube](https://www.youtube.com/watch?v=luMKAHcBeGc)
https://www.youtube.com/watch?v=luMKAHcBeGc

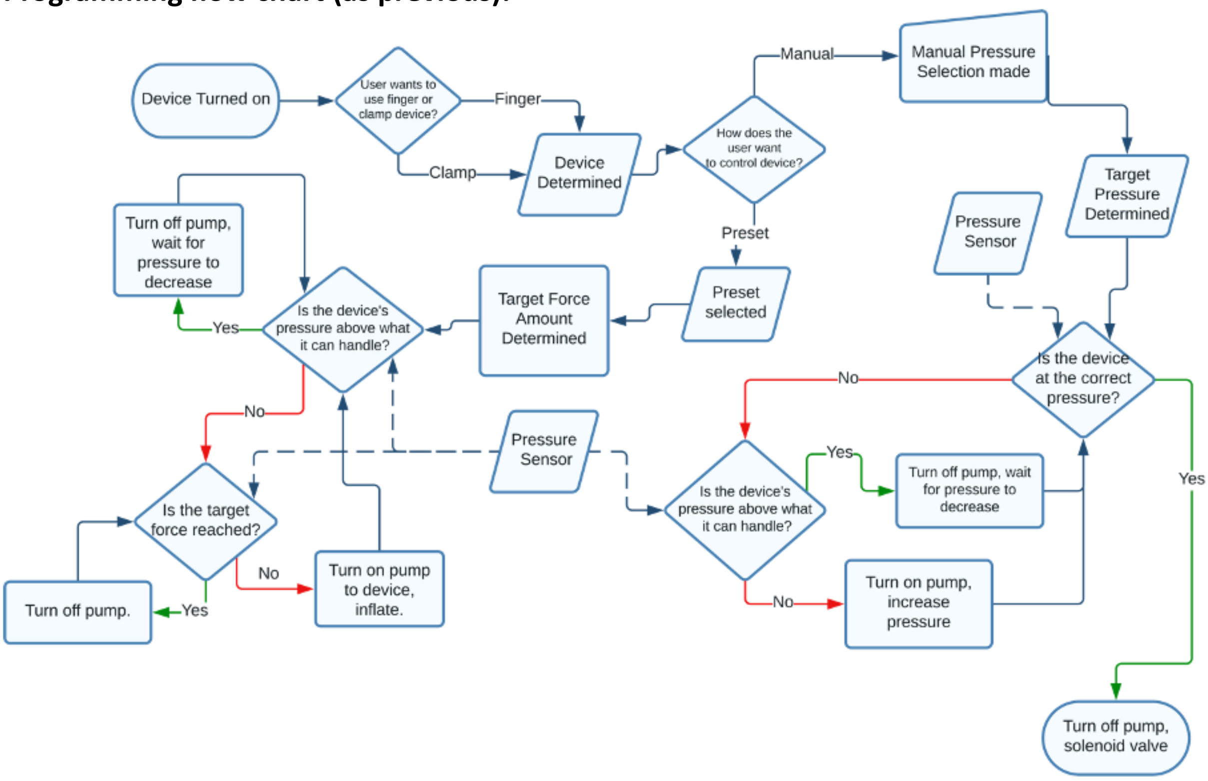
b) Detailed Photos of design




Force Sensing Resistors

c) Engineering designs (CAD, circuit designs)

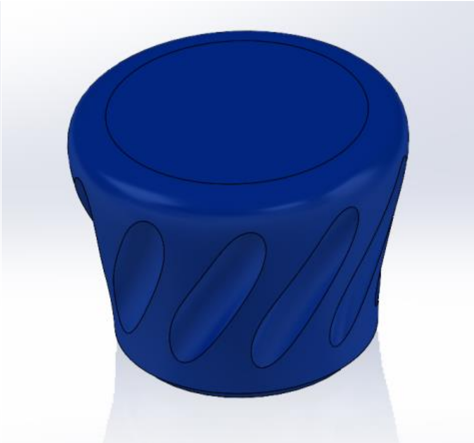
Programming flow chart (as previous):



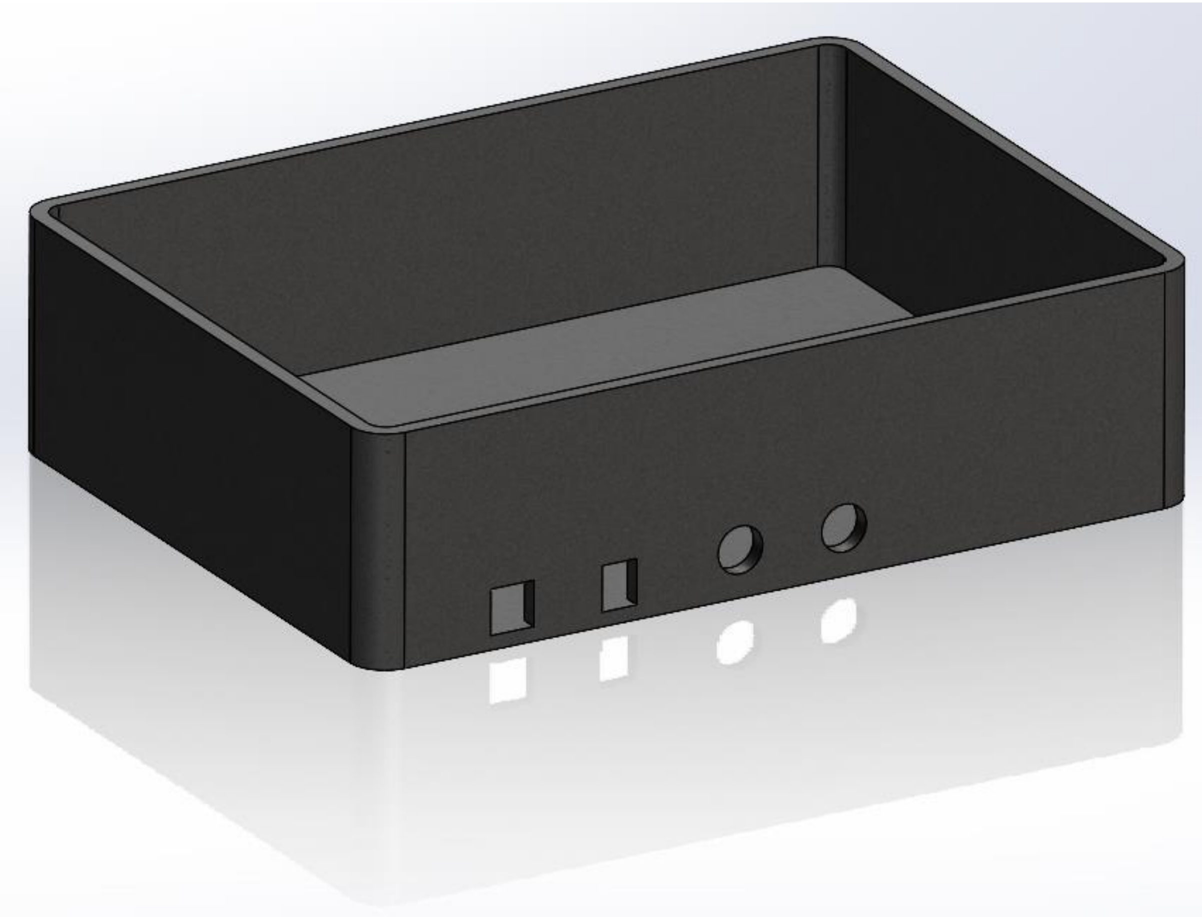
CAD Designs

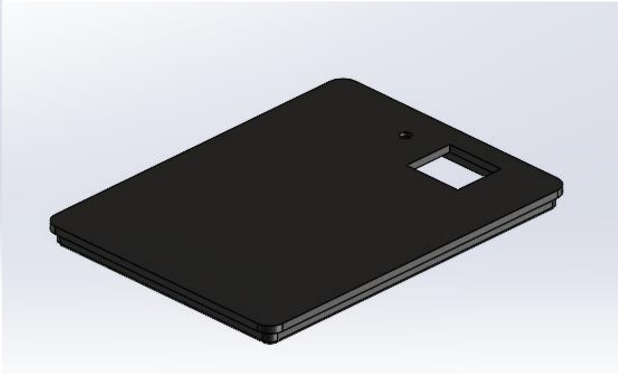
https://github.com/timo-wilson24/Soft-robot-kitchen-assistant/tree/fbe950fc147cd823435d51dc1ff3e5a68aaa6c2e/Solidworks%20CAD%20files

Accessible knob

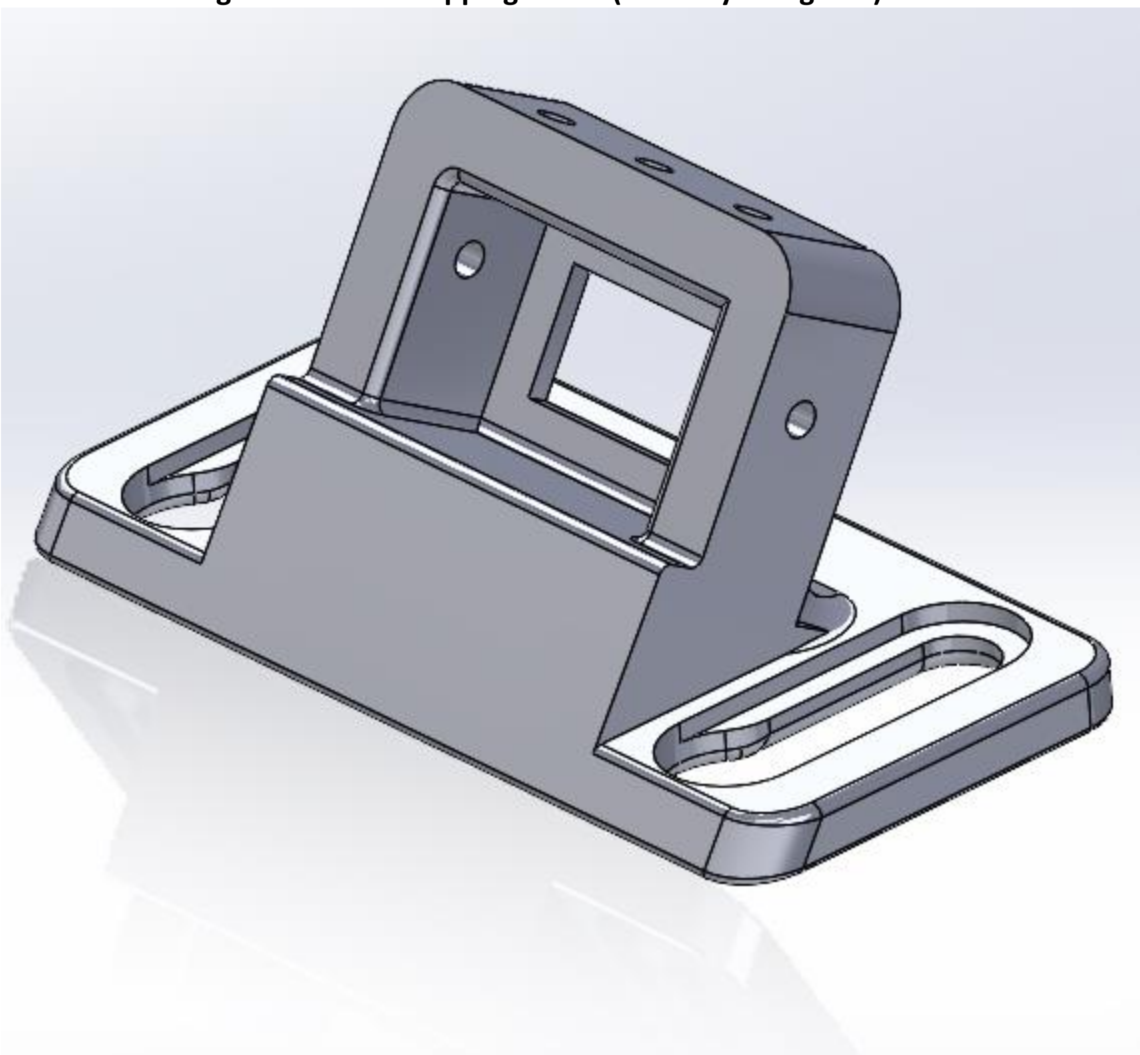


Electronics Box/enclosure with lid

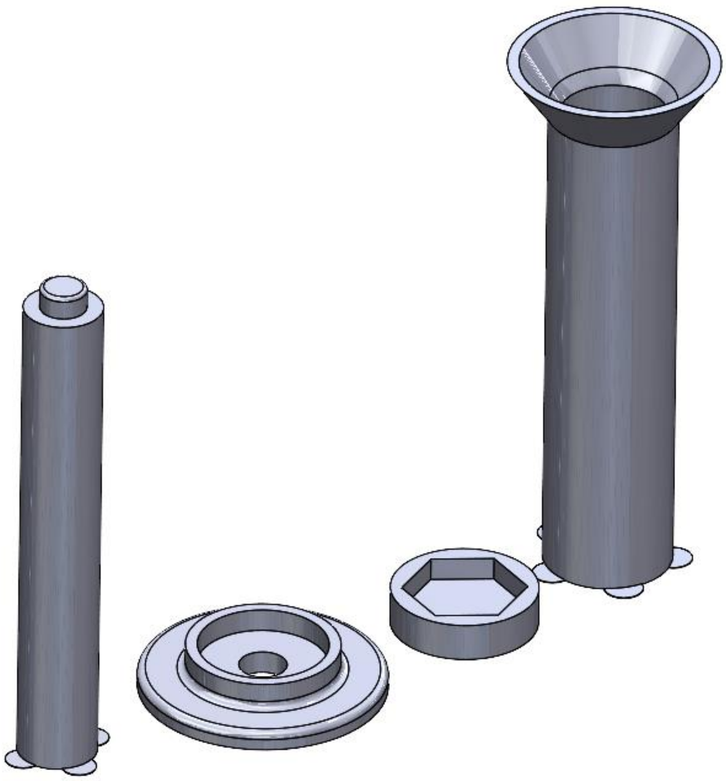


Part for attaching PneuNet to chopping board (with keyhole guide)



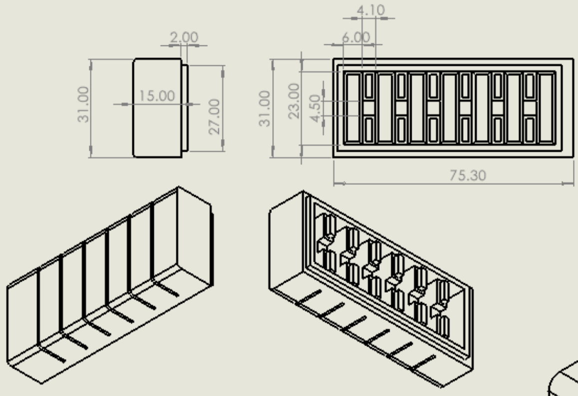
Prototype soft robotics linear extension moulds



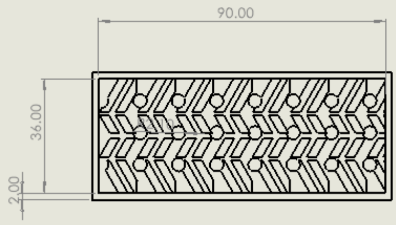
Engineering Drawings

https://github.com/timo-wilson24/Soft-robot-kitchen-assistant/tree/1f0e81280b5753aea2adc9df44ec5698dffbd508/Solidworks%20CAD%20files/Engineering%20Drawings

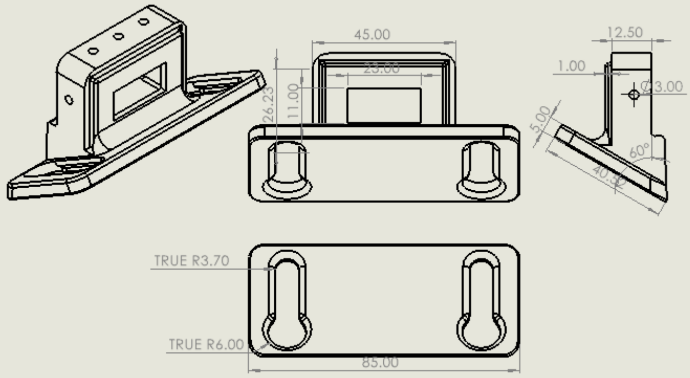
PneuNet 'Finger' Actuator (positive)

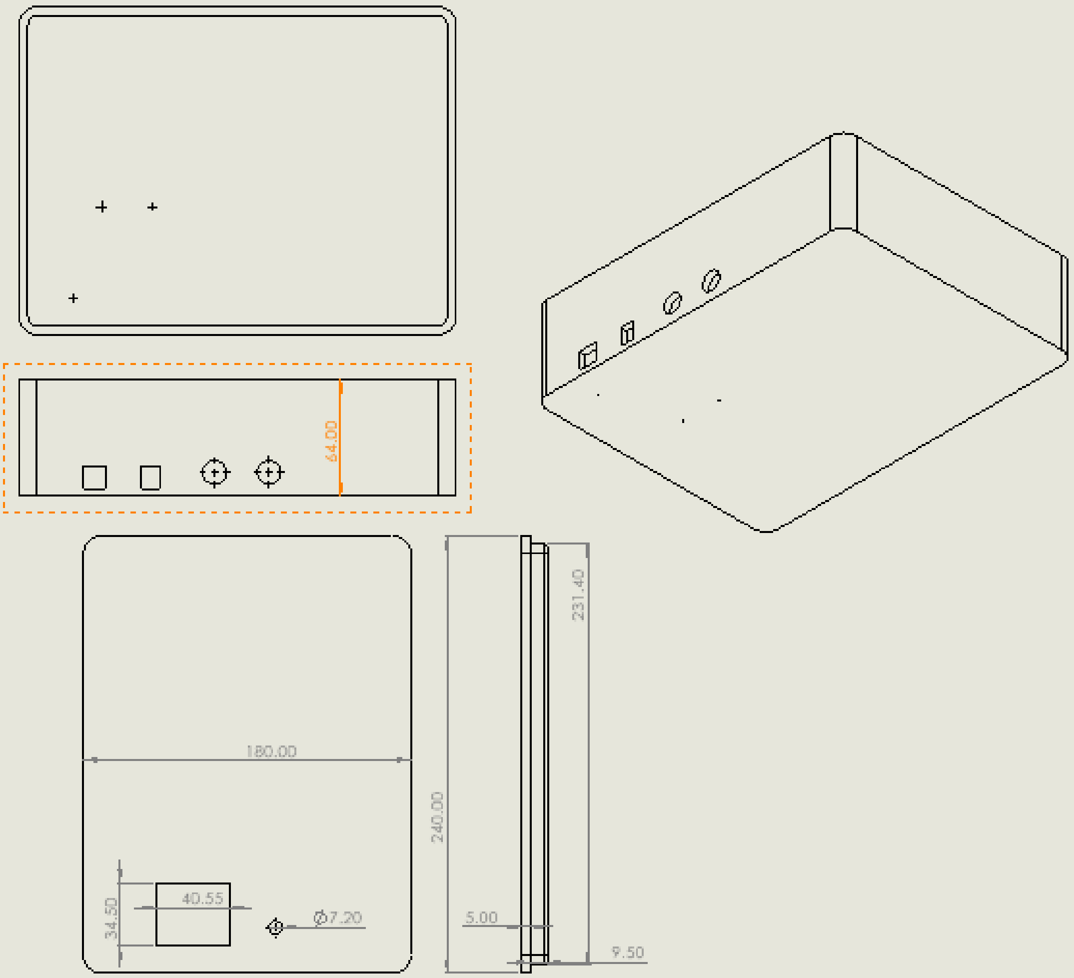


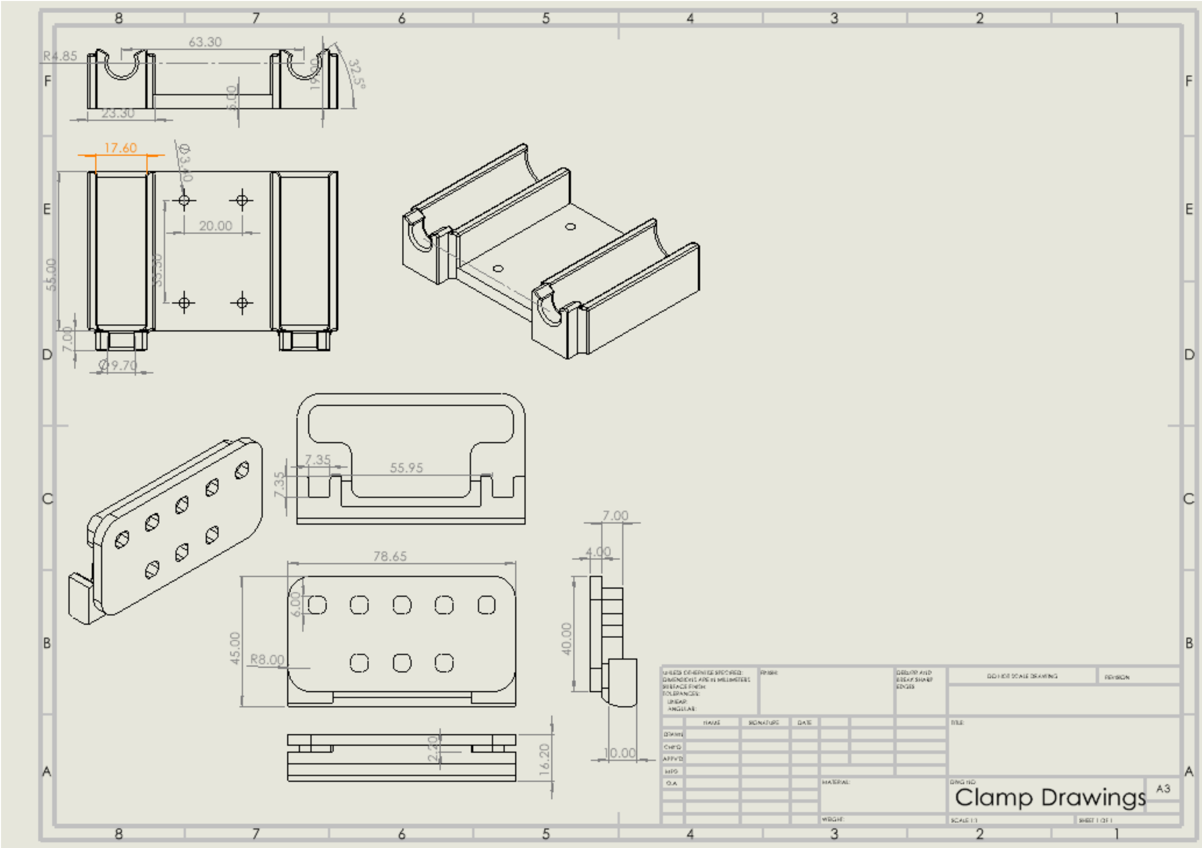
Textured base for 'finger' actuator



Attachment for actuator







Clamp Drawings
A3

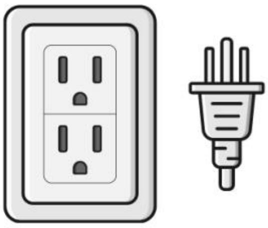
Product User Operation Manual/Instructions for User

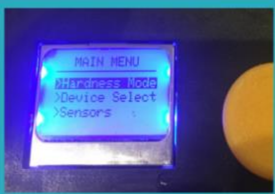
User Manual

KITCHEN CHOPPING ASSSISTANT

Power On

Conenct the 12V transformer to the mains outlet. Plug round connector into the side of the black control box.





Select Mode And Device

Press in the yellow knob to enter the Hardness Mode. If you want to use a preset, select it from the list by holding the knob. Select the device you need to use from the second menu.

Put Fresh Produce in Device

Cut normally. You do not need to hold the produce

Set the Hardness Mode to "Retract" to take out your chopped fruit