SDP 25

Team #15
Knolling Bot

Meet the Team

Aryaman Ghura
CompE & CS

Software

Ishaan Salian
CompE

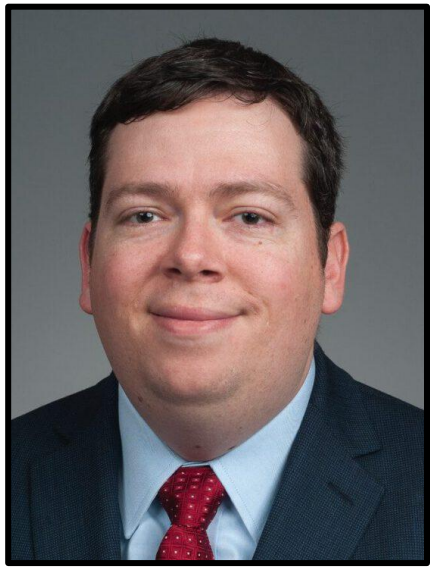
Motors & PCB
Logistics

Mary Esenther
CompE

Power Delivery

Kavya Manchanda
CompE

Processor & Camera
Budget



Professor Marco Duarte

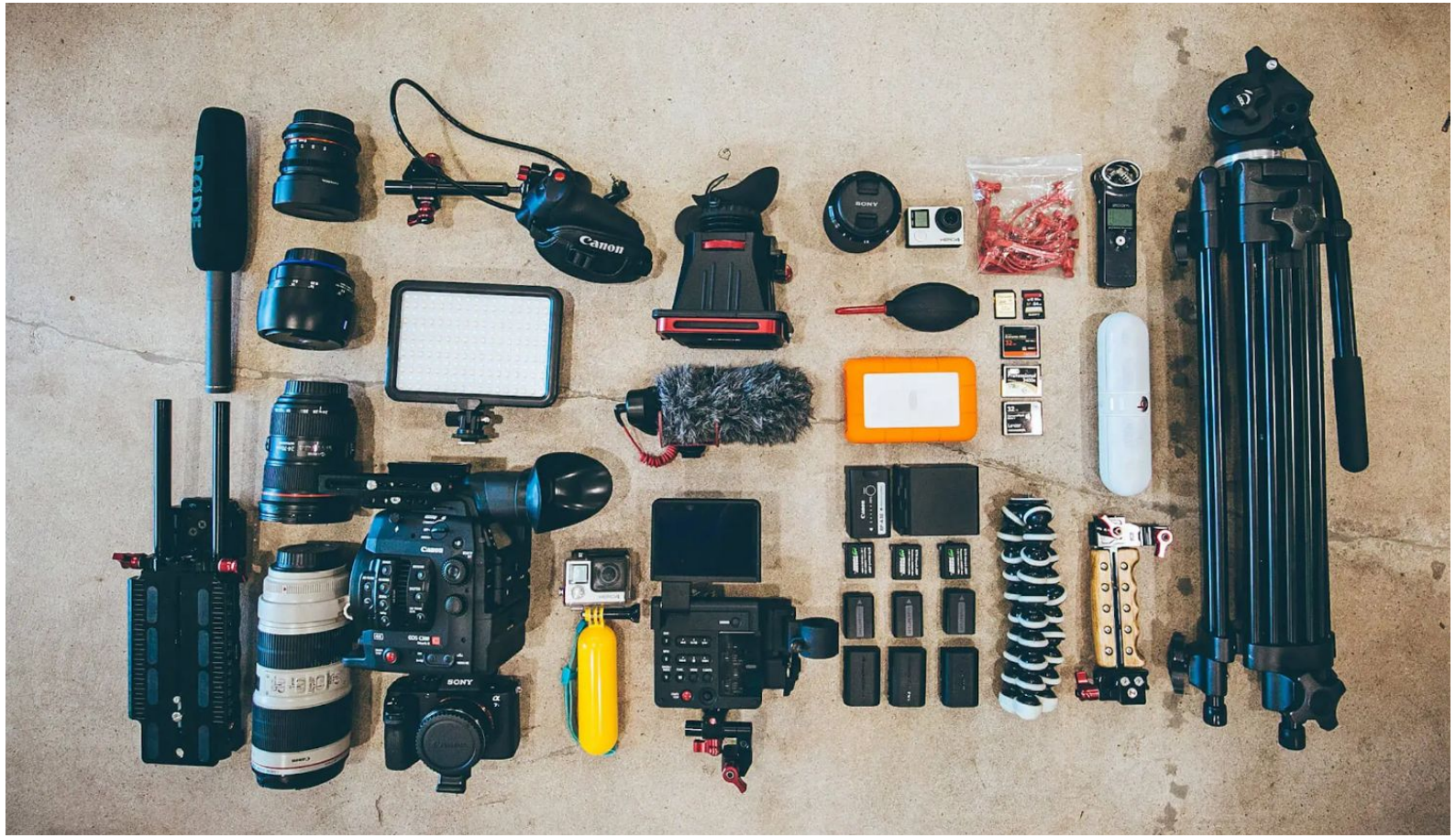
Advisor

Problem Statement

- A cluttered desk can negatively affect productivity and mental health.
- Studies show that messy workspaces increase stress. [1]
- 57% of Americans associate messy desks with laziness. [2]

[1] "The Psychological Consequences of Clutter," Psychology Today, 2021.
[2] L. Alton, "The Negative Relationship Between a Messy Desk and Productivity," Inc.com, Feb. 16, 2017.

Background: Knolling



Project Goal

To create a distributed system that can organize your workspace autonomously by employing object detection, path finding and self charging.

Similar Solution: Vector Robot

Pros:

- Small and capable of moving objects
- Built-in camera
- Capable of self-charging

Cons:

- Cloud Computation
- Limited Applications

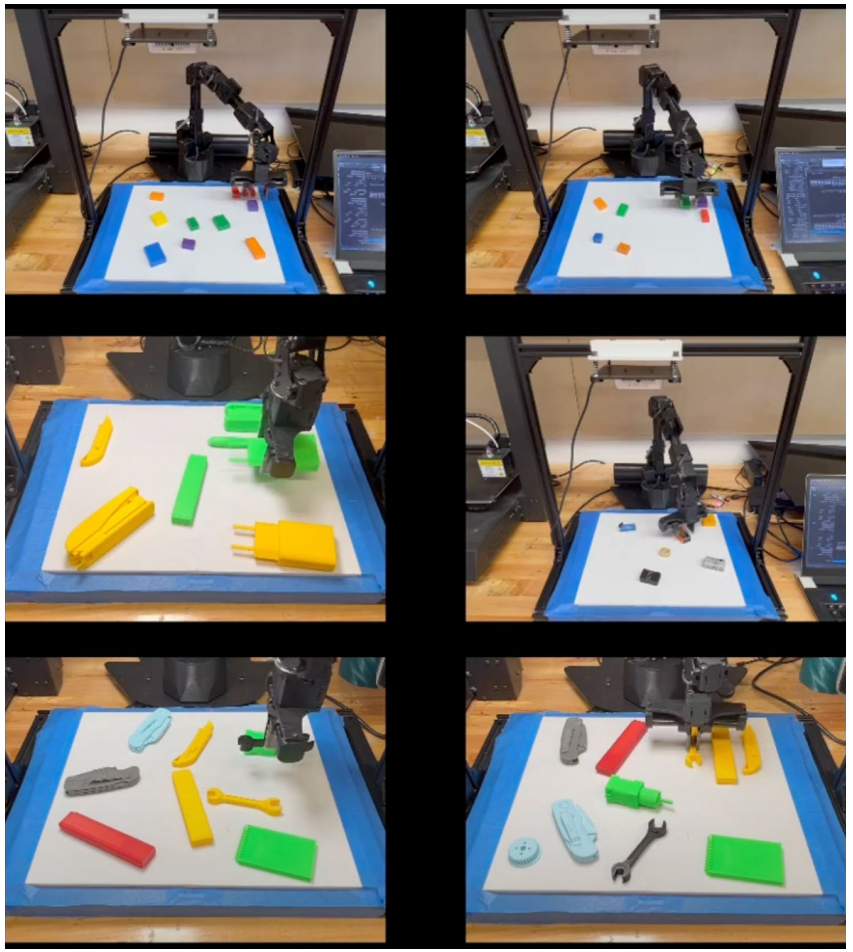
Similar Solution: Knolling Bot

Pros:

- End-to-end pipeline on the device
- Self-supervised cleaning with training data

Cons:

- Limited reachability



Y. Hu, Z. Zhang, X. Zhu, R. Liu, Philippe Martin Wyder, and H. Lipson, “Knolling bot: Learning robotic object arrangement from tidy demonstrations,” 2023.

Partial Solution: Roomba i5+ Robot Vacuum

Pros:

- Advanced navigation algorithms
- Automatically returns to charging dock
- Avoids obstacles

Cons:

- No object or image recognition
- Not ideal size for desk application

Summary of Similar Solutions

	Object Organisation	Mobility	Size	Offline Functionality	Price
Anki Vector					
Knolling Bot					
Roomba					
Our Solution					

Our Solution

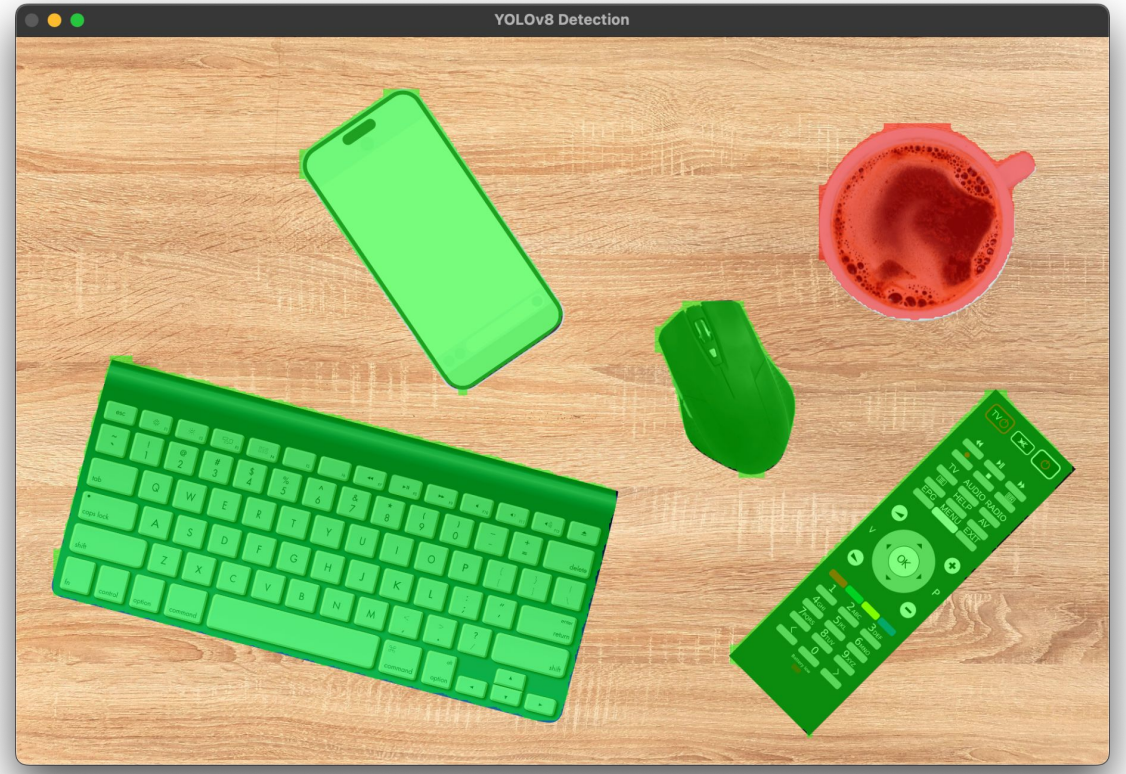
- Practical use cases
- Fully offline functionality
- Fully autonomous battery management system.
- Compact size for desktop application, without compromising on torque.

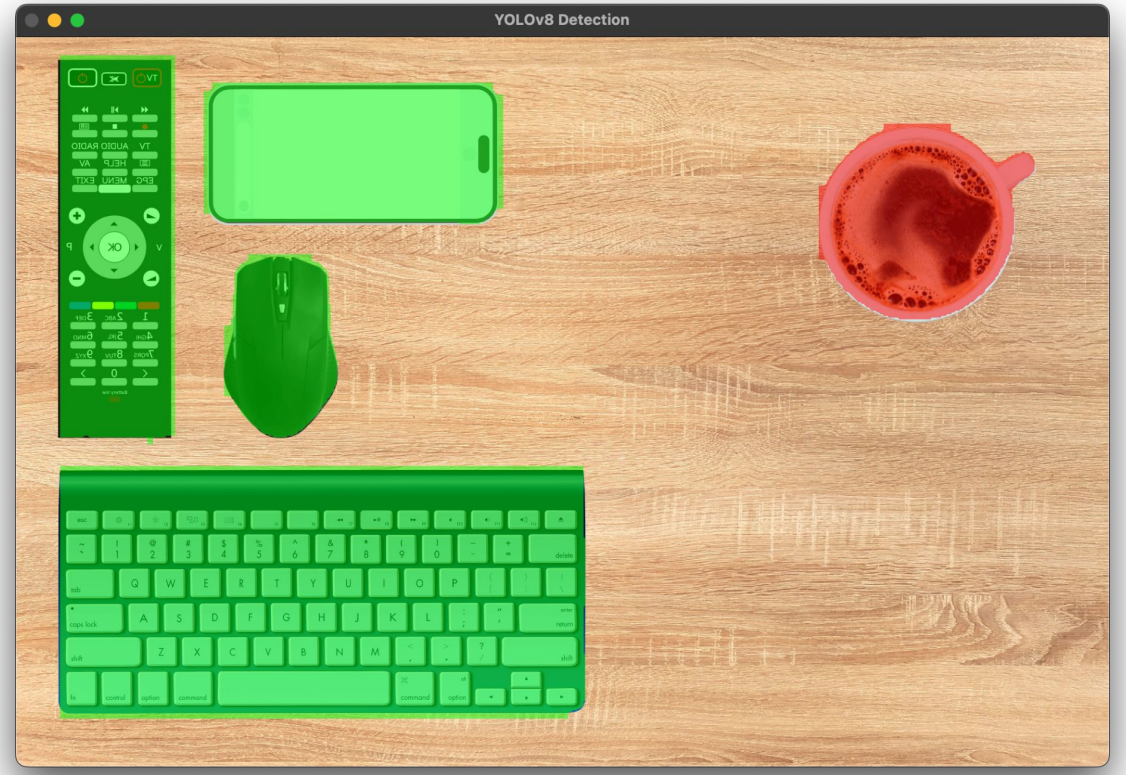
Classification of Objects

BAD

GOOD

Classification of Objects





*Object detection model mentioned later

Preliminary Design Specifications

Overhead Computer

- Detect human absence with 98% accuracy to start knolling.
- Map and find viable paths for object placement.
- Align objects at ~90° angles with a variance of ±5°.
- Identify objects to avoid, like liquids or monitors, with 98% accuracy.
- Recognize table boundaries to prevent overshooting.

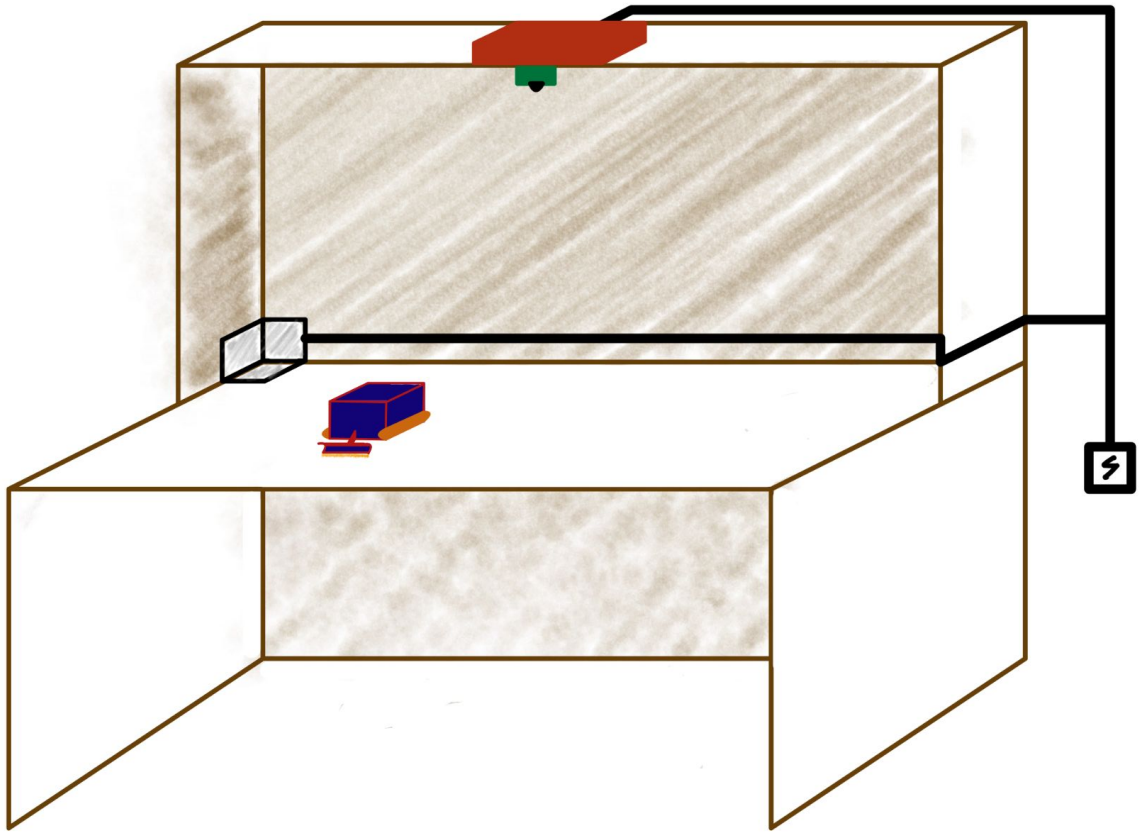
Robot

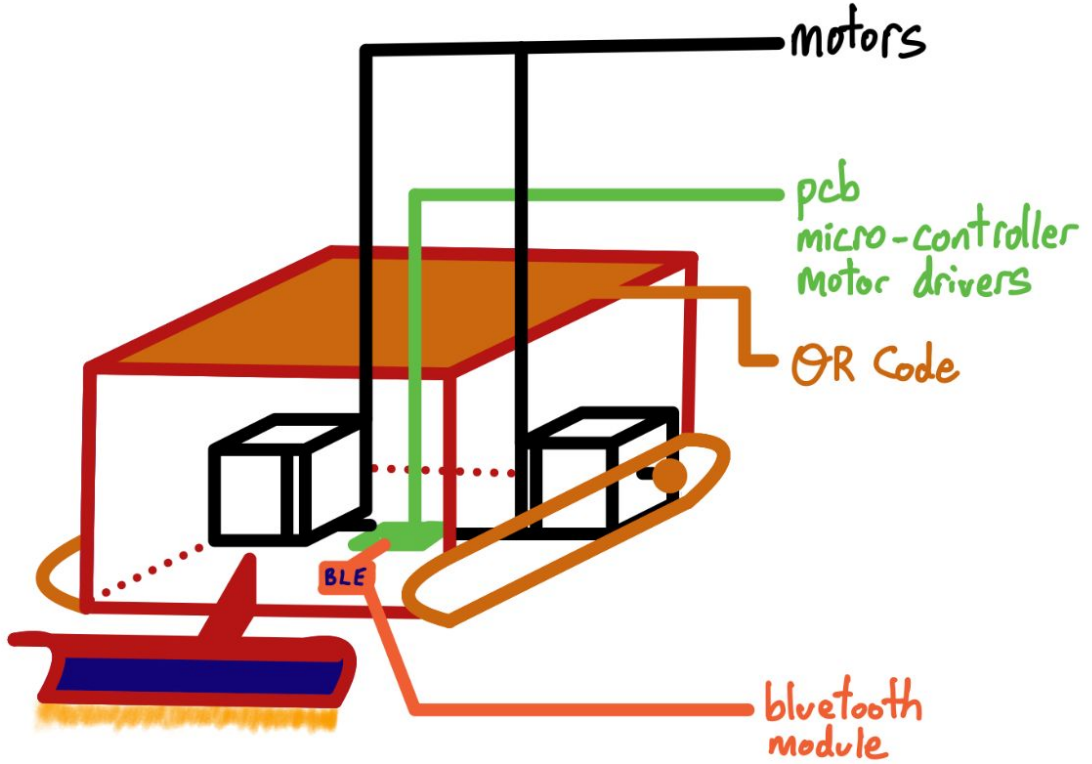
- Run for 30±5 minutes on one full charge.
- Knoll objects up to 4.5lbs, like a MacBook.
- Knoll upto 10 objects.

Testing Plan based on Preliminary Design Specifications

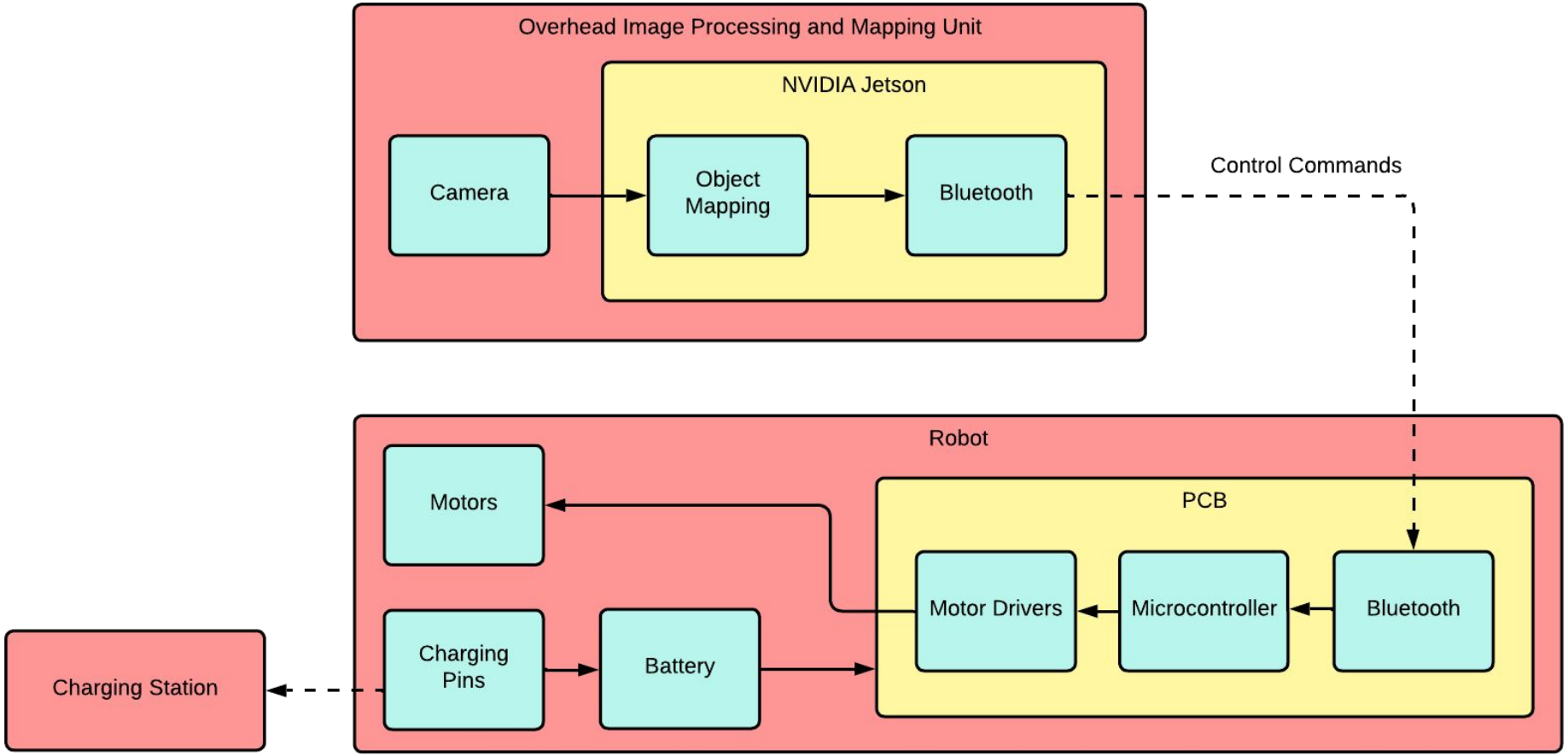
Design Specification	Testing Plans
Detect human absence	Robot movement starts only after 2 minutes of human absence in at least 98 out of 100 trials (reduced from 20 minutes for demo purposes)
Map viable paths for object placement	The robot should successfully navigate around obstacles to find viable paths without getting stuck, if there exists one.
Align objects at ~90±5° angles	Measure the angle of the knolled objects using edge of the table as a guide
Identify objects to avoid	System should identify various forms objects (open cup, bottle, user-defined objects) with correct classifications in at least 98 out of 100 trials
Recognize table boundaries	No objects, nor the robot, should exceed the table boundaries
Run for 30±5 minutes on one full charge	Prevent robot from reaching charging station until 25 minutes. Robot must still have enough charge to dock itself onto the charging dock.
Move objects up to 4.5lbs, like a MacBook	The robot should successfully push objects weighing up to 4.5lbs
Knoll upto 10 (varying) objects	The robot should knoll all 10 objects accurately in at least 95% of trials, ensuring no objects are missed or improperly aligned

Mechanical Diagram





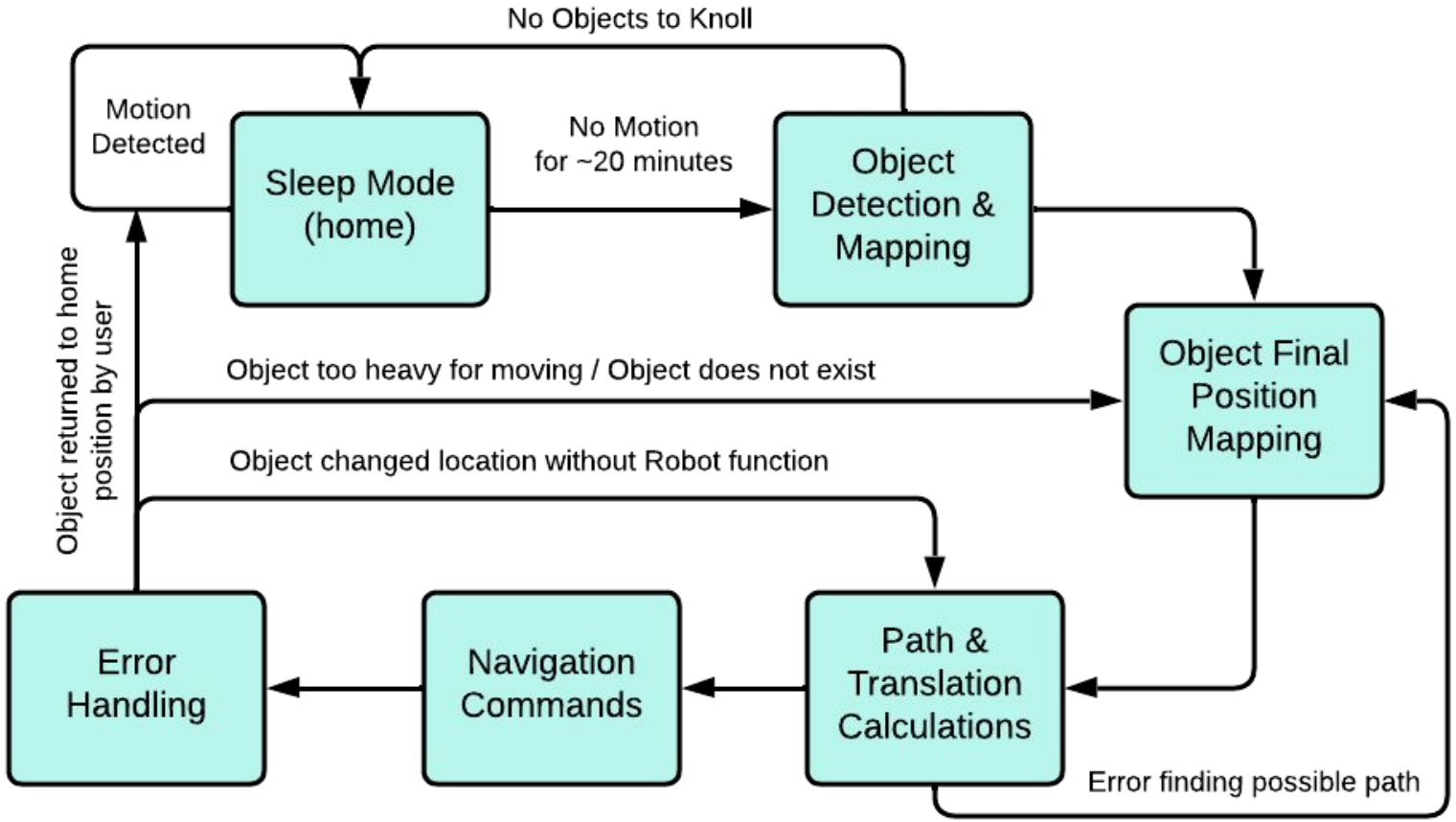
General Block Diagram



Overhead Computer:
NVIDIA Jetson Nano (Computer)
JETSON CAMERA (Webcam)
Edimax N150 (BLE)

Robot:
ATmega328/P (MCU),
HC-05 (BLE)
TMC2209 (Drivers)
Stepper Motors
22V Li-Po Batteries

Software Diagram



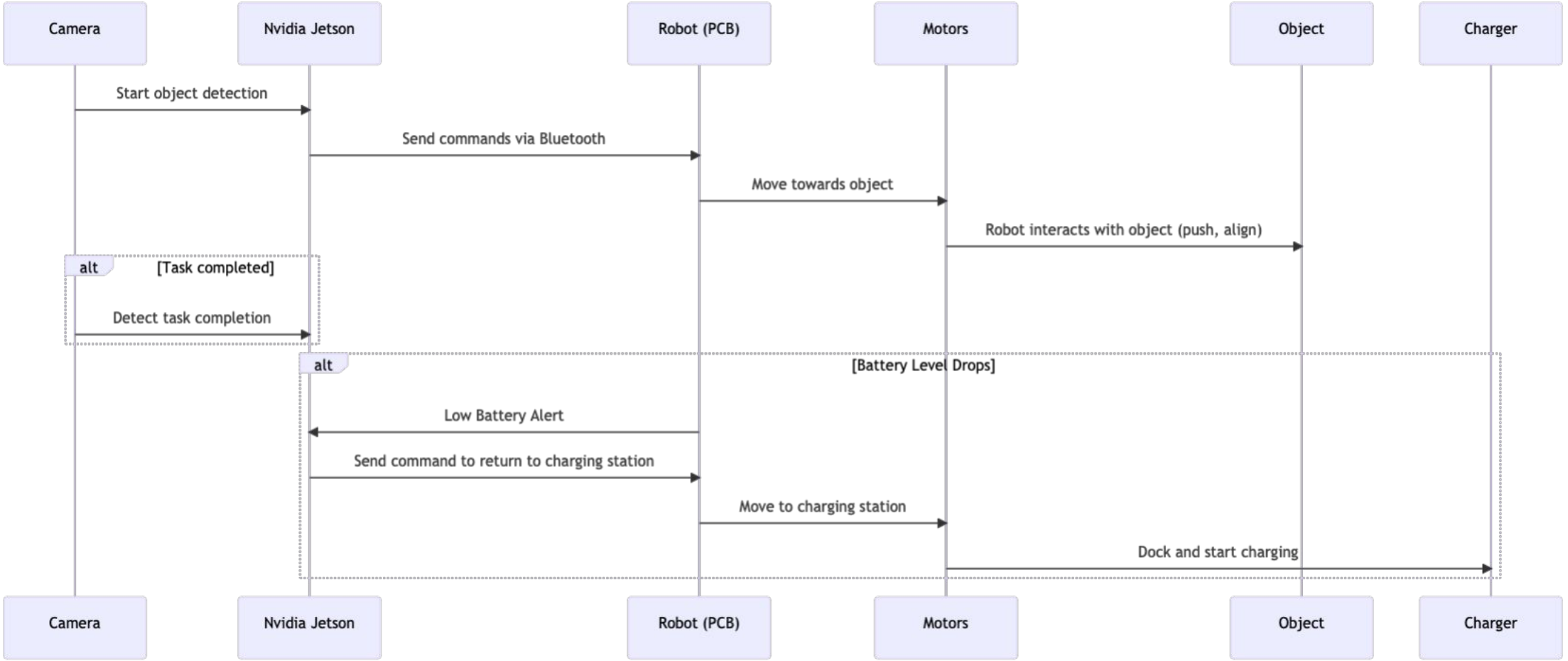
OpenCV:
Image processing and object detection.

PCL (Point Cloud Library):
2D mapping and object pose estimation.

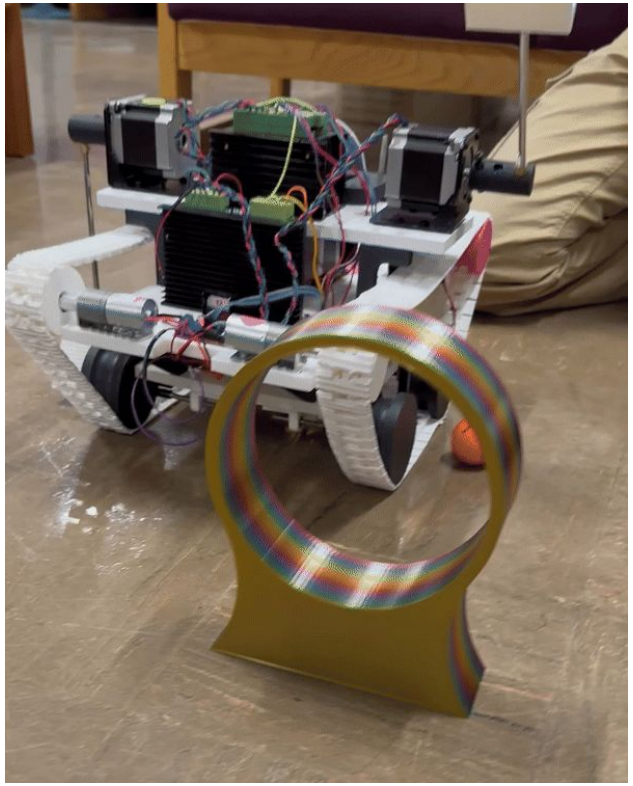
ROS (Robot OS) (Hold):
Tools for robot control, motion planning, and sensor integration.

PyTorch/TensorFlow (Hold):
For building and training custom object detection models.

Process Diagram



Relevant Experience



MDR Deliverables

Overhead Computer + Software

- Camera and Jetson successfully working with software executing on inputs from camera.
- Ability to detect human presence and if current environment is knolled according to specifications.
- Ability to detect a randomly placed computer monitor, coffee mug, and phone on the desk and differentiate between the objects requiring knolling and those to be avoided.
- Ability to map each “knoll-able” object to a final “knolled” location virtually.
- Ability to find viable path for robot to propel object from initial position to its final “knolled” location using the A* algorithm (desk will be divided into a grid for robot to find path).
  - A* guarantees to find the shortest path in a graph if one exists.
  - We will apply a high “cost” to paths that have objects to avoid.

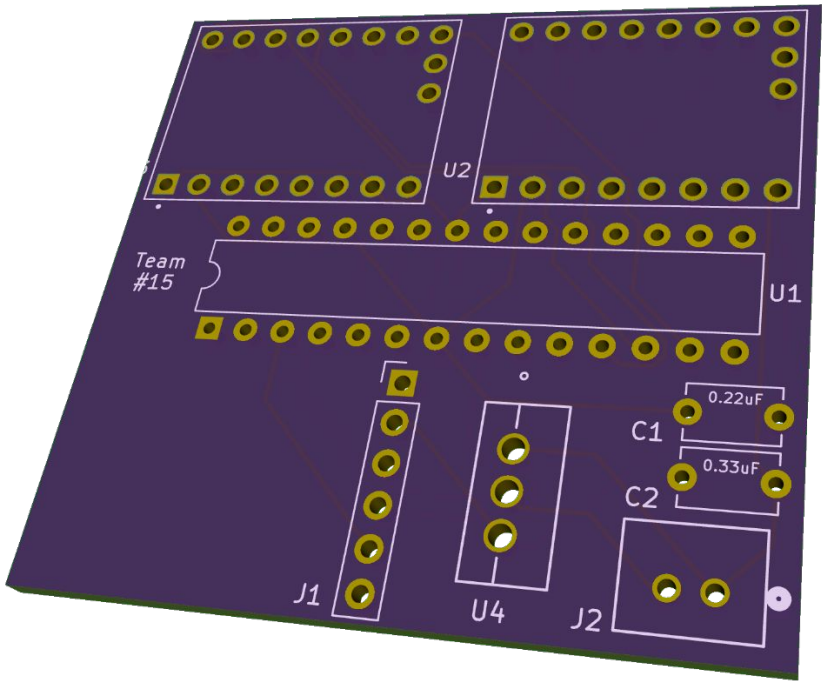
Robot

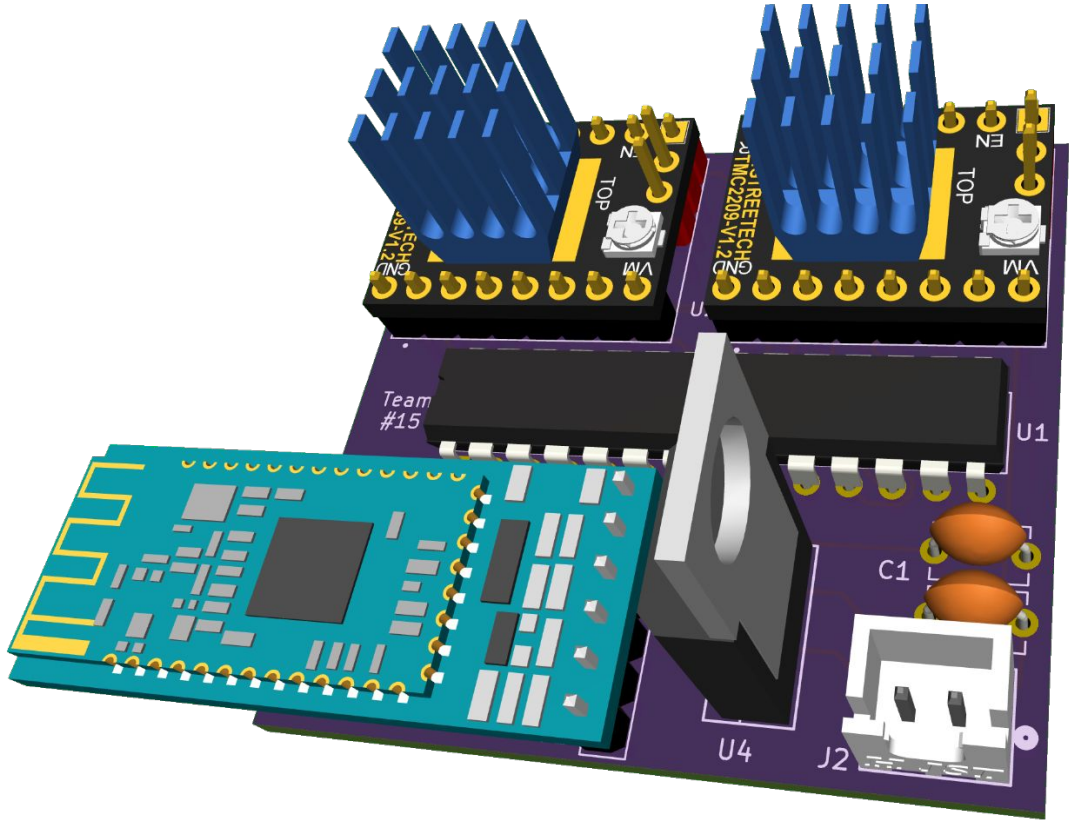
- Robot is capable of traversing the table using Serial commands from computer.
- First iteration of the robot body is ready.

Power Delivery

- Finalize charging mechanism.
- Successfully charge a 5V LiPo using the finalized charging mechanism.

PCB Plan


U2
Team
#15
U1
0.22uF
C1
0.33uF
C2
J1
U4
J2


TOP
VM
EN
TOP
VM
EN
Team
#15
U1
C1
U4
J2

Project Expenditures

Item	Quantity	Cost	Reason	
HC-05	1	$7.00	Bluetooth Module	
ATmega328p	2	$5.26	Microcontroller	
TMC2209	2	$9.80	Driver for Motors	
Stepper motors	2	$55.50	Robot movement	* Various Parts
ESP32	2	$30.00	Alternate Microcontroller	** SDP Lab
Lipo Battery	1	$32.99	On-Robot Battery	
PCB print	1	$5.03	Robot PCB	
PCB shipping	1	$21.24	PCB Shipping Cost	
NVIDIA Jetson Nano	1	**	Overhead Computer	Legend:
Jetson Camera module	1	$23.12	Camera for CV	ROBOT
	Total	**$189.94**		HARDWARE
	Remaining	**$310.06**		MISC.

PHASE	TASK	TASK OWNER	PROGRESS	WEEK 6 10/06 - 10/12	WEEK 7 10/13 - 10/19	WEEK 8 10/20 - 10/26	WEEK 9 10/27 - 11/2	WEEK 10 11/3 - 11/9	WEEK 11 11/10 - 11/16	WEEK 12 11/17 - 11/23	WEEK 13 11/24 - 11/30	WEEK 14 (MDR) 12/1 - 12/7
				M T W Th F	M T W Th F	M T W Th F	M T W Th F	M T W Th F	M T W Th F	M T W Th F	M T W Th F	M T W Th F
1	**Robot**											
1.1	PCB Component Selection	IS	50%		PDR							
1.2	Initial Motor Drive Testing	IS	0%		PDR							
1.3	PCB Schematic Design	IS	0%		PDR							
1.4	Motor Driver Protoype	IS	0%		PDR							
1.5	PCB Schematic Revision	IS	0%		PDR							
1.6	BLE Communication Verification	IS	0%		PDR							
2	**Power**											
2.1	Set Power Requirements	ME	0%		PDR							
2.2	Research Power Delivery Methods	ME	0%		PDR							
2.3	Add Power to PCB	ME + IS	0%		PDR							
3	**Overhead Hardware + 3D Modelling**											
3.1	Hardware Enclosure - Camera and Jetson	KM	0%		PDR							
3.2	Motor Mount & Placement Design	KM	0%		PDR							
3.3	BLE Communication Jetson	KM + IS	0%		PDR							
4	**Overhead Processing**											
4.1	Set up NVIDIA Jetson with camera and BLE	KM	0%		PDR							
4.2	Object Detection and Mapping	AG + IS	75%		PDR							
4.3	Object Final Position Mapping	AG	0%		PDR							
4.4	Path and Translation Calculations	AG	0%		PDR							
4.5	Coversion to Nagivation Commands	AG	0%		PDR							
4.6	Error Handling and Progress Tracking	AG	0%		PDR							

https://docs.google.com/spreadsheets/d/13YVHZK6UHJRp5mrNjDS3swXoNIhkR-2ZMn9xTu6tttw/edit?usp=sharing

Questions?