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

Architectural Design Specification
CSE 4316: Senior Design I
Summer 2024

IGVC Engineers
Intelligent Ground Vehicle Competition - Qualifier

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Revision History

Revision	Date	Author(s)	Description
0.1	04.11.2024	JS	Document Creation
0.2	04.11.2024	JS	Title page & revision history
0.3	04.27.2024	VC	Rough Draft - Introduction, System Overview, Drive System Layer Description, Website Layer
1.0	05.03.2024	JS, VC, AF, CB, SV	First Draft
2.0	07.31.2024	DB, DG, HA, JC, NA, CN	First Release

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1 Introduction

This section serves as a reinforcement of the product background and requirements to be met to ensure a successful product launch.

1.1 Product Concept

The main product will be a vehicle that can navigate around a closed course. The vehicle will comply with the rules and regulations of the annual Intelligent Ground Vehicle Competition (IGVC) AutoNav Challenge.

The vehicle is a collection of systems that are integrated together to achieve successful autonomous navigation. The product also includes packaged documentation for use and development for respective parties. Standard documentation relating to product use will be available to all needing to use the product. Source Code documentation will only be available to developers. Documentation may be accessed via custom website built to track progress.

1.2 Key Requirements

The key requirements for the vehicle are listed as follows:

- Computer Vision
  - The vehicle will have the capability to detect and avoid obstacles.
  - The vehicle will have lane detection.
- Platform/Vehicle Base
  - The vehicle will have a base that adheres to the physical restraints posed by the competition regulations.
  - The vehicle will support a 20lb payload and will maintain its course until the end of the path.
- Drive and Motion
  - The vehicle will navigate a path and complete its course with minimal stalling or pauses in motion.
  - The vehicle will maintain speed within the speed limits listed in the competition rules.
- GPS
  - The vehicle will receive and transmit positional information through the use of a Cube Orange and a base station.
  - Remote signaling will occur if a correction is to be made to the path.

Note: Please view the System Requirements Specification (SRS) document for a complete list with greater detail.

2 SYSTEM OVERVIEW

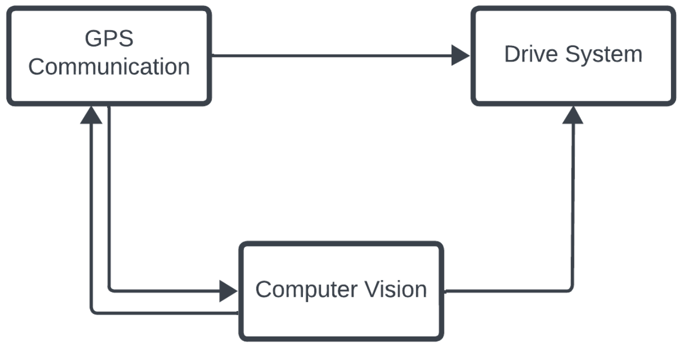

Figure 1: IGVC Vehicle Software System Architecture Diagram

The layers depicted in figure 1 are named after their respective components. It was concluded that the names given to each layer, sufficiently contain the subsystems found within. The layers are centered around the drive system layer as that is the core software component of the vehicle.

2.1 DRIVE SYSTEM LAYER DESCRIPTION

The drive system is the central system of the vehicle. This is where all movement will be registered and executed. The power management layer will relay information on how much power to draw for a specific target speed or maneuver. The drive system will take the information and produce a specific movement. The drive system layer will include a motion subsystem responsible for 360 degree movement. It will take as input the movement instruction from the computer vision layer or GPS layer and map the input to a power function that gets executed through the drive system. The drive system is responsible for all motorized movement. The drive system will not have any kind of response or feedback. Any interrupts will be handled by Computer vision and the main drive will be provided by the GPS layer.

2.2 COMPUTER VISION LAYER DESCRIPTION

Computer vision will be used in an "as needed" basis. While the system is active, the computer vision layer will continually poll the area for obstacles. While no obstacles are nearby, computer vision will only poll for information. When the robot encounters an obstacle, it will be the job of computer vision to interpret that there is an obstacle, and interrupt the main drive program with "object avoidance software". Computer vision will supply the drive component with new directives to circumvent the obstacle. After the object has been defeated the main drive system will regain control.

2.3 GPS COMMUNICATION LAYER

GPS will be the core feature to the navigation with computer vision being used as an "if needed" basis. The basis for the GPS navigation will be through mission planner software system. Mission planner uses active GPS locating with a mapping feature that can supply information on where the robot will travel. Interrupts will be used from computer vision to override the GPS coordinates set by mission planner. The GPS coordinating layer will take over and supply direction to the drive system while the computer vision system is idle.

3 Subsystem Definitions & Data Flow

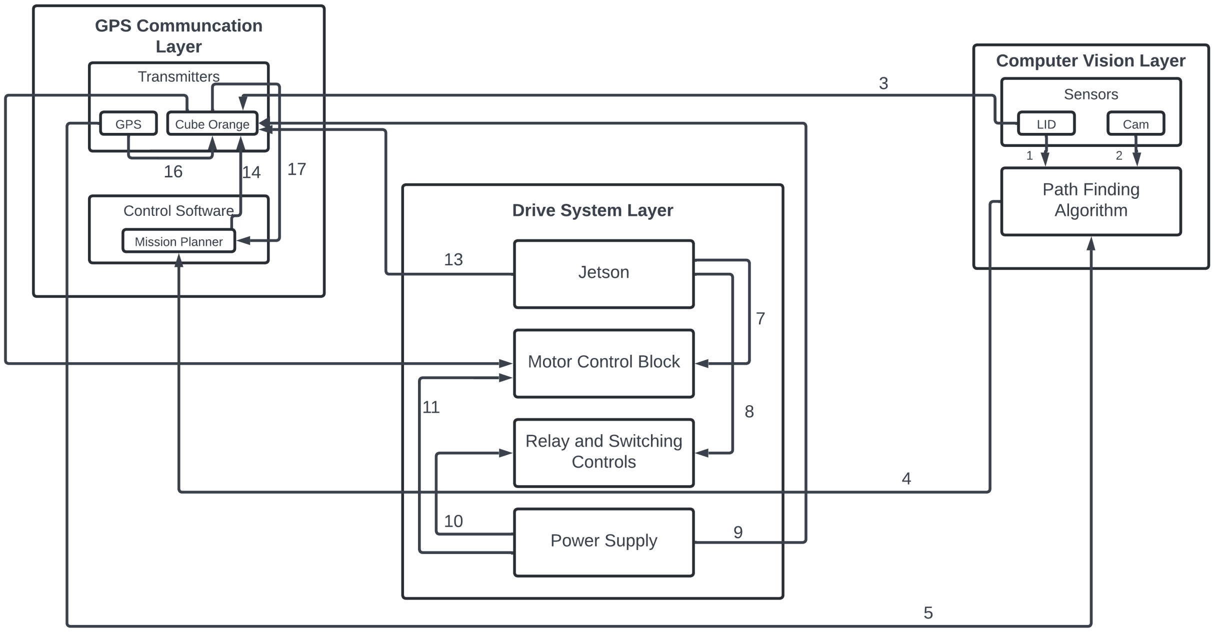

Figure 2: Data flow of product layers. Input/output pair denoted by an arrow

4 Computer Vision Subsystems

The IGVC computer vision subsystem integrates two primary sensor components, LiDAR and cameras, to gather environmental data. This data is processed by the computer vision subsystem, which encompasses object detection and lane detection functionalities. Object detection algorithms identify obstacles, signs, and pedestrians, while lane detection algorithms identify road markings for navigation. Through the fusion of LiDAR and camera data and the implementation of computer vision algorithms, the subsystem enables the vehicle to perceive its surroundings, detect obstacles, and navigate lanes autonomously, crucial for safe and efficient operation in the IGVC competition.

4.1 Sensors

The sensor subsystem will gather and process data for the path-finding algorithms subsystem. Within this subsystem, a LiDAR sensor is employed to precisely measure distances to objects or surfaces, while a camera captures images essential for recognition tasks. Together these sensors provide critical information for navigation and decision-making processes within the IGVC framework.

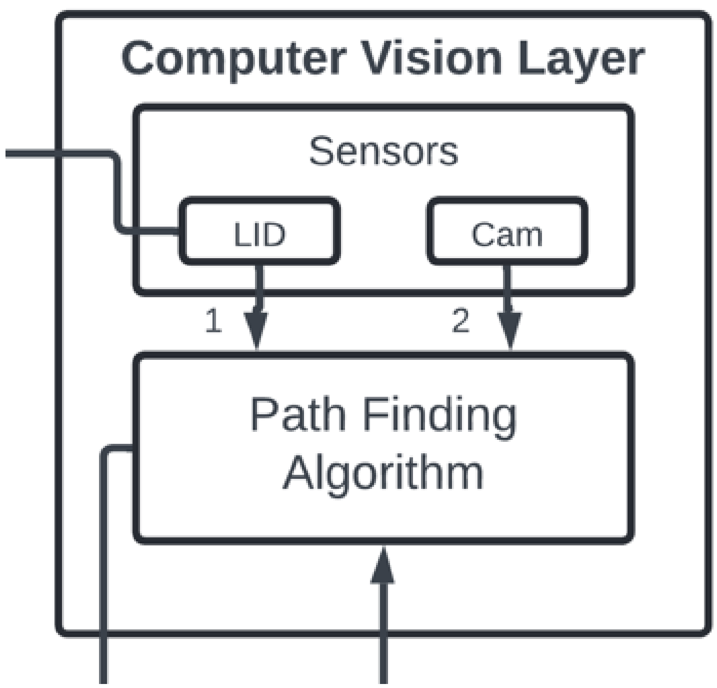

Figure 3: Sensors subsystem description diagram

4.1.1 Sensor Assumptions

The sensors assume to provide accurate and reliable data for distance measurement and image capture, as well as compatibility with the communication protocols and interfaces required for integration with the path finding algorithms subsystem.

4.1.2 Sensor Responsibilities

It comprises several key components, each with distinct responsibilities crucial for the effective operation of the Intelligent Ground Vehicle Competition (IGVC). The LiDAR sensor is tasked with measuring distances to objects or surfaces with exceptional accuracy, generating 3D point clouds of the environment, and providing real-time data for obstacle detection and localization. Concurrently, the camera is responsible for capturing high-resolution images of the surroundings, facilitating object recognition, lane detection, and semantic segmentation tasks. It must ensure optimal focus, exposure, and image quality under varying lighting conditions while transmitting images promptly for processing by the path finding algorithm subsystem.

4.1.3 Sensor Subsystem Interfaces

The sensors subsystem provides image and data inputs for the path finding algorithm module.

Table 2: Sensor Subsystem interfaces

ID	Description	Inputs	Outputs
#xx	Camera object recognition	Compressed image	Image data
#xx	Camera processing image compression	Image frames	Compressed image
#xx	LiDAR	Light waves	Light waves 3D Point Cloud

4.2 Path Finding Algorithm

The Pathfinding Algorithm subsection assumes responsibility for effectively navigating the Intelligent Ground Vehicle Competition (IGVC) environment by integrating object detection and lane detection functionalities. Leveraging data from LiDAR and cameras, it identifies obstacles like pedestrians, vehicles, and static objects with precision, ensuring real-time updates to facilitate obstacle avoidance and path planning. Additionally, it processes visual data to detect lane markings and boundaries, ensuring the vehicle maintains proper alignment. Through robust path planning algorithms, it generates safe and efficient routes, considering factors such as obstacle avoidance and route optimization.

4.2.1 Path Finding Assumptions

A predefined model is provided to assist in correctly identifying objects and lanes respectively. It is assumed that the image data has been captured and processed in real-time, enabling timely analysis and decision-making.

4.2.2 Path Finding Responsibilities

The subsystem is responsible for accurately classifying objects to dictate the vehicle's actions and behavior during navigation. Depending on the identified obstacle, whether it is a cone or ramp, the classification will influence the IGV's movements, aiding in obstacle avoidance and path planning. The subsystem is responsible for accurately classifying objects to dictate the vehicle's actions and behavior during navigation.

4.2.3 Path Finding Subsystem Interfaces

This subsystem will take inputs from the camera sensor and LiDAR that is used to detect lanes and obstacles in real time.

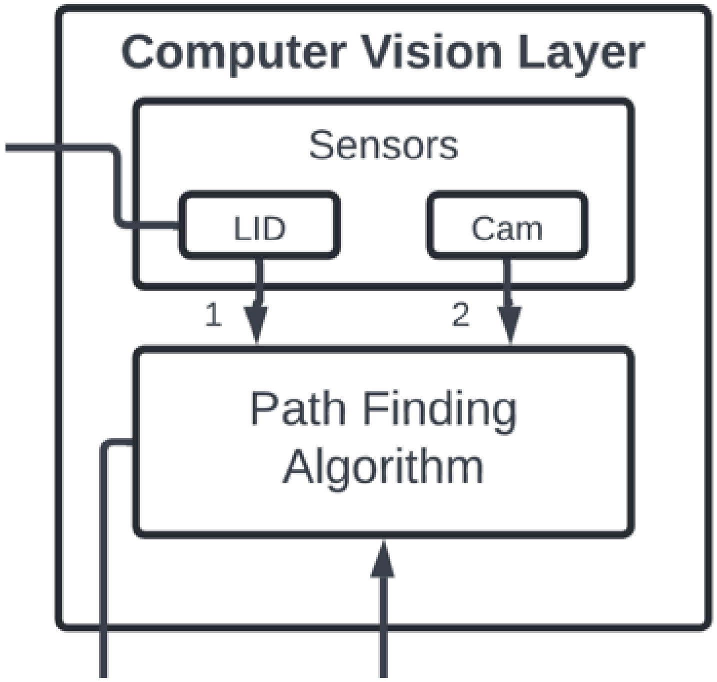

Figure 4: Path Finding Algorithm subsystem description diagram

Table 3: Path Finding Subsystem interfaces

ID	Description	Inputs	Outputs
#xx	Object detection	Image data Compressed image	Obstacle grid
#xx	Lane detection	Image data Compressed image	Lane grid
#xx	GPS	Coordinates	Path

5 Drive System Subsystems

5.1 Motor Control Block

This section details the motor control block which is the front line of execution of any control commands issued by the system. There are priorities of commands sent to the MCB (Motor Control Block) since one command may be more urgent than the other. The priorities of the two commands sent to the MCB are FSU Control (Low Priority) and Micro-Controller Commands (High Priority). This is shown in Figure 10 and elaborated in Table 8 about the signals it comprises of. It is to note that the priority signals as shown in the figure are mixed between Hardware and software layers and have been established for coherence.

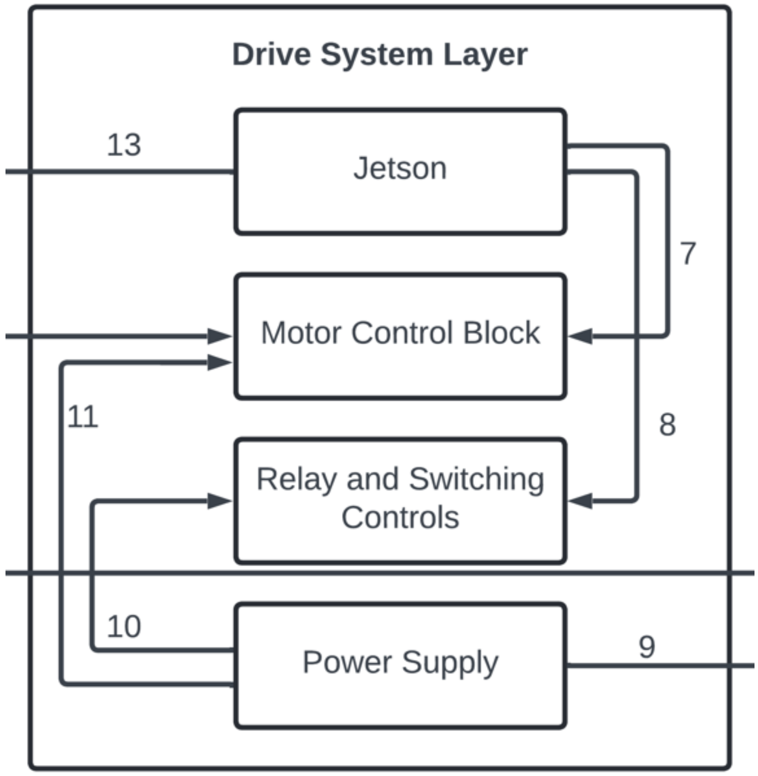

Figure 5: Motor Control Block of the Vehicle

5.1.1 Assumptions

It is assumed that there is synchronous and uninterrupted communication between the micro-controller and the Flight Sensory Unit to determine what priority of command needs to be executed.

5.1.2 Responsibilities

The responsibility of this block is to ensure that upon later implementation there will be coherence for manned (manual) and unmanned (autonomous) missions and the same motor logic will be used without making any changes to the hardware.

5.1.3 Subsystem Interfaces

The motor driver receives both types of commands and executes them concerning their priority. Within the system, the subsystem interfaces play a crucial role as they receive precise PWM signals, enabling effective control over various components. To ensure smooth functionality, the subsystem draws power from the batteries, providing the necessary energy for operation. Once powered, it efficiently delivers the required DC voltage to activate and regulate the motors performance, contributing to the overall systems seamless operation.

Table 4: Subsystem interfaces of Motor Control Block

ID	Description	Inputs	Outputs
#12	Cube Orange to Motors Control Block	N/A	Current
#11	Power Supply to Motor Control Block	N/A	Controls
#8	Jetson to Motor Control Block	N/A	Controls

5.2 Relay and Switching Controls Layer

This section details the Flight Sensory unit which though has been called Cube Orange in many parts of this document, comprises a wide range of sensors and connections to execute manned operations and or guided modes. Figure 11 shows a block diagram of the logical units inside the FSU.

5.2.1 Assumptions

It is assumed that there is synchronous and uninterrupted communication between the components and sensors to and from the FSU (Cube Orange)

5.2.2 Responsibilities

The responsibility of this block is to regulate that there is adequate information for guided or unguided missions and help autonomous controls.

5.2.3 Subsystem Interfaces

The following are the system interfaces in the FSU unit.

Table 5: Subsystem interfaces of Relay and Switching Controls Layer

ID	Description	Inputs	Outputs
#10	Power Supply to Relay and Switching Controls	Data	Controls
#7	Jetson to Relay and Switching Controls	Data	Controls

5.3 Jetson Layer

5.3.1 Assumptions

The assumption laid in this block is that there is bi-directional communication between the Cube Orange and the Jetson, this means that all parameters are globally shared to all devices such that there is no command bypassing the primary control of the unit.

5.3.2 Responsibilities

Responsibilities of this control block are to deliver low-level control functions from the Jetson and allow a bypass from the Cube Orange regarding guided missions and become a companion computer for the

Primary control unit to allow faster high-level code execution. This module is also ensuring key UGV roles such as hardware speed regulation and safety controls when needed.

5.3.3 Subsystem Interfaces

The following are the interfaces needed by the Jetson: NOTE: All control signals are of Serial Interface, No PWM generation will be needed.

Table 6: Subsystem interfaces of Jetson Layer

ID	Description	Inputs	Outputs
#13	Serial Interface from Cube Orange	Machine State and heartbeat information	Controls
#8	Motor Control Serial interface	N/A	Controls
#7	Relay and Switching Controls	N/A	Controls

5.4 Power Supply Layer

5.4.1 Assumptions

All power is pre-regulated by Hardware thus no DC smoothing or offsets are present

5.4.2 Responsibilities

This module is responsible for implementing an individual powering system for the AGV which is electrically managing power use, battery states, reverse voltage protection, and implementing a circuit cut-off on sub-system failure using no control signals at all.

5.4.3 Subsystem Interfaces

Table 7: Subsystem interfaces of Power Supply Layer

ID	Description	Inputs	Outputs
#9	Cube Orange to Power Supply	N/A	Current
#11	Power Supply to Motor Control Block	N/A	Controls
#10	Power Supply to Relay and Switching Controls	N/A	Controls

6 GPS Communication Subsystems

The GPS Communication subsystem is design to facilitate the navigation capabilities within the autonomous system, integrating two key components: the GPS unit and the Cube Orange controller. The GPS unit is tasked with providing precise location data, which is essential for real-time positioning and navigation. The data is relayed to the Cube Orange, which processes the information and interacts with the Mission Planner software to manage navigation paths and communication. The Subsystem ensures that the vehicle operates effectively within its environment, adapting to various conditions and finding the most optimal path.

6.1 GPS Transmitter

This subsystem encompasses the GPS unit. The GPS unit provides real-time positioning data for navigation and coordination tasks.

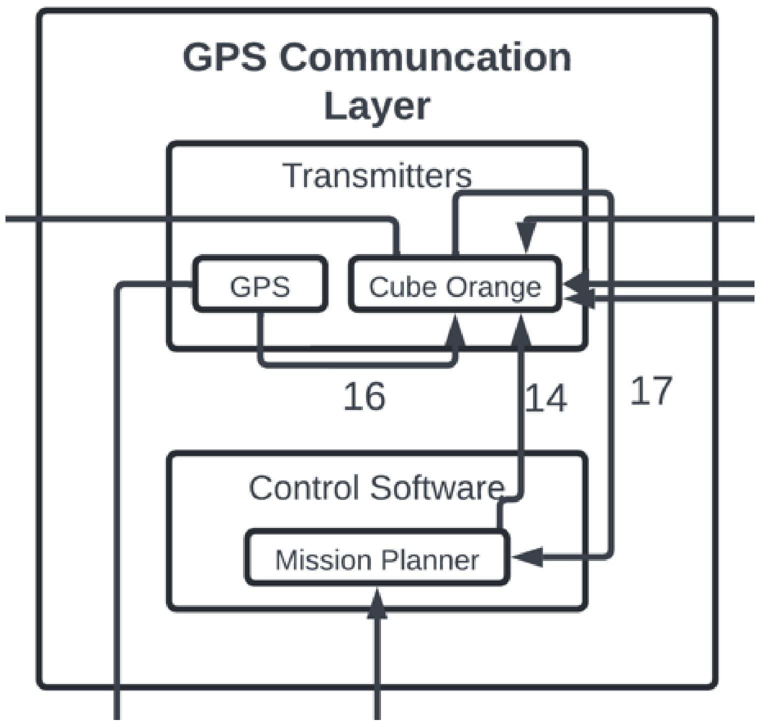

Figure 6: GPS Subsystem Diagram

6.1.1 Assumptions

For the GPS unit, we assume they are precisely calibrated to provide location data with minimal deviation. The accuracy of the GPS is essential, the system needs the vehicle's coordinates to stay within 2 feet of actual readings to effectively navigate in lanes that are 15 feet wide and maintain a clearance space of 5 feet around obstacles.

6.1.2 Responsibilities

The primary responsibilities of the GPS unit is to obtain the exact location of the vehicle and transmit this information to the Cube Orange. The data gathered is forwarded to the companion computer for archiving purposes, giving us value data points for future testing and to refine the system's accuracy and reliability.

6.1.3 GPS Interfaces

Table 8: Subsystem interfaces

ID	Description	Inputs	Outputs
#5	Connection to the Cube Orange Module	N/A	GPS Coordinates
#16	Connection to Path-finding Algorithm	N/A	GPS Coordinates

6.2 Cube Orange Transmitter

The Cube Orange is the center processing unit, interacting with various other subsystems to manage and distribute tasks effectively.

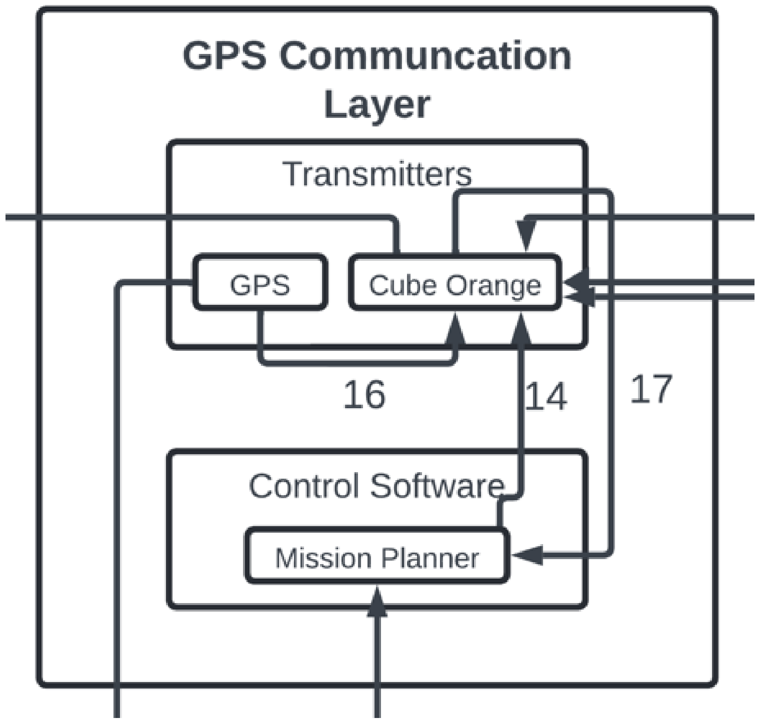

Figure 7: Cube Orange subsystem diagram

6.2.1 Assumptions

For the Cube Orange, it is assumed to reliably gather and transmit system data including motor position, speed, GPS location of the vehicle, and the battery's charge state.

6.2.2 Responsibilities

The Cube Orange is tasked with ensuring a seamless integration and command execution across various subsystems. It processes the LiDAR data into a point cloud format, which is essential for navigation and obstacle detection, it then forwards the information to Mission Planner. Cube Orange also receives navigation commands from Mission Planner, directing the vehicle to adjust its path if required, either to avoid obstacles or follow the predetermined path set by Mission Planner.

6.2.3 Cube Orange Interfaces

Table 9: Subsystem interfaces

ID	Description	Inputs	Outputs
#3	Connection from the LiDAR to the Cube Orange	Point Cloud Data	N/A
#9	Connection from the Power Supply to the Cube Orange	Current	N/A
#12	Connection from the Cube Orange to the Motor Control Block	Control [PWM]	N/A
#13	Connection from the Jetson to the Cube Orange	Control [Serial]	N/A
#14	Connection from the Mission Planner to the Cube Orange	Command Data	N/A
#15	Connection from the Cube Orange to the Mission Planner	N/A	Point Cloud and current GPS Coordinate Data
#16	Connection from the GPS to the Cube Orange Module	Coordinate Data	N/A

6.3 Mission Control Software

The Mission Planner software maps navigation courses for the vehicle using GPS data to generate a detailed map of the environment. It processes obstacle and lane information provided by the sensor layer and facilitates the route planning and control.

6.3.1 Assumptions

Our assumption is that the Mission Planner software will effectively utilize precise GPS data, along with obstacle and lane detection information, to accurately map and plan navigational paths.

6.3.2 Responsibilities

Mission Planner is primarily responsible for creating and managing the navigational routes the vehicle follows. Using the data received from Cube Orange and the sensor layers, Mission Planner actively makes real-time decisions to navigate around obstacles. Furthermore, it is tasked with updating and transmitting necessary route adjustments back to the Cube Orange, this ensures that the vehicle can dynamically respond to the environment to find the optimal path.

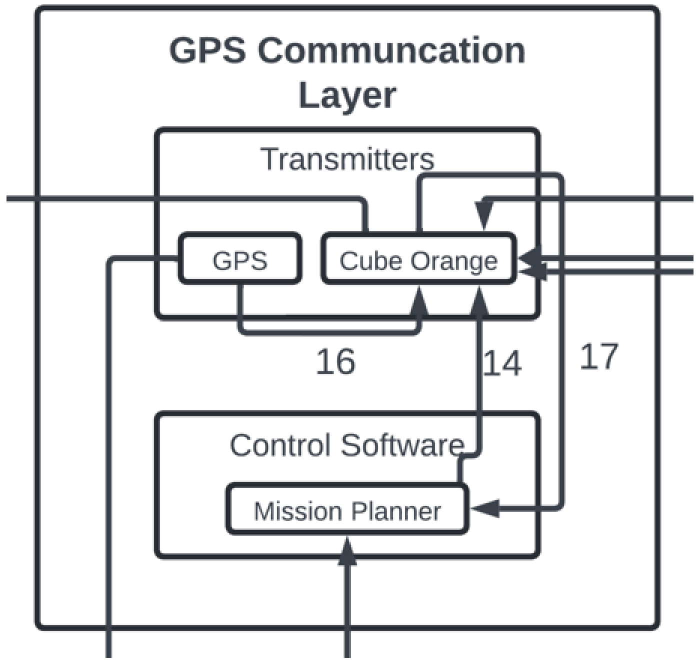

Figure 8: Mission Planner subsystem diagram

6.3.3 Mission Planner Interfaces

Table 10: Subsystem interfaces

ID	Description	Inputs	Outputs
#4	Connection from the path-planner to the Mission Planner Module	Obstacle and Lane Data	Nodes for A*
#14	Connection from the Mission Planner Module to the Cube Orange Module	N/A	Data Commands
#15	Connection from the Cube Orange Module to the Mission Planner Module	Point Cloud Data	Nodes for A*

References

N/A