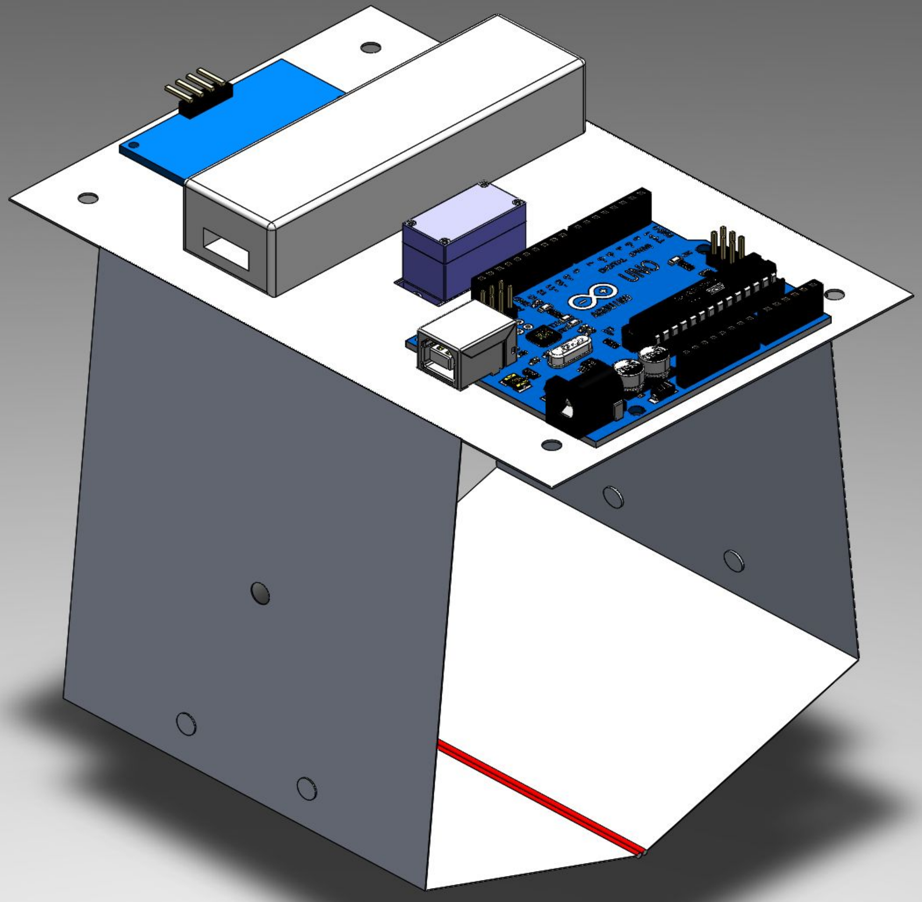
S.M.A.R.T Claw

Team T7



01

Introduction

Meet the T7 Team

* ***Disclaimer*** *- Each member contributed to each component of the project. The titles below each name simply reflect the leadership roles of members, in specific components.* *

Christian Lee
Lead Designer

Rohin Dhaliwal
Prototypes & Experiments Lead

Shaiv Ramdhani
Programming Lead

Om Chaudhari
CAD & Drawings Lead

Tony Tang
Claw Manufacturing Lead

Design Challenge

The APSC Times

January 1, 2025– LATE BREAKING REPORT! An Unidentified Flying Object (UFO) has crash landed in the Pacific Ocean! The crash is reported to have occurred approximately 200 km West of the NW tip of Vancouver Island, where the ocean is approximately 3000 metres deep. A local Vancouver company, Coastal Recovery, is leading the effort to retrieve items from the wreckage. Due to the unpredictable sea conditions this time of year, and the unknown state of the wreckage, a fully autonomous retrieval system is required. Since this is out of Coastal Recovery's realm of expertise, they are contracting out the design of the system. They will be hosting an open design competition for teams to showcase their designs to prove which concept has the greatest potential. This team will be granted the contract and go into full scale production. Due to the timely nature of this event, the competition is scheduled to occur in Week 5 of the term.

Our goal is to design a fully autonomous retrieval system. The design should serve as a small-scale prototype of a device to be used in retrieving the UFO from the Pacific Ocean.

Design Specifications

A list of requirements and evaluation criteria influenced by the competition rules

Requirements	
R1	Device must use NO MORE THAN ONE of each of (1) Arduino board, (2) servo motor, and (3) ultrasonic sonar
R2	Device must be able to pick up and release an object autonomously; only raising and lowering can be controlled by a human operator
R3	The device must only be constructed from materials listed in Table 1 of the Module 5 rules document
R4	The device must be able to deposit objects into a 8ft x 8ft box with a height of 2in
Evaluation Criteria	
C1	The greater the number of Round 1 objects that the device can retrieve, the better
C2	The greater the number of 1.25in cubes the claw device can simultaneously retrieve, the better
C3	The smaller the delay between detecting the object and retrieving / releasing it, the better
C4	The lesser the degree of unwanted swinging or rotating when attached to the crane, the better
C5	The lower the number of moving parts (and hence the lower the risk of mechanical failure), the better

Design Strategy

Extensive Prototyping

- Prototype as many feasible designs as possible
- Experiment and prototype using rapid construction materials

Code Optimization

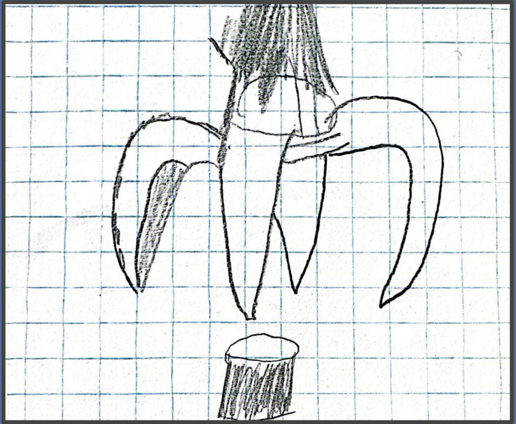
- Approach code design with the same degree of rigour as the retrieval device
- Code should minimize wasted time and accurately retrieve objects

Risk Management

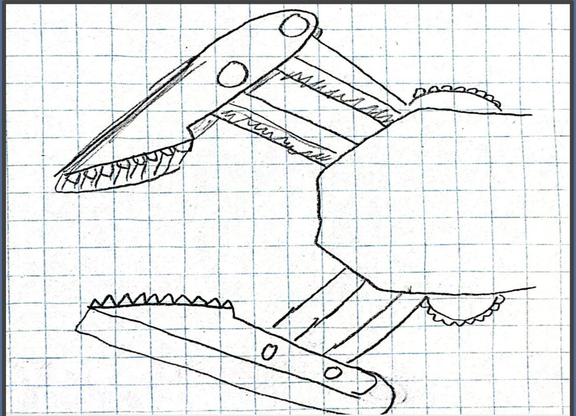
- Use risk identification and registers throughout our project
- Minimize risks through experiments

Concept Generation

Initial C-Sketches

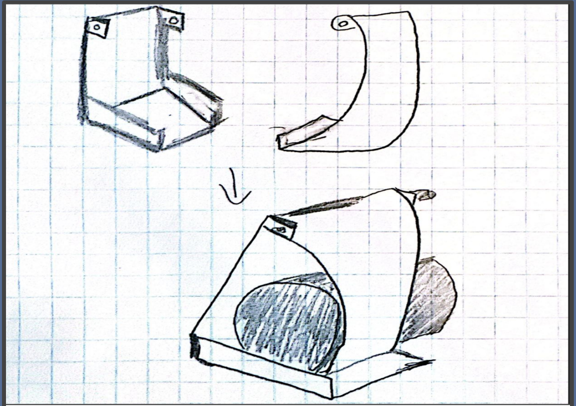


Half Octopus - C.L.

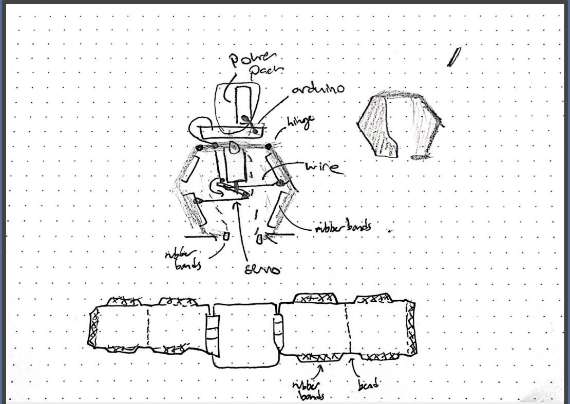


The Crab - R.D.

The Trapper - O.C.

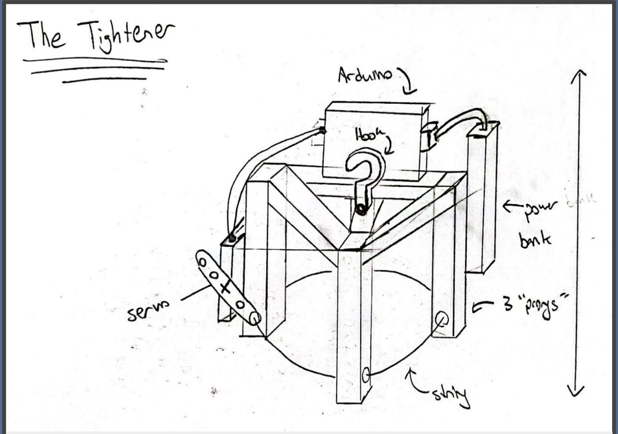


Scooper - T.T.

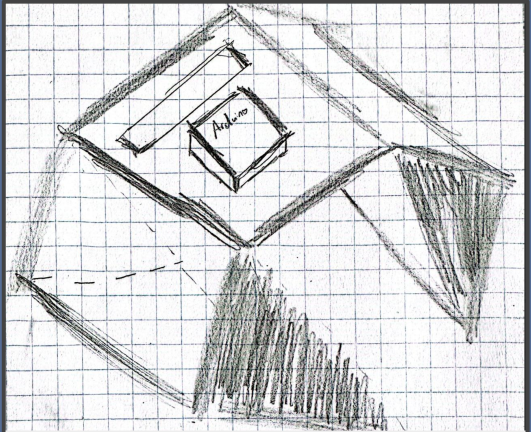


Engulfer - S.R.

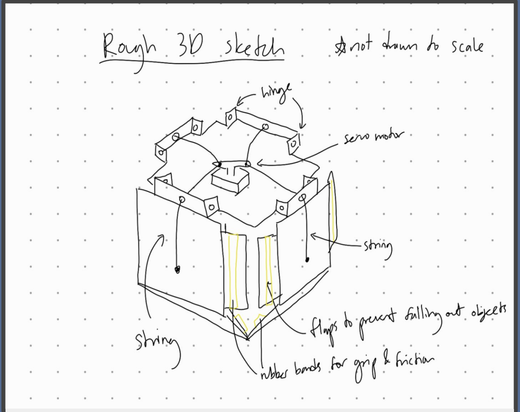
Individual Sketches



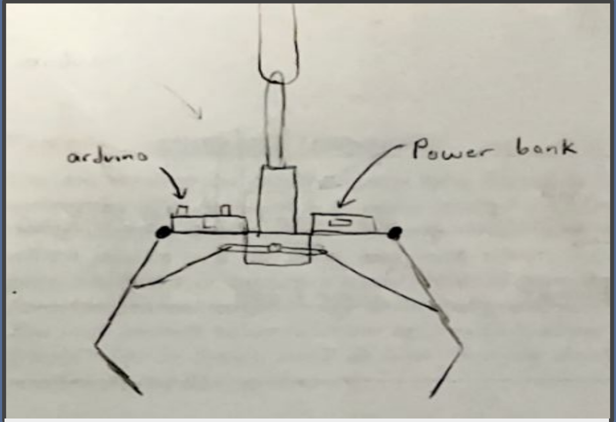
The Tightener - R.D.



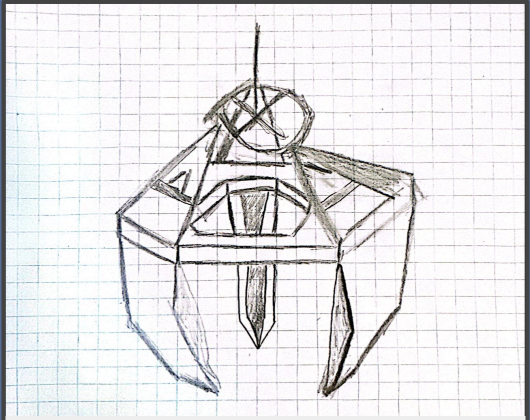
The Trapper - S.R



The CAGE claw - C.L.



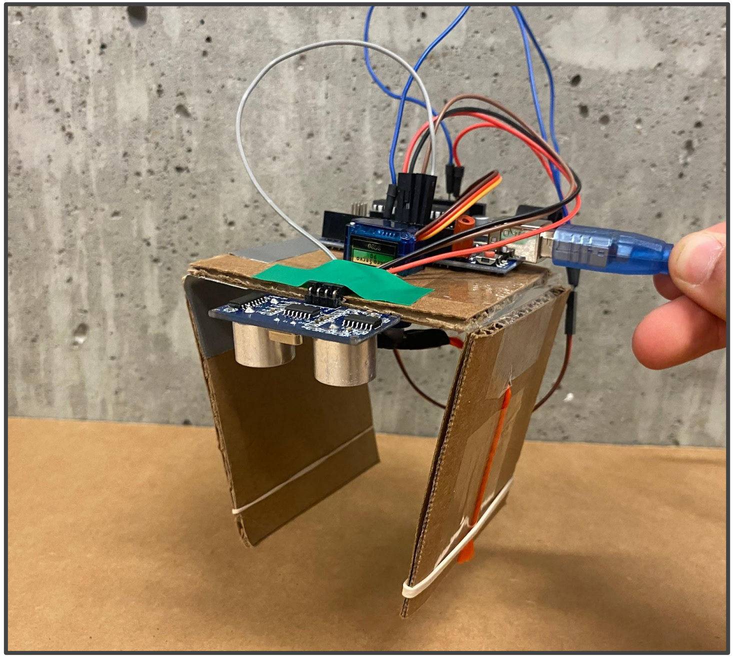
The Excavator - O.C

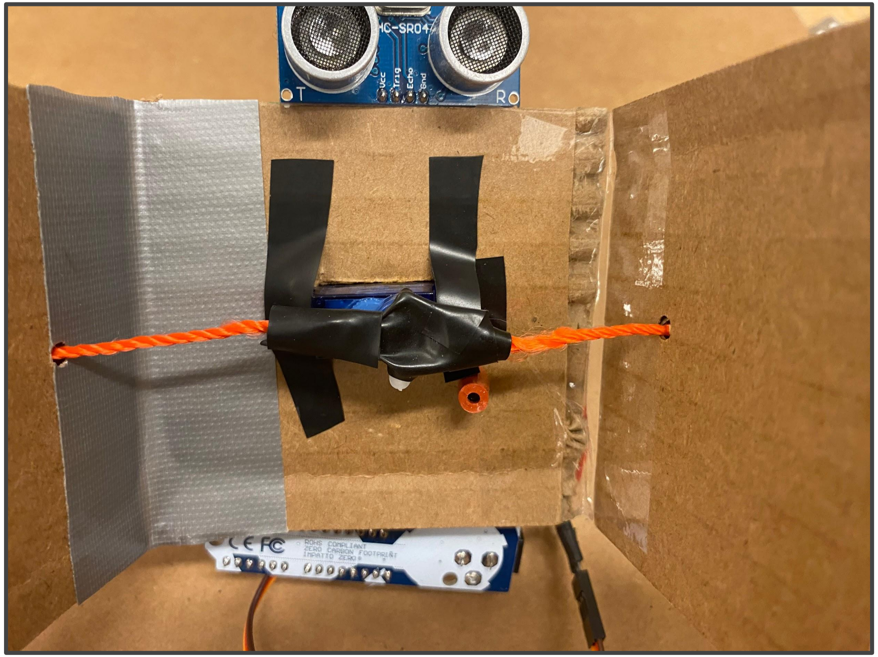


Three-Way Split- T.T

Prototypes & Concept Evaluation

First Prototype – “Trapper” Concept

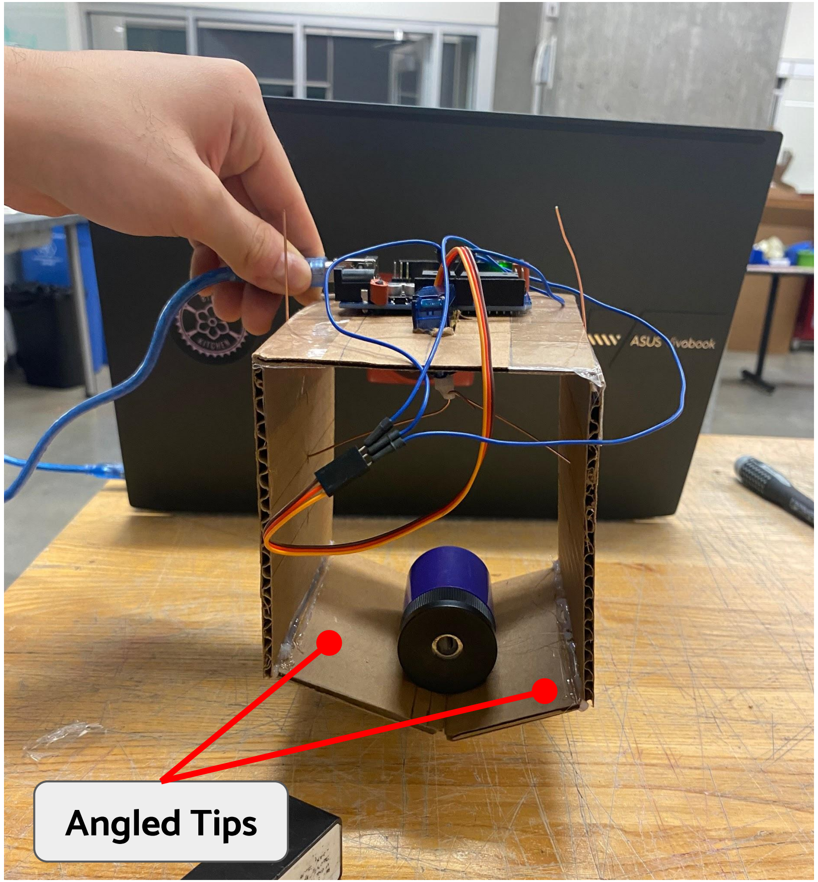




Strengths: easy to build; strings provide enough force to lift a pencil case

Weaknesses: limited range of motion; claw relies solely on friction to lift objects

Second Prototype – Adding Angled Tips



We added angled tips onto the bottoms of the claw arms to increase the maximum weight that can be picked up by the claw.

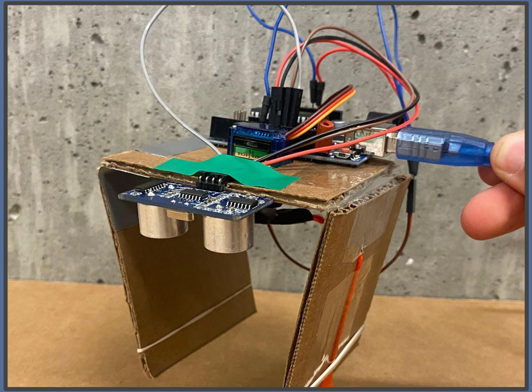
Strengths:

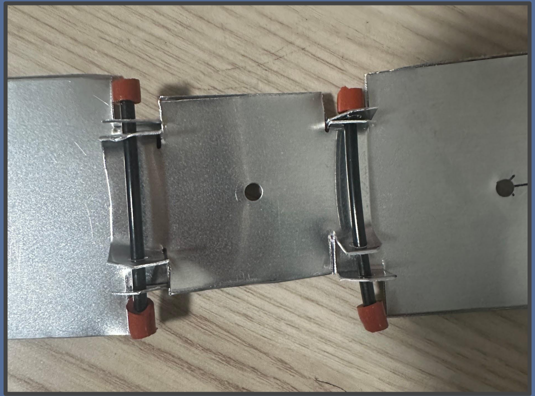
- Can pick up heavy objects (e.g. stapler)
- Replacement of string with rigid wire increased range of motion of claw (wires can both pull *and* push the claw arms)

Weaknesses:

- Round objects may slide out of the sides of the claw arms
- Cardboard connected with hot glue is structurally weak

Prototyping Hinge Mechanisms





Tape Hinge

Strengths:
- Easy to construct
- Quickly Adjustable

Weaknesses:
- Lower strength (but enough to hold Round 1 & 2 objects)
- Slightly flimsy

Rank - 1 (Chosen Design)

Side Hinge

Strengths:
- Smooth rotation
- Full range of motion

Weaknesses:
- Construction time is lengthy
- Difficult to align claw arms precisely

Rank - 2

Three Section Hinge

Strengths:
- Highest durability
- Precise alignment of arms

Weaknesses:
- Assembly of panels is difficult
- Additional friction increases force required by servo motor

Rank - 3

Testing Use of Rubber Lining

With Rubber

Strengths:
- Stronger grip on objects
- Less force required from servo

Weaknesses:
- Can disrupt alignment of claw arms
- Can get caught on the ground

Conclusion: Ideal for Round 1
Increased friction improves chances of retrieving a wide variety of objects

Without Rubber

Strengths:
- Can scoop objects by smoothly sliding against the ground

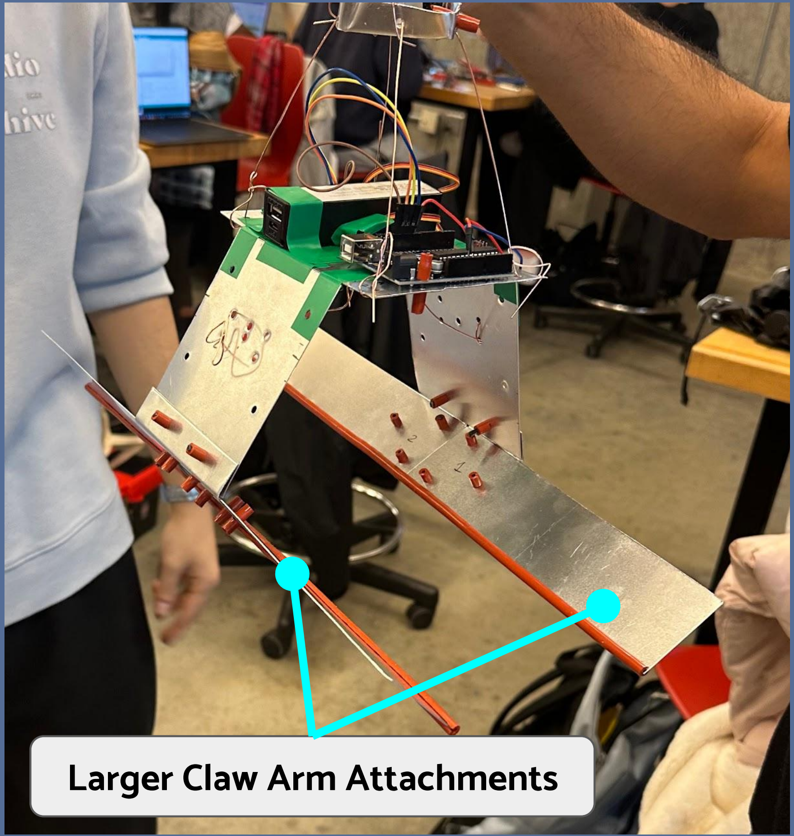
Weaknesses:
- Cannot hold heavier objects with low coefficients of friction
- More force needed from servo

Conclusion: Ideal for Round 2
Aluminum edges can scoop along the floor and simultaneously retrieve multiple objects

Testing Round 2 Specialized Claw

Test Notes:

- We tested a larger claw arm tailored for Round 2 that could attach and detach onto our device
- The imprecise cuts in the metal prevent an equal force distribution, causing a few cubes to slip out of the claw arm
- A potential solution could be using a lighter, rigid material to extend out the sides (e.g. popsicle sticks, bamboo sticks) to firmly carry a row of cubes



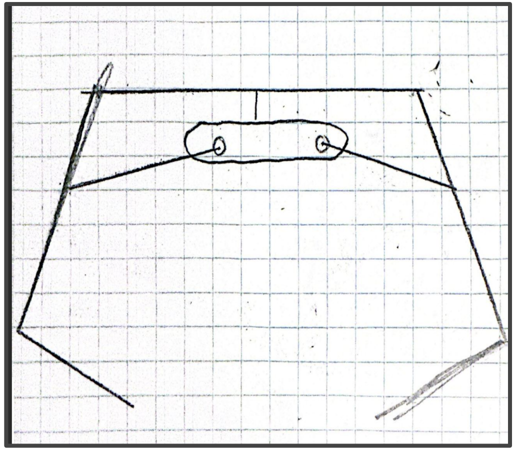
Risks, Experiments & Concept Selection

Risk Register			
Risk	**Classification**	**Rating**	**Risk Management Strategy**
Servo motor does not produce enough force to pick up objects.	Technical Preventable	**6**	• Design an experiment to test the ideal placement and attachment of wiring in order to maximize the force
Sonar sensor has issues and interrupts the flow of our code.	Technical Strategic	**12**	• Implement debouncing mechanism in code to counter variance • Trial sonars to find best functioning one • Backup code functioning off a timer
Any mechanical or technical failure on the day of the competition.	Project Management Preventable	**5**	• Find functioning components and fully charge batteries • Don't excessively test our components
Scarcity of aluminium may require the use of weaker cardboard. Cardboard components are flimsy impacting our claws performance.	Technical Strategic	**4**	• Test to see high stress areas in our claw • High stress areas can be made of aluminium • Lower stress area can be made of cardboard
Rubber tubing attachments drag on floor and prevent full closure.	Technical Strategic	**8**	• Test between having the tubing and not having it • Use two attachments that can be swapped out depending on object

Risk Experiment 1: Wire Attachment Optimization

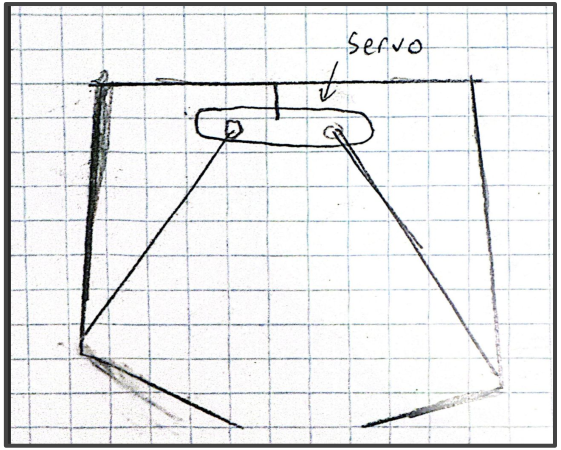
Research Question #1: What is the optimal positioning for the wires connecting the claw arms and the servo?

Research Question #2: How can we maximize the force without comprising the width of the claw?



Higher Wire Attachment

- Less force translated through claw
- Risk of lowering output force when retrieving objects
- Larger claw width



Lower Wire Attachment

- More force translated through claw
- Smaller width of claw
- Risk that jaw opening may not be wide enough to grab objects

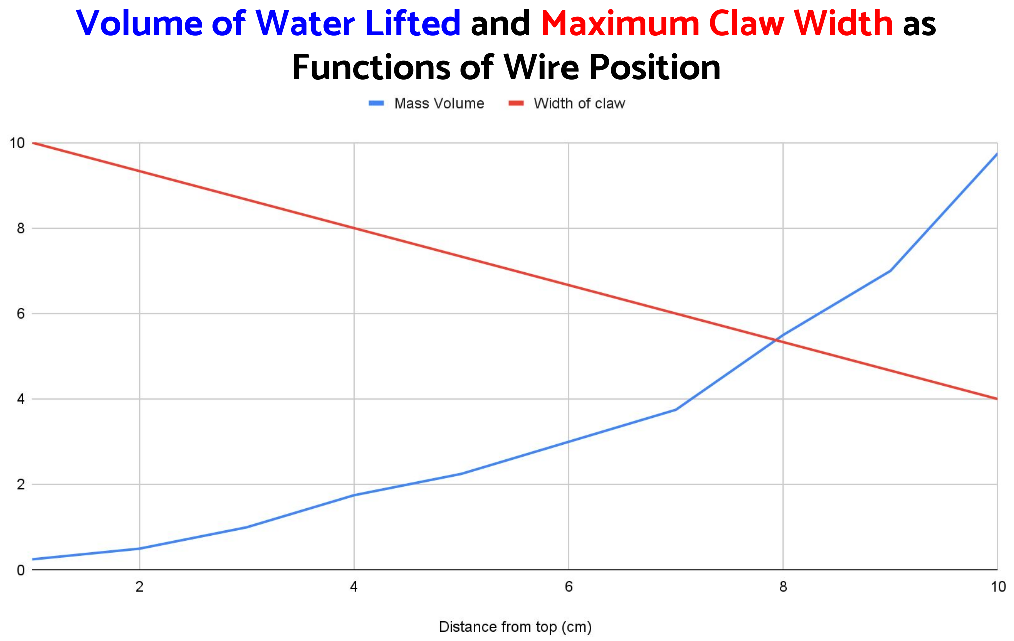
Risk Experiment 1: Wire Attachment Optimization

Experimental Setup & Procedure

- Tested attaching the wires at distances 1-10 cm from the top of the claw
- Measured the maximum amount of water in a water bottle held for each increment.
- Measured the widest gap in between the two claw arms
- Graphed scaled results

Conclusion:

A wire position of 8 cm from the top yielded ideal results to mitigate risk.

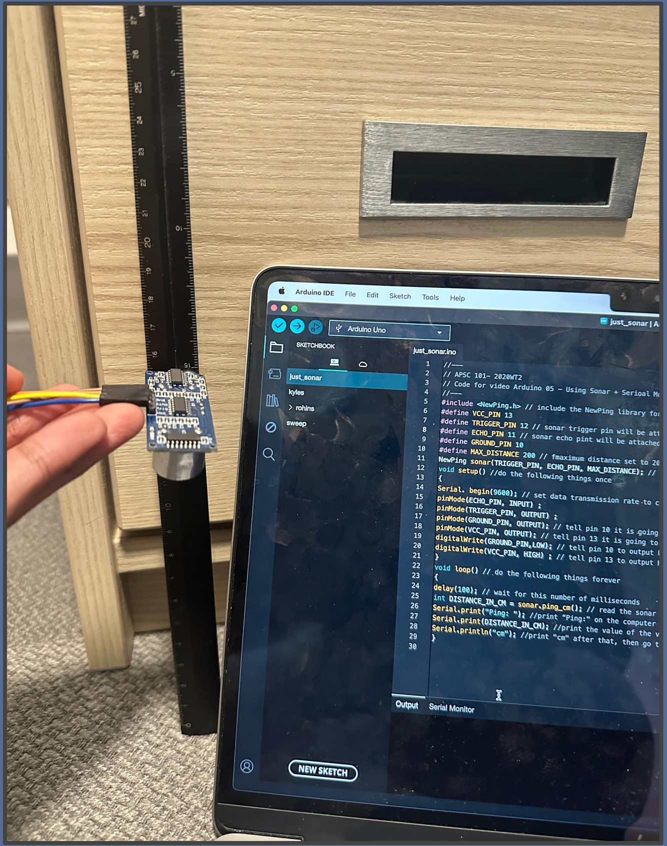


Risk Experiment 2 - Sonar Reliability

Research Question: At what distance from the ground is the sonar most reliable?

Experimental Setup & Procedure

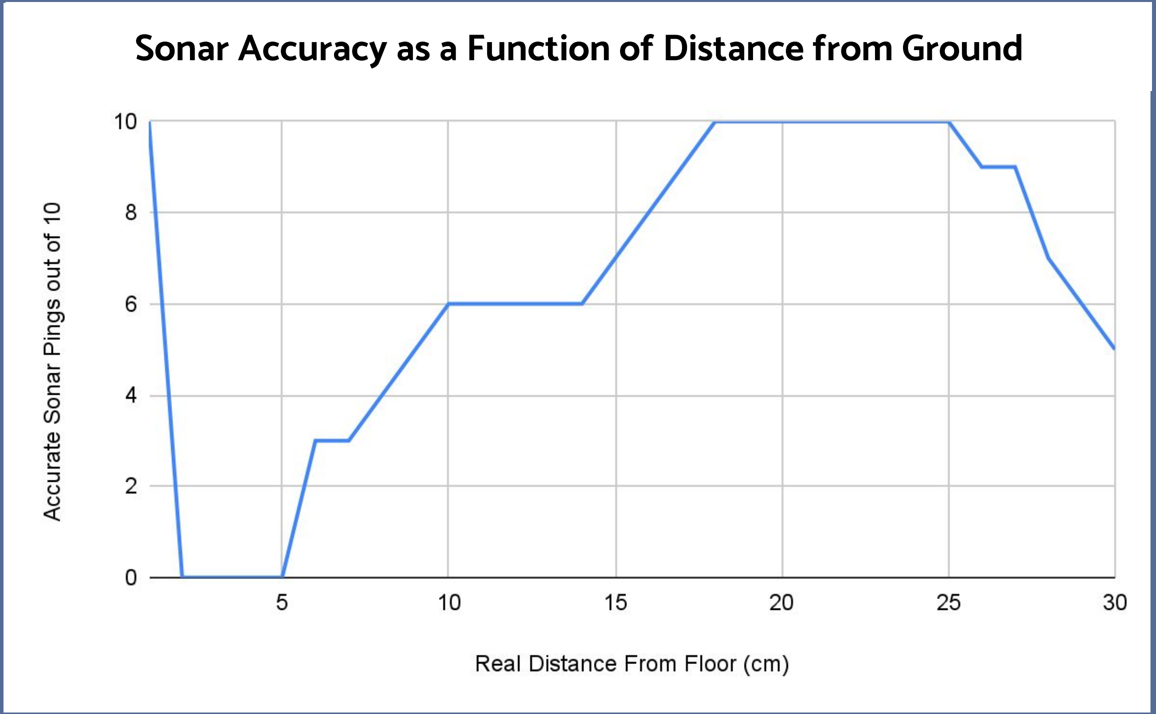
- We positioned the sonar at distances from 0-30cm above the ground
- Testing for 10 seconds at each distance, we made the program print the sonar's reading once per second
- We recorded how many times (out of 10) it output the right data



Risk Experiment 2: Sonar Reliability

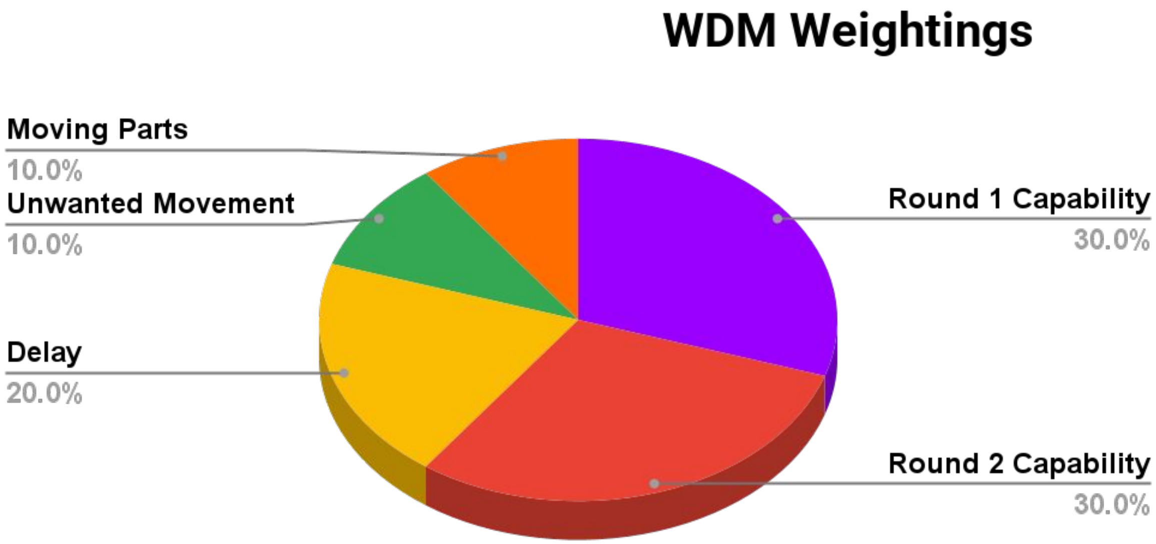
Key Findings

- 0 cm was consistently accurate
- Between 1 and 5 cm did not register anything
- Peak accuracy between roughly 17-25 cm from the ground
- This means our sonar should be set to trigger within this optimal range to avoid sonar malfunctions



Weighted Decision Matrix

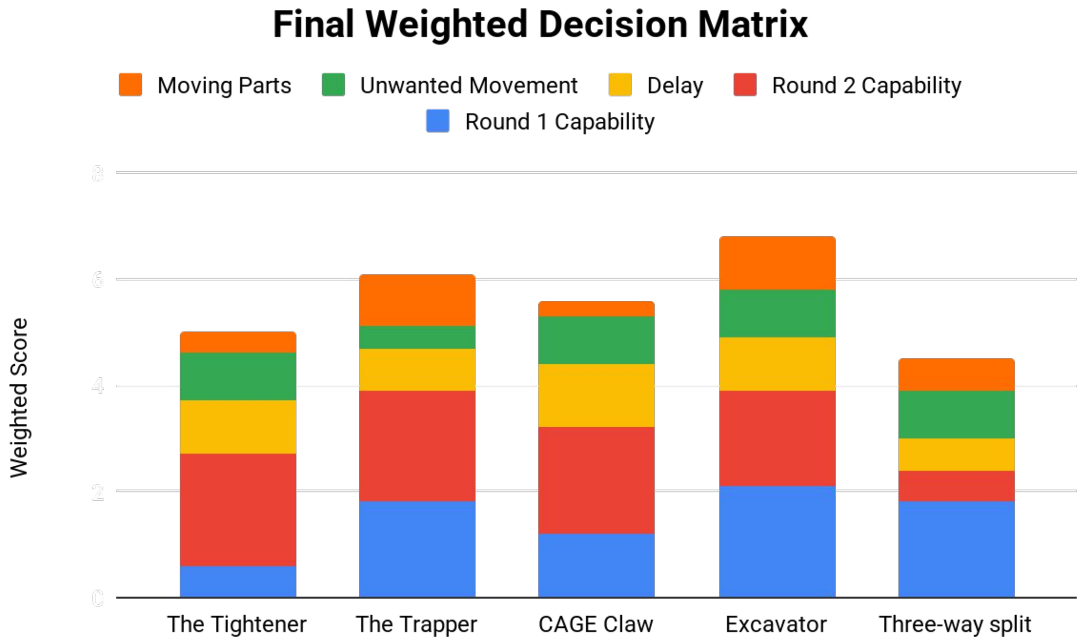
- All 5 concepts passed screening
- We elected to skip ranking due to low number of concepts
- We created a WDM to evaluate our 5 concepts systematically
- We built our criteria based on our evaluation criteria and integrated **Experiment 1 & 2 results** in our evaluation
- We distributed the criteria weights based on competition rules and team strategy



Weighted Decision Matrix

- Final WDM resulted in ***The Excavator*** being the most promising concept.

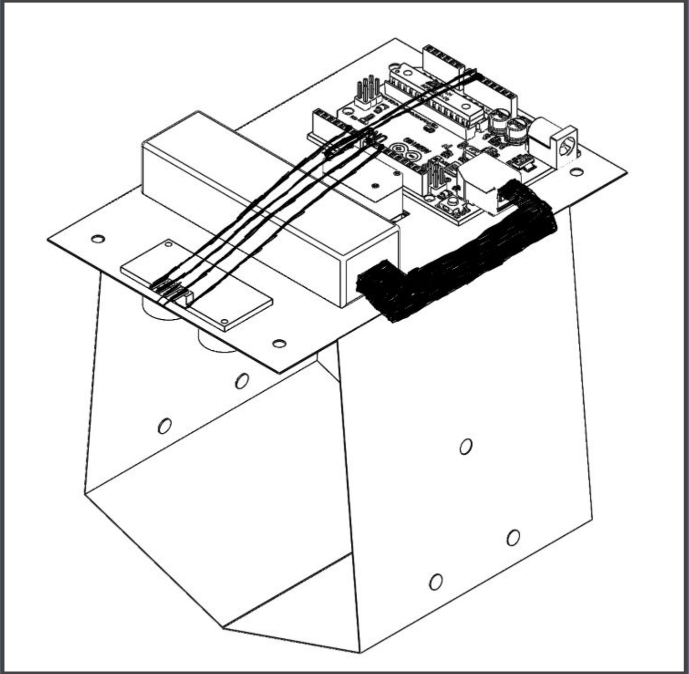
- Sensitivity analysis to ensure robustness:
  - Excavator remained our top concept
  - Minor changes across lower scoring concepts
  - Indicates our results are valid

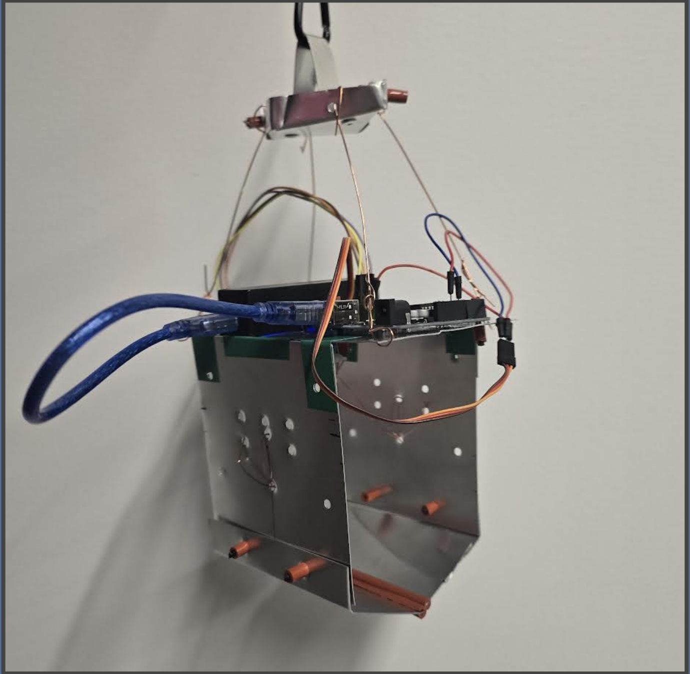


Final Design

Final Design: The S.M.A.R.T Claw

S - Sensor-Integrated: Sonar sensor is integrated for object detection.
M - Modular: The attachable gullet and claw tips help our device adapt to different environments
A - Actuated: The servo motor creates precise movement
RT - Retrieval Tool: The claw functions as a retrieval device

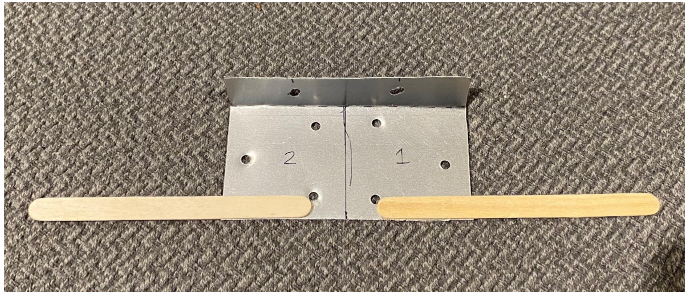




Modular Attachment 1

- For Round 1 (Variety Objects)
- Applies a focused force across a 4in span
- Useful for heavier objects such as the can

Modular Attachment 2

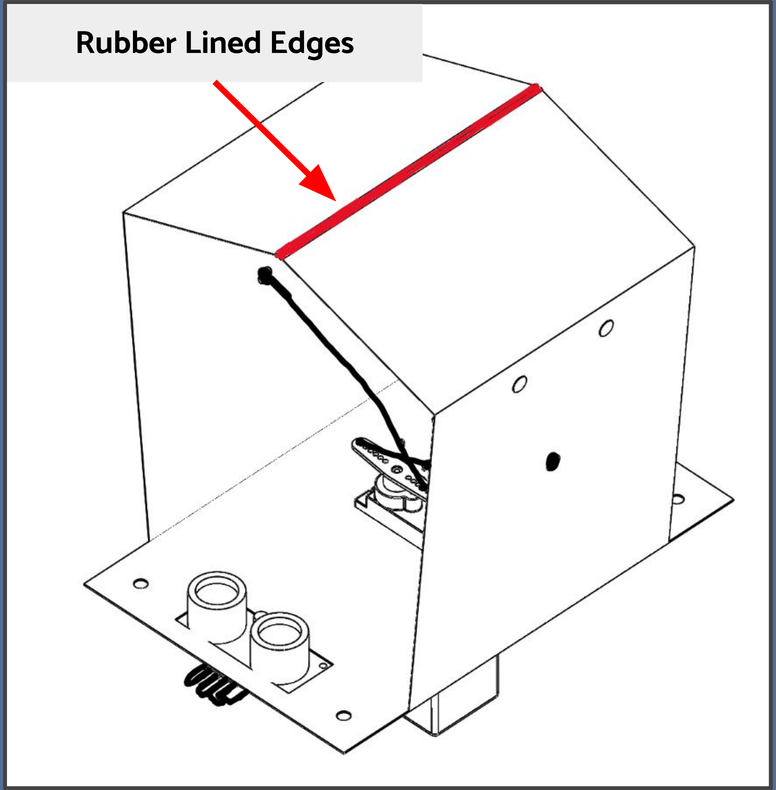


- For Round 2 (bulk objects)
- Distributes force across 8in length for lifting multiple objects
- Cubes are lightweight so we can pick up roughly 16 at once (8 x 2 grid)

Pins

- Pins are made from red tubing and black rod
- Pin system creates secure connections

Final Design Features



Rubber Lined Edges

Insertable red rubber lining on the edges of the claw, enhancing grip, handling, and friction between claw and object

Tape Hinges

Loosely attaches claw arms, minimizing the force required to open and close the arms while still providing a secure connection

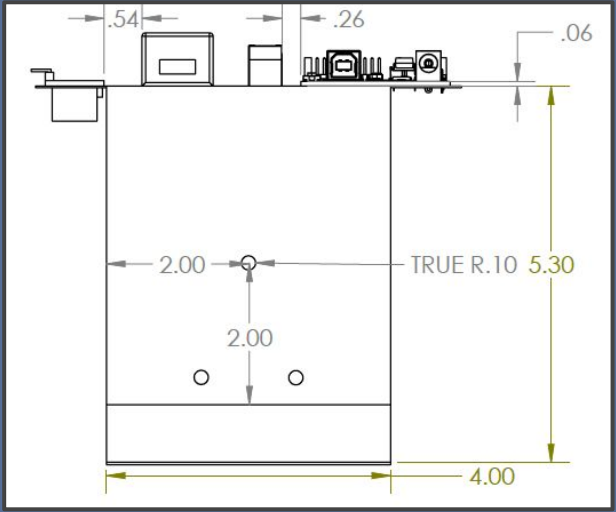
Copper Wire Mechanism

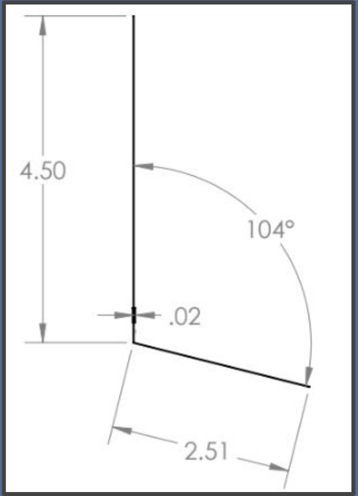
The use of rigid wires efficiently generates force to open the claws wide, and sufficient force to firmly grab any Round 1 or 2 object without slipping

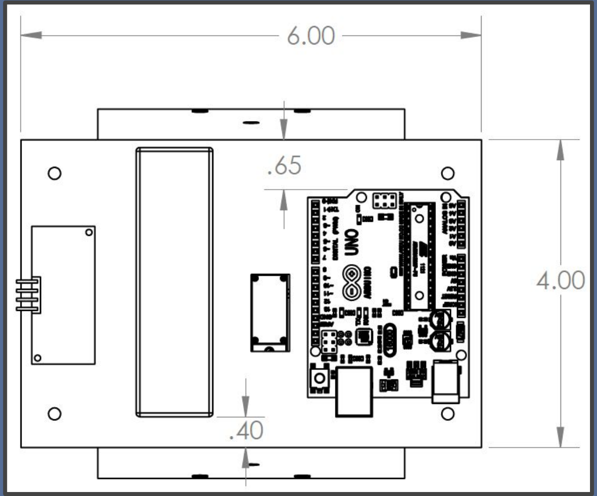
Final Design Dimensions

Analysis:

- The **6x4 in²** dimensions of the base ensure that the widest object in the competition can be fully enclosed inside of the boxed claw
- The **4x5.3 in²** dimensions of the claw ensure that the tallest object in the competition can be fully enclosed inside the claw
- Overall volume of roughly **80.8 in³**, allows any object in the competition to be easily and securely retrieved
- The claw edges make a **14° angle** to the claw arm, which is suitable to retrieve an object while minimizing friction with the ground



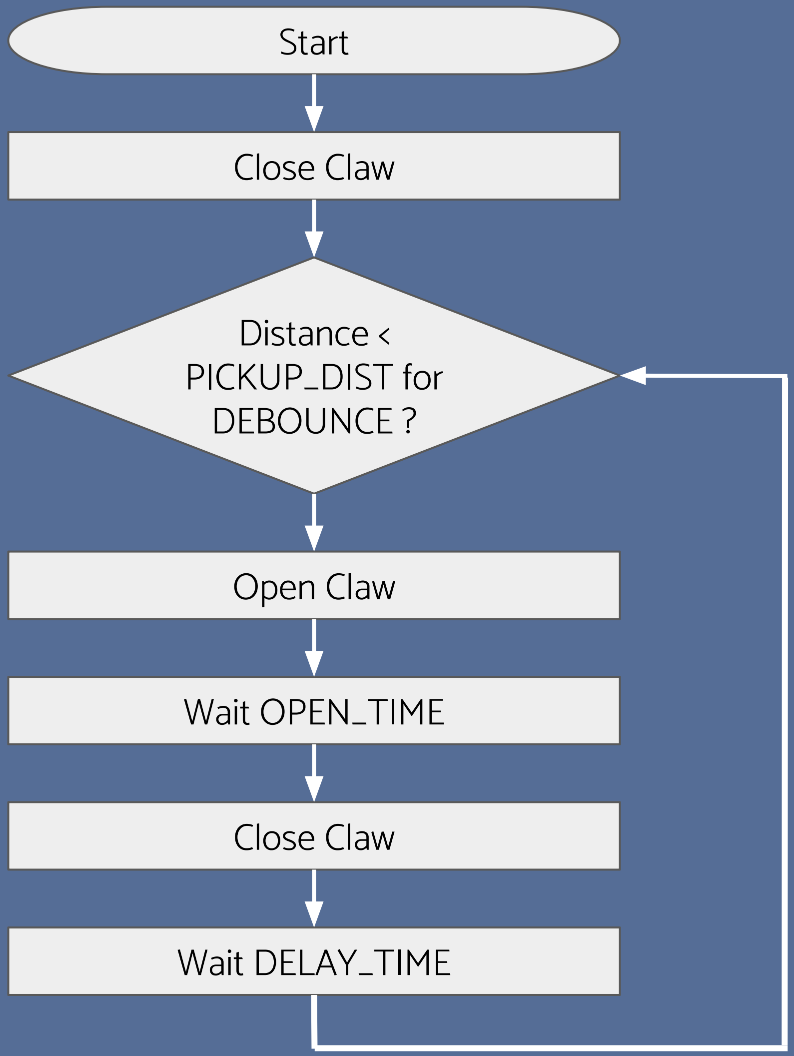




Final Design Code Flowchart

Symbolic Constants:

- PICKUP_DISTANCE = 25cm
- OPEN_TIME = 3000ms
- DELAY_TIME = 2000ms
- DEBOUNCE = 500ms



Reflection

Competition Reflection

Round 1

Reflection

- Code functioned as intended
    - Sonar risk experiment results eliminated any sonar malfunctions
- Challenges emerged in positioning of objects

Improvements

- Develop a claw where spinning about the vertical axis is not as problematic
- Improve claw width
    - In our risk experiment 1, we prioritized force over claw width
    - This decision may have been misguided as smaller claw width required more accuracy to pick up objects

Round 2

Reflection

- Modular attachments enhanced pickup capability and overall performance
    - Enabled claw to pick up many cubes at once
- Prototyped rubber lining maximized grip and reduced the force required per cube

Improvements

- Uneven force distribution across claw arms caused cube instability when transporting to drop off zone

Contributions

- **Om Chaudhari:** Project Introduction & Risks
- **Rohin Dhaliwal:** Prototypes & Concept Selection
- **Christian Lee:** Concept Generation & Final Design
- **Shaiv Ramdhani:** Experiments & Final Design
- **Tony Tang:** Reflection

Team T7 did not utilize Generative AI in this project