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Project Proposal

Problem Framing

Our team wishes to design, construct, and autonomously control a robot that is able to plug in a charger plug into a charge port within 2 minutes. As a team, based on our common values, we will be designing for 5 primary DfX's (listed in order of importance from most important to least important):

1. **Design for Reliability**: We want the robot to yield consistent results and have high repeatability of accuracy and success between the trials.
2. **Design for Usability**: We will aim to design the robot so that it can be easily used by anyone, not just members of our team. Hence, our design should be easy to set up and be able to fulfill its tasks with minimal human interference.
3. **Design for Stability**: The physical design of the robot will emphasize stability and sturdiness; the design will minimize risks of components falling apart, robot toppling over, etc.
4. **Design for Simplicity**: Simplicity in our design is a foundational aspect in order for our other DfX's to be fulfilled. A simple design with fewer steps leads to less room for error, making the design more reliable and easier to use. Although simplicity may compromise some aspects of functionality, we value repeatability of simple results over achieving all of the additional settings at the cost of a complex robot that we may not be able to fully control.
5. **Design for Flexibility**: Our team wishes to design a robot that is applicable to the situations of the real world, where flexibility of the design is very important since the situations of the real world are highly unpredictable and varied. Hence, we will design our robot to be flexible in both its range of movement and its speed of movement.

Given our team's list of DfX's that we value the most, we have chosen to satisfy the following goals in our design:

1. **Plug in all 3 types of charger plugs** specified in the Project Guideline (a 3D printed dummy charger plug with and without alignment tab and a J1772 charger plug with spring loaded clip into the charge port.
    a. This is congruent with our DfX of **design for flexibility**. In the real world, there will be a variety of charger plugs used depending on the brand or model of the electric car, so we wish for our design to be compatible with a large variety of different chargers.
    b. This also plays into **designing for usability**. If our design is able to dock more chargers, it will be able to be used by more people.
2. The **charge port can move in 3 degrees of freedom** (X direction: 0 to 1 m, Y direction: 0 to 0.5 m, Z direction: 0.37 to 0.6 m):
    a. We chose to give up the 4th degree of freedom in the yaw direction due to our desire to **design for reliability**. After researching the different mechanisms for object detection, we believed that detecting angles would make it difficult to complete each trial under the allotted the time and there would be more room for error.
3. Indicate with a visual signal once the charger has been plugged in.
    a. We decided to use a visual signal to indicate task success rather than an audio signal due to our value of **designing for simplicity**. A visual signal is cheaper and simpler to implement.
4. Retract the charger plug after having plugged it in for 5 seconds and return to start location.

Objective	Metric	Measurement Process
The design should minimize room for error.	Number of steps required to complete task (lower being better).	Count the number of mechanical parts that must move to complete the task as well as the number of instructions given in the software.
The design should be easy to use.	Amount of knowledge and number of steps required to use the design such that it achieves its full functionality (less being better).	Validate the designs with other people and see if they understand how to set up the robot and start it.
The design should be cost efficient.	Amount of money required to build the design (lower being better).	Make a Bill of Materials for each design and compare the total costs.
The design should comprise of materials that are easy to obtain.	Number of days it takes to receive the components (lower being better).	Compare the different methods of acquiring materials and determine if they are able to be acquired in a timely manner.
	Availability of all components (Yes/No; Yes being better).	See if all components can be either purchased or 3D printed.
The design should be stable and sturdy.	Amount of weight it can withhold (higher being better).	Conduct a weight test to see if the design and the charger holder can hold 400 g of weight (since the heaviest charger we are designing to hold is 380 g).
The design should be able to return to its original spot.	Yes/No (yes being better).	Test if the designs can return to their original location in a short amount of time.
The design should finish its task quickly.	Amount of time required to detect charge port and plug the charger in (less being better).	Given the time constraint, we do not believe it's realistic to make each of the alternative designs work fully, so this metric will be tested by an estimation based on the number of components that need to be moved, the detection rate, and the detection accuracy.
The design should be power efficient.	Amount of power consumed in one trial (less being better).	Sum up the amount of power required by all components combined (mostly motors).
The design should be flexible in its range of movement.	Number of degrees of freedom the charge port is to be located (higher being better).	Preliminarily determined based on the object detection mechanism and the movement mechanism.
	Range of each degree of freedom (higher is better).	

Alternative Designs

1) CatBot:

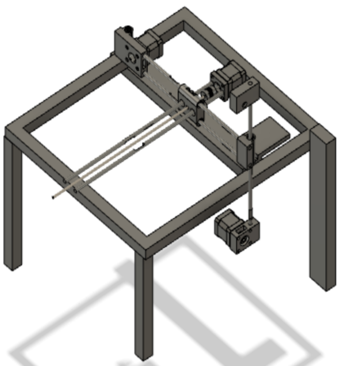


Figure 1: CAD Prototype of the CatBot Design

CatBot is a Cartesian robot that can move in the X, Y, Z directions using linear motion. We examined three main mechanisms for linear motion, which are servo motor-driven lead screw, timing belt, and pulley systems. The size of the robot is 1050 x 550 x 650 mm, which is approximately the size of the allowable space for the car. Such size allows the robot to manage all the possibilities of position that the car can have. Catbot acquires its vision using a circle tracking algorithm in OpenCV. It captures real-time video stream of what is occuring in the environment, converts the video frames to grayscale images and employs the aforementioned algorithm to track the centroid of the charger hole. Enabling CatBot to have a way to reliably align the centroid of the camera and the charger hole helps our robot move in precise x, y, z directions.

Benefits	**Risks**
• Design for Flexibility: Allows full range of motion in the X, Y, and Z directions. • Design for Usability: Returns to its starting location easily. • Design for Reliability: Linear motion increases precision. • Design for Stability: Can be constructed to be very sturdy since the structure is box-like.	• Linear motion components can be expensive, so must carefully budget the linear motions components to not go over the budget at the sacrifice of precision (ie. lead screws are more precise but also more expensive than timing belts so may have to give up precision). • Due to its large size and the number of stepper motors needed, power efficiency may be an issue.

2) Tank Design:

This design is modelled after a tank and was mainly designed for its stability and simplicity. Its movement mechanism in the X and Y direction comprises a quadrature encoder and stepper motor to improve precision since they can both turn in small angle increments. The motor drives wheels encapsulated in a rubber wheel belt. The reason we incorporated the rubber wheel belt over the wheels is because one of the biggest issues with having wheels is the slipping that happens as a result. Even if the stepper motor and encoder are able to move at precise angles, the wheels may not move precisely when the motor and encoder start and stop. Thus, the rubber belt is added to provide traction and minimize this issue. To satisfy the degree of freedom in the Z direction, a DIN3 rail is used to move the charger up and down. For the object detection mechanism, this design uses a Raspberry Pi camera, which offers a high degree of precision.

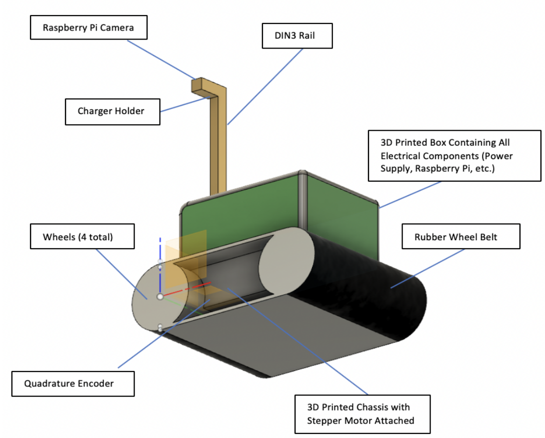


Figure 2: CAD Prototype of the Tank Design

Benefits	Risks
● Design for Flexibility: Allows full range of motion in the X, Y, and Z directions (can even be modified to incorporate the yaw). ● Design for Reliability: The increased traction in the movement mechanism combined with the precision of the quadrature encoder makes its movement very precise. ● Design for Simplicity: The design is easy to assemble and does not comprise of many parts. ● Design for Cost Efficiency: Components can be acquired at relatively low cost.	● Some conflict of interest between the components, the wheel belt might compromise the precision in turning that the encoder and motor offer. ● Raspberry Pi camera may lose field of vision if too close to the target

3) Scissor Lift - Triangle Design:

This design essentially consists of two main sections which are a triangular based rover and a scissor lift-like arm where the charger would be secured. In order to complete the task of plugging in a charger to a charger plug, the robot moves in the x and y directions with the wheels, and the scissor lift moves in the z-direction.

To create variety between our alternative designs, we agreed upon using a sensor for object detection. An ultrasonic range sensor would be suitable for this design as they are cost-effective and reliable for detecting presence and measuring distance. Additionally, ultrasonic sensors are ideal for real-life applications since they work in environments with snow, dust fog and steam which can be challenging for other sensors [1].

In order to ensure that the design was sturdy enough, we opted for a triangular base. This is because triangles are extremely stable; when a force is applied on any link or joint, the force will be distributed all over the structure, which makes the structure more rigid [2].

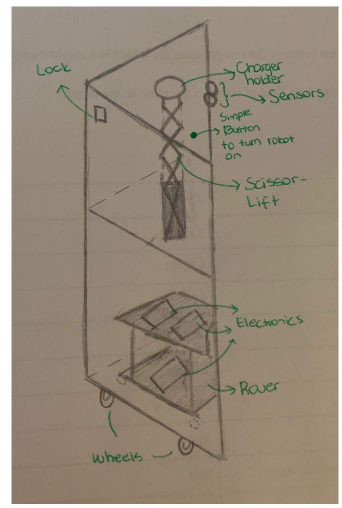


Figure 3: Sketch of Scissor Lift - Triangle Design

Benefits	Risks
● Design for Simplicity: This design was minimized to very few necessary components to achieve adequate functionality with lesser components. It consists of two very simple main parts, which are the rover and the scissor-lift. ● Design for Stability: The rover and the scissor-lift were designed such that they provide high strength and stability. The base of the rover is a triangle, as opposed to a circle or a rectangle, as triangles are more stable. ● Design for Cost Efficiency: Due to having a low-cost constraint for this particular project, we minimized the number of components integrated into the design. Additionally, when purchasing the parts of the design, we carefully picked affordable but optimal components.	● Ensuring that ultrasonic sensors would be able to detect the charger hole within the time constraint. ● The weakness of ultrasonic sensors is that they can't accurately detect distance at an angle. [3] ● Harder to control motion with 3 wheels than with 4 wheels.

Convergence Process

Figure 4 below illustrates our convergence process of two rounds, as a result of which we decided to proceed with the CatBot design.

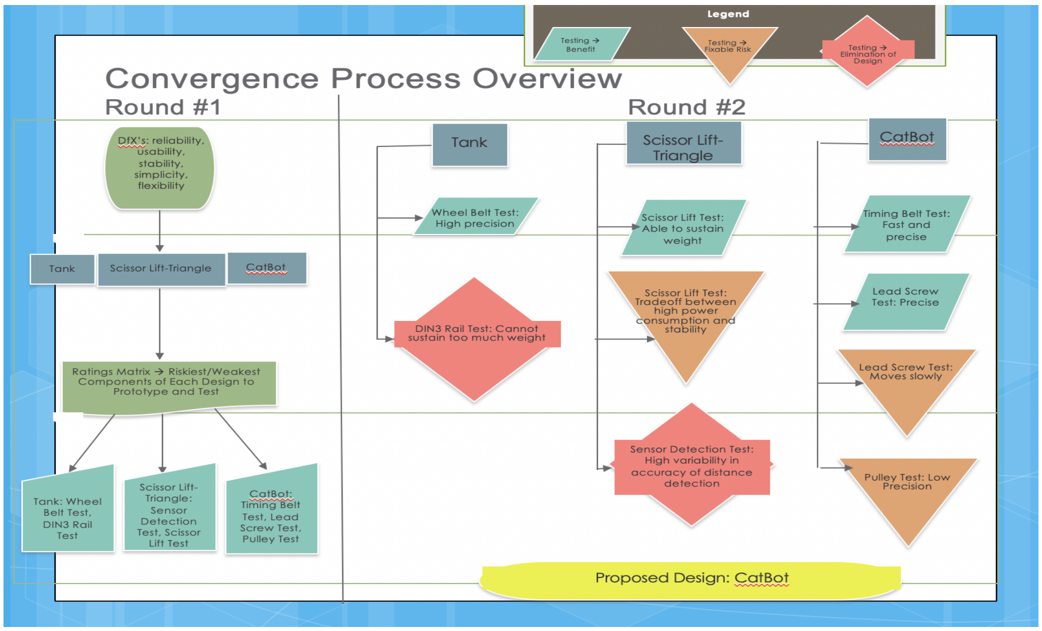


Figure 4: Convergence Process Overview

<u>Convergence Tool #1: Ratings Matrix</u>

Table 1: Convergence Tool #1: Ratings Matrix

Metric	**Scissor Lift-Triangle**	**Tank**	**CatBot**
Number of steps required to complete task (lower being better).	4 (drive to correct X coordinate, scissor lift charger to correct Z coordinate, drive forward to correct Y coordinate, drive back to starting location)	4 (drive to correct X coordinate, elevate the rail to correct Z coordinate, drive forward to correct Y coordinate, drive back to starting location)	3 (move to correct X coordinate, move to correct Z coordinate, move to correct Y coordinate, retract charger)
Amount of money required to build the design (lower being better).	$251.38	$260	$
Availability of all components (Yes/No; Yes being better).	Yes	Yes	Yes
Amount of weight it can withhold (higher being better).	>400 g	<400 g	>400 g
Whether or not design is able to return to its original spot.	Yes	Yes	Yes (easier)
Amount of time to detect port and plug in charger (less being better).	Less time required.	More time required.	Less time required.

Amount of power consumed in one trial (less being better).	Less power	More power (high power consumption to operate scissor lift)	More power (needs to power 3 stepper motors)
Number of degrees of freedom the charge port is able to be located (higher is better).	3 (X, Y, yaw)	3-4 (X, Y, Z, yaw)	3 (X, Y, Z)

Convergence Tool #2: Prototyping & Testing

1. **Triangle Design**
    a. **System Testing**

We tested this design at a system level by simply constructing a triangular prism in which we placed our rover from Workshop 1. We cut 4 equilateral plastic triangles of 39.5 centimetres in length, and cut a hole in the middle, for organizational purposes. We cut two rectangles off from the base triangle where the wheels of the rover would be placed. Fig. 5 shows a photo of the base triangle, and Figures 6 and 7 show photos of the physical prototype of this design that we constructed. Although this is a rough prototype, it allowed us to test the sturdiness of the structure and the ease of movement. Overall, the design is able to move and rotate with ease and is stable in its movement.

Figure 6: Physical Prototype of Scissor Lift - Triangle

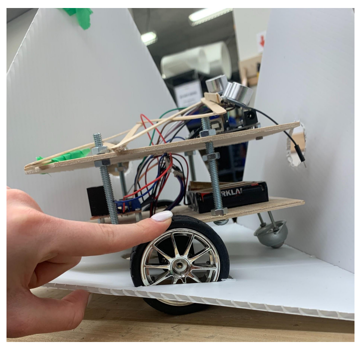


Figure 7: Physical Prototype of Scissor Lift - Triangle (Side View)

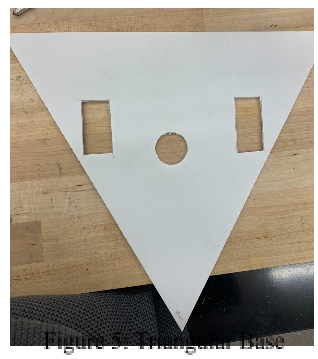


Figure 5: Triangular Base

    b. **Component Testing**

Ultrasonic Sensor: We tested detection of the charger port using the sensor and it yielded very varying results, which does not satisfy our objective of designing for reliability. We found that in the trials where the hole was really close, the sensor readings varied significantly from the actual distance.

Scissor Lift: We performed a weight test on a variety of scissor lifts (including ones made of aluminum oxide, stainless steel, and brass) and realized that there is a trade-off between sturdiness and power consumption. The scissor lifts that were able to hold up more weight required more power to operate.

2. **Tank Design**
    a. **Component Testing**

Wheel + Belt System: Driving the wheel and belt system with a stepper motor, we noticed that the tank design was able to start and stop with minimal wheel slipping. However, when the design had to rotate its wheels to turn, sometimes the wheel got stuck due to the rigidity of the rubber belt around the wheels, decreasing the repeatability of successful results and thereby its reliability. We then warmed up the rubber belt to make it less stiff, and this problem occurred significantly less. If we do choose this design, potentially a less stiff rubber material can be used instead to completely fix this problem while still maintaining accuracy.

DIN3 Rail: The rail that provides movement in the Z direction moved very fast when powered by a stepper motor, which satisfies design for flexibility. One problem we noticed with this rail is that it is not able to withstand a lot of weight. When we tried placing around 400 g of weight onto the rail, it kept sliding down.

3. CatBot

a. Component Testing

Legs vs. Box Frame: When designing the body of the robot, we considered various structures, two of which were a rectangular base with 4 legs and a box frame that does not include any legs. We went ahead and built two simple boxes, one with 4 legs and one without legs using the extra unwanted wood pieces from the Myhal Fabrication Facility. We tested the strength and the stability of both of the structures by applying the same amount of force on both of them, and we did not observe a significant difference in strength. Additionally, constructing a box frame would require more material which in turn result in a higher total cost of the robot.

Linear Motion in Z Direction - Pulley vs. Lead Screw: In order to move the platform in the z-direction, we considered two structures that would achieve such a function. First, we constructed a pulley-lift mechanism for the platform whose drawing can be seen in Figure 8. We built a small prototype of this mechanism, and tested it against a few metrics and constraints. We constructed a small platform which we connected to the pulley through a rope. As the pulley was rotating, the platform was moving in the z-direction. This prototype worked on a small scale, however, we wanted to ensure it would also function properly in a larger frame. To test parts of this mechanism, we used the same rope on the box frame we had built for part a of this section. It turned out that for longer distances than 10 centimetres, the pulley would start wiggling and lose its stability. To further verify this mechanism, we placed a box that was approximately the same size as the dummy charger plug on the platform. The structure was not sturdy enough to hold the box securely in place, which is why we decided to eliminate this option.

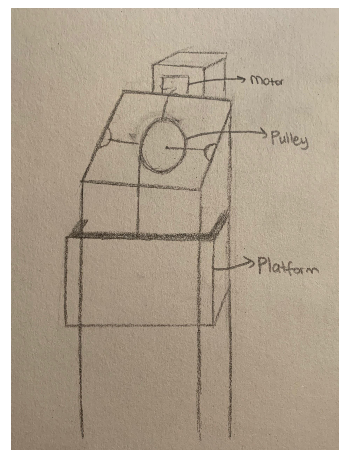


Figure 8: Electric Lift Design with Pulley

Proposed Design Solution

As a team, we have decided to proceed with the CatBot design as our proposed design solution, as we during our converging sessions we have come to the conclusion that it is the most efficient, durable and reliable design concept.

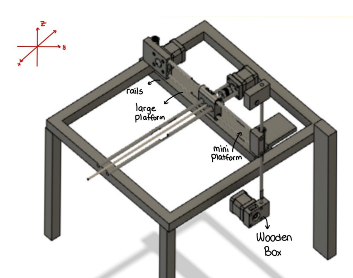
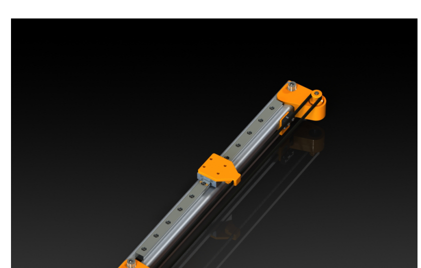


Figure 9: CAD Prototype of the CatBot Design (Labelled)

1. **Mechanical Design & Design for Mobility**

   The mechanical design of CatBot is shown in Figure 9. CatBot is essentially a Cartesian robot that works under the idea of linear motion, and is able to move in all three directions.
   The robot will start detection and motion in x, z and y directions respectively.

   - **X- Direction:** In the x-direction, the robot simply consists of a timing belt which rotates. CatBot starts object detection in the x-direction, and the timing belt keeps rotating until the desired x location is reached. As the



timing belt spins, the wooden box that is hanging from the top plate of CatBot also moves in the same direction.

- **Z- Direction:** In order to move the wooden box in the z-direction (upwards and downwards), the box is connected to the top of the robot with lead screws. Additionally, the wooden box has a hidden platform inside where the charger will be secured onto. This box will simply move in the z-direction with the lead screws until the perfect z-position is reached.
- **Y- Direction:** Once the z-direction object detection is finished, CatBot will proceed to move in the y-direction. The y-direction consists of two long rails that extend throughout the whole y-direction. There is a timing belt in the middle of the rails that rotates in the y-direction. On top of this timing belt is a mini platform which is located just under the wooden box, such that as the belt starts rotating, the platform will stick out of the robot with the box, allowing the charger to be plugged into the plug.

Figure 10: CAD Prototype of Timing Belt for X & Y

Figure 11: Lead Screw for Z-Direction

As for the frame that supports all the linear motion components, the two sides of the frame in the X direction are 1050 mm long to allow full range of motion. By similar reasoning, the Y direction frame sides are 550 mm. The material we chose to construct the frame out of is Spruce Plywood because it is both cheap and quite strong. [4]

Due to the fact that the 550 mm platform will be sliding out in the Y direction, and at the front end of the platform will be where the 380 g charger is along with the lead screw. Thus, there will be a heavy moment at the front of the robot. After measuring the total weight of the charger, the lead screw, and the platform and performing moment calculations, we concluded that the 4 legs of the frame will be 60 x 80 x 300 mm such that the weight of the frame will counteract the moment of the Y direction platform.

2. Electrical Design

CatBot requires quite a few electrical components in order to accomplish its desired function of moving in the x, y and z directions.

- **Power Supply:** An XBox 360 power supply that is 216 Watts and delivers 16.5 amps at 12 Volts, will be used to power up the robot. We chose to use this due to its high and stable power output. As seen in Table 2, the amount of power (145.5 W) needed for CatBot is significantly below the power the XBox power supply can deliver. The plug of this power supply will be disassembled and cut off right below to connection, such that all of the wires are exposed. The plug has 4 black wires, 4 yellow wires, a red and a blue wire which can be seen in Fig 12. The black wire is the ground, the yellow are the positive, and the blue and the red control power on and power standby. Connecting the red and the blue wires together turns the power supply on when plugged in. These wires will be extended and longer wires will be spliced in such that a turn on/off switch can be installed. The yellow wires will make the power connector for the driver.

Figure 12: XBox Power Supply - Wires Exposed

Table 2: Voltage, Current and Power Values of Electrical Components [5] [6]

Component	**Voltage (V)**	**Current (A)**	**Power (W)**
Nema 17 Stepper Motor x 3	12	12	144
Raspberry Pi & Camera	5	0.3	1.5
Total			145.5

- **Nema 17 Stepper Motor 45Ncm & Stepper Motor Driver A4988:** We chose to use stepper motors in our design because of their ability to move precisely to a known location as well as their ability to hold themselves at that location. Though servo motors offer the same advantages, the range of motion needed to fulfill our objectives cannot be satisfied by servo motors. Once we converged on using stepper motors, we then analyzed the different types of stepper motors against our objectives. Through this, we found that the 45Ncm stepper motor is both decently priced and has enough torque to fulfill the tasks. [5]

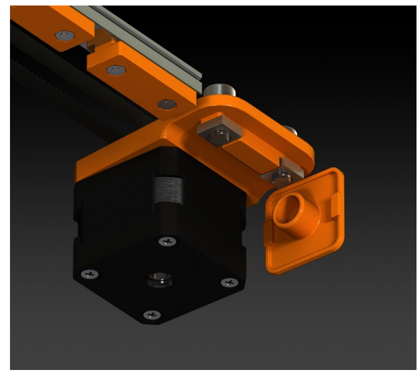


Figure 13: CAD Prototype of Stepper Motor

- **Raspberry Pi:** Raspberry Pi will be used for object detection, specifically for detecting the hole where the charger will be plugged in. The Raspberry Pi will be connected to an Arduino, for which a schematic can be found under the "*Integration Between Location and Driving System*" section of this proposal. The algorithm that Raspberry Pi will execute is detailed under the *"How the Design Achieves Autonomy"* section.

3. Programming and Designing for Mobility

CatBot acquires its vision using the Raspberry Pi module and the PiCamera v.2. At a high level, we aim to first identify the centroid of the circular hole and find the pixel distance between the the centroid with the center of the camera frame. As the center (x,z)-coordinates of the hole is computed and the center of the camera frame is always fixed, we can output a set of instructions to command CatBot to move in the X, Z to align the two centers. The final step is to command the robot to move forward towards the charger location in the Y direction. An ultrasonic sensor would be mounted under the charger to sense if the charger has been plugged. Such logic allows us to turn off the motor promptly and signals is to move in the reversed direction to return to its original starting position.

Identifying the Circle and Its Centroid

In order to detect circles in images or video streams, we need to make use of the cv2.HoughCircles function [7] - a method in OpenCV, which is an open-source library that caters to real-time computer vision [8]. The function takes in several parameters that make it suitable for our simple charger hole detection problem. Indeed, the function signature is as follows:

cv2.HoughCircles(image, method, dp, minDist)

The most important parameter to get right is minDist, which tells us the circumscribed region that the PiCamera should look for circles. If minDist is too large, we detect more circles than needed which may not necessarily be the charger hole. If minDist is too small, the algorithm may fail to detect the right circle. Fine-tuning the minDist such that the right circle is detected is one of the important objectives of this object detection algorithm. As our CatBot would be moving, its field of view would be changing. Thus, we continuously update minDist proportional to the distance that the robot has moved forward, so the detection of the circle is not lost. Some preliminary hole detection results are shown below in Figure 14.

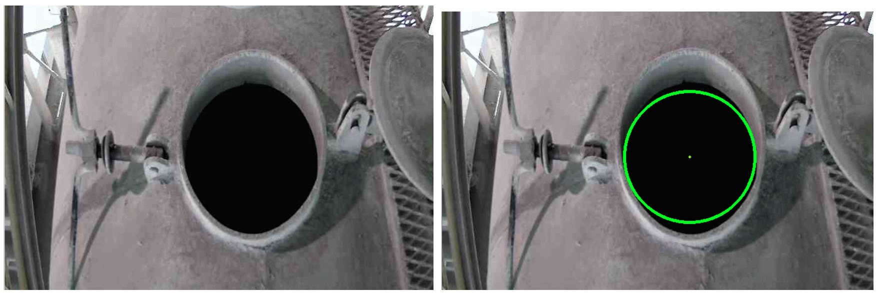


Figure 14: Preliminary Hole Detection Results

The output of this step could be the x, z-coordinates of the hole's centroid.

Computing the Euclidean Distance Between the Hole's Centroid and the Camera Frame's Center

Raspberry Pi Camera Module v2 is the camera we are using. It is a high quality 8 megapixel camera using Sony IMX129 image sensor [9], which allows students to create HD videos at a relatively cheap cost. It is capable of capturing 1280 x 720 px videos at the rate of 40-90 frames per second. Therefore, we can easily calculate the center of the center of the camera frame, which is (640,320) pixels. Now, we can find the distance in the X and Z between two points in pixel values.

To convert from pixel distance to real distance, we can use the following formula: $real\ distance\ =\ pixel\ distance \times \frac{real\ world\ diameter\ of\ hole}{pixel\ diameter\ of\ hole}$. Using this method, we can return the real-world X, Y values and communicate that to the Arduino board. Another Arduino's utility program would convert such distance to the corresponding number of revolutions of the servo motor. This analog output will then be received by the servo motor, driving the timing belt forwards.

Commanding CatBot to Move Forward in the Y - Direction

As the camera is mounted on the z axis right above the charger plug, the aligned centers between the camera frame and the centroid of the charger's hole implies that we should move the charger up by 26.1 mm. Although we can employ the same logic flow as above to drive the charger plug forward, a question arises: How do we know when y-direction actuator should pause for 5 seconds before retracting? This is where ultrasonic sensors come in. By mounting an ultrasonic sensor on the z axis directly below the charger plug, CatBot can measure how close the charger is relative to the hole. At a distance of 40mm, it means that the charger is completely plugged in. Such conditional statement in the Arduino program can command the z-axis servo to pause before starting to drive in the opposite direction.

4. Integration Between Locating and Driving System

To recap, the driving system relies on timing belt and lead screw-driven actuators that are attached to servo motors. The servo motors are also connected via wires to the Arduino board. On the other hand, the locating system relies on Raspberry Pi Module 4 and PiCam v.2. We can connect the RaspberryPi interface with the Arduino controller simply via USB-to-Serial connection, as shown in Figure 15.

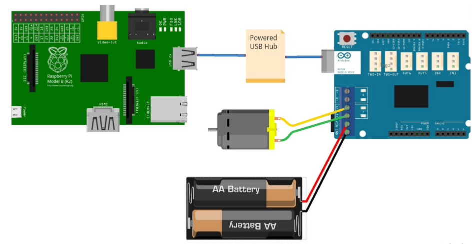


Figure 15: Raspberry Pi, Arduino, Motor and Battery Circuit System

A complete picture of how mechanical, electrical, and programming systems integrate is summarized in Figure 16 below.

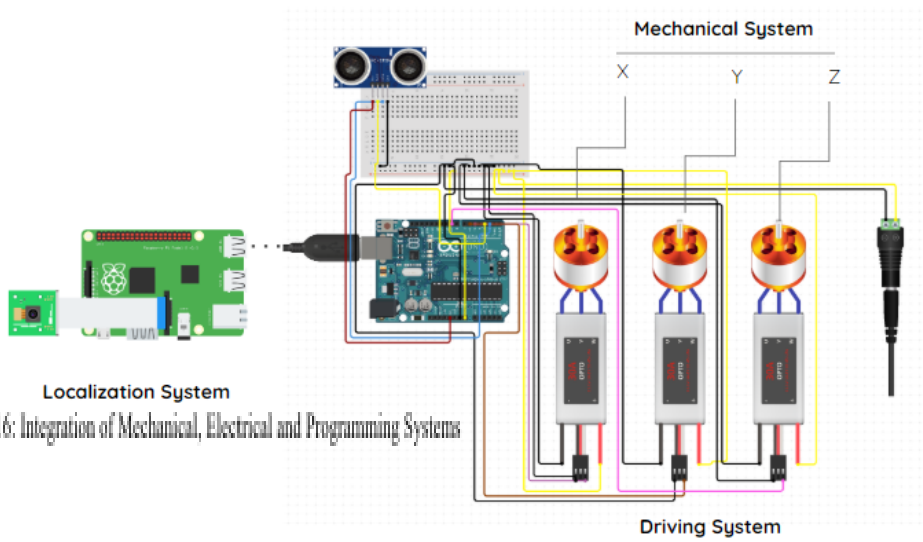


Figure 16: Integration of Mechanical, Electrical and Programming Systems

5. Bill of Materials

Table 3: Bill of Materials

Component	**Quantity**	**Cost**	**Link to Purchase**
Linear Motion Rod Set - 8mm diameter x 500mm length steel linear shaft (4 per set) - 42x32x11mm aluminum rail support guide (8 per set) - 8x34.5mm steel linear motion ball bearing (4 per set)	1	$42.85	https://www.amazon.ca/gp/product/B01KLE9QEU/ref=ppx_yo_dt_b_asin_title_o01_s01?ie=UTF8&psc=1

Xbox One Power Supply Brick	1	$24.99	https://www.amazon.ca/gp/product/B07PZCBHQH/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&psc=1
DCDC 3A, 3.2-35V to 1.25-35V	1	$1.27	Myhal LFF
Timing Belt Set: - 5m GT2 timing belt (1 per set) - 20 teeth timing pulleys (4 per set) - Mount blocks (4 per set)	2	$14.99 x 2 = $29.98	https://www.amazon.ca/gp/product/B07PQRJL2W/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&psc=1
Nema 17 Stepper Motor 45 Ncm with 1m Pin Connector	3	$14.99 x 3 = $44.97	https://www.amazon.ca/gp/product/B07KZQ77VH/ref=ppx_yo_dt_b_asin_title_o00_s01?ie=UTF8&psc=1
Stepper Motor Driver A4988	3	$1.83 x 3 = $5.49	Myhal LFF
Lead Screw Set: - T8-400mm lead screw (1 per set) - Copper nut (1 per set) - Coupler (1 per set) - Pillow bearing block (2 per set)	1	$21.98	https://www.amazon.ca/gp/product/B07ZKWHLW4/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1
Raspberry Pi Camera v.2	1	$26.39	https://www.amazon.ca/Camera-Module-175%C2%B0High-Definition-Raspberry/dp/B07T1HMF7R/ref=sr_1_5?keywords=raspberry+pi+camera&qid=1582483136&s=industrial&sr=1-5
Raspberry Pi Module 4	1	$46.95	https://www.buyapi.ca/product/raspberry-pi-4-model-b-1gb/
Arduino Uno	1	$5.49	Myhal LFF
Ultrasonic Sensor	1	$1.13	Myhal LFF
2' x 4' x 3/4" (18.5 mm) D-Grade Spruce Plywood	2	$17.49 x 2 = $34.98	https://www.homehardware.ca/en/2-x-4-x-34-185-mm-d-grade-spruce-plywood/p/2817215?page=category%20page#ccode=1525535408909
Standard 1.75mm PLA Filament 0.5kG	1	$9.57	https://filaments.ca/products/econofil-1kg-pla-filament-grey-1-75mm
Total	**$296.04**		

6. Risk Assessment

Table 4: Risk Assessment of Proposed Design

Risk Type	Risk	Severity	Likelihood	Risk Level	Remedy	Responsible
Mechanical	Alignment issues in linear motion due to large size of robot	Tolerable	Possible	Med	Ensure that bearings are spaced properly and re-calculate using tools such as igus lifetime calculator [10] if necessary. Construct the wooden frame so that they are completely parallel to each other.	Katherine
	Robot may tip over due to the heavy Y portion that extrudes to deliver the charger plug.	Undesirable	Improbable	Med	Risk can be avoided by carefully selecting materials with the appropriate weight on the left/right, back/front of the robot as well as performing load/ torque calculations.	Elif
Electrical	The RPi module when working with WiFi may be more sporadic and less reliable than working with Ethernet.	Acceptable	Possible	Low	Most WiFi routers run using Dynamic Host Configuration Protocol (DHCP) [11], which means the server assigns a dynamic IP address and other network parameters to connected devices. Each dynamic IP has an expiration period, thereby disconnecting the RaspberryPi if one runs it for too long. This can be fixed by writing a static IP address to the RaspberryPi's SD card for WiFi configuration.The chances of the static IP failing is quite rare.	Hannah
	CatBot doesn't have sufficient power to operate.	Acceptable	Improbable	Low	Can be easily prevented by using a multimeter to measure voltage delivered to different components and performing and simple discharge rate calculation to determine how many hours the battery can continue to operate. If budget permits, new batteries can be used.	Elif
Programming	Object detection algorithm detects the wrong circle in the environment.	Tolerable	Possible	Med	Fine-tune minDist in House Circle algorithm and test it under various environments to see which minDist achieves the most reliable performance. If that does not work, we can tape a high contrast color (like green) around the charger plug hole, and use RGB Color Detection function in OpenCV to distinguish the bright color from the background and properly create a bounding box around the charger hole.	Hannah
Integration	Integration of ultrasonic sensor with Raspberry Pi camera may confuse the motors on which one to listen to.	Undesirable	Possible	High	Strategically place the ultrasonic sensor so that its field of detection is the same distance away from the camera's field of vision as the radius of the charge port. This makes it so that they one is detecting the edge of the hole while the other is detecting for the hole itself. Can also code the ultrasonic sensor instructions such that it is a second line of defense and is not activated until the camera believes it has located the hole.	Katherine & Hannah

7. Project Timeline

Individual Responsibilities

Each team member is responsible for specific aspects of the design, as shown in Table 5 below.

Table 5: Main Responsibilities of Each of the Team Members

	Main responsibilites	Examples
Katherine	Logistics	Researching and ordering materials from suppliers
	Budget management	Ensuring that the team stays under budget
	Mechanical	Fabricating structures through 3D printing, soldering, wood handling, etc.
Elif	Electronics	
	Circuits assembly	Managing communication and assembly of Arduino, circuits and electronic components like motors, sensors, etc
	Sensors	Researching various types of sensors and how each can act as checkpoints besides computer vision
Hannah	Project management	Setting timeline and ensuring everyone understands what they're doing using Gantt Chart, Calendar, Excel, Trello...
	Computer vision	Determining most efficient camera and algorithm for fast image processing and detection
	Software and hardware integration	Oversees how various software and hardward components fit into the bigger picture

Weekly Milestones

- **Week 5 Goal: Framing and creating a diverse set of 6-10 designs**
  - Assigned to: All
  - Diverged and explored alternative designs, as well as their associated risks and benefits
  - Discussed team's core values and DfX to align designs with
  - Used the Wishing Method to explore creative, possible scenarios
  - Each team member individually came up with 3-4 designs.
  - Researched materials and costs associated with each individual designs

- **Week 6 Goal: Narrowing down to top 3 designs**
  - Assigned to: All
  - Finish the first round of converging. Finalize the top three designs.
  - Team meeting to give feedback and pass around each other's designs (i.e. the 365 method)
  - Used Praxis I/ II's convergining techniques, such as Borda Count, Decision Matrix, while incorporating our values during the decision making process, to come up with the CAD designs for three main designs.

- **Week 7 Goal: Prototyping to converge on top and final design**
  - **Hannah**: Prototype object detection algorithm to test for **reliability** of the camera under several environments and lightning (Is the same object detected when placed in different spaces?), for **speed of processing** (Does the detection happen under 5 seconds?), for **quality of image acquisition** of Raspberry pi camera (Is the image good enough
  - **Katherine, Elif:** Prototype the riskiest aspects of other alternative designs, such as:
    - How precise is the conveyor belt wheel of the Tank Design?
    - How much weight can a scissor lift sustain for our Scissor Lift Design?
    - What's the speed of the lead screw design? How to mitigate alignment issues when using parallel rods and lead screw to enable linear motion?

        - How power efficient is each of the designs? Does it meet the power consumption constraint of Myhal Fabrication Center?
    - **Katherine, Elif:** Get feedback from Teaching Assistants Team on credibility of prototyping
    - **Team:** Converge on top design with desired components after testing
    - **Hannah:** Draw circuit diagram on how electronic, hardware and software components integrate with one another
    - **Hannah:** Finalize preliminary Bill of Materials

- **Week 8 Goal: Building for Mobility**
    - **Katherine:**
        - Calculate load of design components and determine weight of the back, front and side wooden frames of CatBot.
        - Acquire required materials for construction
    - **Elif:**
        - Build linear motion rails
        - Construct wooden frame for CatBot
    - **Hannah:** Integrate linear motion with systemic circuit design
    - **Team:** Testing for linear motion. Refer to "*Risk Assessment*" for potential problems and solutions.
- **Week 9 & 10 Goal: Building for Localization and Integrating Systems**
    - **Hannah:** Finish coding and debugging centroid tracking algorithm for car under various lighting conditions
    - **Katherine, Elif:** Setup and troubleshoot interfacing between Arduino, RaspberryPi, PiCam, and mechanical linear motion
    - **Team:** Testing for object detection. Refer to "*Risk Assessment*" for potential problems and solutions.

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