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

Project Charter
CSE 4316: Senior Design I
Fall 2023

IGVC Computer Vision Team
IGVC Modular Computer Vision System

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Revision History

Revision	Date	Author(s)	Description
0.1	09.22.2023	ATN, JLC, BJB, SD	Document creation
0.2	09.25.2023	JLC, ATN	Proofread first draft

Contents

List of Figures

1 Problem Statement

This project is a component of the current vehicle expected to compete in the Intelligent Ground Vehicle Competition held in Detroit. This component consists of researching and developing the computer vision solution that will allow the IGVC vehicle to be able to identify and mark its surroundings in order to be able to avoid them. The vision model must be able to identify specific white circles painted on the ground as potholes and miscellaneous objects in its path such as traffic cones, bins, etc and keep track of them on the course.

2 Methodology

We will create a modular component to be equipped with a Lidar sensor and cameras in protective housing, which can easily be mounted onto and removed from the current IGVC vehicle. This component is expected to be equipped with a computer vision neural network explicitly trained for the IGVC competition course in adherence to its guidelines.

3 Value Proposition

In the grand scheme of things, this project aims to provide a strong and modular starting point for current and future iterations of not only IGVC but many other autonomous vehicle competitions, allowing the sponsor to demonstrate the expertise and capabilities of the College of Engineering at UTA, attracting companies and future students that might become interested in the university due to its performance in said competitions.

4 Development Milestones

This list of core project milestones should include all major documents, demonstration of major project features, and associated deadlines. Any date that has not yet been officially scheduled at the time of preparing this document may be listed by month.

Provide a list of milestones and completion dates in the following format:

- Project Charter first draft - September 2023
- System Requirements Specification - October 2023
- Architectural Design Specification - November 2023
- Demonstration of Data set and Training Model - December 2023
- Detailed Design Specification - February 2024
- Demonstration of Gyroscope Sensor Mount - February 2024
- Demonstration of Sensor Array module with Gyro - March 2024
- Demonstration of Computer Vision Model - March 2024
- CoE Innovation Day poster presentation - April 2024
- Demonstration of Integration with IGVC Vehicle - April 2024
- Demonstration of Complete Vision solution - April 2024
- Final Project Demonstration - April 2024

5 Background

There is currently a senior design team working on the IGVC vehicle and although equipped with a rudimentary vision system it is in need of a highly specified computer vision system for the IGVC competition which is held every year in Detroit. Competing and innovating for this competition is necessary since autonomous vehicles have the potential to bring about unprecedented leaps forward in road and vehicle safety, however in order to fully realize this potential there is still a great deal of work that needs to be done in order for progress to be made. There were reports of autonomous "robotaxis" causing traffic jams in San Francisco as recently as August of 2023. [7] According to tests conducted by AAA in June 2022, the company reported that the future of autonomous vehicles is a long way off as their tests found that safety features designed to prevent crashes failed in multiple situations. [5] To maximize the benefits that these vehicles can offer to society we must, first and foremost, make sure they have reached an exceptional level of safety and dependability. That is why investment and support in this project and its development efforts are paramount. The more milestones that are reached and surpassed, the more our society and its future will be reshaped for the better.

6 Related Work

Autonomous ground vehicles (AGV) have been developed and advanced for many decades with many solutions contributing to the achievements of AGV in different forms such as conferences, academic research papers, and commercially available products.

The concepts of computer vision application for autonomous vehicles are applied through the use of localization, a map, detecting objects, and tracking objects. Bersan et al. [2] utilizes three main modules to create their augmented map representation. Developing a map of the surroundings using the Gmapping SLAM algorithm, which produces a grid-based map provided with depth information. Detecting objects using a pre-trained object class through a neural network using "You only look once" (YOLO). They are processing the position of the object through an RGB-D image that localizes and tracks previously localized objects in the map detected by YOLO.

When designing a computer vision system, sensors and cameras used must relay information read and sent in real-time, accurately, and reliably. Pidurkar et al. [6] implemented a monocular camera as the basis for the computer vision system for autonomous vehicles instead of opting for a multi-LIDAR sensor, due to its cost. Comparatively, the monocular camera can perform better at data processing, reduce cost to the overall system, and estimate object distance more accurately. The restrictions to this design are reliant on the FOV and height of its mounted position which can hinder the performance unless other sensors are implemented as well.

Navigating an autonomous vehicle needs to incorporate a vision for the system to view recognized objects and avoid obstacles. Sharmitha D and Thirumoorthi P [3] use the captured image and transform it to a grey image to improve the system work speed and reduce computation and sensitivity. They use a sliding window-based search to examine the radius of the curvature of the lane and the location of the vehicle from the center. Additionally, they use edge detection of the lane to numerically estimate the lane curvature and exact location of the vehicle. No other information was noted about object detection and is solely for lane detection and staying in the center.

He [4] studied the YOLO object detection algorithm for road scenes in computer vision. YOLOv4 (algorithm utilized) is a single-stage detector that identifies traffic obstacles. The structure of YOLOv4 is broken down into four sections: input, whole image or video stream, backbone, extract image features neck, feature enhancement, and prediction, detects the extracted features and outputs the results desired. YOLO will be considered for the application of object detection and tracking due to its accuracy and speed.

Aldibaja et al. [1] divided the roads into nodes to increase efficiency and time which can generate large-scale maps using Graph-Slam (Simultaneous Localization and Mapping). The relative positions in revisited areas increase the accuracy of the map in an Absolute Coordinate System (ACS). This can contribute when the vehicle faces an obstacle and needs to find free space and already recognizes the objects.

The references mentioned help build the foundation of how computer vision will be integrated and intertwined with other aspects of AGV. Many solutions proposed can be integrated into this vehicle, however need to be adjusted and consider the costs of the development such as the sensors and cameras used.

7 System Overview

For this project, the team was tasked to work on the computer vision aspect of the IGVC in order to identify potholes, obstacles, and lanes. The team will be utilizing powerful LIDAR sensors, an Intel RealSense depth capture system or an alternative camera, and tire treads to minimize errors in movement data.

The team will be working with other teams for IGVC and will only work on the computer vision aspect, where the main vehicle will be provided and built to be deployed and the path planner will be handled by another team. Considerations such as making the vehicle light and portable will be beyond the team's scope and will focus on the camera and sensors and data collection.

For how the data will be collected, the camera will be mounted on top of the vehicle and will be optimized to cover the majority of the area, based on the focal length, and will consider using multi-cameras if a monocular camera cannot satisfy the requirements. If we do use multi-cameras there needs to be a consideration for how to calibrate the cameras so that the information is consistent and accurate. The team will use a powerful LIDAR sensor to measure the depth of our objects accurately in 3 dimensions instead of 2 dimensions, although the sensor is costly, but will be provided by the department and will not affect our team budget. Additionally, an Inertial Measurement Unit (IMU) and GPS will be used for the localization module to map our surroundings using the SLAM module.

For the training models, the team will either plan to collect data in the parking lot and train the model using that or use a predefined model and tweak it to fit the vehicle. An object detection system will be implemented through a YOLO algorithm that would help identify obstacles such as traffic cones, potholes, and other objects included in the test course. YOLO algorithm would allow the vehicle to operate real-time tracking and not just object detection. The LIDAR sensor will measure the distance to objects detected and create a point cloud of the object in 3 dimensions. The data generated by the sensors and algorithms will be sent to the path planning team to further enhance the vehicle's performance.

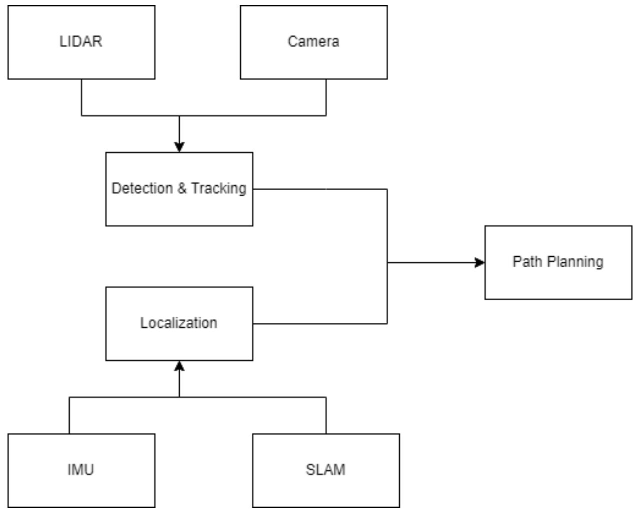


Figure 1: Figure 1: System Overview

8 Roles & Responsibilities

The team's sponsor is Dr. Mcmurrough who will also serve as the primary consultant for the project and its scope. We will rotate scrum masters for each sprint to keep everyone involved. Team members will be assigned to roles that will suit their expertise and experience, although not restricted if they wish to work on other assignments. The current team will also shadow the current IGVC vehicle team and coordinate with all IGVC teams currently developing solutions. Stakeholders are the future senior design students who will improve the IGVC and the to-be-established IGVC Research and Development Team.

Neural Network: Refers to the team members that design the neural network structure and reinforcement model

SLAM: Refers to Team members responsible for utilizing Simultaneous Localization and Mapping that can build a virtual map in an unknown environment.

Localization: Refers to Team members responsible for using localization methods such as SLAM and Inertial Measurement unit to provide better accuracy.

Data integration: Refers to Team members responsible for integrating data collected from the sensors into their respective perceptions, such as localization or object detection and tracking.

Data validation: Refers to Team members responsible for the accuracy of the data collected and analyzed.

Training the Model: Refers to the team members responsible for training the neural network with the approved data sets

CAD Modelling: Refers to Team members responsible for designing and prototyping the Gyroscope sensor mounts and the Modular Computer Vision System using CAD/3D software.

Component Integration: Refers to Team members responsible for coordinating with the existing IGVC teams and integrating the prototype into the existing vehicle and is expected to shadow the current IGV vehicle team.

ROS Implementation: Refers to the Team members working with ROS to process the deep learning solution. Team Members:

- Abu Talha Nayyar - Component Integration, CAD Modelling, Neural Network, Machine Learning
- Brandon Joel Bowles - Data Integration, Training the Model, CAD Modelling

- James Caetano - SLAM, Localization, Machine Learning, Training the Model
- Sameer Dayani - Data Validation, SLAM, Localization, Data Integration

9 Cost Proposal

The entire project would be fully funded by the UTA's Department of Computer Science and Engineering as part of the Senior Design Project.

9.1 Preliminary Budget

By default, the team has been granted a budget of 800 Dollars, with a range of flexibility of an additional 100 dollars if necessary(may change).

9.2 Current & Pending Support

The main funding source would be the UTA's CSE department which had a by default budget of 800. We might require more funding to be able to work with Intel RealSense, or superior outdoor-specific Lidar equipment while also being able to afford the necessary equipment for the entire gyroscope head mount and cameras.

10 Facilities & Equipment

Our main working space would be the engineering lab located on the third floor of the Engineering and Research Building at UTA, where we are expected to meet regularly and work on the project. We have been allowed 24/7 access to work inside the Nedderman Hall Labs as well. The most crucial part of our project is to collect a large enough data set and annotate it successfully to be able to effectively train our computer vision system. To achieve that we need a large enough space where we can simulate the course as well as be able to have hurdles similar to the IGVC competition, making use of barrels, and traffic cones and be able to mark with white paint or tape potholes onto the ground. To be able to set up this environment and be able to record data in it we might need to request permission and reserve an area. We expect coordination from the Parking and Transportation Department at UTA. To fabricate any prototype hardware housings we will be using designated Lab 3D printers, FabLab 3D printing, and acrylic cutting machinery. All critical parts will be purchased after consultation with Professor McMurrough and a consensus of the team. Our main vendor of purchase would be Amazon or Home Depot. Other resources, we are expected to make use of are, Raspberry Pi 4's and personal machines(laptops). For this project, we would be requesting our professor for some of the objects that have to be borrowed like the LIDAR from the the existing IGVC project.

11 Assumptions

The following list contains critical assumptions related to the implementation and testing of the project.

- The ideal Lidar equipment is available in time for Senior Design 2 (Spring 2024)
- Prototypes made of borrowed equipment are at least 70 percent functional and ready by the 4th sprint cycle.
- Blueprints should be finalized and available by at least 4th sprint cycle.
- Working on the back end of this project's software-based aspects is expected to be started by the 4th sprint cycle.
- Vehicle has already been developed to apply computer vision solution.

12 Constraints

The following list contains constraints related to the implementation and testing of the project.

- Final prototype demonstration must be completed by April 30th, 2024
- The Vision Solution must be able to fit onto the current IGVC vehicle.
- The Model must be trained on IGVC competition-specific data.
- Total development costs must not exceed $900 (may change)
- Final product must be able to successfully map the vehicle's surroundings.

13 Risks

The following high-level risk census contains identified project risks with the highest exposure. Mitigation strategies will be discussed in future planning sessions.

Risk description	Probability	Loss (days)	Exposure (days)
Damage to LIDAR Sensor Module	0.05	30	10.0
Data set mislabelling and incorrectly trained model	0.20	14	4.0
Damage to Sensor housing	0.60	7	2.5
Gyroscope calibration errors	0.50	17	3.0
Errors in integrating with IGVC vehicle	0.15	10	1.5

Table 1: Overview of highest exposure project risks

14 Documentation & Reporting

14.1 Major Documentation Deliverables

14.1.1 Project Charter

This document will be maintained by the entire team and will undergo updates in case any major modification is made to the project or requested by the supervising body of this project. The initial version will be delivered on September 25, 2023, and the final version will be delivered in April 2024.

14.1.2 System Requirements Specification

This document is to be updated at least once every month for the time span of the project. The initial version will be delivered on October 16, 2023, and the final version will be delivered in May 2024.

14.1.3 Architectural Design Specification

This document is to be updated at least once every month for the time span of the project in case of any changes are made to the architectural design of the project. The initial version will be delivered on November 6, 2023, and the final version will be delivered in May 2024.

14.1.4 Detailed Design Specification

The Document is to be submitted on February 20, 2024.

14.2 Recurring Sprint Items

Recurring Sprint Items are to be updated as per the demands of the project supervisors, sponsors, and the team.

14.2.1 Product Backlog

How will items be added to the product backlog from the SRS? How will these items be prioritized? Who makes the decision (product owner, group vote, etc.)? What software will be used to maintain and share the product backlog with team members and stakeholders?

14.2.2 Sprint Planning

Sprint plans are to be set up in weekly teams/discord meetings where individual tasks are distributed amongst the team.

14.2.3 Sprint Goal

Sprint goals are set by the team depending on the progress of the team. In matters of key importance, the advice of the project supervisors is to be taken into account in the form of teams/in-person meetings.

14.2.4 Sprint Backlog

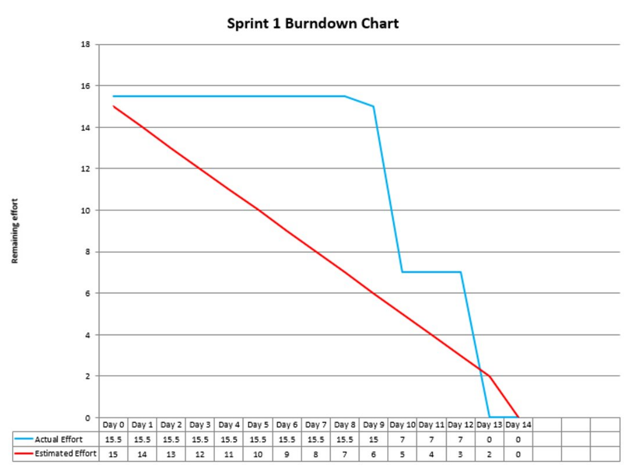
Backlogs are to be maintained individually. The team determines what deliverables are put into backlog by the nature of their priority/immediate necessity.

14.2.5 Task Breakdown

Tasks will be assigned based on individual capabilities and interests. These breakdowns will be documented.

14.2.6 Sprint Burn Down Charts

Sprint Burn Down Charts will be split evenly among the team over the semester. Each team member is to report their allocated time to the project to the member responsible for that iteration of the SBD Chart.



	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
Actual Effort	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15	7	7	7	0	0
Estimated Effort	15	14	13	12	11	10	9	8	7	6	5	4	3	2	0

Figure 2: Example sprint burn down chart

14.2.7 Sprint Retrospective

Sprint Retrospectives are to be held on the agreed-upon meeting day following the presentation if not after the presentation.

14.2.8 Individual Status Reports

Individual Status Reports are to be turned in. These are expected to include any hindrances faced in task completion, any discoveries made, and completed tasks concerning any items in the backlog.

14.2.9 Engineering Notebooks

Engineering notebooks are not required for this course.

14.3 Closeout Materials

14.3.1 System Prototype

We are unsure if there will be a PAT or FAT but the final prototype is to be functional and demonstrated in conjunction with the already completed IGVC vehicle. The final system prototype includes a gyroscope head that will have sensors mounted onto it housed inside a full system housing that can be mounted on top of the IGVC vehicle modularly while containing a functionally trained Computer vision system.

14.3.2 Project Poster

The poster is expected to include images of the identified objects, how the computer vision neural network perceives the surroundings, details of the approach, and training data used to train and design it. The poster is to be delivered in April 2024.

14.3.3 Web Page

It will include all deliverable documents for the project and will be maintained throughout the project's timeline.

14.3.4 Demo Video

The demo video is expected to consist of our findings and a demonstration of the Final deliverable, being between 7-12 minutes in length.

14.3.5 Source Code

Source code is to be maintained using GitHub in a private repository. Authorized personnel of the IGVC teams are to be allowed access to the repository.

14.3.6 Source Code Documentation

Final Documentation is to be provided in a readme or pdf file format.

14.3.7 Hardware Schematics

Hardware schematics for the Gyroscope head mount for the sensors as well as the sensor housing schematics and specifications will be provided along with the closing documents.

14.3.8 CAD files

Any CAD files used will be provided along with the final documentation.

14.3.9 Installation Scripts

These details will be provided as the project progresses.

14.3.10 User Manual

A digital manual(that can be printed if needed) will be provided with instructions.

References

[1] Mohammad Aldibaja, Noaki Suganuma, Reo Yanase, and Keisuke Yoneda. Reliable graph-slam framework to generate 2d lidar intensity maps for autonomous vehicles. In *2020 IEEE 91st Vehicular Technology Conference (VTC2020-Spring)*, pages 1–6, 2020.

[2] Dhiego Bersan, Renato Martins, Mario Campos, and Erickson R. Nascimento. Semantic map augmentation for robot navigation: A learning approach based on visual and depth data. In *2018 Latin American Robotic Symposium, 2018 Brazilian Symposium on Robotics (SBR) and 2018 Workshop on Robotics in Education (WRE)*, pages 45–50, 2018.

[3] Sharmitha D and Thirumoorthi P. Lane detection and steering control of autonomous vehicle. In *2022 6th International Conference on Intelligent Computing and Control Systems (ICICCS)*, pages 100–105, 2022.

[4] Haomin He. Yolo target detection algorithm in road scene based on computer vision. In *2022 IEEE Asia-Pacific Conference on Image Processing, Electronics and Computers (IPEC)*, pages 1111–1114, 2022.

[5] Chris McGinness. Fully autonomous vehicles still a long way off, report finds, 2022.

[6] Ashish Pidurkar, Ranjit Sadakale, and A.K. Prakash. Monocular camera based computer vision system for cost effective autonomous vehicle. In *2019 10th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*, pages 1–5, 2019.

[7] Jordan Valinksky. Complete meltdown: Driverless cars in san francisco stall causing a traffic jam, 2023.