Group 6

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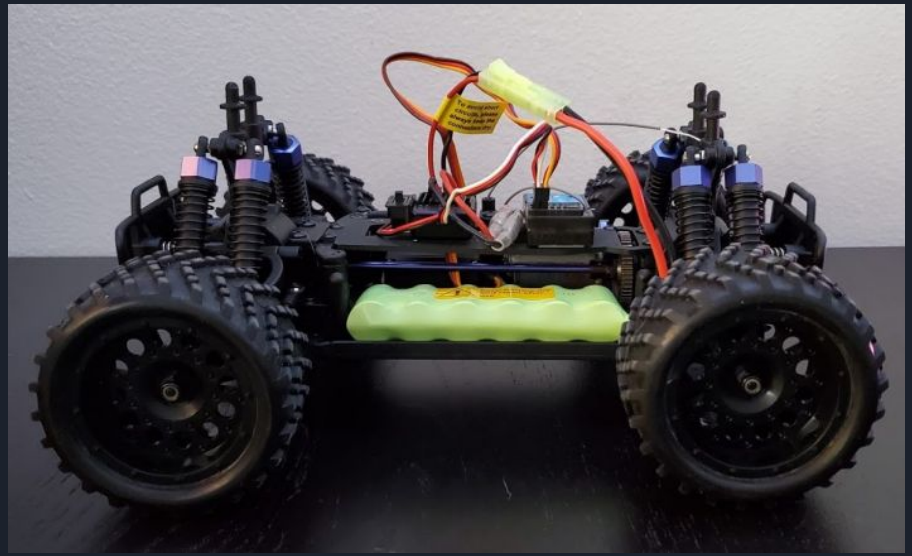
Project Overview

For our project, we are building a robot that autonomously navigates an empty indoor building and calls a human emergency contact if an intruder is detected.

The robot is made from an RC car and uses a Raspberry Pi as its central processor. It uses ROS, the Robot Operating System, to process sensor data, navigate, and trigger events.

Our robot will be named LookSee.



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Motivations

01 We wanted to select and design a project that is challenging.

02 We needed to design a project that has many different components, so that we do not have to rely on in-person collaboration.

03 We wanted to develop our professional skills.

04 We wanted a project we could all be excited about.

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Primary Requirements

01 By the end of the semester, LookSee should be able to autonomously navigate a space similar to the average office building for at least 10 minutes without getting stuck.

02 By the end of the semester, LookSee should be able to identify a human moving around in front of its path with at least 70% accuracy.

03 When LookSee identifies a human intruder, it must call the emergency contact, and allow the contact to take over navigation of the robot.

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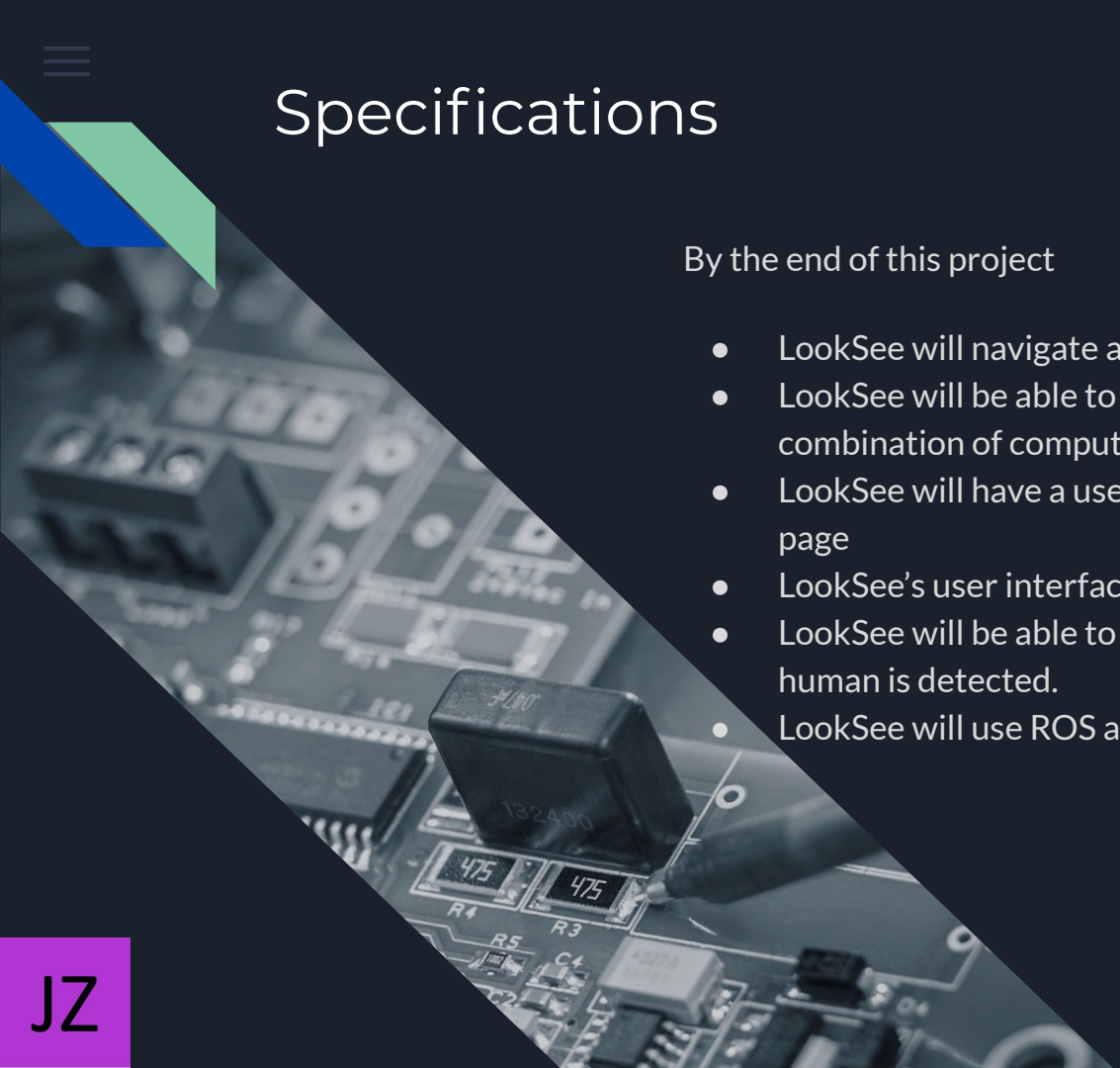
Specifications



By the end of this project

- LookSee will navigate autonomously with Find-the-Gap navigation
- LookSee will be able to identify a human in the room through a combination of computer vision and thermal sensing
- LookSee will have a user interface that can be accessed through a web page
- LookSee's user interface will allow a human operator to drive the robot
- LookSee will be able to video call an emergency contact using Skype if a human is detected.
- LookSee will use ROS as its software backbone.

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Target Audience

The target market for this robot is owners of small to medium-sized businesses. LookSee is designed to be much cheaper than installing a CCTV system or hiring a night guard to patrol or any other surveillance equipment, so it will appeal to businesses looking to save money on insurance and wages, and avoid risks related to human error or casualty related to health risks undertaken by a night guard.

As this is a small, low-budget platform, its use case does not include government or defense contractor facilities, or anything else of that nature.

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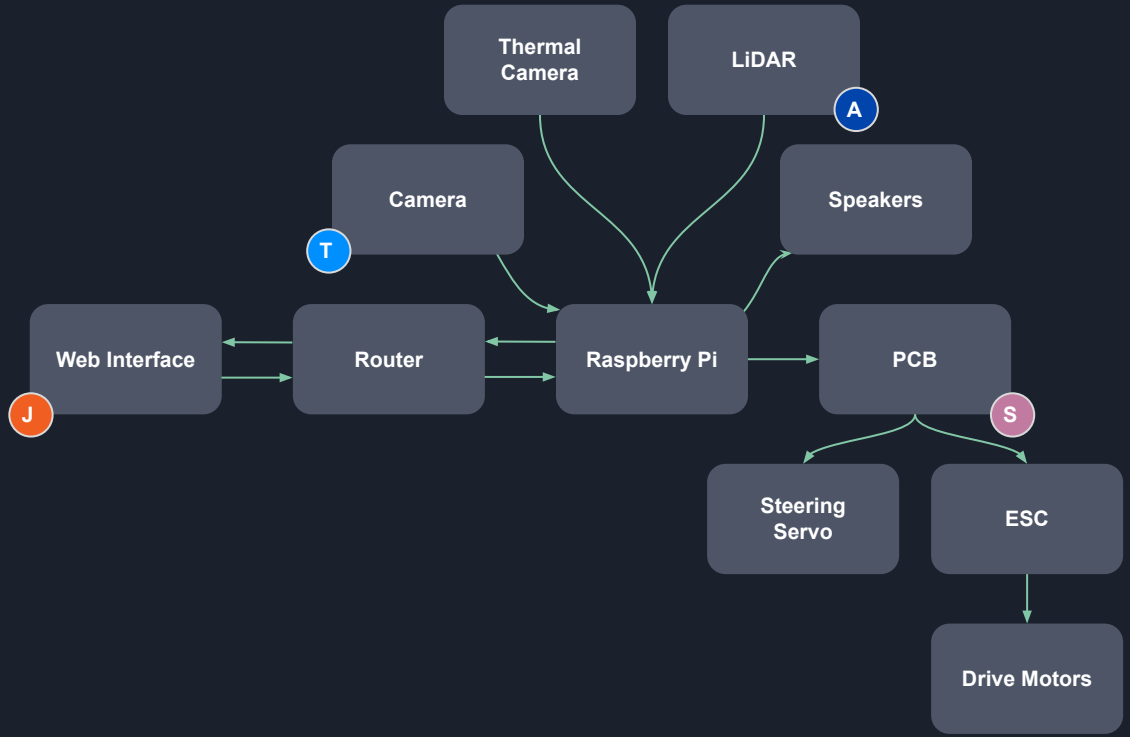
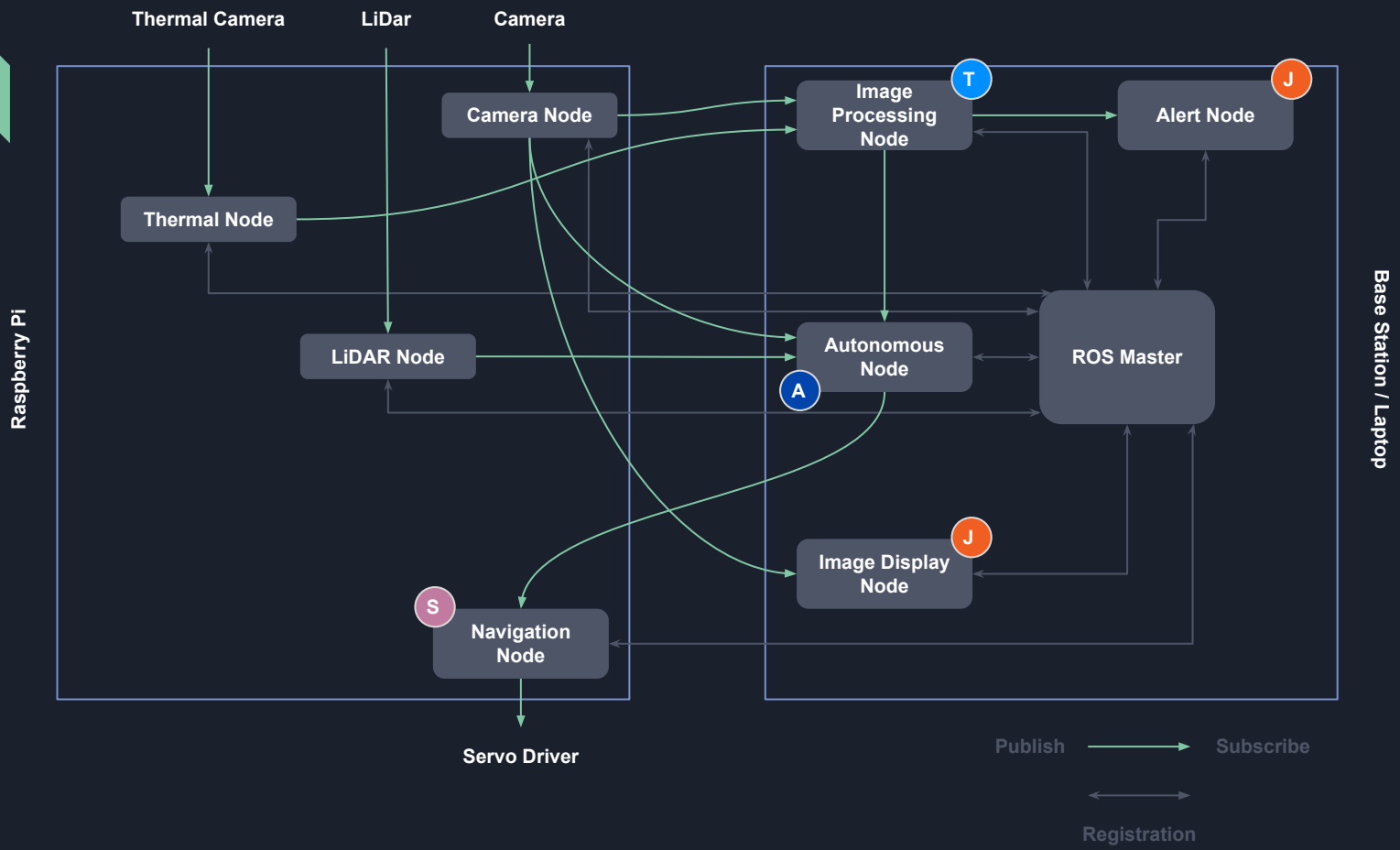
Hardware Diagram



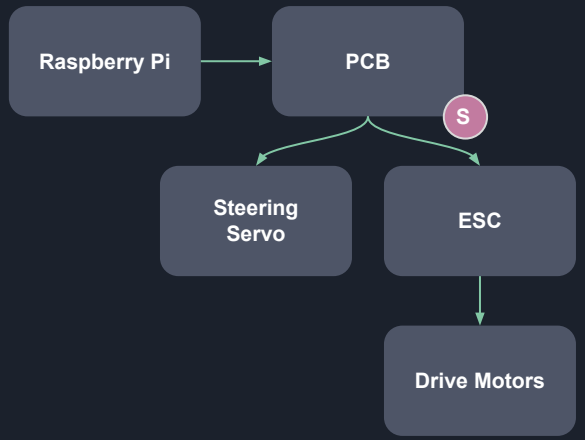
Software Diagram



Hardware Topics

PCB

Our PCB will be our servo driver that will fully control our motor and servo to maneuver our RC car as desired. It will be using a PCA9685 chip that is an I2C-bus controlled 16-channel LED controller.



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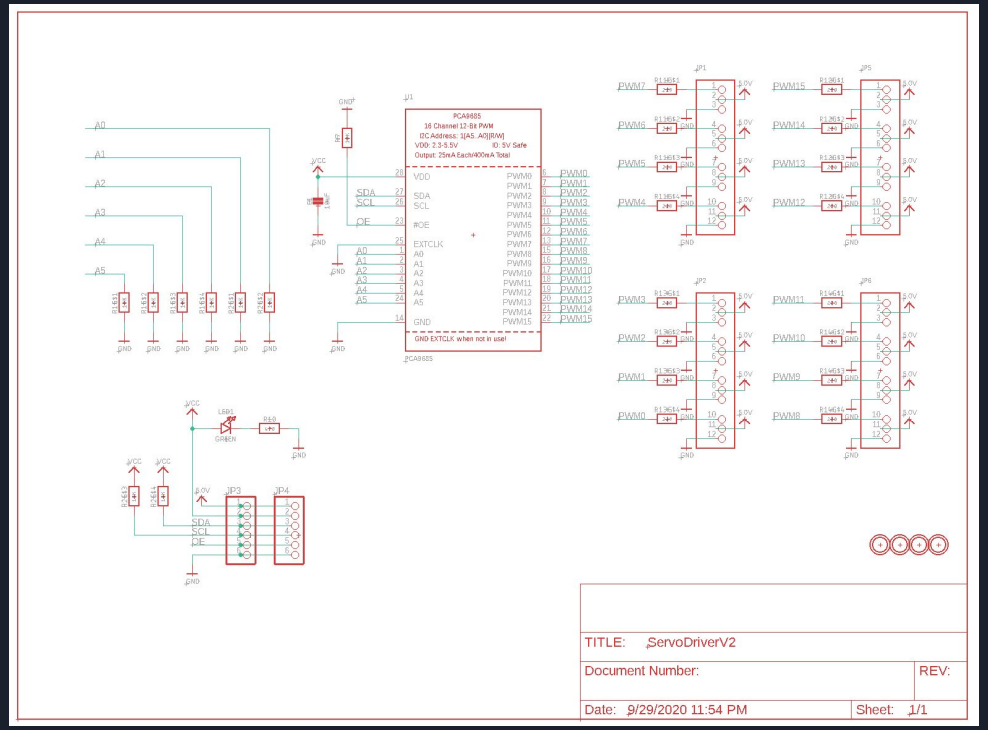
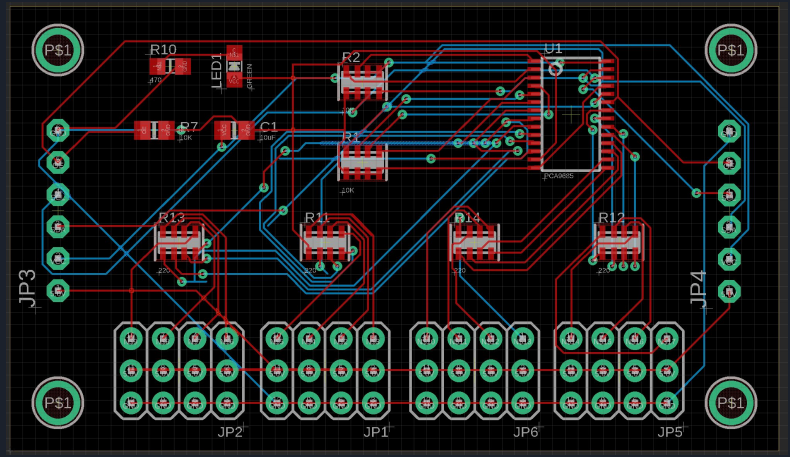
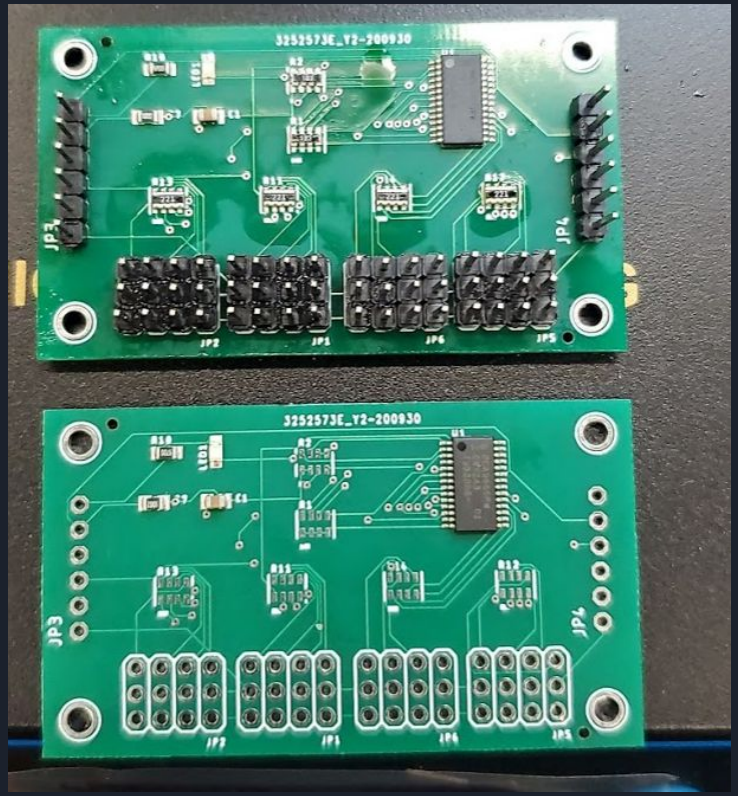
PCB Design


PCA9685
16 Channel 12-Bit PWM
I2C Address: 1[A5...A0][R/W]
VDD: 2.3-5.5V
IO: 5V Safe
Output: 25mA Each/400mA Total
GND EXTCLK when not in use!
TITLE: ServoDriverV2
Document Number:
REV:
Date: 9/29/2020 11:54 PM
Sheet: 1/1


P$1
R10
LED1
R2
U1
R7
C1
R1
R13
R11
R14
R12
JP3
JP4
JP2
JP1
JP6
JP5

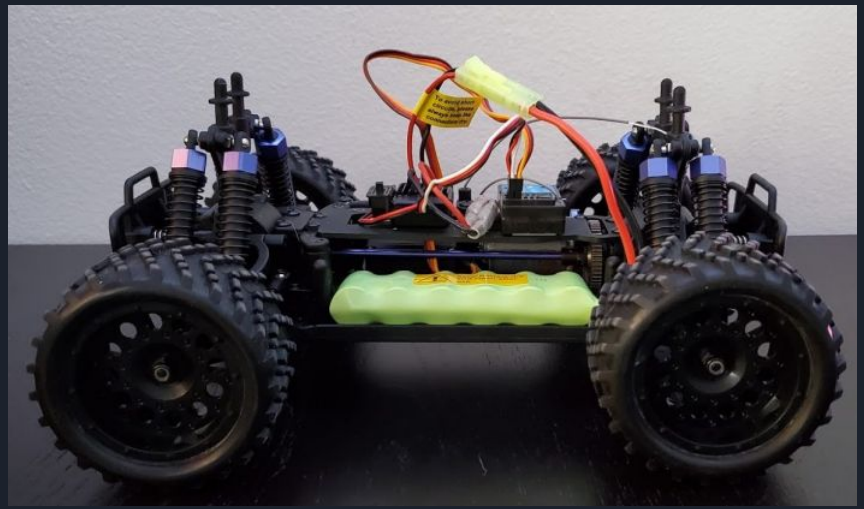


Components:

- Chip Resistor Array consisting of 4 resistors. 220Ω and 10kΩ
- PCA9685 Chip
- Pin headers for our wires

Mechanical System - RC Car

- Exceed RC Magnet EP Electric RTP Off Road Truck
- Four Wheel Drive
- Double wishbone suspension
- Double Coil spring shocks
- Rubber non slip tires
- All terrain
- $120



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Mechanical System - Motors

- Exceed-RC RC380 Brushed Motor
- Exceed-RC Sp6003 High Torque servo
- Turn Steering method
- Electronic speed controller used
- Geared to send power to all four wheels

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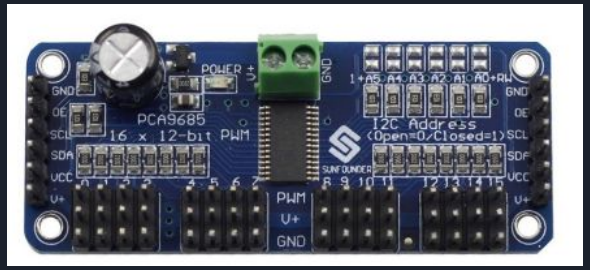
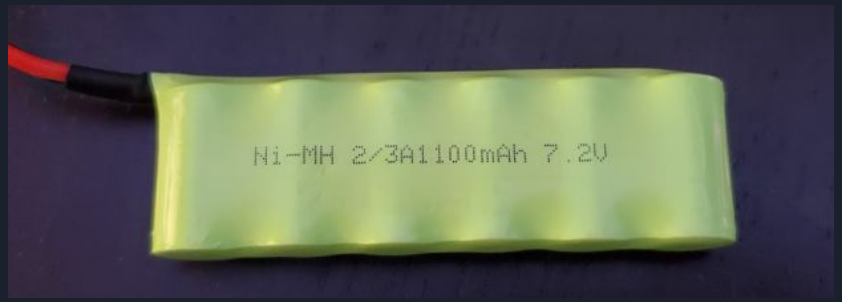
Electrical System - Batteries and Power Distribution

- Servo Driver
- High Capacity (11000mAh) 7.2V Ni-MH battery
- AUKEY Portable Battery
- RC Battery Powers RC car
- Portable Battery Power Rasp Pi
- Rasp Pi Powers Sensors





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Sensors - General

The individual component(s) have been carefully selected for integration within our ROS Melodic ecosystem for ease of integration. Price of the component was also weighed in decision making.

Each sensor will have extensive testing for their respective marks of accuracy. To ensure no product was damaged in transit.

In order to meet our objective goals for autonomous control, obstacle avoidance, collision detection, and intruder detection. Through sensor fusion (simulated through Gazebo). Various sensors will be required to work in conjunction with each other in order completely cover all aspects of LookSee's responsibilities.

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Sensors - Camera

Kuman Raspberry PI Camera Module

- 5 MegaPixels
- 1080p at 30 FPS
- Infrared sensors for night vision
- Inexpensive
- Uses GPIO connection

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Sensors - IR Array

The MLX90640 Thermal Camera Breakout (110°) from Pimoroni was in part due to the value of the Melexis MLX90640 with regard to the (768 pixel - 32x34-$25) resolution when in comparison between the GRIDEYE (64 pixel - 8x8-$60) and consumer available FLIR (4,800 pixel-80x60-$200) the MLX90640 offers a significant boost in performance for a very reasonable price.

When used in conjunction with the camera, the infrared image will be composed of an assigned color (blue for cold, red for hot) corresponding to a calculated temperature value (calculated from the reflected temperature and emissivity of an object) using the drivers written by Melexis. Once each of the 768 pixels has an assigned color a frame can be generated and then the process of chaining together frames can be accomplished to create relatively low cost thermal imaging. (Available at https://github.com/melexis/mlx90640-library) High temperature resolution may come at the cost of overall image resolution or a lower frame per second count.

For LookSee temperature and thermal imaging may be useful in confirming the identity of an object suspected to be human (an intruder) or potentially in the operator controlled override of LookSee giving the operator clear vision in dark areas.

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Sensors - Lidar

The RPLidar A1M8 offers an introduction the realm of Lidar scanners, providing a 2D - 360° scan capable of detecting within 6 meters. It has a configurable variable scan frequency and is all offered for an incredibly affordable $100. In comparison 3D scanners quickly scale into the thousands of dollars which is impossible given our student funded budget.

Besides the phenomenal price for the Lidar and compatibility with our selected microcontroller; Slamtec has made a software development kit offering various functions to interact with the RPLidar directly as well as a separate open-source ROS node for integration with our other subsystems through ROS via publishing and subscribing.

Autonomous traversal requires information about the surroundings to make decisions, and may requires some form of odometry to establish the location of the robot and Lidar accomplishes this task by providing a laser scan of the environment, and through calculation the position of the robot relative to that scanned environment.

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Microcontroller - Raspberry Pi 4b

For the relatively low entry price of 35$ the Raspberry Pi 4b comes with a Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz and a variable choice of ram (2gb, 4gb, 8gb) with standard gigabit ethernet, and an onboard wireless networking card that is bluetooth compatible. Of course it has the standard 40 pin GPIO header as well as various connecting points for peripherals: micro HDMI, 2 USB2 ports, 2 USB3 ports, and USB-C for power supply.

With this low cost comes the added benefit of popularity, with a wider user base at various skill levels comes the benefit of a strong network for support from fellow users who have troubleshooted issues in the past, as well as support from developers who know the most popular platform will likely be used in conjunction with their product.

With a plethora of tools designed with the Raspberry Pi in mind, components are readily available and software development tools are also bountiful.

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Prototyping

RC Car Prototype

Base plate to mount electronics

Portable battery mounted under base plate

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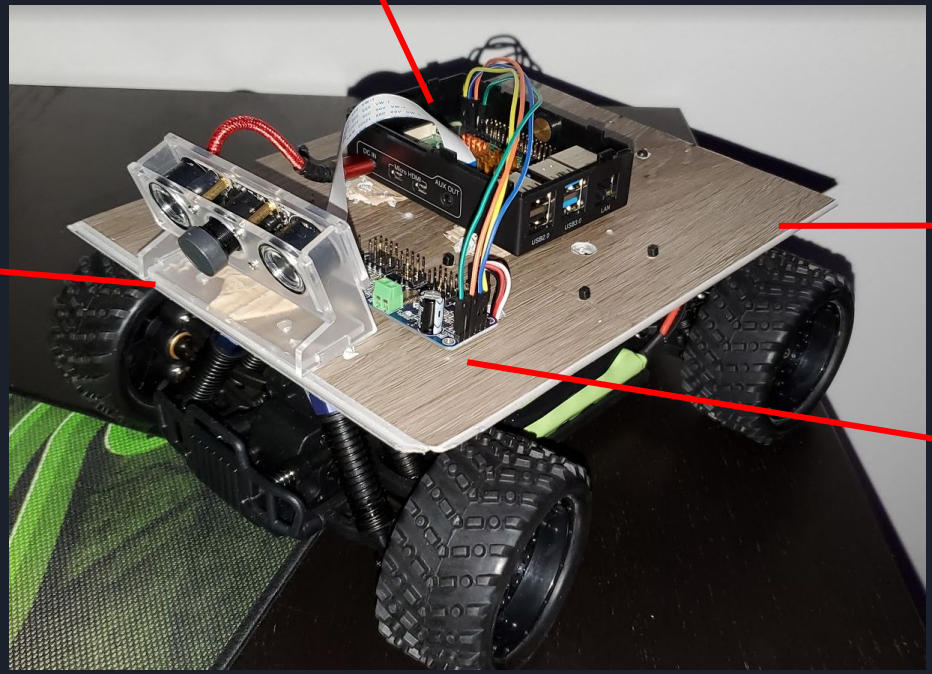
RC Car Prototype



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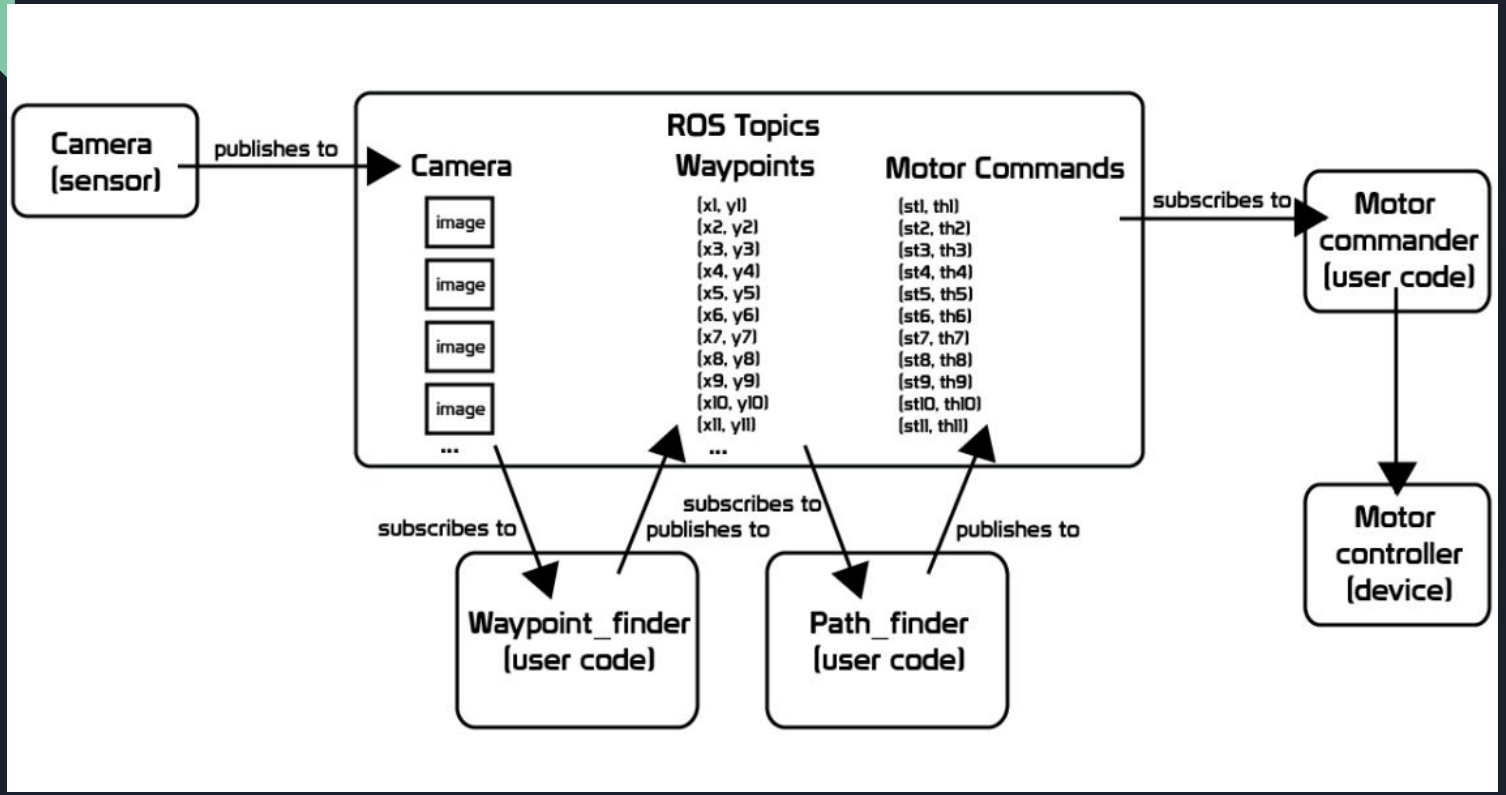
Software

Software Framework - ROS



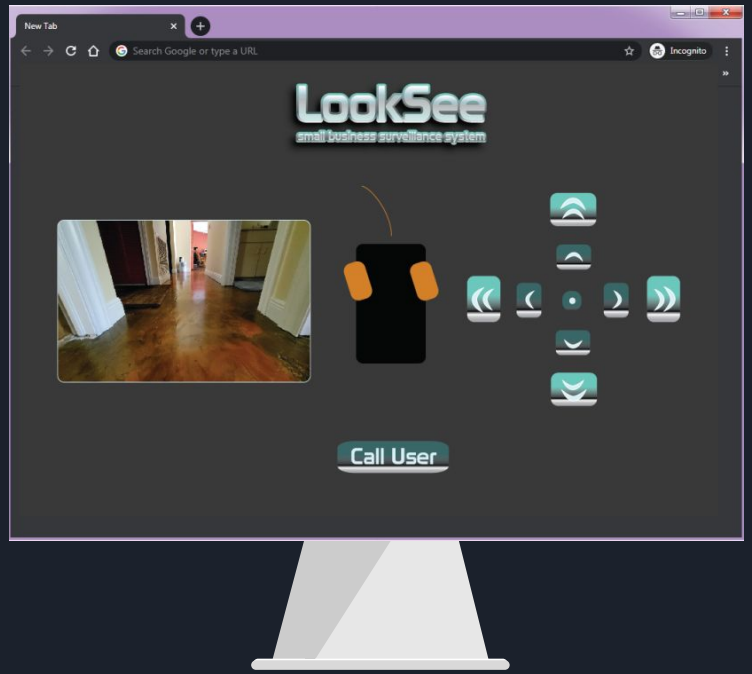
Software - User Interface

LigHTTPD is a web server that can run on the Raspberry Pi.

The User Interface will consist of a page that looks like the one to the right, with several buttons.

When a user clicks a button, it will trigger a ROS command, which will either initiate a Skype call or move the robot's wheels.

The User Interface will also have a video stream from LookSee's camera.



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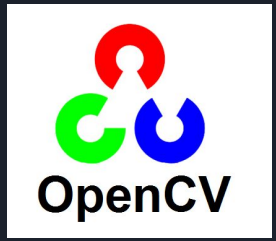
Software - Human Detection

Detecting a person using the camera is one of the main goals. We aim for a 70% detection rate.

The main things to consider is that we may only see someones legs or torso but we would want to count as a detection.

The goal is to use an integration of TensorFlow for object / person detection and ROS.

A combination of computer vision from our camera and thermal readings from our thermal camera should increase our accuracy.



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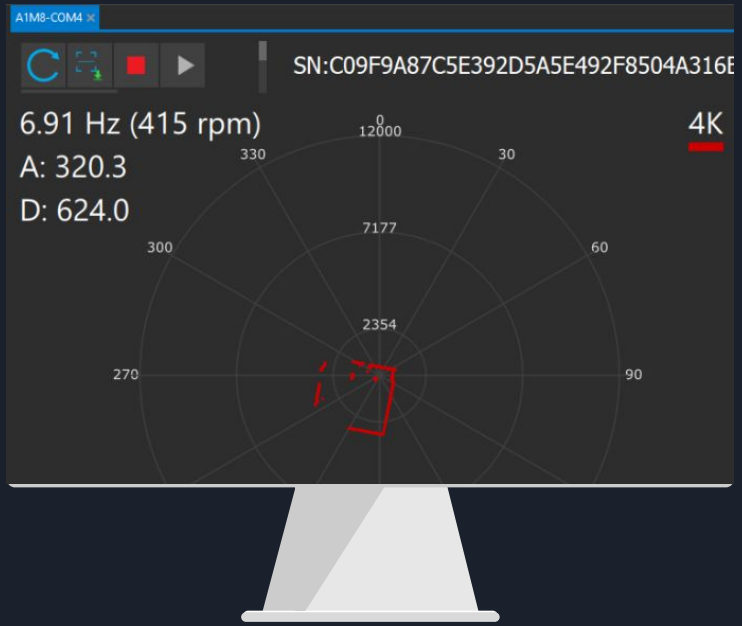
Software - Lidar

With the capabilities of the RPLidar demonstrated thoroughly with various examples in the software development kit, in addition to the ROS node created by Slamtec. Autonomous navigation is achievable through algorithms like Finding the Gap, or Following the Wall.

In addition there exists a far stretch goal for our project of SLAM (Simultaneous localization and mapping) as the name implied a map of an area would be generated as LookSee traverses an unknown environment autonomously.



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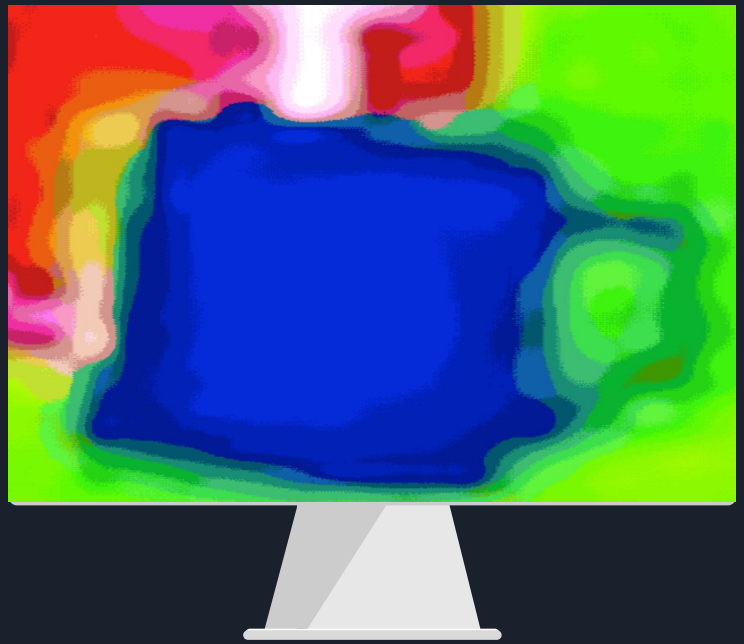
Software - Thermal Imaging

Melexis software development kit has detailed and well written documentation on how to use the SDK given. Additionally, various other write ups from users and companies retailing the MLX90640.

With the capabilities of the Raspberry Pi 4 image interpolation processing can be used to improve the resolution via the SciPy python library.



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Budget

Item	Quanity	Vendor	Donated	Cost with Qty.
RC Car	1	Exceed-RC		$119.95
RC Battery	1	Exceed-RC		$0.00
RC Battery Charger	1	Exceed-RC		$0.00
Power Bank	1	AUKEY	Yes	$72.99
Raspberry Pi 4	1	Raspberry Pi	Yes	$74.99
Voltage Transformer	1	DaFuRui		$9.99
Servo Driver	1	SunFounder		$9.99
PI Camera Module	1	Kuman		$10.99
Camera Holder	1	Kuman		$8.00
Microphone	1	TBD		$39.99
LiDAR	1	RPLIDAR		$99.00
Thermal Sensor	1	Pimoroni		$59.99
PCB	1	TBD		$19.99
Micro SD Card	1	SanDisk	Yes	$9.99
Router	1	TBD	Yes	$49.99
Wiring/Sleeving	1		Yes	$19.99
		Total		$605.84
		Donated Parts		$227.95
		Net Total		$377.89

Our aim is for the project to cost no more than 200 dollars to each member of the team. As our objective is to make this a low cost robot. We are able and willing to spend any extra if needed due to the possibility of something breaking or not working.

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Plan for Completion

We have a meticulous plan for each of us to complete certain tasks during specific weeks. We broke up our responsibilities into modules that require minimal in-person interaction until later in the semester.

The four modules are:

- Computer Vision - Tyler
- Autonomous Navigation and Thermal Imaging - Austin
- Teleop Navigation and User Interface - Jade
- Hardware/Power/PCB - Stavros

Week	Computer Vision	Navigation/Thermal	User Interface	Hardware
1	All: Install Linux and ROS on personal computer, verify functionality. Verify all parts have been received and are functional.			
2-3	Write a program that can identify a human in an image and output a confidence value.	Write a program that can check the temperature at a location in an "image" received from the thermal array.	Create a user-facing page for a web server with nine buttons, space for a camera feed, and appropriate graphics.	Design PCB and place order. Pay for express shipping.
4	Modify above program so that the location of the suspected person is published to a ROS topic.	Modify the above program so that it checks the location published by the computer vision program, and publishes a flag to a new ROS topic if 60% confidence is exceeded.	Modify code for buttons so that all buttons publish to their respective ROS topics.	Create additional layers on chassis to securely hold sensors and other electronics.
5-6	Work with Hardware to integrate all code the team has completed thus far into ROS on the Raspberry Pi that will be used on LookSee.	Begin implementing find-the-gap navigation and testing in Gazebo if hardware has not yet been received.	Write Skype call software.	Work with Computer Vision to integrate all code the team has completed thus far into ROS on the Raspberry Pi that will be used on LookSee.
7	Work with User Interface to begin testing intruder detection and alert features.	Work with Hardware to test and fine-tune autonomous navigation.	Work with Computer Vision to begin testing intruder detection and alert features. Implement UI video stream.	Assemble the robot. Work with Navigation to test and fine-tune autonomous navigation, test hardware.
8	All: Meet to perform all tests again, identify problem areas, strategize for the remainder of the semester, and decide which stretch goals to pursue.			
9-End	All: Fix issues that may have been identified, pursue advanced and stretch goals, perform tests.			

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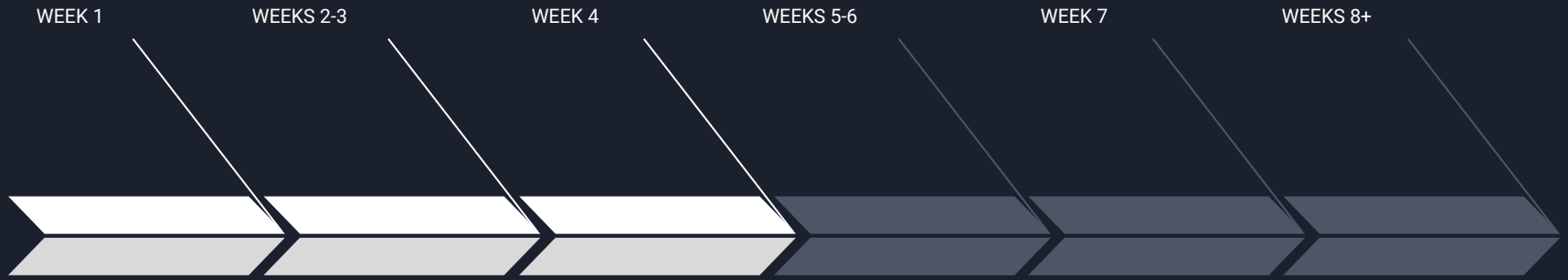
Timeline



Installations and Checks

All members install all software and test any hardware they are responsible for.

Preliminary Coding

Programmers write a version of their code that runs independently of ROS. The PCB is designed and ordered.

ROS Integration

Programmers modify code to work with ROS. Chassis assembly finalized.

Code Integration

Everyone works together to put finishing touches on the code and make it work on the robot instead of personal computers.

Preliminary Testing

All tests are performed, notes are taken to determine what needs to be focused on.

Adjustments, Improvements, Final Testing

Adjustments are made based on test results, and tests are redone. Optional additional features may be added.

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Thank you!