AUTOMATIC REAR-VIEW MIRROR

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PROFESSOR: ALEX BLINDER | COURSE: ECET 400 | DATE: DECEMBER 2, 2024

Project Team

Diego Andrade

Born and raised in Ecuador until the age of 10, then moved to the United States.

Began college at NJIT in 2020, pursuing an Electrical and Computer Engineering Technology.

Interests: Power generation & distribution, control systems, automation, robotics, and renewable energy.

Valentina Clavijo

Born in Colombia, studied Mechatronics Engineering for two years and earned a technical degree in Mechatronics.

Began a bachelor's degree in Electrical and Computer Engineering Technology at NJIT in 2022.

Interests: Control systems, automation, robotics, and power systems.

Kyuung (Casey) Cha

International South Korean software developer and recent retiree from the Korean military.

Currently pursuing Electrical and Computer Engineering Technology and Game Development at NJIT.

Interests: software development, video games, and computer graphics.

Nigel Ng

Born and raised American Chinese Test Engineer currently working at Cygnus LLC.

Began studying at NJIT after transferring from ECC in 2021.

Interests: Renewable energy, alternative transportation and

Mohammad Rahman

Born and raised in Kuwait till age 16 moved during my high school years and always aspired to be an engineer. Although mechanical at first.

Came in NJIT during covid and Switched major from general engineering to ECET around a year later.

Interests: Embedded systems, and Integrated circuits.

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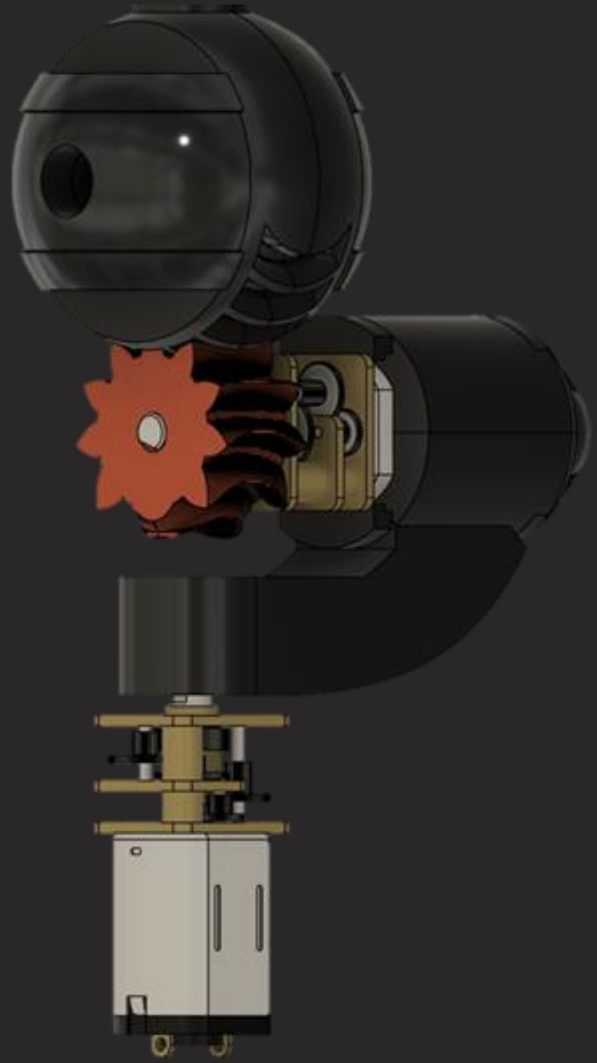


Problem Statement

- **Rise in car sharing**
  - Allied Market Research states **Car-sharing services are on the rise.**
  - National Household Travel Survey reports the average car per household is **below 2.0.**
- **Increase in car sharing → Different Driver → Frequent Rear-View Mirror Adjustment**
- **Issues**
  - Mirror adjustments can be tedious and easy to overlook.
  - Mid-drive adjustment or incorrect adjustment can lead to accidents.

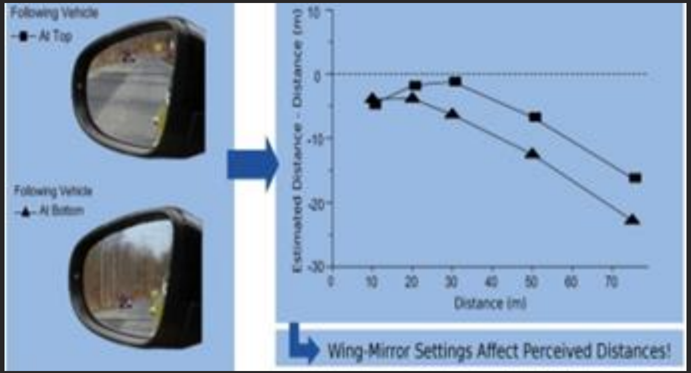
▲Allied Market Research. (2024). *Car sharing market by service type, vehicle type, and application: Global opportunity analysis and industry forecast, 2023-2032.*

▲National Household Travel Survey. (2022). *2022 National Household Travel Survey summary of travel trends.*

Issue Data

	% Distracted	Incidence		Total Economic Crash Costs		
		Total	Distracted	Total	Distracted	Other
PDO Vehicles	15.23%	19,288,139	2,936,833	$101,282	$15,421	$85,861
MAIS0	14.98%	4,525,901	678,162	$14,718	$2,205	$12,513
MAIS1	15.21%	3,875,265	589,546	$74,963	$11,404	$63,559
MAIS2	13.84%	427,119	59,131	$30,504	$4,223	$26,281
MAIS3	13.45%	141,167	18,982	$39,629	$5,329	$34,300
MAIS4	12.80%	19,285	2,469	$13,031	$1,668	$11,363
MAIS5	11.75%	7,187	845	$7,039	$827	$6,212
Fatalities	8.70%	36,500	3,177	$58,643	$5,105	$53,538
Total	15.14%	28,320,563	4,289,145	$339,809	$46,183	$293,627
Percentage of Total		100.00%	15.14%	100.00%	13.59%	86.41%

Accidents caused by distraction



Importance of precise mirror adjustment

▲F., Klauer, S., *The economic and societal impact of motor vehicle crashes, 2019 (Revised)* (Report No. DOT HS 813 403). National Highway Traffic Safety Administration.

▲"Designing a User-Centric In-Car Interface: A Case Study on Rear-View Mirror Adjustment." *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 38, 2015,

Concept for Automatic Rear-View Mirror

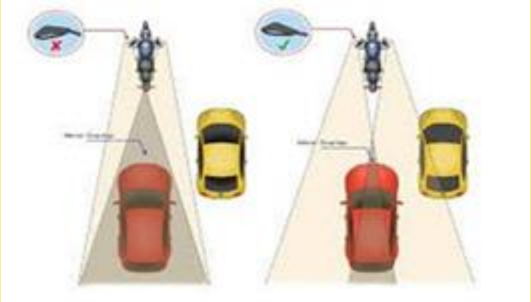
Develop a system that automatically adjusts the rear-view mirror to the optimal position, ensuring improved driver convenience, safety, and adaptability to individual preferences or conditions.

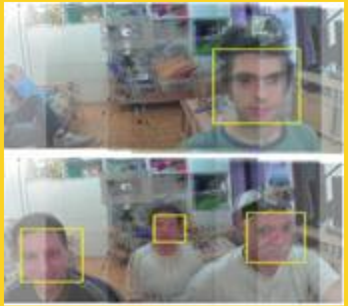
Key features

- Eye Tracking through Computer Vision
- 3 Dimensionally Adjustable Ball-Joint Motor
- Powered by Raspberry Pi
- Optional Auto / Manual mode

Related Patents

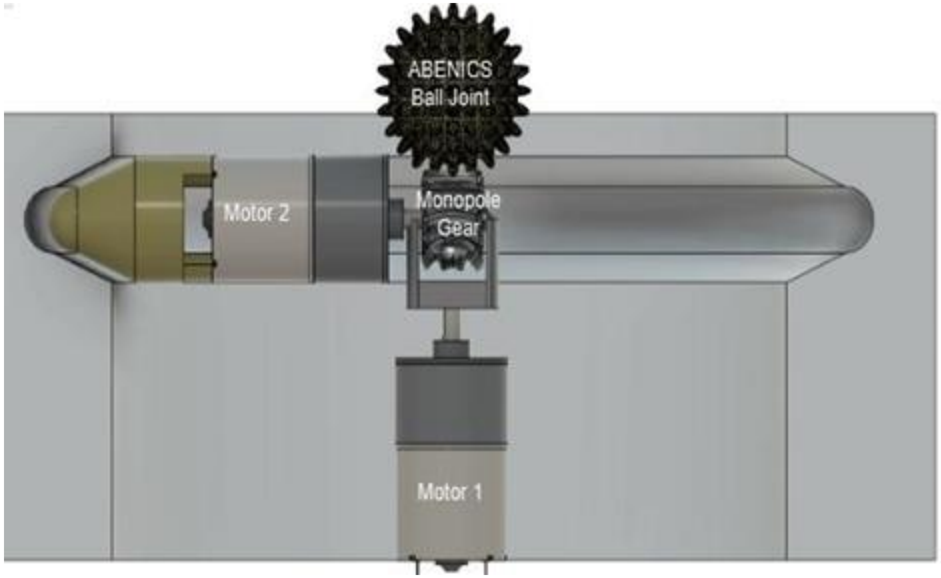
- **Vishwakarma Institute of Technology**
  - Developed an automatic rear-view mirror for bikes.
  - Mirror angle was adjusted based on vehicle visibility.
- **Tongmyong University**
  - Explored the eye-tracking technology’s potential for rear-view mirror adjustment to improve driver safety.
  - Only conceptualized.
- **University of Bologna**
  - Created a prototype of motor adjustment through face tracking.
  - Used Windows as main operating system.

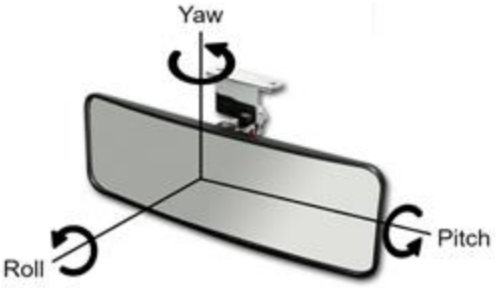


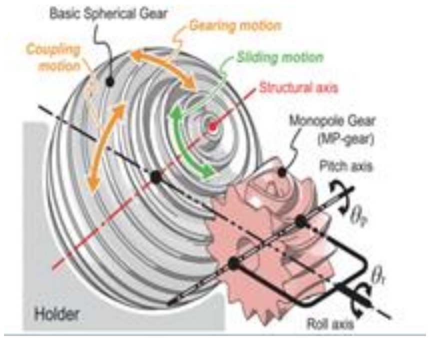


▲Karvir, S. (2023). Automatic Adjustable Rear-View Mirror Using Servo Motor and Arduino for Bikes

▲Rota, F., & Stefano, L. (2017). Automatically adjustable rear mirror based on computer vision. *2017 International Conference of Electrical and Electronic Technologies for Automotive*, 1-7





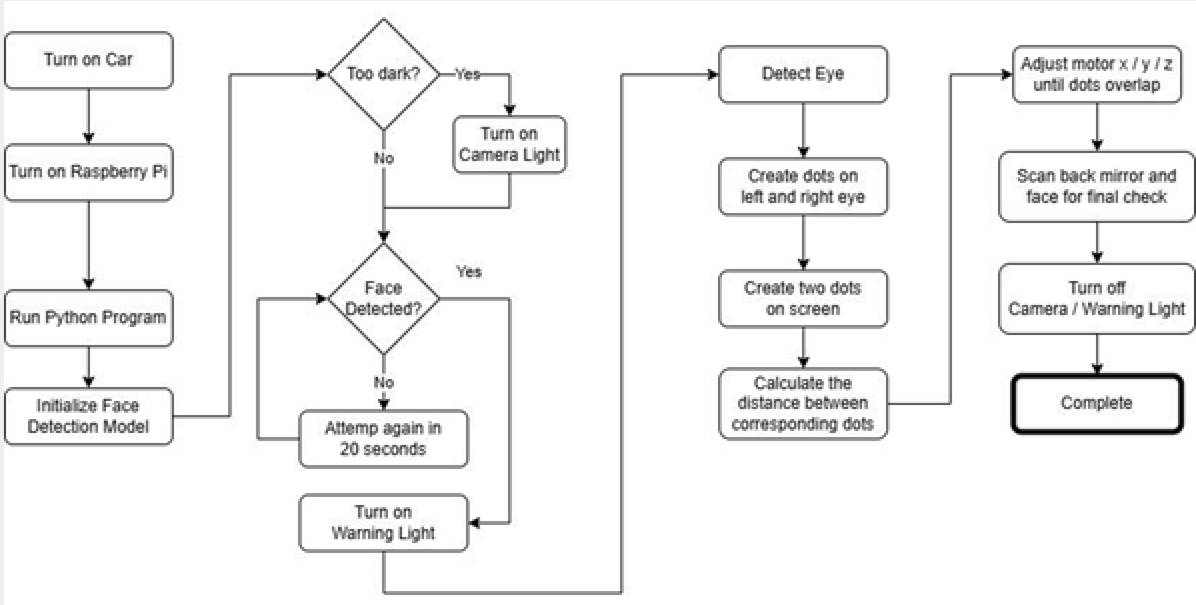


Prototype Mechanism

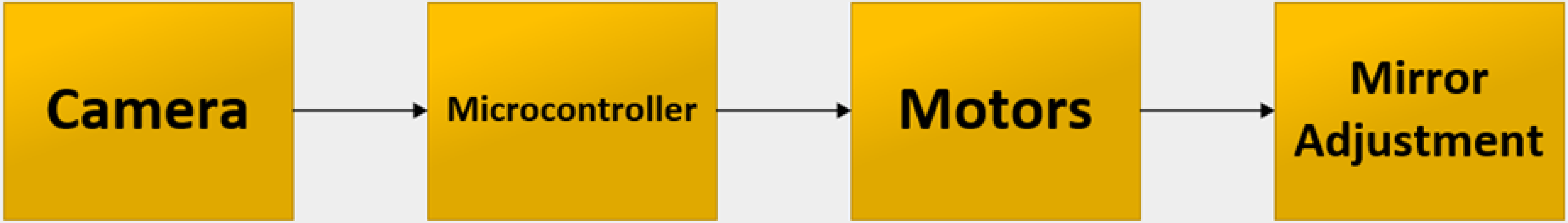
- ABENICS ball joint is crucial for the main operation of the system.
  - Multidirectional axial movements: yaw and roll.
  - Gruebler's equation is used to find the degrees of freedom.
- Adjustments are made to the rear view mirror through data collected from the camera.
- The rear-view mirror is adjusted and held in place via a connection with an ABENICS Ball joint and a monopole gear.
- The yaw and roll of the ball joint is controlled by two DC motors, where Motor 1 controls the roll and Motor 2 controls the yaw.

Concept Flowchart

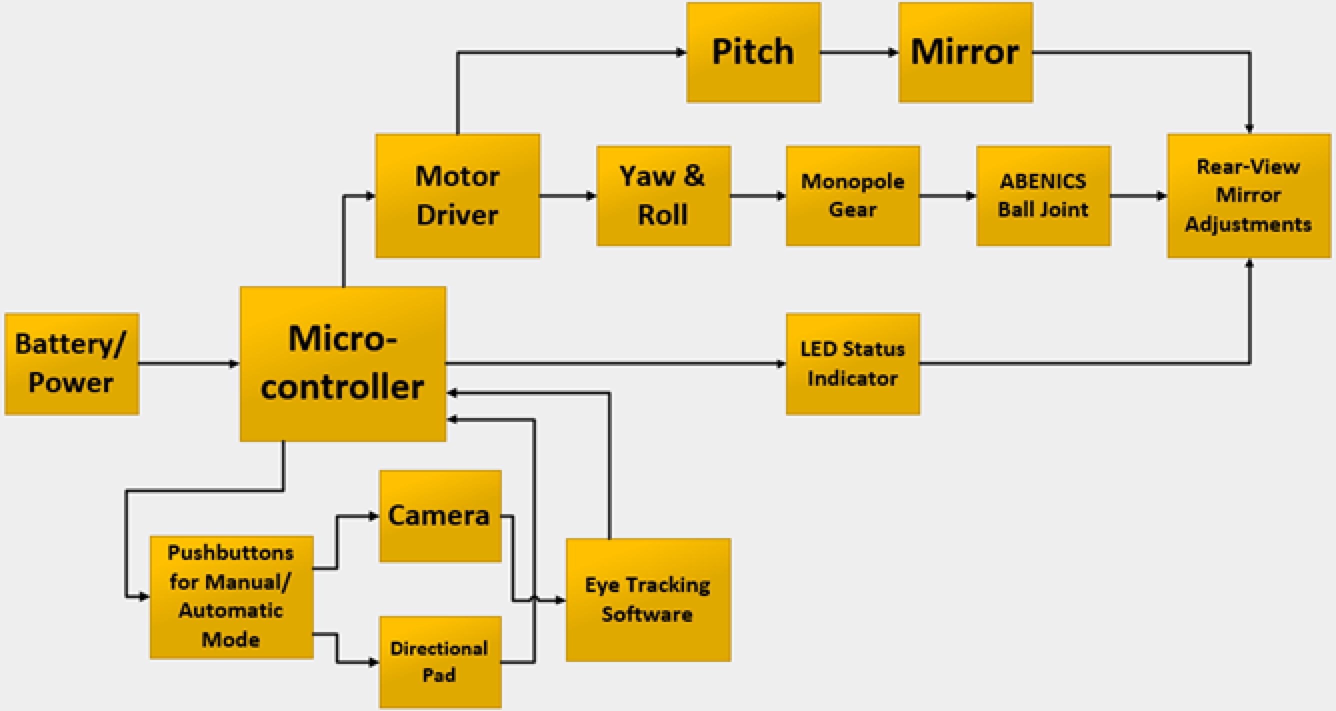
- Initialization
- Preparation
- Calculation
- Adjustment



Top Level Block Diagram



Second Level Block Diagram



Final Prototype Requirements

Software

Hardware

Embedded Systems

Software Overview

Summary

Python: main programming language

MediaPipe: computer vision library

OpenCV: video capturing

PyGame: controller input

Functionality

Capture driver’s eye coordinates

↓

Measure the distance between driver’s eyes and predefined location

↓

Calculate the required angle adjustment flow

↓

Signal motor functions in sequence

↓

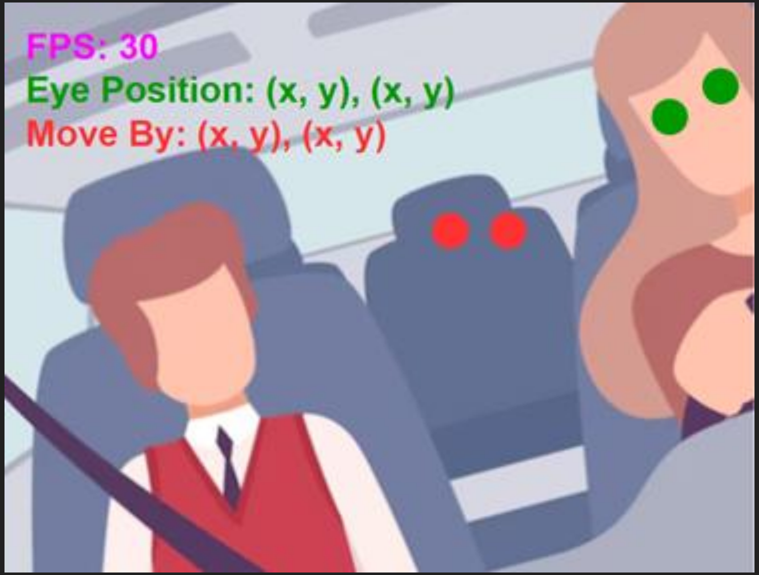
Scan the result

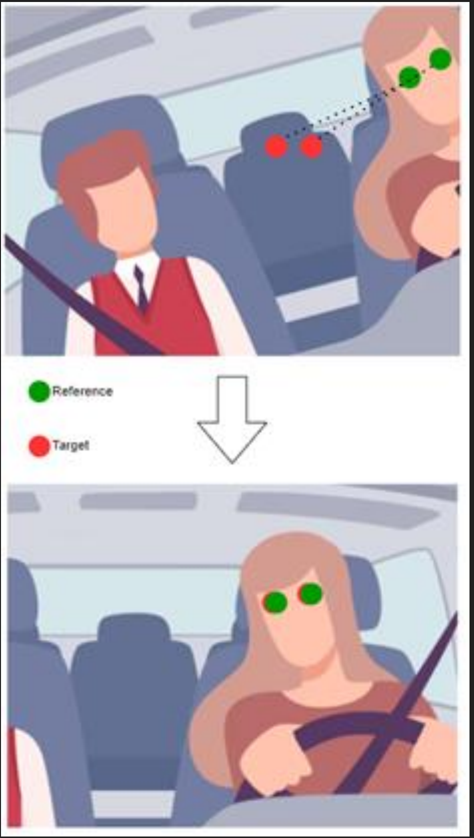
Key focus

- ❑ Optimization to run on Pi’s limited hardware
- ❑ Offline functionality for Data Privacy

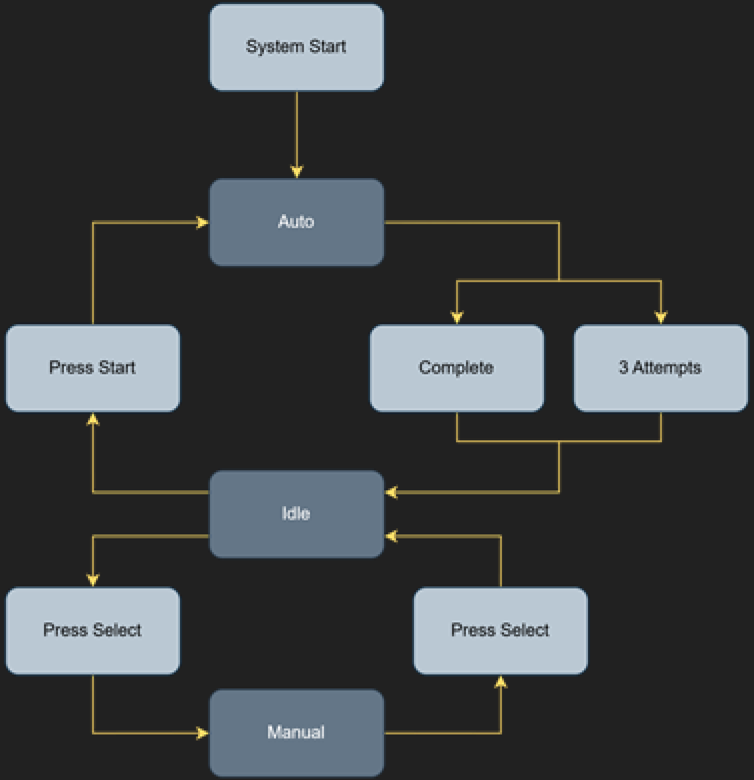
Adjustment Process Example

Camera’s perspective





Software State Machine



EyeTracking.py

```python
if results.pose_landmarks:
    left_eye = (
        int(results.pose_landmarks.landmark[mp.solutions.holistic.
        PoseLandmark.LEFT_EYE].x * self.frame_width),
        int(results.pose_landmarks.landmark[mp.solutions.holistic.
        PoseLandmark.LEFT_EYE].y * self.frame_height)
    )

    right_eye = (
        int(results.pose_landmarks.landmark[mp.solutions.holistic.
        PoseLandmark.RIGHT_EYE].x * self.frame_width),
        int(results.pose_landmarks.landmark[mp.solutions.holistic.
        PoseLandmark.RIGHT_EYE].y * self.frame_height)
    )
```

- Retrieve camera input using OpenCV
- Process the input through the MediaPipe Holistic model
- On face landmark detection, map left and right eye coordinates based on screen frame size

EyeTracking.py

```python
current_angle = calcualte_angle(left_eye, right_eye)
angle_difference = self.target_angle - current_angle
if angle_difference < -180:
    angle_difference += 360

if abs(angle_difference) > ANGLE_RANGE:
    if angle_difference < 0:
        self.instruction_sequence.append(Direction.CW)
    else:
        self.instruction_sequence.append(Direction.CCW)

x_average = (x_movement_left + x_movement_right) / 2
y_average = (y_movement_left + y_movement_right) / 2

if abs(x_average) > DISTANCE_RANGE:
    if x_average < 0:
        self.instruction_sequence.append(Direction.LEFT)
    else:
        self.instruction_sequence.append(Direction.RIGHT)
```

- Compare the distance and the angle between the mapped eye position and the target position
- Retrieve the necessary adjustments to create the instruction sequence

EyeTracking.py

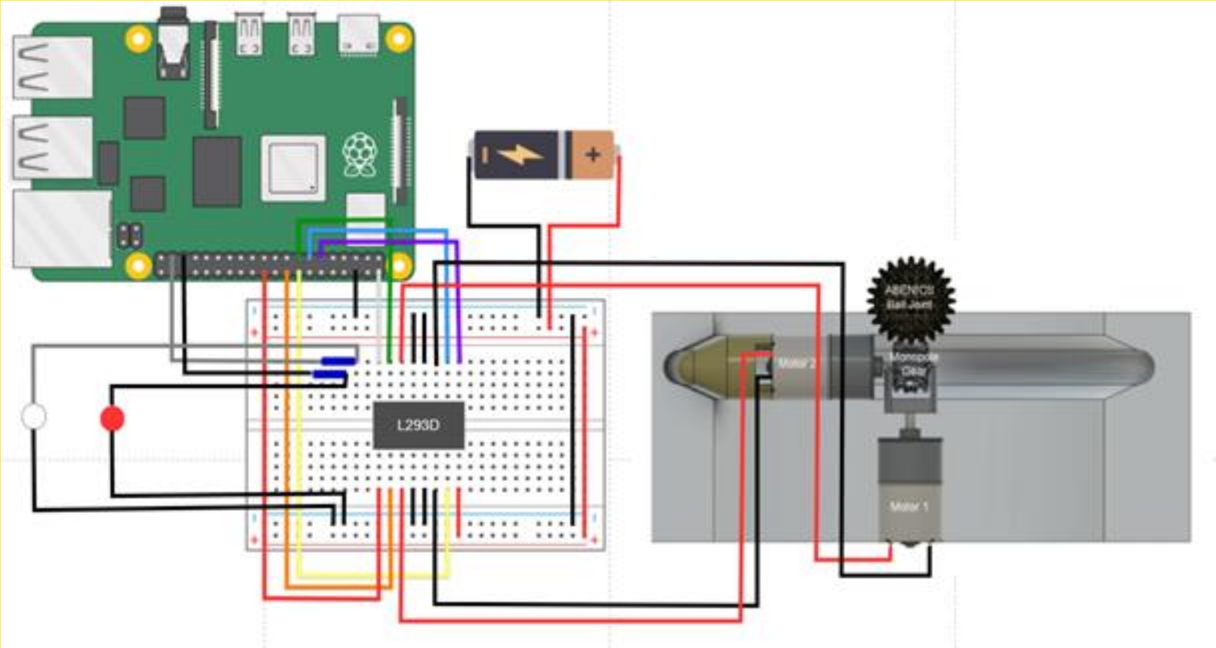
```
first_instruction = eye_tracking.instruction_sequence[0]

match first_instruction:
    case Direction.CCW:
        motor.moveMotor1(True)
    case Direction.CW:
        motor.moveMotor1(False)
    case Direction.LEFT:
        motor.moveMotor2(False)
    case Direction.RIGHT:
        motor.moveMotor2(True)
```

- Adjust the specified motor based on the instruction in order
- Once instruction sequence is empty, adjustment is complete

Hardware Components

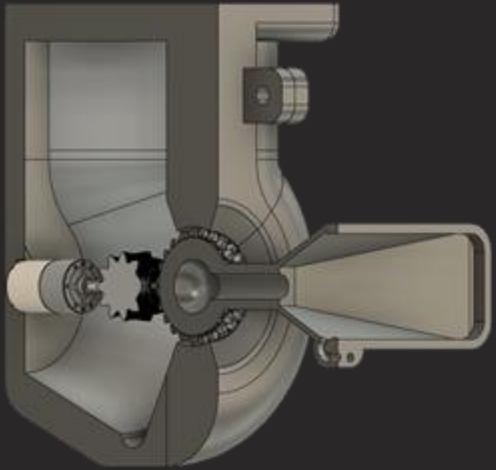
- Raspberry Pi Model 4 Microcontroller
- DC Motor Set - Micro Gear Motor 6V Mini Gearbox
- Directional Pad
- 3D Printer Filament
- Rear-view mirror
- Motor Driver L293D
- Battery 9V
- Camera C950
- Pack of Pilot Lights
- Breadboard
- Wires

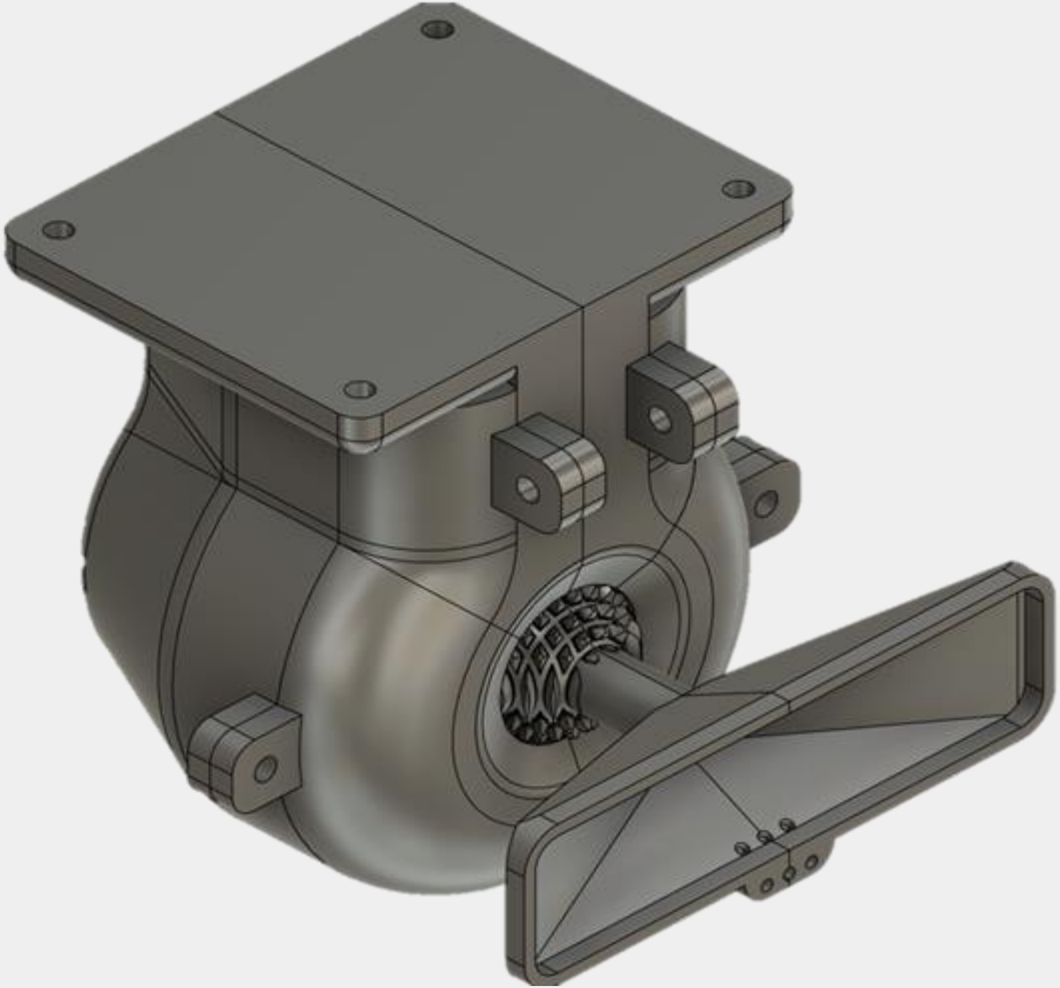
Embedded Systems



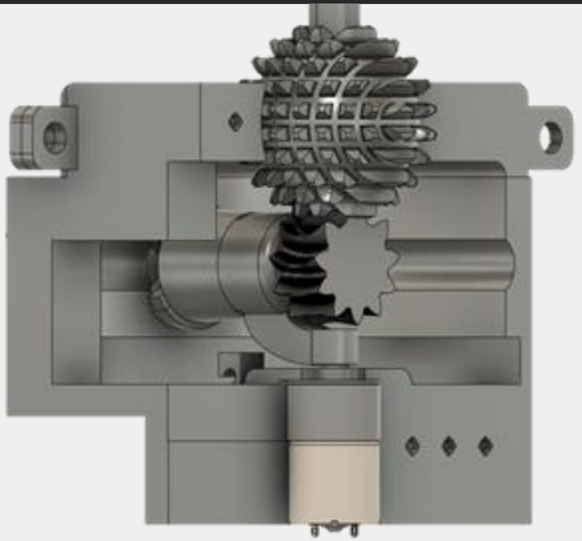
Prototype Designs

Concept Design





Motor Testing Design



Designed to test the motor rotation within the housing unit, with an open space left to observe the motor's movement while interacting with the housing.

1

Issue

3D Printed ABENICS Ball Joint was too loose within its housing

2

Issue

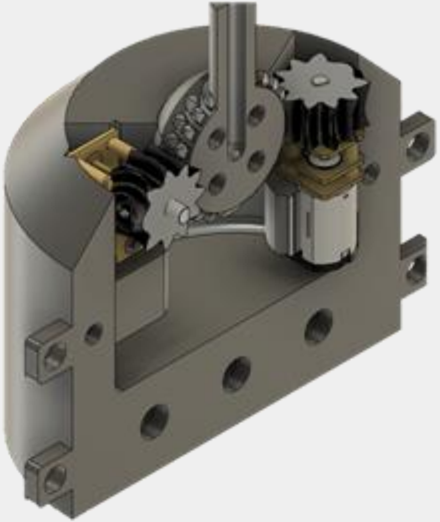
Difficult for Monopole gear to make contact with Ball Joint

3

Issue

Design is massive and inconvenient

Stationary Motors Design



Designed to eliminate errors caused by the motors movement within the housing unit.

1

Issue

Monopole gear was not able to move along with the ball joint

2

Issue

Ball joint teeth would get stuck against housing unit

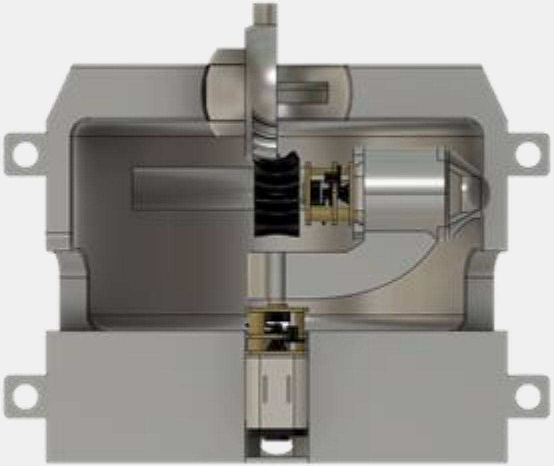
3

Issue

Unpredictable ball joint movement

Working Prototype

Created using the concept design along with an updated ABENICS ball joint, specifically engineered to eliminate the pitch axis, which was identified as the most unstable.

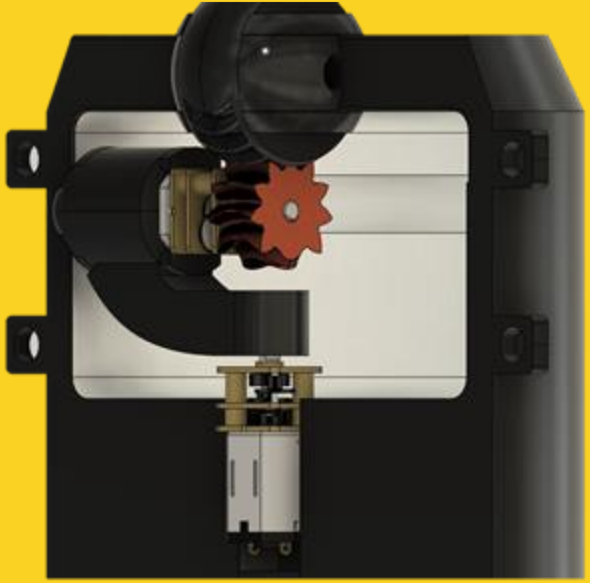


1. **Issue**
   A wiring issue caused wires to snag

2. **Issue**
   Monopole gear jams if not properly positioned

3. **Issue**
   The design does not include the housing for the Raspberry Pi

Embedded Systems Working Prototype



Final Prototype Design

Testing Deliverable 1 Results

Step #	Procedure	Check List	Tester's Results	Pass/Fail	Signature Data/Time	Notes
1	Open the command prompt terminal application in the window's start menu. Type in the following command in the terminal to start the Python Code: **python3 Desktop/Senior-Project/TestEyeTracking.py**	Does a 800 x 600 pixels window frame display on the monitor?	Yes	Pass	[illegible]	N/A
	Press enter to run the command to activate and open the eye tracking and webcam footage frame/window.	Is the tester's face visible in the webcam window?	Yes	Pass	[illegible]	N/A
2	Examine the features within the frame for the webcam footage. Are the texts visible in the frame?	Green "FPS" text is displayed at the top left of the webcam footage window, can the tester see it?	Yes	Pass	[illegible]	N/A
		Red "EYE POSITION" text is displayed at the top left of the webcam footage window, can the tester see it?	Yes	Pass	[illegible]	N/A
		Blue "MOVE BY" text is displayed at the top left of the webcam footage window, can the tester see it?	Yes	Pass	[illegible]	N/A
		Green directional text indicators are displayed as (**Left / Right, Up / Down**), they will each be displayed on the top left of the webcam footage window below the blue "MOVE BY" text, can the tester see it?	Yes	Pass	[illegible]	Green Text Should Also Say Move to [illegible] User
		Two **GREEN** dots will appear hovering over the tester's eyes within the webcam footage window, can the tester see the displayed **GREEN** dots?	Yes	Pass	[illegible]	N/A
		Another pair of **RED** dots will appear hovering within the webcam footage window near the center of the frame, can the tester see the displayed **RED** dots?	Yes	Pass	[illegible]	N/A

Testing Deliverable 1 Results Cont.

		Four additional colored dots (WHITE, BLACK, PINK, and YELLOW) will appear hovering within the webcam footage window (UP/TOP, BOTTOM, LEFT, and RIGHT) respectively. Can the tester see the displayed dots?	Yes	Pass	[illegible]	white & black dots should be switched
3	The tester will move themselves over to the left and shift their face to the left until the tip of their nose reaches the PINK dot located at the left edge of the frame.	The GREEN dots will follow the tester's eyes as they move to the left edge of the webcam footage frame and position their nose at the PINK dot, are the GREEN dots following the tester's eyes?	Yes	Pass	[illegible]	N/A
		GREEN "RIGHT" text will be displayed on the screen at the top left once the tester has moved their nose onto the PINK dot, can the tester see the displayed text?	Yes	Pass	[illegible]	N/A

4	The tester will move over to the right and shift their face to the right until the tip of their nose reaches the YELLOW dot located at the right edge of the frame.	The GREEN dots will follow the tester's eyes as they move to the right edge of the webcam footage frame and position their nose at the YELLOW dot, are the GREEN dots following the tester's eyes?	Yes	Pass	[illegible]	N/A
		GREEN "LEFT" text will be displayed on the screen at the top left once the tester's nose has moved their nose onto the YELLOW dot, is the text being displayed?	Yes	Pass	[illegible]	N/A
5	The tester will move and be positioned in the middle of the frame, they'll slowly stand up to the point where their face reaches the top edge of the frame and position the tip of their nose on the WHITE dot. (Stepping closer is acceptable depending on the angle the webcam is pointed).	The GREEN dots will follow the tester's eyes as they move to the top edge of the webcam footage frame and position their nose at the WHITE dot, are the GREEN dots following the tester's eyes?	Yes	Pass	[illegible]	N/A

Testing Deliverable 1 Results Cont.

		GREEN "DOWN" text will be displayed on the screen at the top left once the tester has moved their nose onto the **WHITE** dot, is the text being displayed?	Yes	Pass	[illegible]	N/A
6	The tester will be positioned in the middle of the frame, they'll slowly kneel down to the point where their face reaches the bottom edge of the frame, and position the tip of their nose on the **BLACK** dot. (Stepping away is acceptable depending on the angle the webcam is pointed).	The **GREEN** dots will follow the tester's eyes as they move to the bottom edge of the webcam footage frame and position their nose at the **BLACK** dot, are the **GREEN** dots following the tester's eyes?	Yes	Pass	[illegible]	N/A
		GREEN "UP" text will be displayed on the screen at the top left once the tester has moved their nose onto the **BLACK** dot, is the text being displayed?	Yes	Pass	[illegible]	N/A

7	The tester will move themselves over until their face is positioned in the center of the webcam footage frame and aim to overlap the **RED** pair of dots and **GREEN** pair of dots.	Green text shown as "**GOOD**," will be displayed in the webcam footage frame. Is the green **GOOD** text displayed?	Yes	Pass	[illegible]	Green Pair should be a little farther apart
8	This is to test low light conditions and how the camera will examine it. The tester will cover the webcam camera with their hand so that the webcam footage within the frame is displaying completely darkened out footage.	Red text shown as "**ROOM TOO DARK**," will be displayed within the webcam footage frame. Is the red **ROOM TOO DARK** text displayed?	Yes	Pass	[illegible]	N/A
9	The tester will remove their hand away from the webcam camera so that their face within the webcam footage is visible again.	Red text "**ROOM TOO DARK**," should no longer be displayed within the webcam footage frame. Did the red **ROOM TOO DARK** text disappear?	Yes	Pass	[illegible]	N/A

Testing Deliverable 2 Results.

Step #	Procedure	Anticipated Result	Tester's Results	Pass/ Fail	Signature Data/Time
1	Measure the voltage on the first motor with a multimeter, set the multimeter to the DC voltage option. First, connect the red probe to the positive terminal and the black probe to the negative terminal of motor 1, then read the voltage on the multimeter display and fill up your results in the column "Tester's Results".	Between 5V and 9V	6.7V	pass	Thomas Mobley 11/25/24
2	Measure the voltage on the second motor, connect the red probe to the positive terminal and the black probe to the negative terminal of motor 2, then read the voltage on the multimeter display and fill up your results in the column "Tester's Results". Finally, turn off the multimeter after completing the measurements.	Between 5V and 9V	6.6V	pass	Thomas Mobley 11/25/24
3	Using the D-pad use the up and down buttons to control the Ball Joints pitch. Press the up button for two seconds. Then, press the down button for two seconds. Do not go beyond the boundary of the housing unit or there is risk of damaging the motors.	Ball Joint rotates on its pitch axis. Up button and down button moves the Ball Joint on its pitch axis.	buttons & motors worked	pass	Thomas Mobley 11/25/24
4	Using the D-pad use the left and right buttons to control the Ball Joints roll. Press the left button for two seconds. Then, press the right button for two seconds. Do not go beyond 90 degrees of turn radius or there is risk of damaging the motors.	Ball Joint rotates on its roll axis. Left button and Right button moves the Ball Joint on its roll axis.	buttons & motors worked	pass	Thomas Mobley 11/25/24

Testing Deliverable 3 Results.

Step #	Procedure	Anticipated Result	Tester's Results	Pass/Fail	Signature Data/Time
1	In the laptop's remote shell, type the following command: **python3 Desktop/Senior-Project/TestLight.py** Then press enter to test the light functionality.	Is the following text displayed on the shell?: **Testing Light!**	Yes	✓	11/25
2	On the controller, press and hold the **RED A** button for 2 seconds.	The **WHITE LED** light turns on, does the LED illuminate?	Yes	✓	11/25
3	Release the **RED A** button.	The **WHITE LED** light turns off, does the LED no longer illuminate?	Yes	✓	11/25
4	On the controller, press and hold the **RED B** button for 2 seconds.	The **RED LED** light turns on, does the LED illuminate?	Yes	✓	11/25
5	Release the **RED B** button.	The **RED LED** light turns off, does the LED no longer illuminate?	Yes	✓	11/25

6	On the laptop, press the following buttons on the keyboard: **Ctrl + C** This will end the process and go back to default state.	The shell displays the following, is it displayed on the shell: casey@raspberrypi:~ $	Keybord Interrupt	✓	11/25
7	In the laptop's remote shell, type the following command: **python3 Desktop/Senior-Project/TestSequence.py** Then press enter to test and thus activating the automation functionality.	Is the following text displayed on the shell?: **Starting Sequence!**	Yes	✓	11/25
		The motor moves without controller input, has the joint begun moving automatically?	Yes, but end has exception error	✓	11/25

Electrical Specifications

- **Power Supply**:
  - 9V Battery.
  - 9V Power Supply.
  - 3.3V and 5V from Raspberry Pi 4 GPIO.
- **Camera**: 3.3V, 1080P @ 30 FPS.
- **Motor Driver**: 4.5V - 36V @ 1.2A - 600mA.
- **DC Motors**: 6V, 10W, @ 10 RPM.
- **Controller**: 3.3V, USB Connected.
- **Microcontroller**: 15W (@ 5V and ~3A), 64-bit processor, 4GB RAM, Gigabit Ethernet, and USB 3.0.
- **LEDs**: 3mm, 3V @ 25mA.

Physical Specifications

- **Ball joint:** Provides axial movement .
- **Raspberry Pi:** Controls and processes data through the use of a camera module utilizing eye tracking software.
- **Directional pad:** Manual adjustment.
- **Camera:** Detects the driver's face and eyes to send input to microcontroller.
- **LED indicator:**
  - Enables the camera to clearly capture the driver's face.
  - Alert the driver during adjustment.
- **Motor and motor driver:**
  - Controls the monopole gear and the ABENICS ball joint.
  - Interface with the microcontroller to control and manage motor speed or direction.

Costs Towards Prototype

Component	Part Number	Description	Quantity	Cost Per Unit	Total Cost
Raspberry Pi	4 model B	Pi 4 4GB Board Only	1	$55.00	$55.00
Controller (D-pad)	Joystick Raspberry Pi	2 Pack USB Wired Controller	2	$7.99	$14.99
3D Printer Filament	N/A	3D Printed ABENICS Ball Joint, Monopole Gear, Motor Housing, and Housing Unit	17 hours	$1.00 per hour	$17.00
Rear-view mirror	BT-4MG9-2IM9	Kitbest Rear View Mirror, Universal 11.4 Inch Interior Clip On Panoramic	2	$9.99	$19.98
Motor Driver	L293D	L293D Stepper Push-Pull Motor Driver Controllers	1	$8.99	$8.99
Battery	9V Energizer max	2 count MAX premium alkaline 9 volt.	2	$3.49	$6.99

Costs Towards Prototype Cont.

Component	Part Number	Description	Quantity	Cost Per Unit	Total Cost
Camera	C950	USB Webcam with Microphone & Physical Privacy Cover	1	$19.99	$19.99
Pack of Pilot Lights	3mm LED Lights	250pcs (5 Colors x 50pcs) 3mm LED Light Emitting Diode Lamp	1	$4.99	$4.99
Breadboard	7545924028	Breadboard Set Prototype Board - 6 PCS 400 Pin Solderless Board Kit	1 pack of 3	$7.99	$7.99
Wires	EL-CP-004	ELEGOO 120pcs Multicolored Dupont Wire Breadboard Jumper Ribbon Cables Kit	1	$6.98	$6.98
DC Motor Set	a16010600ux0130	Micro Gear Motor 10RPM DC 6V Mini Speed Reducer Gear Box	2	$9.99	$19.98
TOTAL COST					$182.88

Mass Production

BEFORE

Embedded Systems
Raspberry Pi
BCM2711 - $25
4GB RAM - $20
Ports
4 USB - $4
2 HDMI - $5
Ethernet - $2
Power Supply - $5
Motor Driver
- $1
Breadboard
- $1
Mirror

AFTER

Dedicated Circuit Board
Alternative Chip
Ex) S905X3 - $10
4GB Ram
- $20
Ports
2 USB
- $2
Imbedded Motor Driver
- $0
Imbedded Breadboard
- $0
Mirror
- $5
Housing
- $3
Components
Monopole Gear
- $0.50
ABENICS Ball Joint

Challenges Encountered

3D Printing/Design Errors

- Motor Cap snapped at the stress lines.
- Ball Joints came out deformed.
- Difficulty assembling Housing Unit.
- 3D printed parts interface failed.
- Inefficient printing time.

Raspberry Pi Camera Module Not Pairing

- Camera Module failed to connect.

Solutions

- Change physical measurements.
- Reprint housing units using a different printing filament.
- Use an advanced 3D printer.
- Use a different camera reference.

Challenges Encountered Cont.

Raspberry Pi Short Circuit

- Excessive current caused a short circuit
- Due to the use of a high battery voltage source, the microcontroller was left damaged.

Revised Housing Design

- Motor 1 area was too deep to allow screws to be inserted.
- Hinge of motor 2 housing broke under pressure as motor 1 began rotating.
- Unstable moving 3D printed parts.

Solutions

- Use 9V battery to power L293D motor driver.
- Use 9V battery to power the microcontroller.
- Use the Raspberry Pi GPIO power to supply components.
- Redesign housing unit.
  - Divots to account for close space within housing unit to fit components inside.
  - Extra holes and hooks to wiring from becoming jammed when DC motors activate.

Starting Over

Time Management

- Reassessing priorities and timelines to optimize productivity.
- A firm schedule ensures better allocation of time for critical tasks and reduces delays.

Design Implementation

- Rebuilding the foundation with improved concepts and strategies.
- Revisiting the design process allows for addressing past issues, enhancing functionality, and ensuring a seamless outcome

Outreach

- Engaging industry professionals and companies for guidance and resources.
- Leverage external expertise to strengthen the project's development.

Product Enhancements

Servo Motor

Using alternatives like servo motors as they are more precise.

Housing Unit

Redesign the housing to align with modern vehicle interiors.

Expanded Motion

Add a third motor for full north hemispherical rotation.

Improved Ventilation

Add ventilation to manage motor heat and ensure durability.

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- ❑ Helped us find resources from the library.

Questions?

Demonstration Time!

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Thank You!