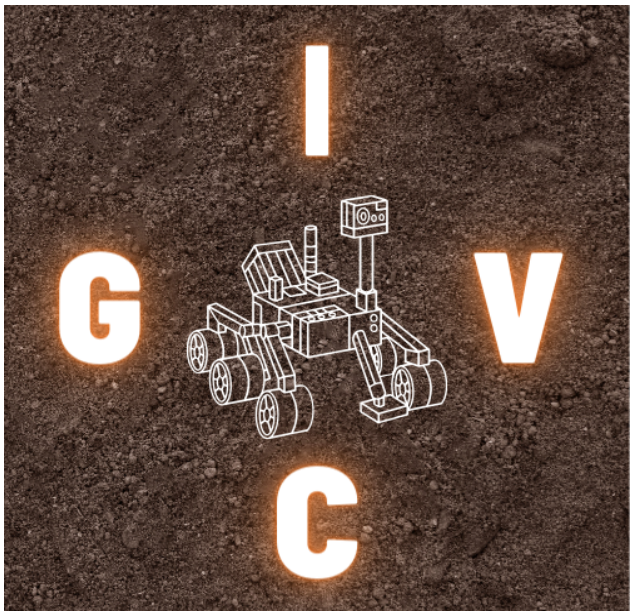
Department of Computer Science & Engineering
The University of Texas at Arlington

Project Charter
CSE 4316: Senior Design I
Summer 2024



IGVC Engineers
IGVC Robot

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Revision History

Revision	Date	Author(s)	Description
0.1	02.28.2024	JS, AF, VC	Document creation
1.0	03.28.2024	JS, AF, VC	First Draft
2.0	07.04.2024	DB, HA, JC, NA, DG, CN	Second Draft

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1 Problem Statement

The Intelligent Ground Vehicle Competition (IGVC) is an annual international competition for students and faculty who are interested in developing autonomous vehicles. The goal of this project is to research, design, and develop a qualifying vehicle to enter into the Auto-Nav or the Self Drive competition in May 2025.

2 Methodology

The final deliverable of this project revolves around designing and constructing an autonomous vehicle capable of navigating trough various terrains and obstacles to compete in the Intelligent Ground Vehicle Competition (IGVC). The primary objective is to create a robust and intelligent system that can operate autonomously while adhering to competition guidelines and objectives.

The research and analysis phase involves studying existing autonomous vehicle technologies, navigation algorithms, and sensor systems, while analyzing past IGVC competitions to understand scope and expectations, and studying common terrain types and obstacles. System design and integration focus on defining vehicle architecture, selecting sensors, integrating sensor data fusion, and implementing a robust control system. Navigation algorithm development includes localization, mapping, and path planning algorithms. Machine learning and AI integration explore techniques for object detection, classification, and decision-making. Testing involves simulation and field trials, while iterative development aims to refine algorithms and systems based on feedback and adapt to evolving competition requirements and technological advancements.

3 Value Proposition

The Intelligent Ground Vehicle Competition (IGVC) project presents a compelling value proposition. As a collaborative endeavor, it offers an excellent opportunity for stakeholders, including industrial sponsors, professors, and the university, to be at the forefront of autonomous vehicle technology. The project promotes innovation in robotics, artificial intelligence, and machine learning. It also enhances the institution's standing in these cutting-edge fields.

Participation in the IGVC equips students with valuable hands-on experience, bridging the gap between theoretical knowledge and its practical application in a multidisciplinary team setting. This approach to learning is instrumental in honing critical skills such as problem-solving, teamwork, and project management, preparing participants for successful careers in engineering and technology sectors. Furthermore, the project strengthens industry and academia partnerships that can lead to collaborative research and development efforts.

The project's success has far-reaching implications, from enhancing the university's reputation to improving transportation and safety. Ultimately, the IGVC project is more than just a competition; it's a beacon for future-focused education, innovation, and collaboration that benefits all parties involved and sets a precedent for excellence in engineering and technology development.

4 Development Milestones

- Project Charter first draft - April 2024
- System Requirements Specification - April 2024
- Architectural Design Specification - April 2024

- SDII Demo and Poster Presentation - April 2024
- Detailed Design Specification - May 2024
- Demonstration of GPS navigation - October/November 2024
- Demonstration of Computer Vision - September 2024
- Final Project Demonstration - December 2024
- IGVC Competition - June 2025

5 Background

The Intelligent Ground vehicle Competition (IGVC) represents a significant challenge that demands innovative solutions in robotics, artificial intelligence, and autonomous systems. Our participation in this project also serves as a continuation for our Senior Design II team's previous involvement in the IGVC. Building upon our past experience, we aim to further refine our skills and knowledge in this domain while addressing the evolving complexities of autonomous vehicle technology. The business case for this project is strengthened by the increasing demand for autonomous vehicles across various sectors, including seeking advanced solutions to enhance efficiency, safety, and productivity, making our participation in the IGVC an opportune platform to demonstrate our capabilities.

The existing status quo in autonomous vehicle technology often falls short in terms of navigating accuracy, adaptability to dynamic environments, and strength towards diverse terrains. By continuing our engagement with the IGVC and developing a competitive vehicle, we aim to tackle these challenges and contribute to the advancement of autonomous systems. Our team's participation in previous IGVC projects has equipped us with valuable insights and lessons learned, which we will leverage to enhance our current work.

In the context of our Senior design II team's relationship with the customer, if there is a clear sponsor or external organization involved, they are likely motivated by the opportunity to support the development of cutting-edge autonomous technology and potentially advantaging outcomes of our project for commercial or strategic purposes. Furthermore, our team's engagement with the IGVC aligns with the objectives of our senior design curriculum, providing us with a hands-on opportunity to apply theoretical knowledge to real-world challenges and contribute meaningfully to the advancement of autonomous vehicle technology.

6 Related Work

The IGVC has various submissions of vehicles with different features and functions. As this is an intercollegiate competition, there were several similar projects competing in previous years of the competition [1]. The University of Texas at Arlington did compete several times in this competition with each project iteration building on the last. Our project will only serve as the most efficient implementation given our team's history with the competition.

As we prepare to implement on our plan we sourced several similar applications, most of which were RC cars that had cameras and basic navigation applications allowing the vehicle to navigate small enclosed spaces. These variations typically come as a teaching kit for young students. While the technology is advanced, it is difficult to source a commercial solution that the average consumer can purchase.

Intelligent ground vehicles are not only growing in popularity among armed forces, but also several transportation departments. In an academeic paper published by Ali et al. in 2023 [2], a study was conducted to examine how useful and efficient intelligent ground vehicles are when incidents occur on roadways. The vehicles in question would connect to traffic network to navigate their way to the incident and control traffic flow through signalling. While the vehicle we intend to implement is by no means road ready or will have that capability, it is incredible to see valuable use cases as such.

7 System Overview

Explain, at a high level, how you will implement a solution to the problem. Include a diagram of major components to the system (not a full architectural design, but a high level overview of the major system

components and how a user or external system might interface). Avoid specific implementation details (operating system, programming languages, etc.). This section should occupy at least 1 full page.

8 Roles & Responsibilities

The stakeholders of this project are Nestor Arteaga, Hayden Ansell, Jocsan Cano, Chau-Phuc Nguyen, Dezean Gardner, Dr. Conly, and Debin Babykutty. The point of contact for this project will be Dr. Conly. The team members are Nestor Arteaga, Hayden Ansell, Jocsan Cano, Chau-Phuc Nguyen, Dezean Gardner, and Debin Babykutty. Each team member will be responsible for tasks on either a voluntary basis or tasked out to them depending on the needs of the team.

9 Cost Proposal

Due to the nature of this project being completed by multiple groups over multiple semesters the majority of the costs from building the machine will already be accounted for.

9.1 Preliminary Budget

	Item Cost	Quantity
Microsoft Azure License	$0.00	5
Jetson AGX Orin 64GB Module	$1,800.00	1
Mecanum Wheels (4 pcs)	$25.00	1

9.2 Current & Pending Support

Our Senior Design Project for the Intelligent Ground Vehicle Competition (IGVC) operates within an $800 budget. The current funding sources for our project include a default funding amount provided by the Computer Science and Engineering (CSE) department. However, we are actively seeking further funding opportunities to supplement our budget. Potential funding sources that haven't been secured yet include applying for grants from industry partners or seeking donations from alumni. With these additional funds, we aim to enhance our project's capabilities and ensure its success in the competition.

10 Facilities & Equipment

The lab space to be utilized is located in the Engineering Research Building, Room 202/203. These rooms provide space for working on the software separately from the hardware. Once confirmed that the vehicle is ready to have software deployed on it, a personal computer will be used as the "sidekick", to process all inputs and execute functionality. Anticipated equipment includes personal Windows laptops. No leasing or outsourcing is necessary.

11 Assumptions

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

- A suitable outdoor testing location will be available
- The GPS navigation system should be operational by October/November
- Drive and Vision systems should be delivered by previous team by August
- Shipping of Batteries to a colleague in Michigan will be on time
- Team will be able to operate the device with the Jetson AGX Orin

12 Constraints

Constraints are essential limitations that our project must navigate. These limitations are not within our direct control but are defined by external factors such as organizational policies, sponsor requirements, and available resources. Identifying these constraints early in the project allows us to strategies to work within our boundaries effectively.

Below are the critical constraints related to our IGVC project.

- Project Timeline Constraints: The system design project must be completed by December 2024, with the implementation phase concluding by the end of May 2025.
- Resource Availability: The availability of specific components or software may be constrained by supply chain issues.
- Budget Limitations: The total budget for the project is capped at $800. This budget must cover all hardware, software, and unforeseen expenses, necessitating careful financial planning and prioritization of resources.
- Regulatory and Competition Rules Compliance: The design and implementation of the vehicle must comply with all IGVC rules and regulations. This includes safety standards, vehicle size and weight limits, and allowed technologies. Non-compliance could result in disqualification or the need for costly last-minute modifications.
- Collaboration with Other Teams: As there are two other Senior Design teams in their final semester, coordination and resource sharing might be required. This could introduce constraints based on their project timelines, resources, and design choices.

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)
Functionality of way-point Navigation	0.50	20	10
Battery Overheating	0.8	1	.8
Broken Solder Joints	0.5	1	.5
Jetson board failure	0.5	14	.5

Table 1: Overview of highest exposure project risks

14 Documentation & Reporting

14.1 Major Documentation Deliverables

14.1.1 Project Charter

The project charter will created, maintained, and updated on Overleaf using Latex. We plan to review the project charter every sprint following submission. Any updates will be compiled and submitted every two months. The initial version was intended to be delivered on March 5th, 2024, but will be submitted April 5th, 2024. The delay is due to a longer than anticipated ramp up for the team to understand

where the current state of the project is at. Updates are expected to be necessary if there are significant project changes, i.e., unexpected delays or other changes. While the deliverable is delegated among the team, any post-submission updates will be handled by one member.

14.1.2 System Requirements Specification

The system requirements specification will created, maintained, and updated on Overleaf using Latex. We plan to review the system requirements specification every sprint following submission. Any updates will be compiled and submitted every two months. The initial version was intended to be delivered on March 31st, 2024, but will be submitted April 8th, 2024. The delay is due to a longer than anticipated ramp up for the team to understand where the current state of the project is at. Updates are expected to be necessary if there are significant project changes, i.e., unexpected delays or specification changes. While the deliverable is delegated among the team, any post-submission updates will be handled by one member.

14.1.3 Architectural Design Specification

The architectural design specification will created, maintained, and updated on Overleaf using Latex. We plan to review the architectural design specification every sprint following submission. Any updates will be compiled and submitted every two months. The initial version will be submitted on April 19. No specific deadline The delay is due to a longer than anticipated ramp up for the team to understand where the current state of the project is at. Updates are expected to be necessary if there are significant project changes, i.e., unexpected delays or specification changes. While the deliverable is delegated among the team, any post-submission updates will be handled by one member.

Our IGVC project strategy involves leveraging the progress made by other teams in coding for auto-navigation. We plan to thoroughly analyze and understand their approaches, algorithms, and implementations to incorporate them into our own system seamlessly. By integrating these advancements, we aim to enhance the autonomous navigation capabilities of our vehicle, ensuring efficient and reliable performance during the competition.

Furthermore, a key aspect of our project will be the development and implementation of safety lights. These lights play a crucial role in ensuring the visibility and safety of our vehicle, especially in dynamic environments with varying light conditions. We will design and integrate robust safety lighting systems that comply with competition regulations and enhance the overall safety of our vehicle and those around it. Through careful planning, collaboration, and implementation of these components, we strive to create a competitive IGVC project that demonstrates innovation, reliability, and adherence to safety standards.

Our team's investment in testing equipment, including a 4WD small vehicle and a Cube Orange with telemetric components, not only accelerates development but also provides us with valuable hands-on experience. With this setup, we can simulate and test other teams' code for auto-navigation without waiting for the completion of the actual vehicle, allowing us to iterate and refine our integration more rapidly.

Additionally, this testing environment offers us the opportunity to gain experience using Mission Planner software. Mission Planner is a powerful tool primarily designed for drone usage, but we will adapt its features to our testing setup. By leveraging Mission Planner, we can further enhance our understanding of telemetry components and refine our testing methodologies. This experience will be invaluable as we continue to develop and fine-tune our autonomous navigation system for the IGVC project.

14.1.4 Detailed Design Specification

The detailed design specification will created, maintained, and updated on Overleaf using Latex. We plan to review the detailed design specification every sprint following submission. Any updates will be compiled and submitted every two months. The initial version will be submitted in the first week of May. No specific deadline The delay is due to a longer than anticipated ramp up for the team to understand where the current state of the project is at. Updates are expected to be necessary if there are significant project changes, i.e., unexpected delays or specification changes. While the deliverable is delegated among the team, any post-submission updates will be handled by one member.

14.2 Recurring Sprint Items

14.2.1 Product Backlog

The product backlog consists of all major written deliverables along with vehicle components and subsystems. From the system requirements specification, any feature to be implemented that is agreed upon by all team members, will be added to the backlog. An Azure backlog board will be used to maintain the project backlog. The software contains functionality to create issues/tasks, manage assignees, manage task status, and view overall analytics. Through the use of an Azure organization, there is the ability to allow stakeholders to view the backlog without modifying.

14.2.2 Sprint Planning

Each sprint is discussed by the team during weekly meetings. There will be eight sprints total throughout this project.

14.2.3 Sprint Goal

The sprint goal is decided by our team during our weekly meetings with input from professors helping with the project.

14.2.4 Sprint Backlog

Similarly to the project backlog, the sprint backlog will be maintained within a board on Azure Devops. During sprint planning meetings, there a scrum master manages and updates the sprint backlog.

14.2.5 Task Breakdown

Tasks will start as voluntary but if a large backlog occurs then they will be tasked out according to the needs of the team.

14.2.6 Sprint Burn Down Charts

14.2.7 Sprint Retrospective

Sprint retrospective discussions will occur the weekly meeting following the end of the sprint. Issue/task completion will be analyzed and a solution will be put in place.

14.2.8 Individual Status Reports

Individual status reports will include, sprint goals, the sprint backlog, individual time expenditures, team burndown chart, individual retrospective, and a peer review of all members.

14.2.9 Engineering Notebooks

There will be no engineering notebook to maintain.

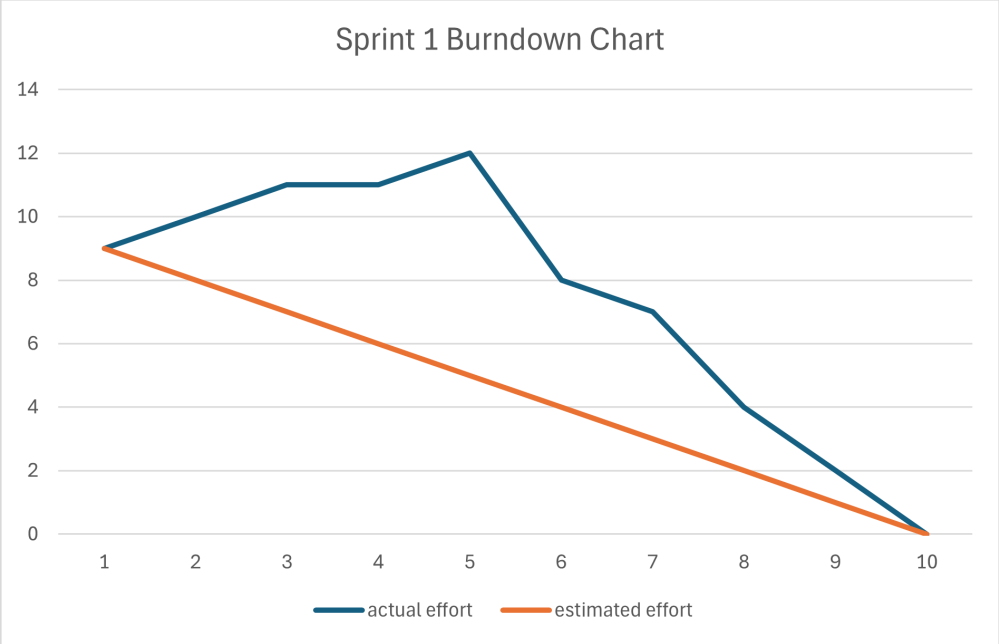

Figure 1: Sprint 1 Burndown Chart

14.3 Closeout Materials

14.3.1 System Prototype

The team will create a small prototype through modification of an RC car that has basic navigation functionality. This is to be completed before August 1st.

The final system prototype will have a functional vehicle that complies with the Intelligent Ground Vehicle Competition rules and regulations. This will include the structural vehicle as well as all software and hardware required to perform in the AutoNav challenge as part of the competition.

There will be no Prototype Acceptance Test (PAT) or Field Acceptance Test (FAT).

14.3.2 Project Poster

The project poster will be a tri-fold board of size 36 inches by 48 inches. This will be delivered as part of the final deliverable at some date in August.

14.3.3 Web Page

A dynamic web app will be created for this project to showcase the project demos, instructions and allow future developers to access the source code in one location. The public can access the basic front end without any authentication to view project status. The web app will be initialized on the first week of May. Modifications will be made until the final submission in August.

14.3.4 Demo Video

There will be several demo videos included with the final deliverable detailing project and feature overview. The videos will be around 2-3 minutes long with several videos detailing project challenges and how the team overcame those challenges. These videos will be included in the web app and presentation.

14.3.5 Source Code

Source code will be maintained through the use of a Git repository. The repository will have one overseer that manages any merge conflicts. There will be two main branches, a main branch (production) and a test branch (test). The test branch will be a direct copy of the production branch. All project issues and tasks will be handled through individual feature branches. When a new feature is to be implemented, members will branch out of main to create a feature branch. Once a feature branch is finished and ready to be tested in an integrated system, members will merge their branch to the test branch. After successful merging and testing, the repository manager will merge the test branch with the production branch.

Source code will only be made public to future project members and not to the public. Source code will be hosted on an Azure DevOps organization where new members can be added to access the repository to read and/or write.

14.3.6 Source Code Documentation

Doxygen will be utilized to effectively document all source code and output to HTML. The documentation will then be included in the project website and is viewable by all future members.

14.3.7 Hardware Schematics

There are no hardware schematics required for the project.

14.3.8 CAD files

There will be no CAD files created by our team. This iteration of the project assumes all hardware mechanical design is completed for our software implementation

14.3.9 Installation Scripts

The installation scripts for the Intelligent Ground Vehicle Competition vehicle will be provided for future team cohorts to review, modify, and build on. One script will contain code to download software used by the vehicle computer vision module. Another script(s) will contain code to install any necessary binaries onto the vehicle hardware.

14.3.10 User Manual

A digital manual will be provided taking the form of a presentation and organized Microsoft Word document. Within the presentation, supplementary videos will placed to serve as demonstrations for particular features and parts that require further modification. This user manual is intended to lead as a guide to how the team after us can ramp up quickly and efficiently but will also explain how to operate and manage the automated vehicle. There will be no printed copy.

REFERENCES

[1] IGVC, "The intelligent ground vehicle competition 1993-2014," [Accessed 04-11-2024].

[2] A. M. Ali, M. A. Ngadi, I. I. Al_Barazanch, and P. S. JosephNg, "Intelligent traffic model for unmanned ground vehicles based on dsdv-aodv protocol," *Sensors*, vol. 23, pp. 1–14, 2023.