Department of Computer Science & Engineering
The University of Texas at Arlington

Architectural Design Specification
CSE 4316: Senior Design I
Fall 2018

IGVC
AutoMav

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REVISION HISTORY

Revision	Date	Author(s)	Description
0.1	11.12.2018	DU, AT, AB, AA, WS	initial draft
1.0	05.10.2019	DU, AT, AB, AA, WS	Subsystem descriptions and diagrams updated to reflect design changes

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1 Introduction

AutoMav is an autonomous ground vehicle that will compete in the IGVC 2019 competition. AutoMav is designed to complete a lane designated course, while avoiding obstacles and navigating to way point locations. AutoMav will be a modularized system, with nodes being created for each subsystem, so that future teams will be able to easily extend and maintain the system.

2 System Overview

The AutoMav system is separated into five modules, Central Control, External Sensors, Hardware, Navigation, and Computer Vision. Each module is responsible for a separate group of core functions within the system.

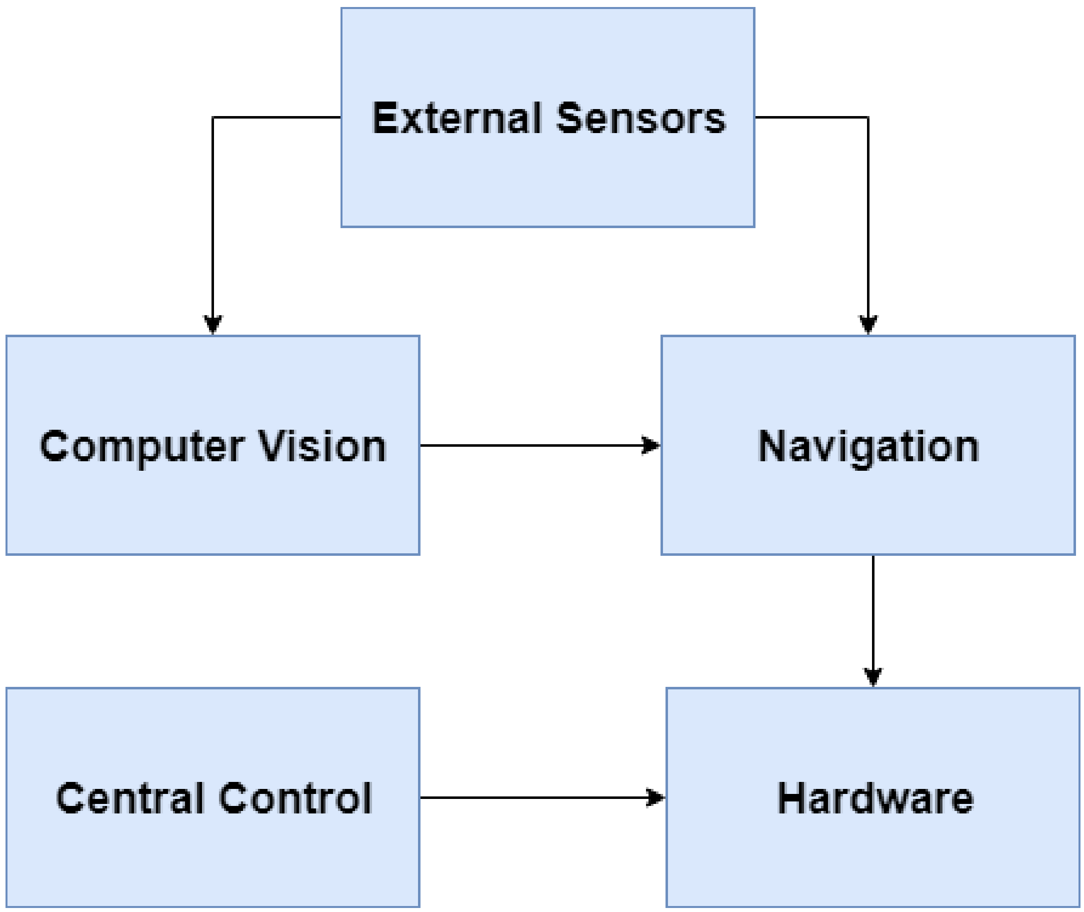

Figure 1: Architectural layer diagram

2.1 Central Control

The central control unit will provide a location for system status information, as well as handling system wide commands, and a platform for all other nodes to interact with the system.

2.2 External Sensors

Devices that sense information about the environment. The vehicle will use 3D camera and GPS as external sensors.

2.3 Hardware

This subsystem deals with the components of the system that handle information exchange at the physical level. This includes any necessary signal processing, electronics, and motion controls.

2.4 Navigation

The navigation system will be responsible for creating a path from its current location to the intended location based on the information it gets from the external sensors and the computer vision systems. The navigation layer will be split up into two distinct subsystems: Path Finding and SLAM.

2.5 Computer Vision

The computer vision system is responsible for taking images captured by external sensors and recognizing obstructions in the vehicle's path as well as recognizing lane lines. Obstacle recognition will utilize a 3D camera that provides depth information to detect objects in front of the vehicle. Lane recognition will use the 2D component of the 3D camera data to search for edges in images containing painted lanes and painted potholes. The output of both computer vision nodes are used to construct an occupancy grid of the vehicle's surroundings and is sent to the pathfinding subsystem.

3 Subsystem Definitions & Data Flow

This section describes how data is passed between each subsystem module. This section also describes each subsystem in further detail and how data flows within each subsystem.

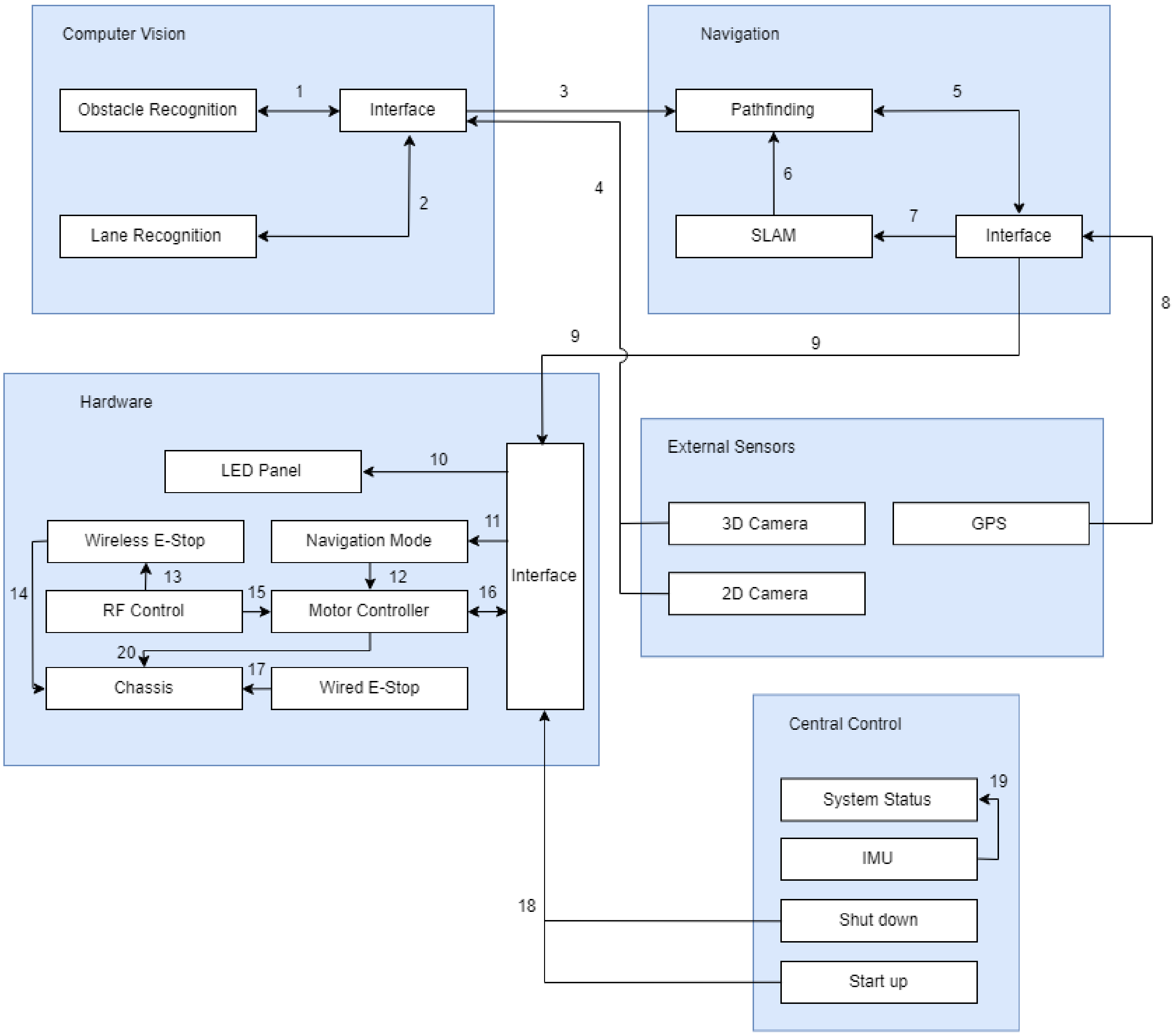

Figure 2: System Data Flow

4 Central Control

The central control unit will provide a location for system status information, as well as handling system wide commands, and a platform for all other nodes to interact with the system.

4.1 System Status

System status will hold all node status data (whether the node is running or not), component values, such as speed, battery life, etc. System status will also output select data to the LED display, which will indicate node availability statues, as well as current driving mode.

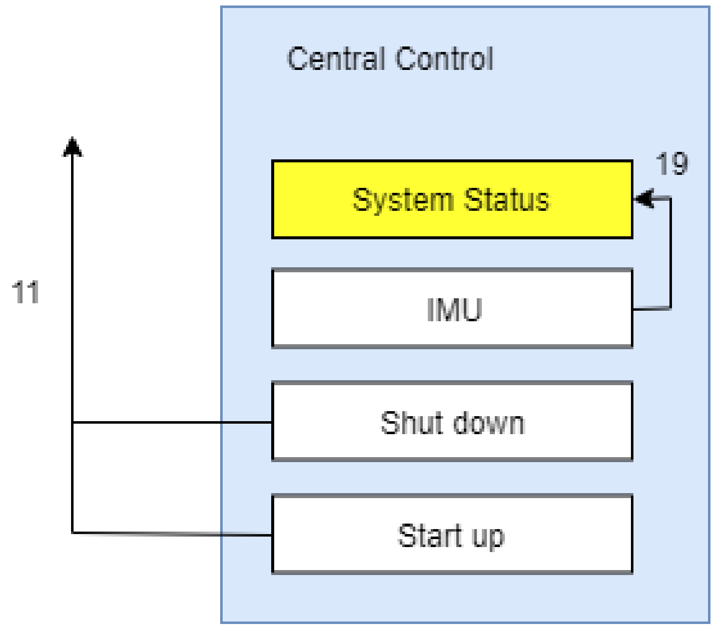

Figure 3: Central Control - System Status

4.1.1 Assumptions

Each node will send a message to System status, containing the required data to accurately account for the current systems status.

4.1.2 Responsibilities

The responsibility of this subsystem is to provide a location for all system related status outputs to be stored and accessed.

4.1.3 Subsystem Interfaces

This subsystem will take inputs from each node, as well as from individual components from subsystems that require a status to be accounted for.

Table 2: System Status interfaces

ID	Description	Inputs	Outputs
N/A	Node status inputs	Node input	Status output
#19	Vehicle Movement Information	IMU Data	None

4.2 Internal Measurement Unit

The IMU is made up of a variety of sensors including gyroscopes and accelerometers that will help the system measure its movements through the environment and keep track of its orientation.

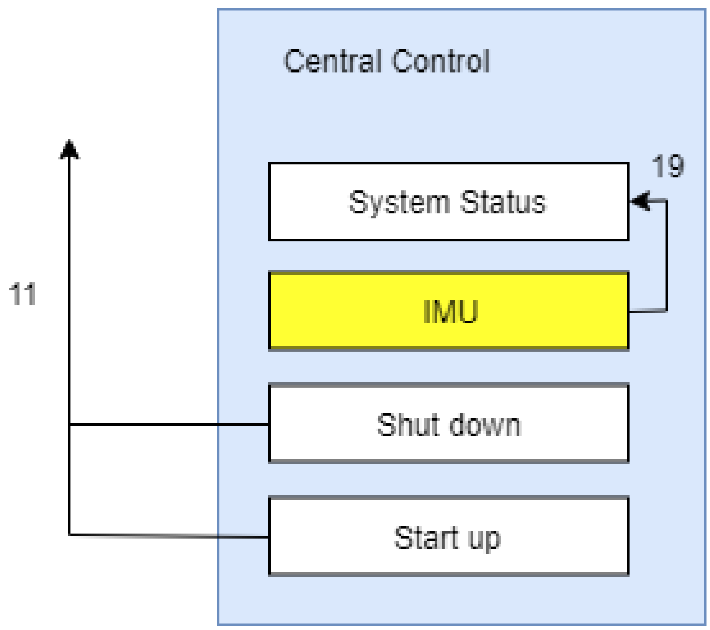

Figure 4: Central Control - IMU

4.2.1 Assumptions

Reading from the IMU will be accurate.

4.2.2 Responsibilities

This subsystem is will be determine the current position and orientation of the system with no regard to the environment.

4.2.3 Subsystem Interfaces

This subsystem is connected to the System Status and feeds data that is used in it to determine orientation and positioning following movements made by the system.

Table 3: IMU interfaces

ID	Description	Inputs	Outputs
#19	output from IMU	None	IMU Position Data

4.3 Shut Down

Shut down will handle the shutting down of the system by properly stopping each node and shutting down the whole system.

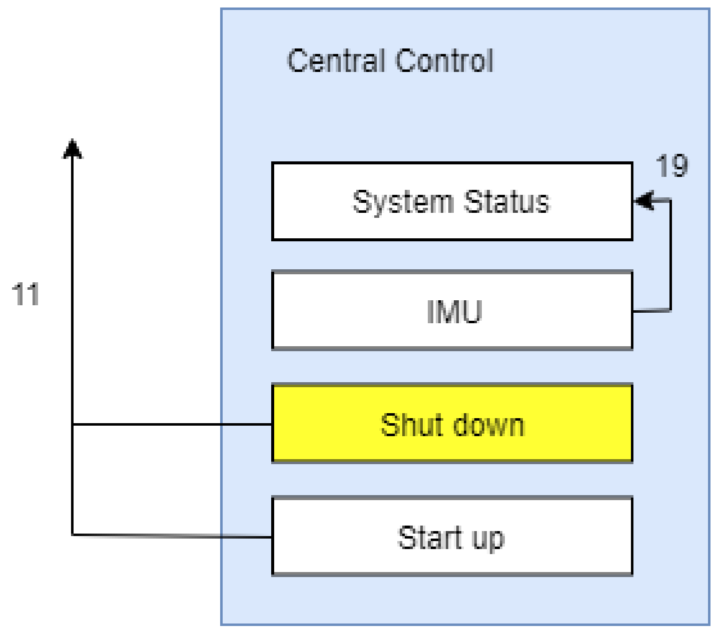

Figure 5: Central Control - Shut down

4.3.1 Assumptions

The Central Control subsystem will act as an operating system and will have an interface with each subsystem.

4.3.2 Responsibilities

This subsystem facilitates the graceful shut down of the system.

4.3.3 Subsystem Interfaces

This subsystem will output a shut down signal to all subsystem nodes.

Table 4: Shut down interfaces

ID	Description	Inputs	Outputs
#11	Connection to each node in system	None	Shut down signal

4.4 Start Up

Start up will handle to start up of the entire system, as well as the proper start up of each subsystem.

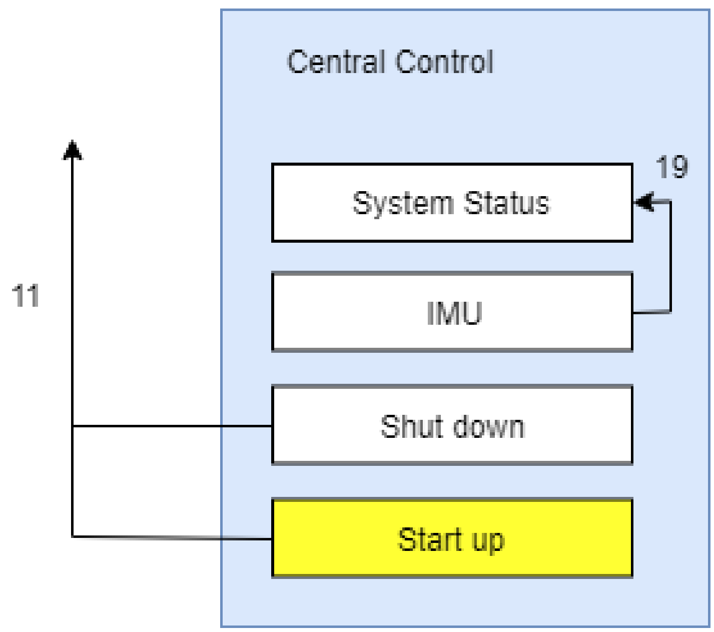

Figure 6: Central Control - Start up

4.4.1 Assumptions

The Central Control subsystem will act as an operating system and will have an interface with each subsystem.

4.4.2 Responsibilities

This subsystem is responsible for the start up of the entire system.

4.4.3 Subsystem Interfaces

This subsystem will output a start up signal to all subsystem nodes.

Table 5: Start up interfaces

ID	Description	Inputs	Outputs
#11	Connection to each node in system	None	Start up signal

5 External Sensors

Devices that sense information about the environment. However, they are not part of the system itself. The vehicle will use 2D camera, 3D camera, and GPS sensors.

5.1 GPS

The GPS subsystem will utilize input from a GPS to provide the system with centimeter-level positioning. This data will be provided to the Navigation layer for further use in path planning.

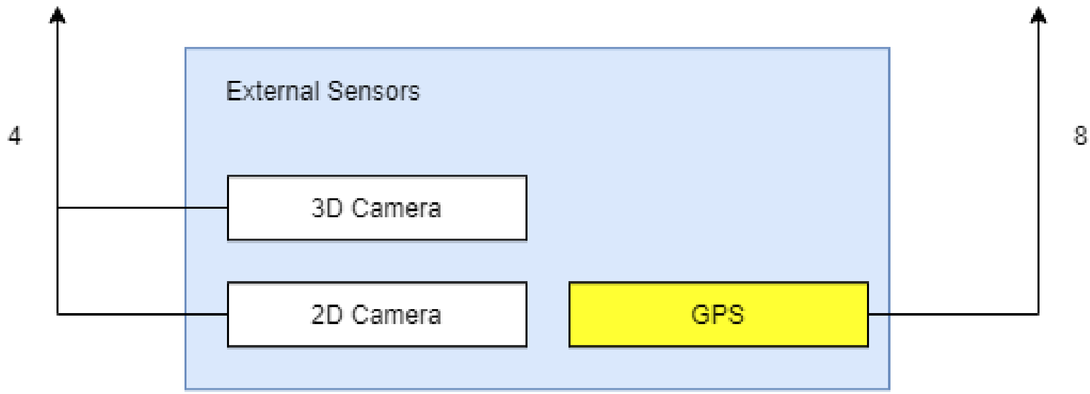

Figure 7: External Sensors - GPS Subsystem

5.1.1 Assumptions

The GPS sensor's data does not need further processing and that the accuracy of the data is such that localization and mapping can use it effectively.

5.1.2 Responsibilities

The GPS subsystem is responsible for capturing the data provided by the GPS sensor and making the data available to all other subsystems require it.

5.1.3 Subsystem Interfaces

Input data is obtained from the GPS sensor and output in a standard format.

Table 6: GPS interfaces

ID	Description	Inputs	Outputs
#08	Output to Navigation interface	None	GPS sensors location

5.2 3D Camera

The 3D Camera subsystem will utilize input from one 3D camera to provide the system with data which will be used in the Navigation Layer for obstacle avoidance.

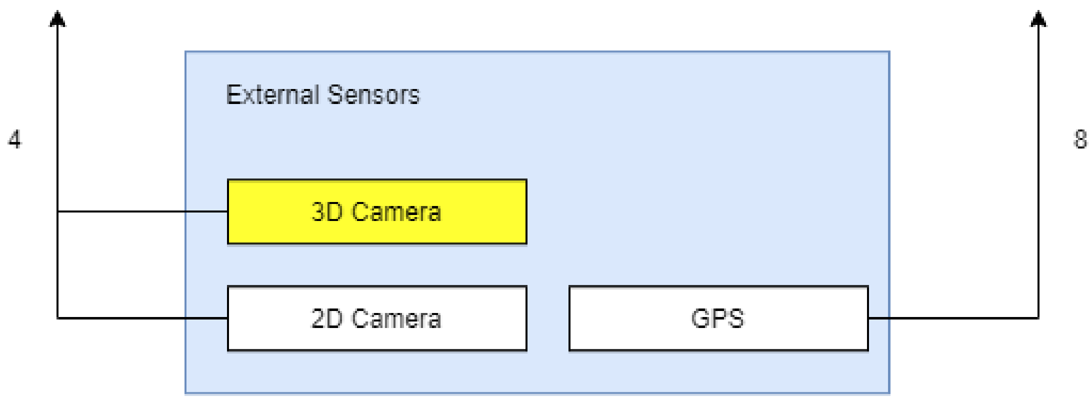

Figure 8: External Sensors - 3D Camera Subsystem

5.2.1 Assumptions

The accuracy of the data is such that localization and mapping can use it effectively.

5.2.2 Responsibilities

The 3D Camera subsystem is responsible for capturing the data provided by the camera sensor and making that data available to all other subsystems that require it.

5.2.3 Subsystem Interfaces

Input data is obtained from the camera sensor and output as a color image and a depth map.

Table 7: 3D Camera interfaces

ID	Description	Inputs	Outputs
#04	Output to Computer Vision interface	None	Unprocessed camera data

5.3 2D Camera

The 2D Camera subsystem will utilize the 2D image component of the 3D camera data to provide the system with data which will be used in the Navigation Layer for Lane detection.

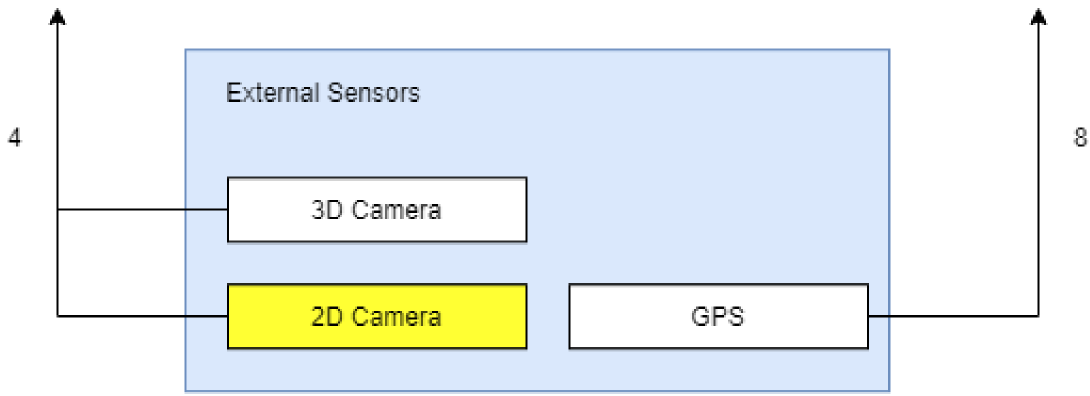

Figure 9: External Sensors - 2D Camera Subsystem

5.3.1 Assumptions

The accuracy of the data is such that localization and mapping can use it effectively.

5.3.2 Responsibilities

The 2D Camera subsystem is responsible for capturing the data provided by the camera sensor and making that data available to all other subsystems that require it.

5.3.3 Subsystem Interfaces

Input data is obtained from the camera sensor and output as a color image and a depth map.

Table 8: 2D Camera interfaces

ID	Description	Inputs	Outputs
#04	Output to Computer Vision interface	None	Unfiltered 2D image data

6 Hardware

This subsection deals with the components of the system that handle information exchange at the physical level. This includes any necessary signal processing, electronics, and motion controls.

6.1 RF Control

The RF control subsystem will take input from an RF controller which will transmit signals to the system.These signals will be received by the system and used as a means of direct motion control when working in manual mode.

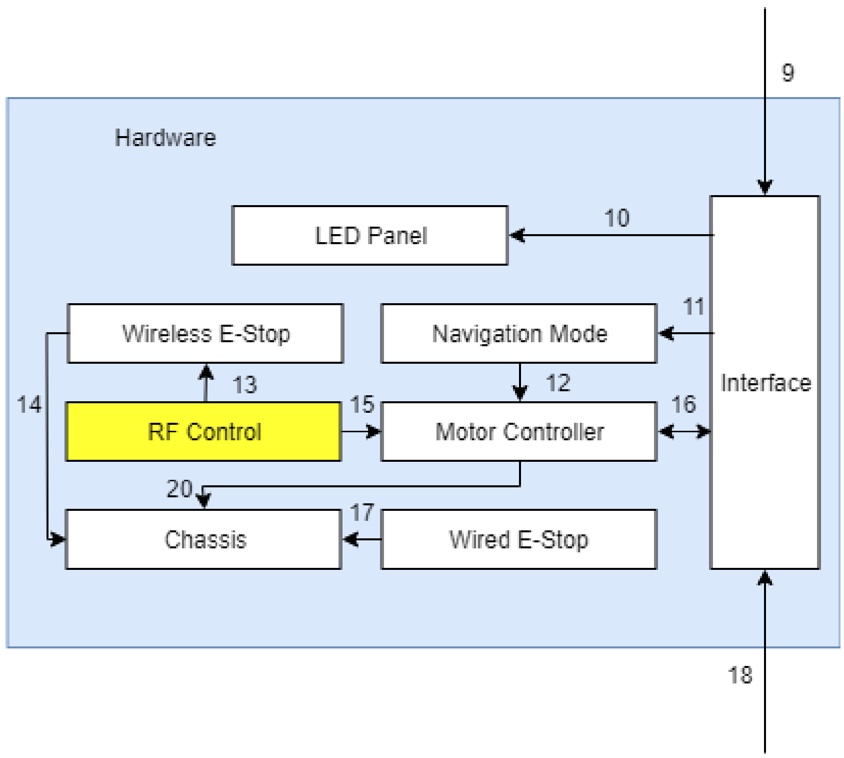

Figure 10: Hardware - RF Control Subsystem

6.1.1 Assumptions

Existing communication protocols will be used to send signals from the controller to the system. They should not have to be built from the ground up.

6.1.2 Responsibilities

The responsibility of this subsystem is to provide an input user face for the end user to send motion control signals to the system. This controller will also have to ability to send a remote emergency stop signal to the system.

6.1.3 Subsystem Interfaces

Each of the inputs and outputs for the subsystem are defined here. Create a table with an entry for each labelled interface that connects to this subsystem. For each entry, describe any incoming and outgoing data elements will pass through this interface.

Table 9: RF Control interfaces

ID	Description	Inputs	Outputs
#13	Movement Signal	Control Stick Input	Motion Signal in direction of input

6.2 Navigation Mode

The Navigation Mode subsystem will serve as a physical switch to transition the system from manual mode to autonomous mode.

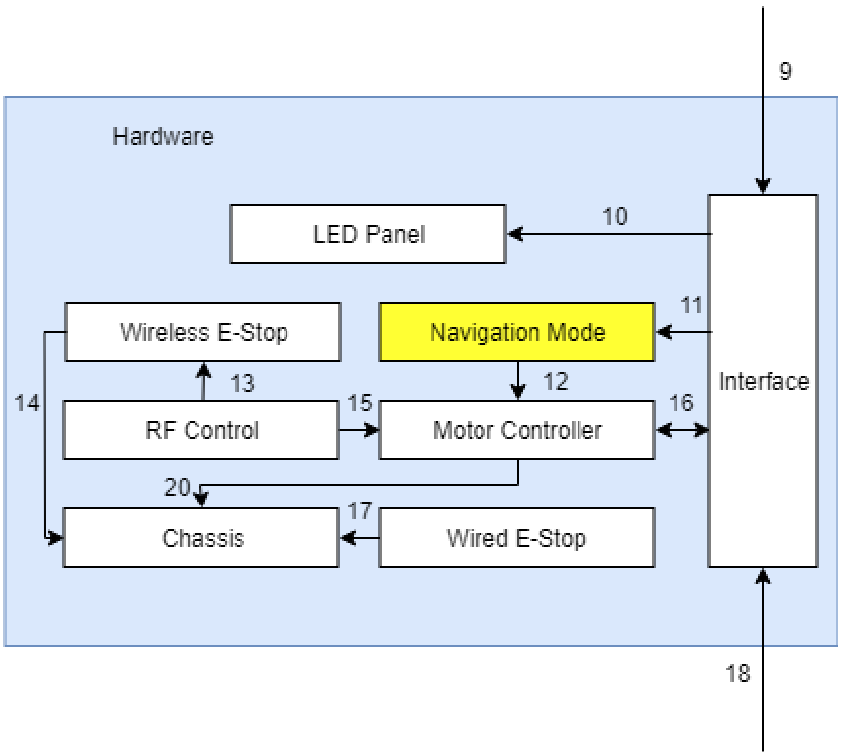

Figure 11: Hardware - Navigation Mode Subsystem

6.2.1 Assumptions

Flipping the switch to autonomous mode shall not prevent the system from receiving emergency stop signals from the remote control.

6.2.2 Responsibilities

Transition the system from manual mode to autonomous mode.

6.2.3 Subsystem Interfaces

There are two states for this interface: ON or OFF. ON being the system will have autonomous control over itself relying on sensor input for navigation and control and OFF being the state where the system will wait for instructions from the end user through the use of the RF controller.

Table 10: Navigation Mode interfaces

ID	Description	Inputs	Outputs
#12	Navigation ON	Switch High	Nav Mode ON

6.3 Motor Controller

The motor controller subsystem will handle control signals from the system and process them so the system will move when specific signals are received from the RF control or the system itself when in autonomous mode.

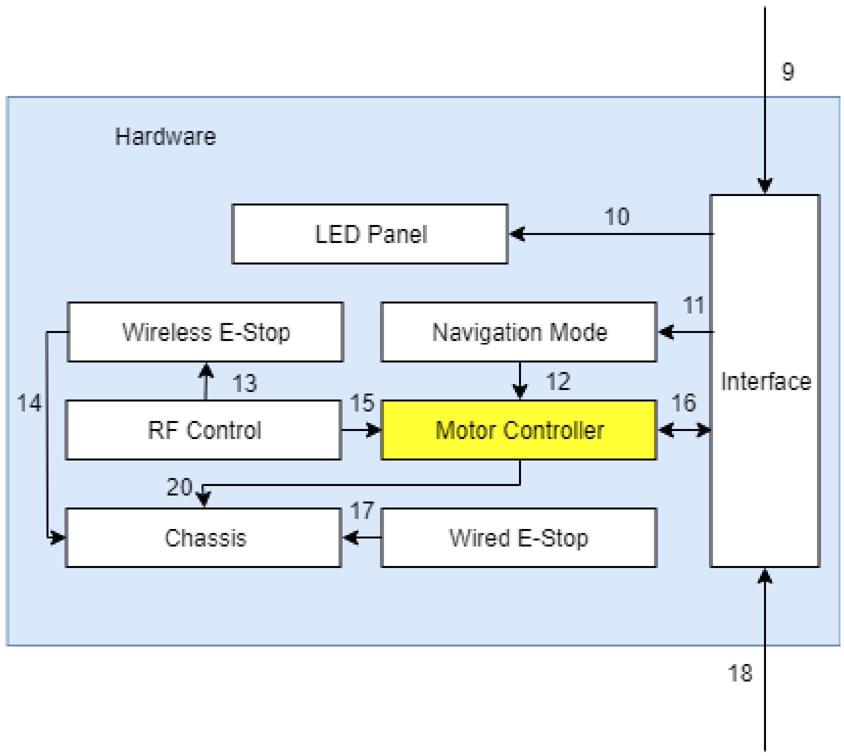

Figure 12: Hardware - Motor Controller Subsystem

6.3.1 Assumptions

The motor controller will be connected to the wheels of the system to enable motion.

6.3.2 Responsibilities

This subsystem will convert control signals into the appropriate motions based on specific commands.

6.3.3 Subsystem Interfaces

The subsystem will recognize a variety of control signals and be able to process them and convert them into respective motions of the system

Table 11: Motor Controller interfaces

ID	Description	Inputs	Outputs
#16	Movement Signal	Control Stick Input	Motor Signal

6.4 LED Panel

The LED panel will serve as a visual cue for individuals around the system to be able to determine the current state of the system.

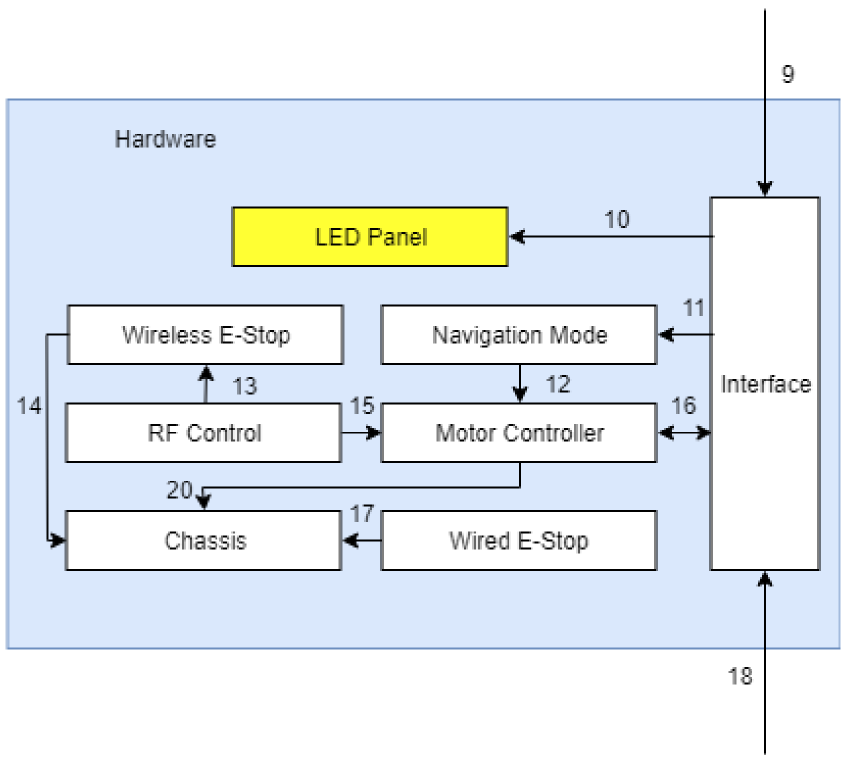

Figure 13: Hardware - LED Panel Subsystem

6.4.1 Assumptions

People viewing the LEDs understand what the light sequences/colors mean.

6.4.2 Responsibilities

Serve as a visual cue to the various states of the system.

6.4.3 Subsystem Interfaces

This subsystem connects to the Central Control and Navigation Mode subsystems when they are online.

Table 12: LED Panel interfaces

ID	Description	Inputs	Outputs
#10	Navigation ON	System Status LED display data	LED ON/OFF

6.5 E-Stops

This subsystem will be the source of the input signal to pull the system out of autonomous mode and back into manual mode.

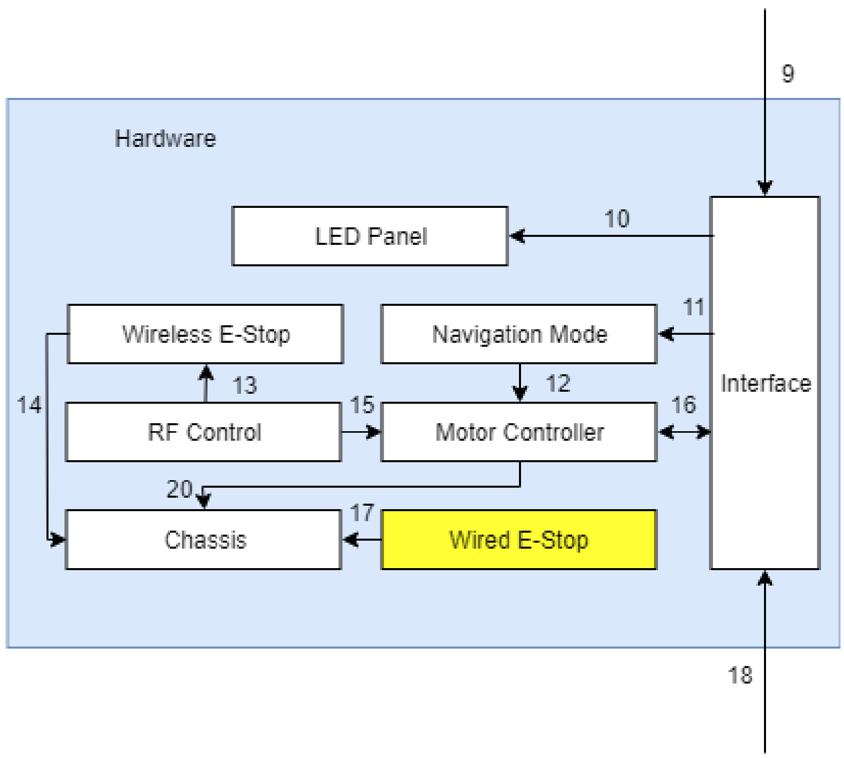

Figure 14: Hardware - E-Stop Subsystem

6.5.1 Assumptions

The E-stops will be able to override all processes as this feature is meant for the safety of people around the system.

6.5.2 Responsibilities

Transition the robot out of autonomous mode back to manual mode.

6.5.3 Subsystem Interfaces

This subsystem receives input from the on-board E-stop as well as the remote E-stop but and signals the navigation mode subsystem to end the autonomous process.

Table 13: E-Stop interfaces

ID	Description	Inputs	Outputs
#17	On board E-stop	Button Press	Nav Mode OFF
#14	Remote E-stop	E-Stop Signal	Nav Mode OFF

6.6 Chassis

This subsystem is the physical frame and mounts of the system which will contain all other systems necessary to create the overall system. This subsystem also encompasses the motors as they will be mounted onto the chassis.

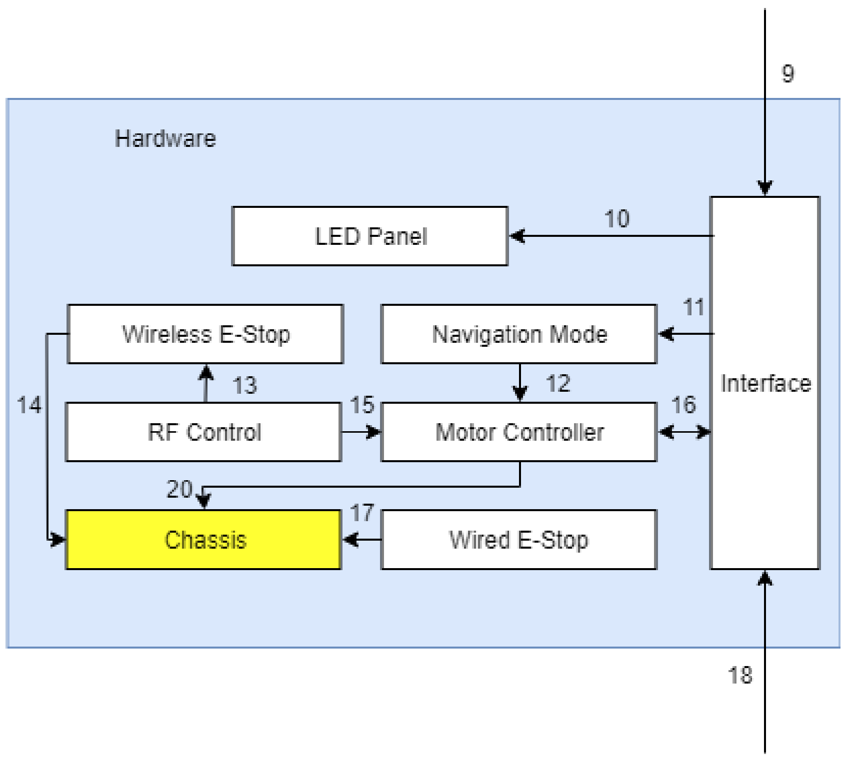

Figure 15: Hardware - Chassis Subsystem

6.6.1 Assumptions

The chassis should be large enough to fit the payload and any electronics necessary electronics and components. The chassis should also be waterproof and resilient.

6.6.2 Responsibilities

Protect the internal components of the system and have space to carry the payload.

6.6.3 Subsystem Interfaces

There are no inputs or outputs for this subsystem as it consists of the housing for other subsystems.

6.7 Interface

This subsystem will handle data processing and send information to and from the computer. This subsystem encompasses the portion of the hardware systems that allow the flow of information, such as the control signals received by the motor controller or the serial communication used to transmit data over a physical connection.

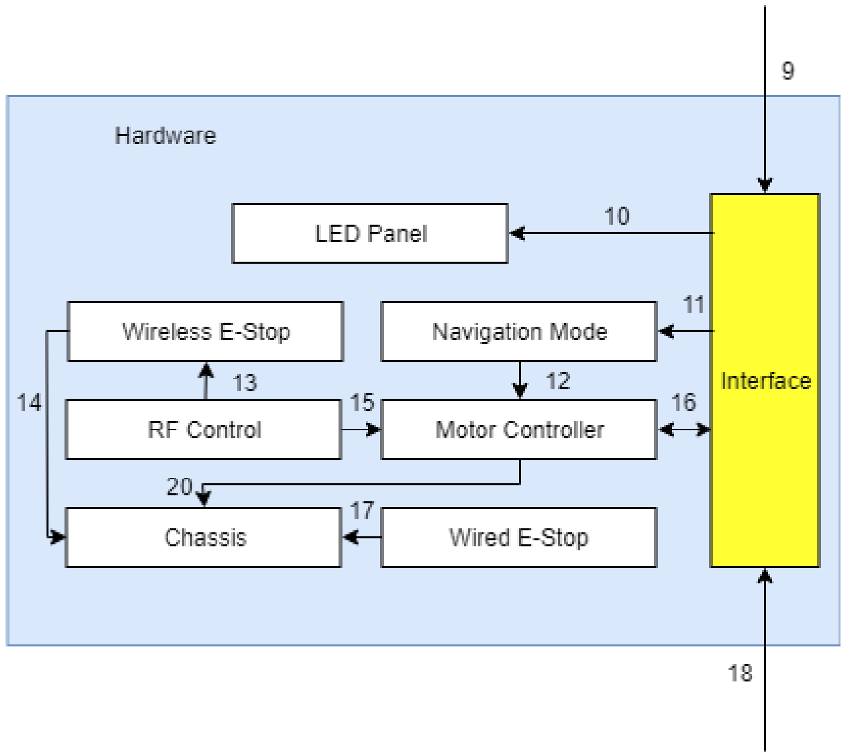

Figure 16: Hardware - Interface Subsystem

6.7.1 Assumptions

All physical connections will be able to support the necessary protocols used for the transfer of data in the system. Odometry data will be correct.

6.7.2 Responsibilities

This subsystem will be able to reliably transfer data from one point to another in the system and interconnect all subsystems that are intertwined to create the overall system.

6.7.3 Subsystem Interfaces

This subsystem is the main interface to the rest of the subsystems and will serve direct the flow of information coming into the motor controller. As such, it is directly connected to that subsystem and receives input from the Navigation interface and central control processes.

Table 14: Hardware interface

ID	Description	Inputs	Outputs
#10	System Status LEDs	System Status Data	Status LEDs ON/OFF
#20	System Movement	Pathfinding Output	Motor Signals

7 Navigation

The navigation system will be responsible for creating a path from its current location to the intended location based on the information it gets from the external sensors and the computer vision systems. The navigation layer will be split up into two distinct subsystems: Path Finding and SLAM.

7.1 SLAM

The Simultaneous Localization and Mapping (SLAM) is the synchronous location awareness and recording of the environment in a map of a computer, device, robot, drone or other autonomous vehicle. The data is received from the Computer Vision system and once slam gets done with the data it is then sent to the pathfinding subsystem.

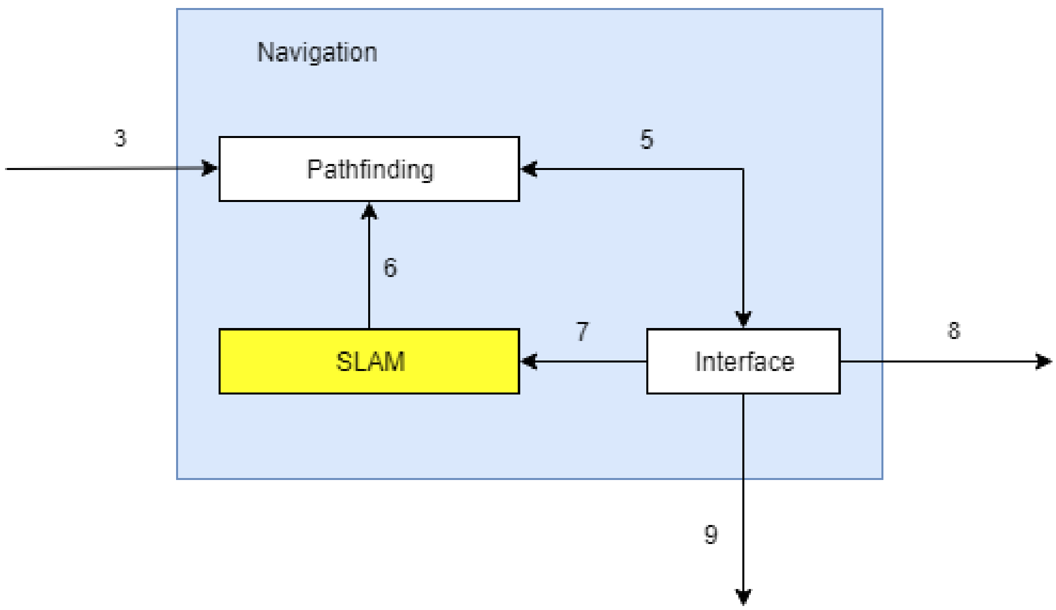

Figure 17: Navigation - SLAM Subsystem

7.1.1 Assumptions

The assumption that is being made is that the data received from the subsystems are correct.

7.1.2 Responsibilities

The SLAM subsystem is responsible for using the data that it receives from the Computer Vision subsystem and creating a map of its environment. After the map is created it will pass that data to the Pathfinding subsystem.

7.1.3 Subsystem Interfaces

Input data is obtained from the Computer Vision and the External sensors subsystems, then it will create a map of its environment from those subsystems and send that data to the Pathfinding subsystem.

Table 15: SLAM interfaces

ID	Description	Inputs	Outputs
#7	Computer Vision	Obstacle recognition Lane recognition	None
#6	SLAM output data	None	Map

7.2 Pathfinding

The Pathfinding subsystem will get the map from the SLAM subsystem and use that map to determine the best path to get to its goal destination. Pathfinding will also avoid collisions with objects and avoid potholes.

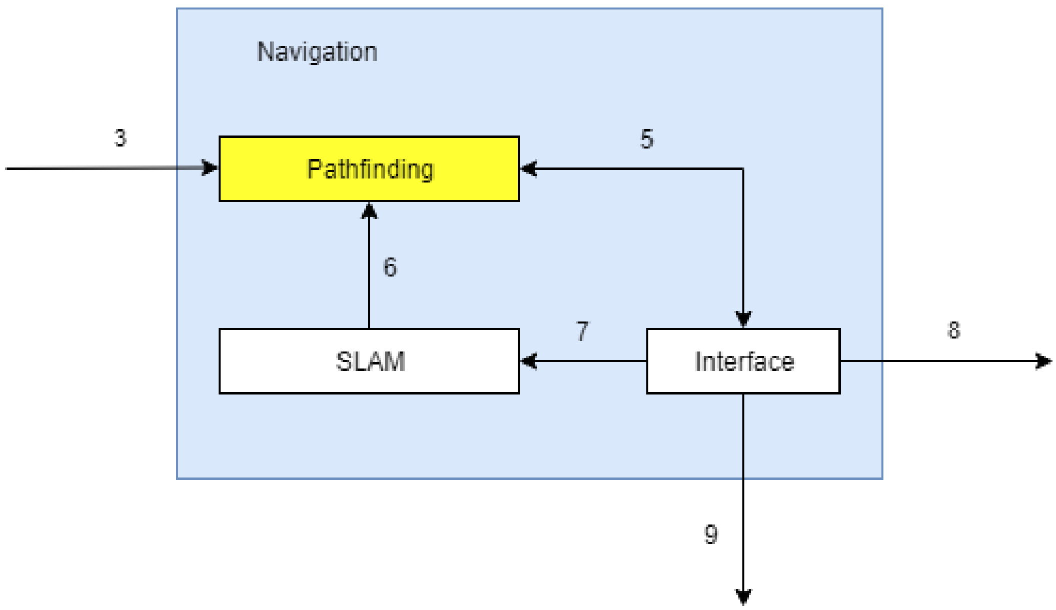

Figure 18: Navigation - Pathfinding Subsystem

7.2.1 Assumptions

The assumptions that will be made is that all the data that is received from the SLAM is correct.

7.2.2 Responsibilities

The Pathfinding subsystem is responsible for ensuring that the AutoMav will get to its goal without any collisions.

7.2.3 Subsystem Interfaces

Table 16: Pathfinding interfaces

ID	Description	Inputs	Outputs
#6	SLAM	Map form SLAM	None
#5	Interface	GPS Data	None
#3	From Computer vision interface	Lane and object recognition	None

8 Computer Vision

The computer vision system is responsible for taking images captured by external sensors and recognizing obstructions in the vehicle's path as well as recognizing lane lines. Obstacle recognition will utilize a 3D camera that provides depth information to detect objects in front of the vehicle. Lane recognition will use 2D camera data to search for edges in images containing painted lanes and painted potholes. The output of both computer vision nodes are used to construct a map of the vehicle's surroundings and is sent to the path-finding subsystem.

8.1 Obstacle Recognition

The Obstacle Recognition node will use data obtained from a 3D camera on the front of the vehicle to map the location of obstacles in the vehicle's path.

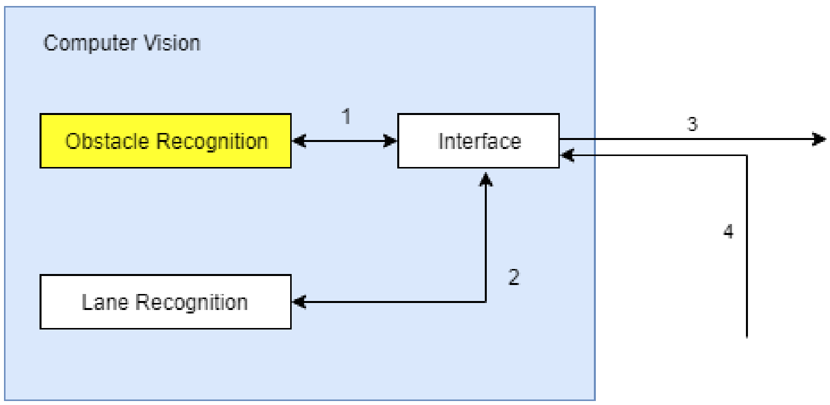

Figure 19: Computer Vision - Obstacle Recognition Subsystem

8.1.1 Assumptions

The system assumes that the 3D camera is operating and providing accurate enough data to reflect the vehicle's surroundings.

8.1.2 Responsibilities

Obstacle Recognition is responsible for taking data provided by the 3D camera and calculating a map of any obstacles that were captured on the camera's sensors. The system is also responsible for ignoring data that is anomalous or insignificant to avoid inaccurate results.

8.1.3 Subsystem Interfaces

The input for the system is 3D image data from the 3D camera and the system outputs a map of recognized obstacles.

Table 17: Obstacle Recognition interfaces

ID	Description	Inputs	Outputs
#1	Obstacle Recognition output map	3D Camera Data	Obstacle Map

8.2 Lane Recognition

The Lane Recognition system will use data obtained from the 3D camera on the front of the vehicle to map lanes within sensing distance of the vehicle.

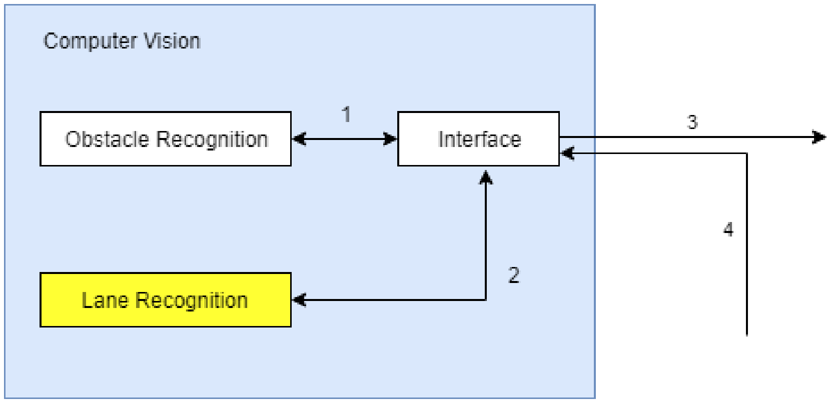

Figure 20: Computer Vision - Lane Recognition Subsystem

8.2.1 Assumptions

The system assumes that the camera is operating and providing accurate enough data to detect lane markings.

8.2.2 Responsibilities

Lane Recognition is responsible for taking the 2D camera data and mapping the location of painted lane markings. The system is also responsible for ignoring data that is anomalous or insignificant to avoid inaccurate results.

8.2.3 Subsystem Interfaces

The input for the system is 2D image data from the 3D camera and the system outputs a map of recognized lane markings.

Table 18: Lane Recognition interfaces

ID	Description	Inputs	Outputs
#2	Lane Recognition output map	2D Camera Data	Lane Map

8.3 INTERFACE

The interface for the computer vision system will organize the input data for both the obstacle recognition and lane recognition systems. The interface will then combine the outputs from both systems to create a final occupancy grid that is sent to the navigation system.

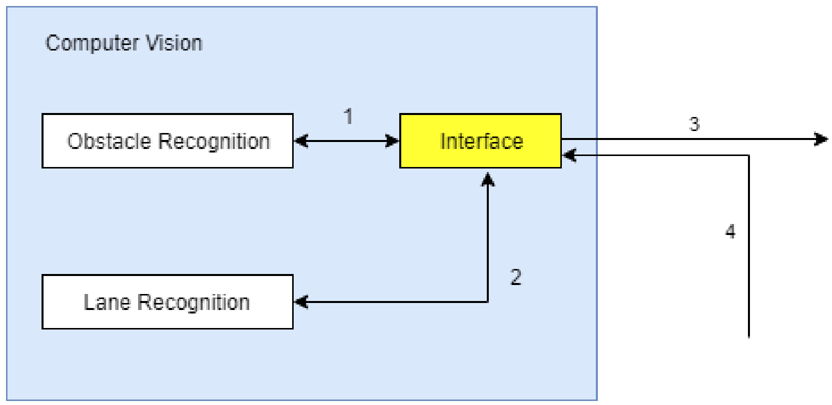

Figure 21: Computer Vision - Interface Subsystem

8.3.1 ASSUMPTIONS

The system assumes that the obstacle recognition and lane recognition systems are functioning correctly and are producing output.

8.3.2 RESPONSIBILITIES

The interface is responsible for receiving image data from the vehicle's external cameras and providing the correct inputs to obstacle recognition and lane recognition. The interface is also responsible for packaging all the outputs of the computer vision system and transmitting it to the navigation system.

8.3.3 SUBSYSTEM INTERFACES

Image data is obtained from the vehicle's external cameras. The interface also obtains the recognition maps from obstacle recognition and lane recognition and sends a combined version to the navigation system.

Table 19: Computer Vision interfaces

ID	Description	Inputs	Outputs
#4	Input data handling	Camera Data	N/A
#3	Map combination	Recognition Maps	Final Map

References

[1] J. Lane and A. Kosinski, "The 27th Annual Intelligent Vehicle Competition (IGVC) and Self-Drive: Official Competition Details, Rules and Format," IGVC, 26 Nov. 2018. [Online]. Available: http://www.igvc.org. [Accessed: 11 Nov. 2018].