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

System Requirements Specification
CSE 4317: Senior Design II
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IGVC COMPUTER VISION TEAM
IGVC Computer Vision Module

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REVISION HISTORY

Revision	Date	Author(s)	Description
0.1	10.06.2023	ATN, JLC, BJB, SD	Document creation
0.2	10.16.2023	ATN, JLC, BJB, SD	Finalized first draft
0.3	5.07.2024	SD, JLC, ATN, BJB, WP	Updated document
0.4	5.08.2024	SD, JLC, ATN, BJB, WP	Finalized document

Contents

List of Figures

1 Product Concept

This section describes the purpose, use, and intended user audience for the computer vision module for the Intelligent Ground Vehicle Competition (IGVC) project. The computer vision module will be used to gather real-world information to help the senior design department's intelligent ground vehicle navigate obstacles and obstructions.

1.1 Purpose and Use

The computer vision module is expected to gather real-world information through the use of cameras. This information will be translated into data sets that will be used to create algorithms that will help the vehicle avoid obstacles such as potholes, debris, and various other possible obstructions by integrating and communicating with the other components of the vehicle.

1.2 Intended Audience

This system is a component of the entire IGVC effort for 2024 by the University of Texas at Arlington. The entire system is to be packaged appropriately with all appropriate documentation and handed over to the incoming IGVC team working on the next iteration of the computer vision system and Dr. Cristopher McMurrough. The product will only be made available to the above-mentioned parties and anyone working towards a vehicle for future iterations of the IGVC as a student or faculty member of the University of Texas at Arlington's Engineering and Computer Science Department.

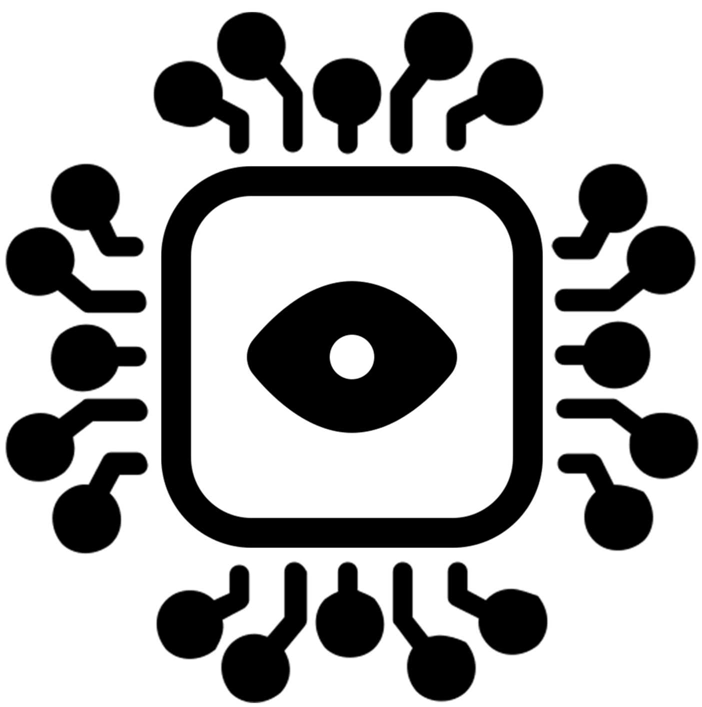

Figure 1: X conceptual drawing

2 Product Description

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.

2.1 Features & Functions

This modular component houses the sensors that will be used to allow the vehicle to map the space it is in. To be able to do that efficiently it must be able to stream inputs from these sensors live and identify the elements around it in time for the vehicle to be able to process a route and follow through with it.

2.2 External Inputs & Outputs

The flow of data begins in the sensors that record the surroundings and pass them down to an onboard computer that will send these streams to a home-base computer that houses the Computer Vision Algorithm that sends its processed information to the path-planner solution system onboard the vehicle.

2.3 Product Interfaces

There are 3 interfaces; one interface is the raw input from the camera, the other interface is the receiving end on the home-base computer and the third interface is the processed data that has been identified, tagged, mapped, and sent to the vehicle's path-planning system.

3 Customer Requirements

We are building the computer vision module for the currently in-development Intelligent Ground Vehicle Competition (IGVC) vehicle for UTA, which has requirements determined by Dr. Christopher McMurrough and the IGVC set of rules. This system must be modular and compliant with the architecture of the current IGVC vehicle. We are also developing the computer vision system for the module and recording a custom-built data set to be used to train the model in compliance with IGVC rules and comprised of obstacles and scenarios that are to be expected at the competition venue.

3.1 Computer Vision Model

3.1.1 Description

We will incorporate lane detection and object recognition to help navigate the vehicle around the course. The lanes will tell the vehicle to stay in its boundary and to not pass the lanes and the obstacles will influence the vehicle's pathing to avoid the obstacle or adjust its speed, such as going up a ramp.

3.1.2 Source

The source of the requirement is Dr. Christopher McMurrough and the IGVC set of rules 2024.

3.1.3 Constraints

The computation power and camera specifications will determine how the vehicle will operate.

3.1.4 Standards

IGVC standards

3.1.5 Priority

The priority of this requirement relative to other specified requirements:

- Critical

3.2 Custom Data Set

3.2.1 Description

We are going to use a push-cart with a camera mounted on top of a custom-built track, containing obstacles such as traffic cones, barrels, and white plot holes on the ground to emulate the competition environment. This data set, along with related data sets that are available to us for usage will be used to train the computer vision model to be specialized in the competition environment.

3.2.2 Source

The source of the requirement is Dr. Christopher McMurrough and the IGVC set of rules 2024.

3.2.3 Constraints

We may not be able to collect a large enough number of data points and be able to label all data sets appropriately which limits the efficiency of the vision model as that is a very taxing amount of work.

3.2.4 Standards

TBD

3.2.5 Priority

The priority of this requirement relative to other specified requirements.

- High

4 Packaging Requirements

This section describes how the hardware and software components of the computer vision module will be packaged and delivered to IGVC 2024, as well as the IGVC teams for further use and development.

4.1 Software Delivery

4.1.1 Description

All software implemented will be provided in a github repository that was utilized by the team.

4.1.2 Source

Sponsor (Dr. McMurrough)

4.1.3 Constraints

Currently requires a powerful computer to run/train the model.

4.1.4 Standards

N/A

4.1.5 Priority

Critical

4.2 Dataset Delivery

4.2.1 Description

The used dataset will be provided in the github repository.

4.2.2 Source

Sponsor (Dr. McMurrough)

4.2.3 Constraints

N/A

4.2.4 Standards

N/A

4.2.5 Priority

High

5 Performance Requirements

The classification must be completed in X (time units). The module must be attachable to the main vehicle in roughly 10-15 minutes. The vision system must be functional for the entire duration it takes the vehicle to complete the IGVC course, with room for errors in path. Line location and distance calculation must be performed and sent multiple times per second.

5.1 Accuracy of Obstacle Classification

5.1.1 Description

The computer vision system needs to detect and identify obstacles with 90 percent accuracy to navigate around the course and take countermeasures against them.

5.1.2 Source

IGVC team implementation

5.1.3 Constraints

The training data gathered, the obstacles, and the environment

5.1.4 Standards

IGVC competition standards

5.1.5 Priority

High

5.2 Real Time Obstacle Detection

5.2.1 Description

The Computer Vision System must detect and identify obstacles within the system's field of view in real time with a latency of no more than 100 milliseconds.

5.2.2 Source

IGVC team implementation

5.2.3 Constraints

Sensor capabilities and system performance

5.2.4 Standards

IGVC competition standards

5.2.5 Priority

High

5.3 Latency for Obstacle Detection and Response

5.3.1 Description

The Computer Vision System must provide obstacle detection data to the IGVC's Path & Planning team with a latency of 100 milliseconds.

5.3.2 Source

IGVC team implementation

5.3.3 Constraints

Data stream speed and processing time.

5.3.4 Standards

IGVC standards

5.3.5 Priority

High

5.4 Line Coordinates and Distance Calculation

5.4.1 Description

An array must be created in order to pass the line location and distance information to the path finding team for each frame.

5.4.2 Source

IGVC team implementation

5.4.3 Constraints

Data stream speed and processing time.

5.4.4 Standards

IGVC standards

5.4.5 Priority

High

6 Safety Requirements

Our assigned task is to generate a modular component that should be equipped with a camera. As majority of the work would be based on the electrical components and wiring, certain precautions would be taken into consideration including the use of safety glasses to prevent direct exposure, proper taping of all electrical wires before operating it, maintaining the ground connection to avoid shocks. Heavy soldering work would also be required, so prohibiting the use of wet hands/without gloves.

6.1 Laboratory equipment lockout/tagout (LOTO) procedures

6.1.1 Description

Any fabrication equipment provided used in the development of the project shall be used in accordance with OSHA standard LOTO procedures. Locks and tags are installed on all equipment items that present use hazards, and ONLY the course instructor or designated teaching assistants may remove a lock. All locks will be immediately replaced once the equipment is no longer in use.

6.1.2 Source

CSE Senior Design laboratory policy and UTA Central Library FabLab policy.

6.1.3 Constraints

Equipment usage, due to lock removal policies, will be limited to availability of the course instructor and designed teaching assistants.

6.1.4 Standards

Occupational Safety and Health Standards 1910.147 - The control of hazardous energy (lockout/tagout).

6.1.5 Priority

Extremely Critical

6.2 National Electric Code (NEC) wiring compliance

6.2.1 Description

Any electrical wiring must be completed in compliance with all requirements specified in the National Electric Code. This includes wire runs, insulation, grounding, enclosures, over-current protection, and all other specifications.

6.2.2 Source

CSE Senior Design laboratory policy

6.2.3 Constraints

High voltage power sources, as defined in NFPA 70, will be avoided as much as possible in order to minimize potential hazards.

6.2.4 Standards

NFPA 70

6.2.5 Priority

Critical

6.3 RIA ROBOTIC MANIPULATOR SAFETY STANDARDS

6.3.1 DESCRIPTION

Robotic manipulators, if used, will either be housed in a compliant lockout cell with all required safety interlocks, or certified as a "collaborative" unit from the manufacturer.

6.3.2 SOURCE

CSE Senior Design laboratory policy and UTA Central Library FabLab Policy.

6.3.3 CONSTRAINTS

Collaborative robotic manipulators will be preferred over non-collaborative units in order to minimize potential hazards. Sourcing and use of any required safety interlock mechanisms will be the responsibility of the engineering team.

6.3.4 STANDARDS

ANSI/RIA R15.06-2012 American National Standard for Industrial Robots and Robot Systems, RIA TR15.606-2016 Collaborative Robots

6.3.5 PRIORITY

Critical

7 Security Requirements

The Computer Vision system for IGVC will take steps to ensure security is implemented. Source code access will need to be managed and restricted only to authorized personnel. Any data or training data will be stored on a cloud or hard drive and routinely backed up for recovery.

7.1 Training Data Storage

7.1.1 Description

Storing large-scale training data into an external hard drive or cloud storage to ensure no unauthorized personnel has access to the data set.

7.1.2 Source

Data protection practices

7.1.3 Constraints

Cloud storage technology and costs or physical need of hard drive.

7.1.4 Standards

Data storage standards.

7.1.5 Priority

High

7.2 Frequent Data Backups

7.2.1 Description

Implement a set of data backup times for training data to prevent data loss or corruption.

7.2.2 Source

Data protection practices

7.2.3 Constraints

Backup procedures and technology used.

7.2.4 Standards

Data backup and recovery standards.

7.2.5 Priority

High

7.3 Code Repository Access

7.3.1 Description

The code repository contains code related to the computer vision system and will need to be managed and accessed by authorized personnel only.

7.3.2 Source

GitHub's security features and practices.

7.3.3 Constraints

Access management and technology used.

7.3.4 Standards

GitHub security standards.

7.3.5 Priority

High

8 Maintenance & Support Requirements

The computer vision system for the IGVC will be maintained and supported to ensure that the IGVC will operate functionally as expected by the team's standards. We will have team members who will address these requirements either by designation, team maintenance, or individual maintenance to resolve these issues. The computer vision system will come with a technical document that will help guide the user or developer to troubleshoot the underlying problem or understand the system. Additionally, the team will be calibrating the computer vision system, reviewing source code, and using version control.

8.1 Technical Documentation

8.1.1 Description

Technical documentation detailing the system architecture, sensor specifications, software source code documentation, and troubleshooting will be available for maintenance.

8.1.2 Source

Sponsor (Dr. McMurrough)

8.1.3 Constraints

Figuring out and making the correct and efficient algorithm for the vision system.

8.1.4 Standards

Maintenance & support documentation standards.

8.1.5 Priority

High

8.2 Calibrating Computer Vision System

8.2.1 Description

The computer vision system, such as cameras and sensors, will be checked and calibrated to ensure accuracy and data are consistent with the IGVC's design.

8.2.2 Source

Sponsor (Dr. McMurrough)

8.2.3 Constraints

Difficulty in stabilizing the camera mount.

8.2.4 Standards

IGVC standards.

8.2.5 Priority

High

8.3 Source Code Review

8.3.1 Description

The source was tested against multiple input data, that were taken at several locations to verify the expected output. Additionally, a live camera feed is provided to check if it functions in a realistic environment.

8.3.2 Source

Sponsor (Dr. McMurrough)

8.3.3 Constraints

Weather conditions make it harder to record the input data videos properly. Inconsistency of pavement texture and color will affect the filter's parameters and values.

8.3.4 Standards

IGVC standards

8.3.5 Priority

High

8.4 Version Control System

8.4.1 Description

The IGVC's computer vision source code will be managed using a version control system, GitHub, for collaboration, tracking code, and potential reverts with the history of code maintained.

8.4.2 Source

Sponsor (Dr. McMurrough)

8.4.3 Constraints

Making the code as efficient as possible so that it consumes less amount of memory and time.

8.4.4 Standards

GitHub standard practices.

8.4.5 Priority

High

9 Other Requirements

This section consists of the requirements that are provided by the project sponsor and what we decided is the most suitable for the realization of the computer vision solution.

9.1 Mapping Obstacles Requirement

9.1.1 Description

The entities that the computer vision model is able to recognize might have to be mapped in a GPS plane as it is uncertain as of yet whether this is something the path planner team is going to do or not.

9.1.2 Source

Sponsor (Dr. McMurrough)

9.1.3 Constraints

Limitations of the onboard computer to be able to withstand all these streams of data.

9.1.4 Standards

IGVC standards

9.1.5 Priority

Moderate

10 Future Items

To-do list and options for improving the system in

10.1 Depth Camera Requirement

10.1.1 Description

Implementing object distance depth based on the object's position. Obstacles such as potholes will be needed as lidar does not detect potholes.

10.1.2 Source

Sponsor (Dr. McMurrough)

10.1.3 Constraints

Constrained by camera specifications and performance.

10.1.4 Standards

IGVC Standards

10.1.5 Priority

Future

10.2 Custom Housing Requirement

10.2.1 Description

Future plans can be made to create a custom, modular housing piece to house any sensors that we use (infrared/proximity/cameras) and the Gyroscopic stabilizers for said sensors to be attached to the IGVC vehicle. In order to properly fit the housing on the vehicle, it will be required that it be in compliance with the vehicle model that has already been designed by the current Senior Design II team with whom we are collaborating.

10.2.2 Source

The source for the housing requirements will be Dr. Christopher McMurrough, the IGVC rules, and the Senior Design II team.

10.2.3 Constraints

The applicable constraints are the design of the current IGVC vehicle, the design of the gyroscopic sensors, and the durability of the housing based on the available material that can be used.

10.2.4 Standards

IGVC Standards

10.2.5 Priority

Future

10.3 Gyroscopic Sensor Stabilizer Mounts

10.3.1 Description

This component would be used to comprise two stepper motors in a 3D-printed housing that allows it to hold a sensor as steady as possible to be able to record the surroundings more efficiently and without having to face shaky imagery that might make it harder for the computer vision system to be able to identify and tag its surroundings. These components are to be made for every recording sensor we choose to equip in our system

10.3.2 Source

The source for the stabilizer mount requirements will be provided by Dr. Christopher McMurrough and, remain in compliance with the IGVC rules.

10.3.3 Constraints

Constraints include the space available for full freedom of movement of the sensors and affect greatly the design of the Housing, as well as the capability of the onboard computer(Raspberry Pi 4) to be able to calculate the appropriate adjustments to the sensor position in time. The material used for this depends greatly on the total payload the vehicle is able to carry.

10.3.4 Standards

IGVC Standards

10.3.5 Priority

Future

10.4 ROS 2 Utilization

10.4.1 Description

ROS 2 Framework allows us to interface the streams from the onboard computer onto a base computer where we can perform process-heavy tasks.

10.4.2 Source

Sponsor (Dr. McMurrough)

10.4.3 Constraints

How compatible it is with the home-based computer and the difficulty of its usage. Communication with different ROS 2 distributors. Additionally, how much resources it will require to run both object recognition and lane detection.

10.4.4 Standards

IGVC Standards

10.4.5 Priority

Future

REFERENCES

N/A