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

Architectural Design Specification
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IGVC Computer Vision Team
IGVC Computer Vision Module

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Revision History

Revision	Date	Author(s)	Description
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Contents

1 Introduction **5**

2 System Overview **6**
2.1 Layer Sensor Description . . . 6
2.2 Layer Output Description . . . 6
2.3 Layer Computer Vision Description . . . 6

3 Subsystem Definitions & Data Flow **8**

4 Sensors Layer Subsystems **9**
4.1 Subsystem Camera . . . 9

5 Computer Vision Layer Subsystems **10**
5.1 Obstacle detection . . . 10
5.2 Lane detection . . . 11

6 Output Layer Subsystems **12**
6.1 Dot Matrix Map . . . 12

List of Figures

1	Simplified architectural layer diagram	6
2	A simple data flow computer vision module diagram	8
3	Camera subsystem description diagram	9
4	Object detection subsystem description diagram	10
5	Lane detection subsystem description diagram	11
6	Output subsystem description diagram	12

List of Tables

2	Subsystem interfaces	9
3	Subsystem interfaces	10
4	Subsystem interfaces	11
5	Subsystem interfaces	12

1 Introduction

The product is a modular component built for the Intelligent Ground Vehicle Competition (IGVC) vehicle and serves the purpose of acting as its computer vision solution. This solution should be capable of identifying obstacles, road constraints of the IGVC course using onboard sensors (cameras), communicating this information to the path-planning aspect, as well as the vehicle competing in the IGVC in 2024.

2 System Overview

In summary, the IGVC computer vision architecture involves an on-board camera, sophisticated processing components, and databases working together to enable a ground vehicle to perceive its environment, make informed decisions, and navigate autonomously. This integrated approach is crucial for the successful participation of vehicles in the competition. As our team is working on the computer vision aspect of this IGVC project, this architecture would consist of cameras, image and data processing components, and databases.

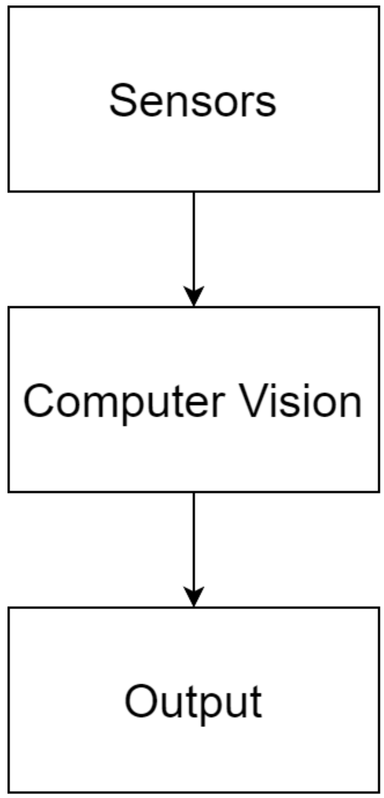

Figure 1: Simplified architectural layer diagram

2.1 Layer Sensor Description

The cameras will collect data based on their surroundings and will be sent to different modules for calculations and detection. The camera will process the surroundings and save images to be sent to the computer vision module.

2.2 Layer Output Description

This layer is concerned with taking inputs from other subsystems and providing outputs to the path planner team. A dot matrix map is to be communicated to the path planner that is generated from the computer vision layer in the off-board computer and is to be packaged with measured distance information to be sent to the path planner at a rate of ten times a second.

2.3 Layer Computer Vision Description

The computer vision technology will recognize obstacles and detect lanes based on the images provided by the camera sensor to help navigate through the course. The image will be compressed to optimize processing power and time. To help detect lanes better, filtering techniques and Hough transforms are applied to enhance the accuracy of lane detection. For obstacle detection, the image processed will be identified through the predefined model actively recognizing the object and outputted as a grid-based representation due to computational resources. Similarly, lane detection will operate the same as obstacle detection for output. The output may change depending on the IGVC's computational resource since the minimum we need is for the camera to notice a meter or less in front of it for lane detection.

3 Subsystem Definitions & Data Flow

This section shows how the flow of information is passed between different subsystems in the layers between different layers.

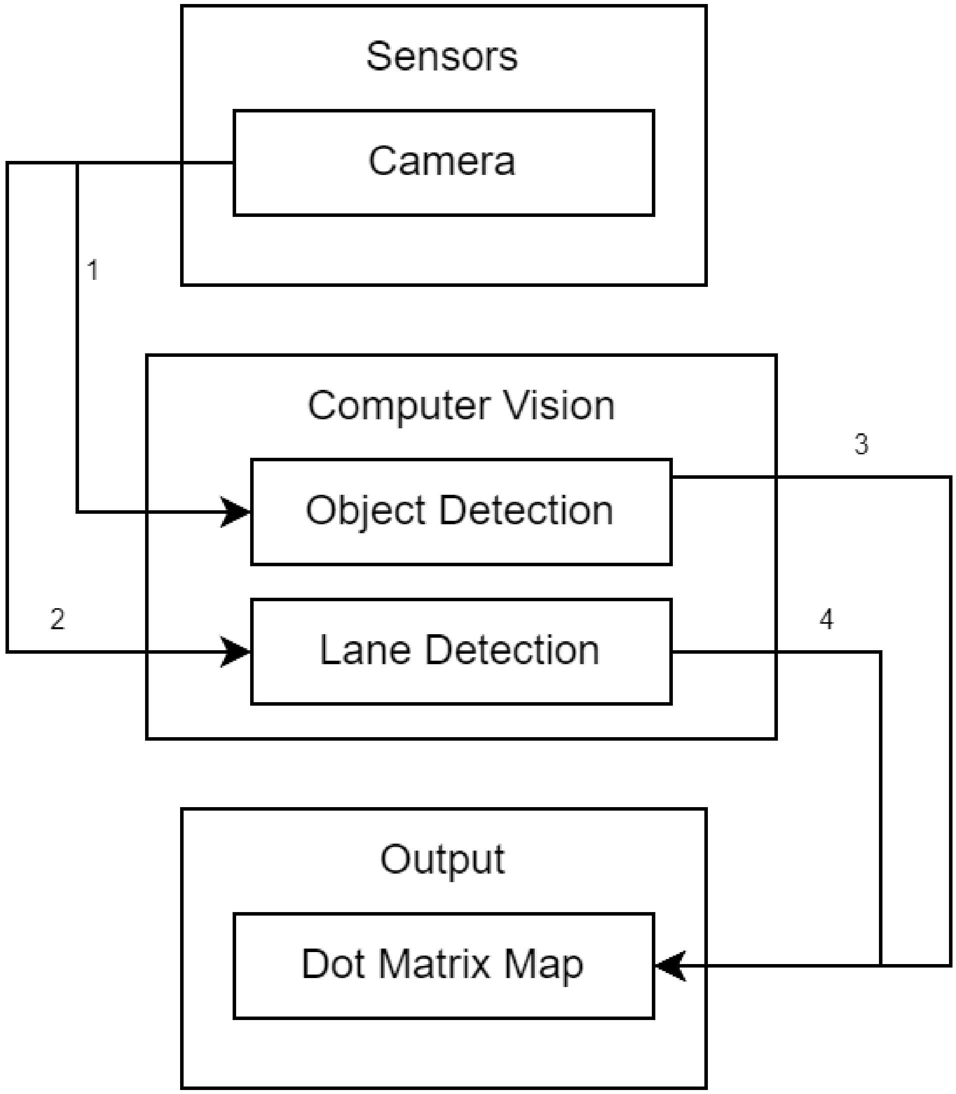

Figure 2: A simple data flow computer vision module diagram

4 Sensors Layer Subsystems

The camera will measure and collect data to provide to the computer vision layer and output layer for the path planning team.

4.1 Subsystem Camera

The camera will be mounted on top of the vehicle to optimally capture the surroundings. The camera will process the images in real-time and will be compressed and sent to the computer vision module as input.

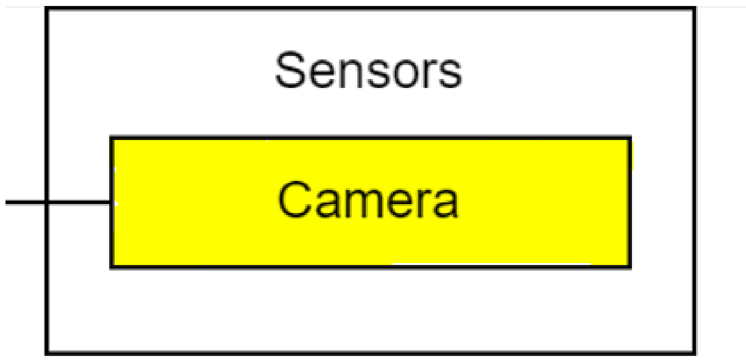

Figure 3: Camera subsystem description diagram

4.1.1 Assumptions

Camera hardware is taken into consideration of its resolution, frame rate, and field of view. The calibration of the camera is optimized to fit our computer vision module's design of distortion correction and focal length. The data processing by the camera will be the images based on the frames of the camera, we'll assume the frame rate of the camera to be 25 fps and real-time processing 1 of every 5 frames, and compress the image. Pre-trained model is created that accepts the real-time processed image and outputs the results.

4.1.2 Responsibilities

The camera will be processed in real-time of its surroundings or desired area coverage and the image will be sent to the pre-trained model for object detection and classification. The camera will be placed at an optimal height that covers the majority of the area the IGVC needs to see to navigate around the course. If multi-cameras are needed for later improvements or redesign, then calibration is considered.

4.1.3 Subsystem Interfaces

This subsystem will capture an image and provide the data to the computer vision module.

Table 2: Subsystem interfaces

ID	Description	Inputs	Outputs
#1	Camera real-time streaming objects	N/A	Data as Images
#2	Camera real-time streaming lanes	N/A	Data as Image

5 Computer Vision Layer Subsystems

The computer vision module will take the surrounding images to identify what the obstacles are and keep track of the lane. The camera will communicate to the computer vision module and give them an image as input and the module will output a video feed of the identified obstacles for further processing eventually detecting the distance.

5.1 Obstacle detection

The obstacle detection will take the input given by the camera and will identify the obstacles around their surroundings.

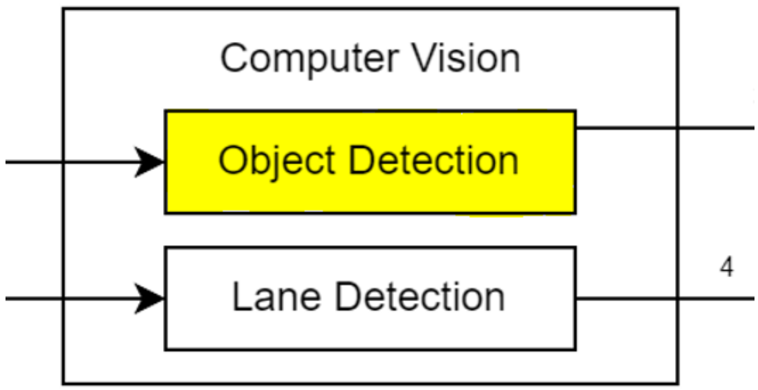

Figure 4: Object detection subsystem description diagram

5.1.1 Assumptions

A pre-trained model is able to confidently identify the obstacles. The image has been captured and processed in real-time.

5.1.2 Responsibilities

Correctly classifies the object to dictate the IGVC's actions and behavior when navigating through the course to progress. Depending on the obstacle, whether a cone, pothole, or ramp, it will influence the IGVC's movements.

5.1.3 Subsystem Interfaces

This subsystem will take inputs from the camera sensor that is used to classify objects in real-time.

Table 3: Subsystem interfaces

ID	Description	Inputs	Outputs
#1	Obstacle classification	Compressed image from camera Predefined model	Video Feed with labeled obstacles

5.2 Lane detection

Lane detection will be implemented by taking the input captured by the camera and using various computer vision techniques such as Canny edge detection, Gaussian blur, erosion and dilation to reduce noise, and Hough transforms to identify and map the edges of the lane lines to help keep the vehicle within those lines.

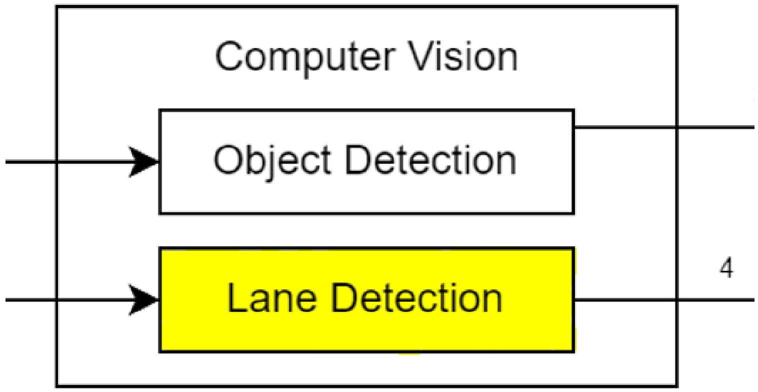

Figure 5: Lane detection subsystem description diagram

5.2.1 Assumptions

The camera is properly calibrated and placed in the optimal position on the vehicle. The video feed of the surface that is being traversed by the vehicle is being captured and processed in real-time in the optimal resolution.

5.2.2 Responsibilities

Lane detection is responsible for correctly identifying lane lines on the surface so that the path of the vehicle can be accurately, and safely, planned and navigated.

5.2.3 Subsystem Interfaces

This subsystem will take input from the camera sensor that is used to detect lanes in real time.

Table 4: Subsystem interfaces

ID	Description	Inputs	Outputs
#2	Lane detection	Video image from camera	Lane grid, Dot-matrix map

6 Output Layer Subsystems

The Output Subsystem controls the output that is sent to the Path Planner team as well as the stabilization instructions that are to be sent to the sensor mounts determined by processing the inputs from the Gyroscope sensor in order to stabilize the sensors.

6.1 Dot Matrix Map

The output that is to be provided to the path planner team is going to be a dot matrix map of what has been detected by the computer vision model with marked detected obstacles. The matrix will contain the location and distance of all detected lines.

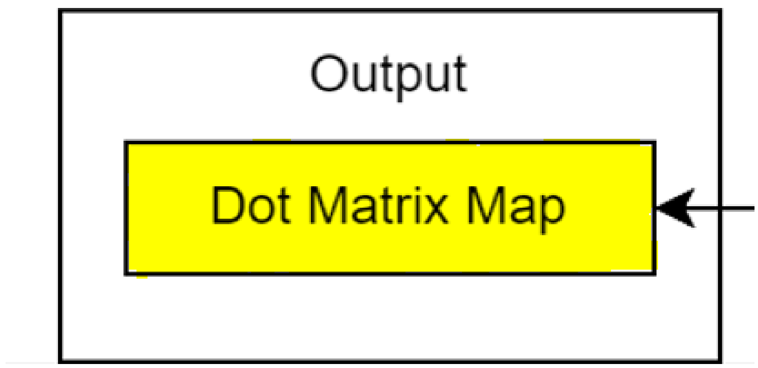

Figure 6: Output subsystem description diagram

6.1.1 Assumptions

It is assumed that these items requested by the path planner team are to be sent via an agreed-upon protocol of wireless transmission through the off-board computer. It is also assumed that the IGVC vehicle remains within range of the off-board computer to transmit the information without experiencing losses.

6.1.2 Responsibilities

The Dot Matrix map to be sent to the path planner team is to be constructed using the Inputs from the computer vision system and then are to be packaged and processed to be delivered to the path planner system.

6.1.3 Subsystem Interfaces

This subsystem will take the provided obstacle grid and the lane grid from the computer vision layer system to provide to the path planner team.

Table 5: Subsystem interfaces

ID	Description	Inputs	Outputs
#3	Output Map to Path Planner	Obstacle Grid	Dot Matrix Map
#4	Output Map to Path Planner	Lane Grid	Dot Matrix Map

REFERENCES