Tactile Gripper Project

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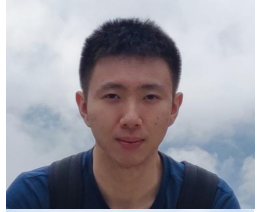
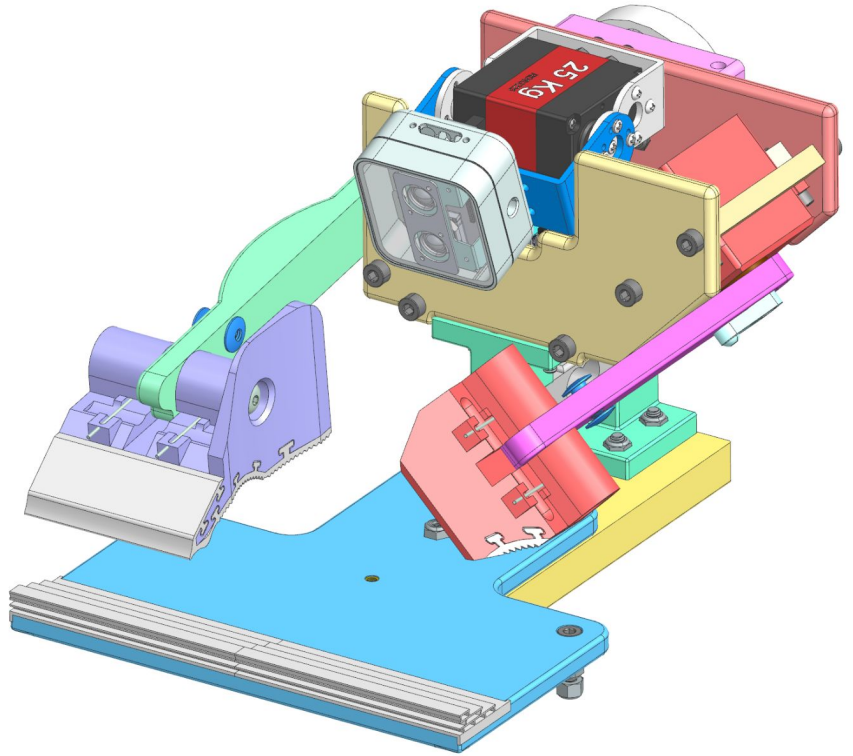
Sponsor: Professor Thomas Howard



Project Overview

The team is tasked to design and build a robotic hand that can detect and pick up a variety of differently shaped common household objects, as well as detect how hard it is gripping the object. This will replace the current two fingered hand on the robot arm, which is not suited to pick up irregularly shaped objects.

Problem Statement

Design a custom end-effector with tactile feedback which integrates with the Baxter / Sawyer Research robot arm, capable of manipulating YCB Benchmark objects. Existing designs are too expensive or lack full mobility.

- An end effector capable of grasping a range of objects from the object sets will allow the Baxter robot to be used for research projects to study how to replicate human motion and better perform complex tasks.

- Additionally this project can act as a stepping stone to decrease human risk and increase safety and efficiency in the field of manufacturing.

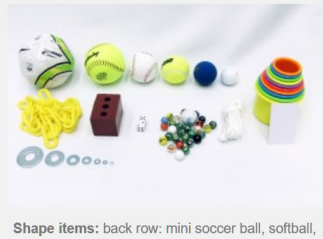
Baxter Robot

Current End Effector

Food items: back row: chips can, coffee can, cracker box, box of sugar, tomato soup can; middle row: mustard container, tuna fish can, chocolate pudding box, gelatin box, potted meat can; front: plastic fruits (lemon, apple, pear, orange, banana, peach, strawberries, plum).

Kitchen items: back row: pitcher, bleach cleanser, glass cleaner; middle row: plastic wine glass, enamel-coated metal bowl, metal mug, abrasive sponge; front: cooking skillet with glass lid, metal plate, eating utensils (knife, spoon, fork), spatula, white table cloth.

Tool items: back row, from left: a power drill and wood block; middle row, from left: scissors, a padlock and keys, markers (two sizes), an adjustable wrench, Phillips- and flat-head screwdrivers, wood screws, nails (two sizes), plastic bolts and nuts, and a hammer; front row: spring clamps (four sizes).



Shape items: back row: mini soccer ball, softball, baseball, tennis ball, racquetball, golf ball; front: plastic chain, washers (seven sizes), foam brick, dice, marbles, rope, stacking blocks (set of 10), credit card blank.

YCB Benchmark Object Sets

Deliverables, Requirements and Specifications

The deliverables, requirements and specifications define what will be done and how to be objective about what it means to have a “successful” project.

Deliverables:

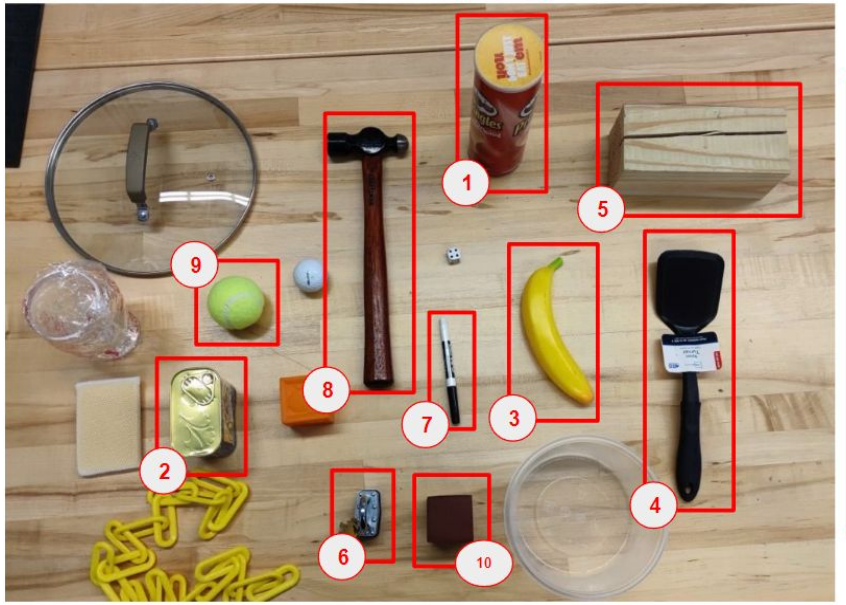
- Gripper (robot hand) prototype + testing mount
- Operation manual and Build instructions
- Design report, technical drawings and CAD files

Requirements:

- Must hold 10 different objects from the YCB Object set
- Include instructions to make, build, and use the prototype
- Be able to mount a camera or sensors for implementing tactile sensing
- Within the weight limit the robot can handle

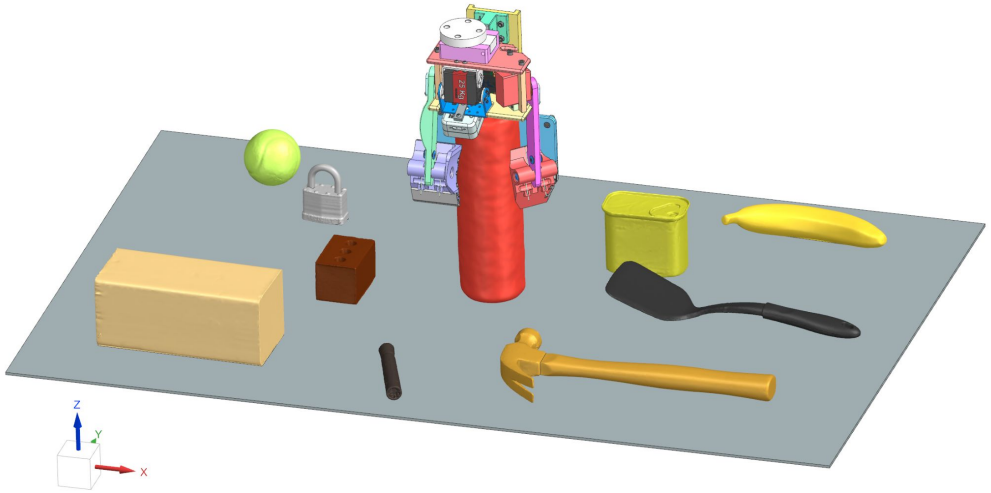
Specifications:

- Mass of gripper must be under 3kg
- Must hold each of the 10 objects for at least 3 seconds
- Stay under $1000 budget
- Gripper can close or open in 1 second



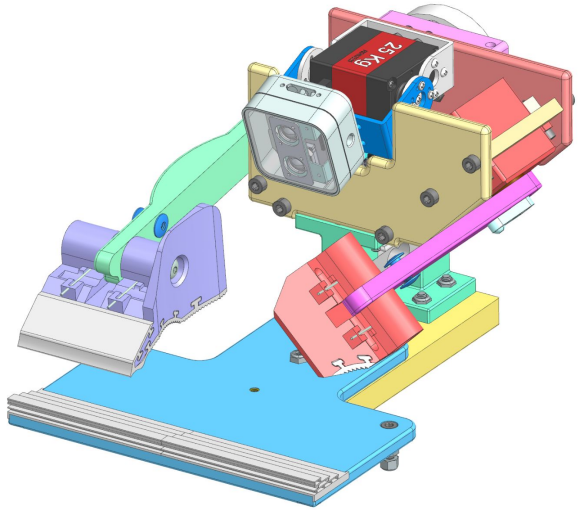
Selected YCB Objects:
1: Chips_Can
2: Potted_Meat_Can
3: Banana
4: Spatula
5: Wood_Block
6: Padlock
7: Large_Marker
8: Hammer
9: Tennis_Ball
10: Foam_Brick

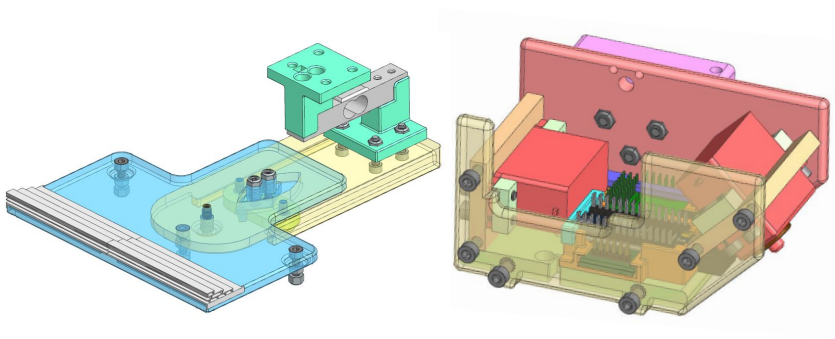
Selected YCB Objects



Current Project Status

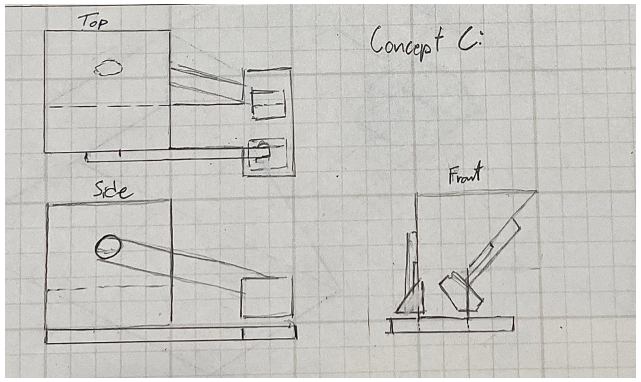
The project is currently complete, all requirements and specifications have been met. All objects are picked up successfully, and a functional prototype is to be presented live at the Design Day demonstration.

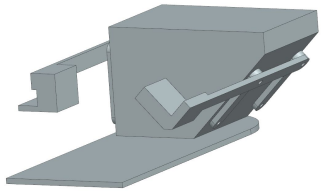


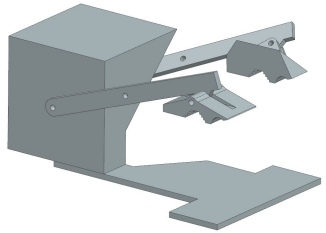


Compliant Mechanism

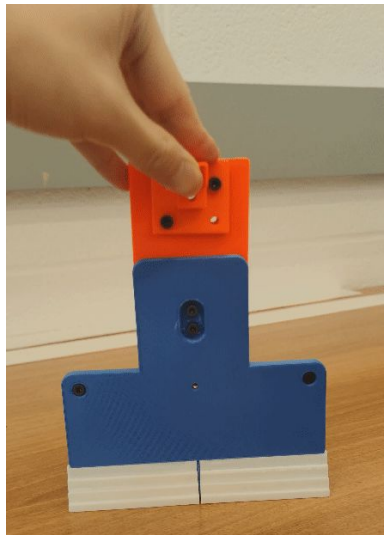
Concepting





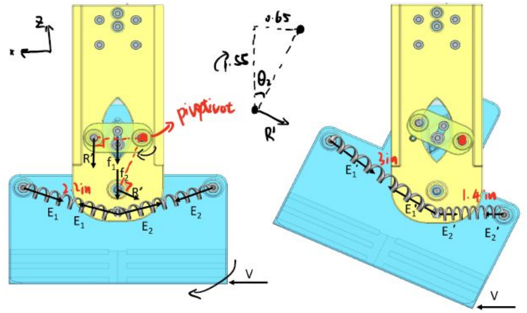


Initial Concept



Current Project Status Continued…

Simulation and Mechanical Analysis



$f_1 = f_2 = 1.2\,C$

$R'_{max} = S_{max} = F/\tan(48.6°)$

$E_1 = E_2 = (2.2 - d_0) k_e \cos(22.2°)$

$\theta_2 = \tan^{-1}\left(\frac{0.65}{1.55}\right) = 22.75°$

$V_{Th} = E_1 + E_2 + R' \times \cos(22.75°)$

$= 2(2.2 - d_0) k_e \cos(22.2°) F/\tan(48.6°) \cos(22.75°)$

Same assumption as z+ direction force case

V_{Th} = Threshold load to activate compliant

assume 1.4in is extension spring's initial length

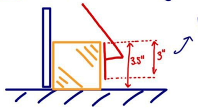
$V_{max} = (3 - 2.2) k_e$

V_{max} = maximum force the springs can provide

Tallest object : Wood_Block → 3.5" x 3.5"

Smallest object: marker → 0.65" ∅

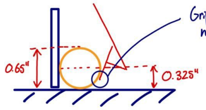
↳ Wood_block informs length of Griptip



When modeling, 3" seemed like a good fit.

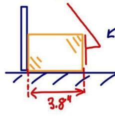
↳ E = 3"

↳ Smallest object radius = 0.65"



Griptip must contact marker no more than 0.325" from ground in order to pick up marker

↳ Widest object : Potted_meat_can (sideways)

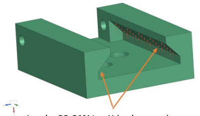


At 3.8" away from backplate, Griptip must be able to be parallel w/ object → influences θ_2, (B), and (C)

Project 2 – Dovetail Analysis
ME 205
Bruno Coelho
04/28/24

Goal is to determine the maximum stress and margin of safety with Linear Statics 101 FEM and to conclude if the dovetail with fail under the given loading.

Applied Load:



Load = **22.81N** in +X (red arrows) on upper angled dovetail, Geometric Dist.

Load Case Justification:

	Baxter Robot	Sawyer Robot
Baxter Robot Rated Payload: (kg)	2.3	4
Max Tool Speed (Unloaded): (m/s)	1	2
Typical Task Tool Speed (m/s)	0.6	1

	Mass (kg)	Weight (N)
Specified End-effector Load Limit:	2	19.62
Measured End-effector:	1	9.81
Heaviest YCB Object: (Wood_Block)	0.73	7.16
End-effector + Heaviest Object:	1.73	16.97

*Time to Accelerate to Max Velocity (s)	0.25
Calculated Acceleration (m/s^2):	8
Max Dyanamic Load (End-effector w/ Heaviest Object with Max Acceleration) (N):	22.81

*Assumption: arm requires 0.25s to accelerate from 0m/s to 2m/s

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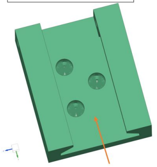
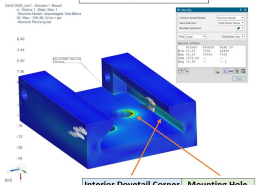
Boundary Condition:



Constraint = **Fixed** at 3 RBE2 Nodes (these model the SHCS used for mounting)

Analysis Overview:
Mesh: CTETRA(10), 0.0333 in
Solution Type: 101 – Linear Statics
Stress criterion: Von-Mises
F/S = 2
Material: ABS (NX)
E = 290075.4 psi
Nu = 0.4
Yield Stress 5801.51 = psi

Results / Conclusion:



	Interior Dovetail Corner	Mounting Hole
Sy (psi)	5801.51	5801.5
Smax (psi)	88.8	156.48
FS	2	2
MS	31.67	17.54

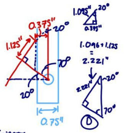
The "Interior Dovetail Corner" was the location of a failure experienced during testing. The stress concentration in conjunction with poor layer adhesion were deemed likely factors. With a customer-specified FS of 2, a minimum margin of safety (MS) of 17.54 was achieved. This indicates that this 100% infill ABS Dovetail **will not fail** under the applied loading.

Starting Values:

E = 3"

$\theta_{2(max)} = 20°$

↳ Solve for D.

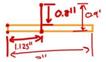


Let connection between Griparm and Griptip intersect at 90°
↳ Non-centered grip tip connection permits greater max ROM.

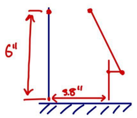
D = 0.8"

↳ Let thickness of griptip = 0.1" at tip.

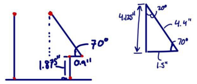
Distance between pin and bottom face of = 0.8" + 0.1" = 0.9.



Widest Object BC:



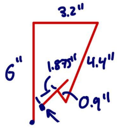
Let backplate be 6" long.



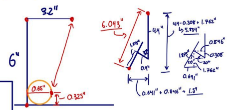
C = 4.4"

A = 6"

B = 3.8" − (1.5" − 0.9") = 3.2"



Verify Calculated values w/ marker BC...



Gripper geometry unable to pick up marker (tip needs to be 0.17" longer) and also scrapes table (6.043" > 6"). To solve this, a "wiper" was created which is able to deform while "scraping" table while providing >0.17" of extra reach (0.2").

Distance between (0.65, 0.325) and (3.2, 6) = 6.22

↳ 6.22" − 6.043" = 0.177"

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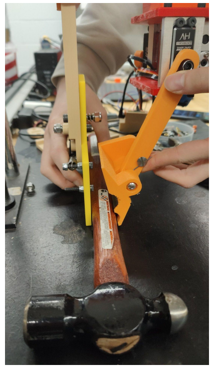
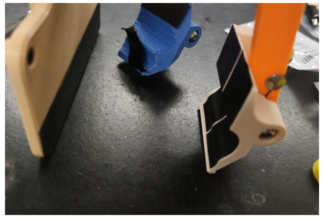
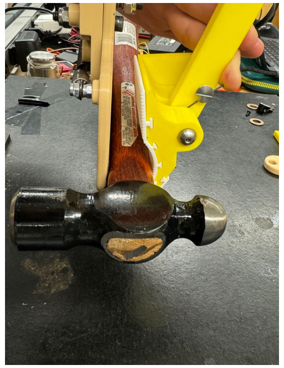
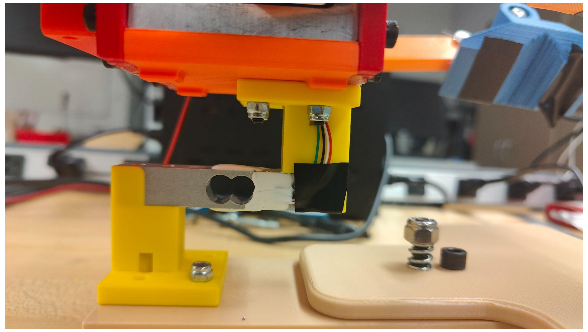
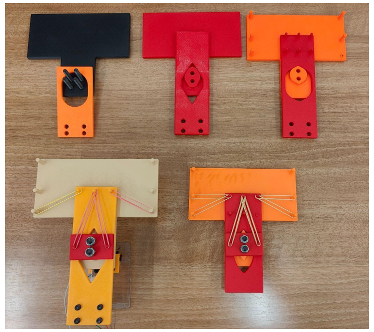
Manufacturing Process and Iterations

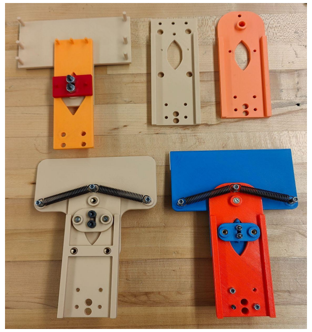


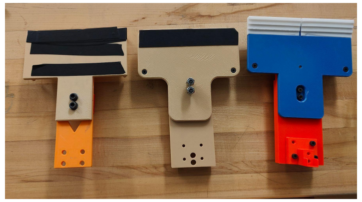








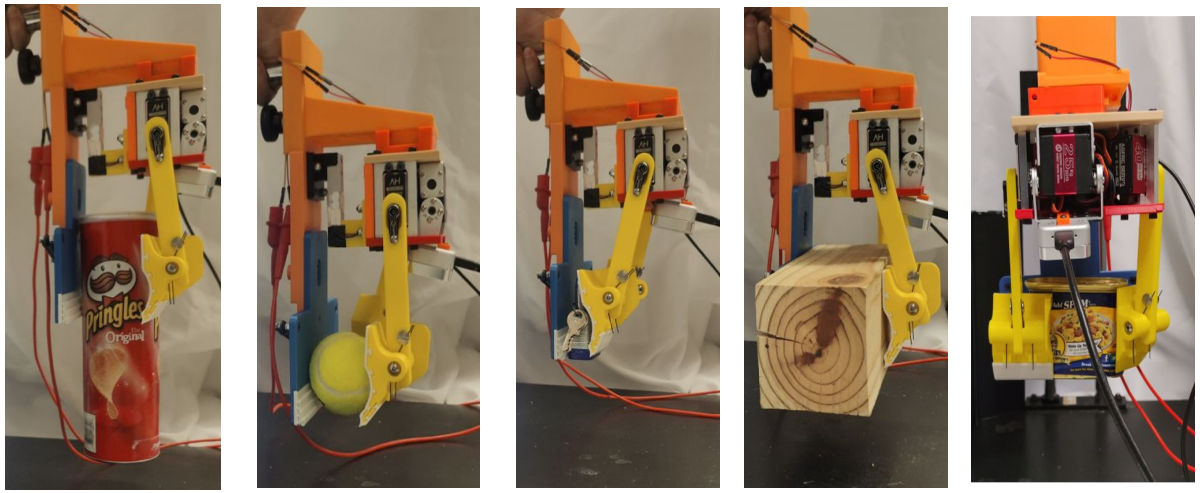


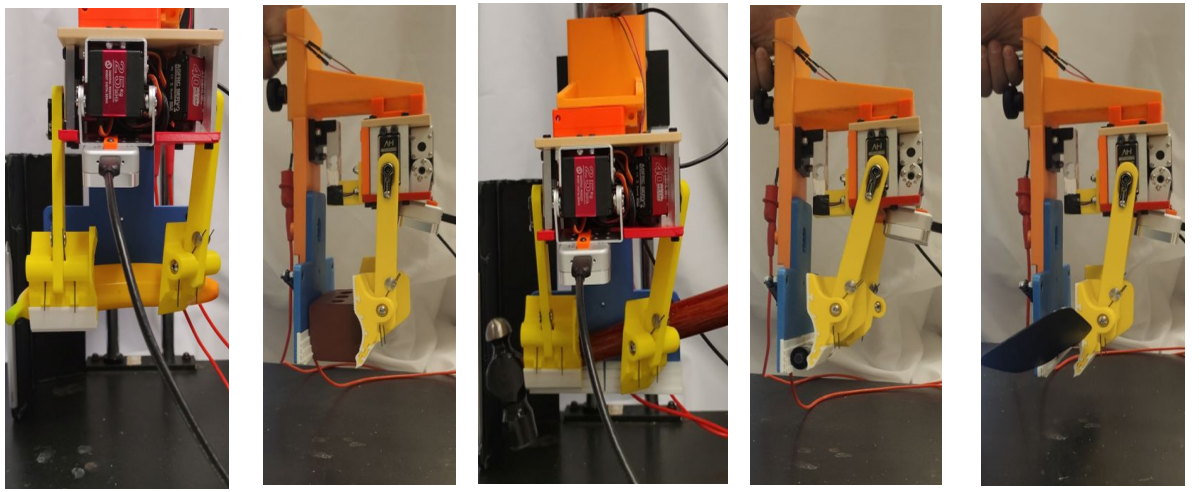


Design iterations of the backplate and fingers

Current Project Status Continued…

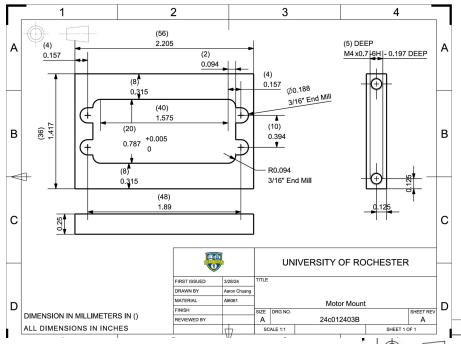
Testing and Gripping objects

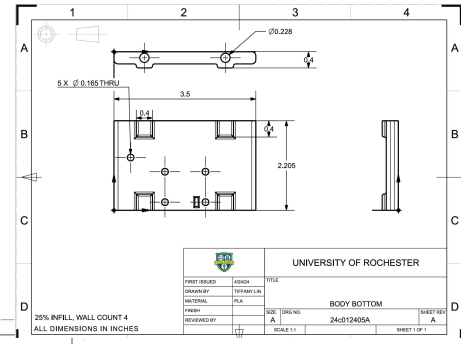


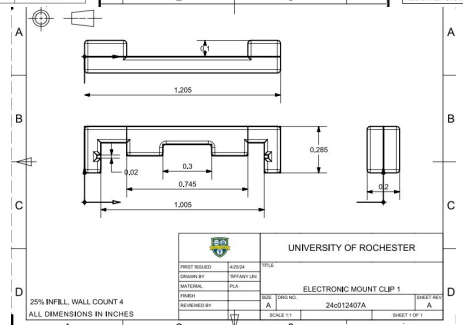


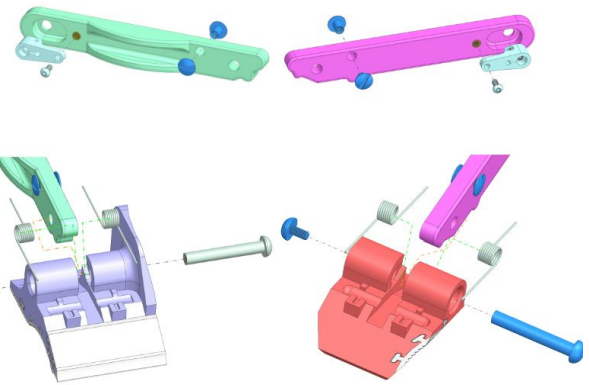
All 10 objects being picked up

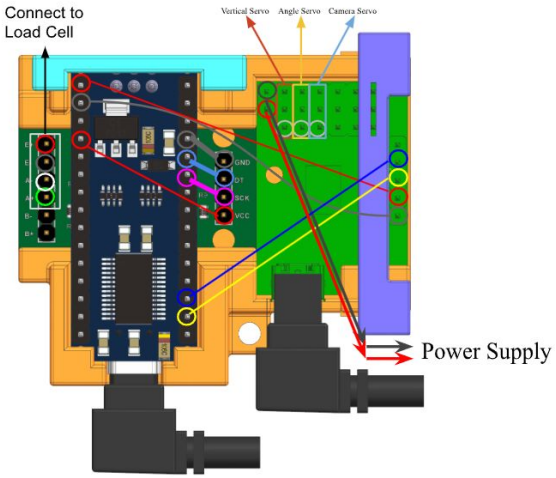
Drawings and Assembly Instructions











Conclusions/Future Work

Recommendations for future work

- Revise the gripper be able to pick up more objects
- Allow the backplate to deform depend on the shape of different objects
- Redesigning the parts to be suitable for injection molding would save time on fabrication
- Perform FEA analysis for more parts to improve the design and materials selection

Acknowledgements

- The team acknowledges the contributions of their sponsor Professor Thomas Howard, and the guidance and assistance of Chris Pratt, Mike Pomerantz, Jim Alkins, Bill Mildenberger, Alex Prideaux, Rebecca Zapiach, and Professor Christopher Muir to make this project possible.