CSE 145: Developing a Multi-Faceted Integrated Navigation System For Triton AI Racing

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1 Project Charter

1.1 Project Overview

Triton AI Racing participates in the annual Formula Student Autonomous (FSA) competition, where teams from around the world build autonomous race cars to compete in various challenges. The organization uses machine learning and computer vision technologies to design and build their vehicles, with a focus on developing cutting-edge algorithms and hardware. My job is to make sure that the vehicle can accurately figure out where it is, which direction it's going, how fast it's going, and how quickly it's accelerating. To do that, I work with three different systems that help the vehicle "see" its surroundings. I make sure that these systems work well together and separately, so that the vehicle can get the best information possible and perform at its best. There are several steps which need to be taken to ensure these systems are working together such as sensor calibration and initializing directional orientation.

1.2 Project Approach

My primary responsibility is to facilitate the integration of the IMU, GNSS, and LIDAR systems, while ensuring the IMU can function independently to achieve optimal performance in accurately determining the vehicle's location, direction, speed, and acceleration. By leveraging these sensors in a synergistic manner, I aim to enhance the vehicle's overall performance and in doing so give the vehicle the best possible chance of success. In addition I will publish a final report, providing detailed information about the project, including its objectives, methodologies, and results. Additionally, it is important to outline how the findings and outputs of the project were integrated with the larger Triton AI initiative, and how they contributed to the organization's overall goals and objectives. By highlighting the impact and value of the project in the context of the larger Triton AI project, the final report will provide a comprehensive understanding of the project's significance and relevance.

1.3 Minimum Viable Product

The minimum viable product for this project will be successfully fusing the IMU and GPS in a meaningful way. To achieve this, we will utilize the P1 SDK, a board developed by Point One that is installed on a smaller vehicle that is ideal for testing and shares many similarities with the Atlas system that will be used for the final product.

It is essential to the organization's success that we have the ability to access the IMU/GNSS fusion capabilities of the Point One P1 SDK and Atlas system through the ROS2 operating system and the Point One fusion engine. The fusion engine is responsible for combining the information generated by the IMU and GNSS sensors in an optimal way to determine the vehicle's next move. This is essential for achieving the project goals since relying on GNSS systems alone can result in high latency due to the slow rate of signals coming from satellites, which is often inadequate for providing the vehicle with accurate directions.

The next critical demonstration is the calibration routines for the vehicle heading and other sensors that are required for movement. This process enables the vehicle to accurately determine its location, direction, speed, and acceleration and establish a baseline for the vehicle's movement system. Accurate calibration is crucial to achieving optimal performance and reliability of the system.

Over the course of the project, I will iterate quickly on top of the MVP, by implementing its features onto the final product as I have time and feedback from the test vehicle. The specific objectives for this quarter are to achieve the MVP, test it rigorously, and gather feedback from the test results. I will also work on enhancing the performance and reliability of the system and expanding its capabilities to include everything we need to deliver the best possible product.

Next steps after the MVP are integrating the LIDAR and IMU systems. LIDAR has a similar problem to GNSS in that it does not get data fast enough to solely make decisions for the vehicle hence the need to “fuse” it.

The long-term goal of the project is to integrate the findings and capabilities of the MVP into the larger Triton AI project, specifically the Atlas system, which will serve as the platform for the final product. This will involve close collaboration with the Triton AI team to ensure compatibility and integration with their system and developing new features and capabilities as required. Ultimately, the project aims to enhance the autonomous capabilities of the Triton AI vehicle and enable it to operate safely and effectively in different environments and conditions.

1.4 Constraints, Risk, Feasibility

This project has several potential challenges that require careful consideration. First, we have a limited timeframe for the project as a quarter is very short and my sub-project received a late start due to complications early on in the class. We are also heavily constrained by a two week window before we need to ship out the final robot and we will be restricted back to the test robot. We need to carefully manage our time to ensure that the most important features are implemented in time and later more minor improvements and strategies can be tested. Additionally, the complexity of the IMU/GNSS fusion capabilities and calibration routines may prove challenging, but the team’s familiarity with this software should help.

I believe that it is realistically feasible to achieve the minimum viable product well before the shipment of the final robot. We have a clear plan in place for how to integrate the required

capabilities of the Atlas and how to ensure correct calibration routines. Furthermore, I will be regularly communicating with my project mentor and my professor to ensure that we stay on track and adjust our approach if necessary.

I also think I will have time to implement the fusion of the LIDAR and IMU systems which is well planned in my project schedule.

Despite our careful planning, there are still several risks that need to be considered. For example, there is a risk that we may encounter unexpected technical issues that could delay our progress or prevent us from achieving our goals. To mitigate this risk, we will be regularly testing our code and hardware to ensure that everything is working as expected..

Overall, with careful planning and proactive risk mitigation strategies, I can successfully deliver a high-quality project within the given timeframe.

1.5 Group Management

Although I am the sole member of my CSE 145 project group, my work is directly contributing to the larger goals of the Triton AI Racing organization. As a result, I will be collaborating with several other team members, including my project mentor, Jack Kuberman, who plays a significant role in the organization's operations. Effective communication with my team members responsible for related projects is crucial to ensure the seamless integration of my work within the larger structure. All decisions regarding my projects schedule, decisions, and deliverables will be decided by Jack and myself. I am only responsible for my own schedule and I communicate with everyone via a Discord group.

1.6 Project Development

For hardware, I plan to utilize the Point One P1 SDK board, Point One Atlas board, Point one Artemis board, Razor IMU, LIDAR Livox MID360, a go-kart, and a test go-kart. As for software, I will employ a vehicle-integrated computer running on the ROS2 operating system. To interface with the hardware, I will utilize the Point One fusion engine and associated firmware for each board. All necessary resources are available to me.

During the project development, I will test incrementally as I work towards implementing the MVP and the rest of the project. The majority of my testing will be performed on the P1, which is attached to a smaller go-kart dedicated to testing purposes. I will conduct tests that involve both the software and the actual vehicle. In addition I will be doing similar tasks for the Artemis board and comparing my findings with the other hardware. In addition I will be fusing the LIDAR and IMU enabling odometry.

I will also take the responsibility of documenting my progress incrementally throughout the project development.

1.7 Project Milestones and Schedule

Low Level Milestones

- Week 4: Complete a background study, get familiar with hardware and firmware, and complete preliminary tests
- Week 5: Test GNSS Atlas, Test GNSS P1 SDK, Test access to different information in the fusion engine including the IMU and GNSS, inspect the fusion engine APIs, learn ROS2 topics and ROSViz, Access the IMU data independently and display it
- Week 6: Work with the team to integrate the Atlas, with complete GNSS/IMU integration into the vehicle cart and test it
- Week 7: Ship the go-cart and go back to working on the scaled P1 driven test robot.
- Week 8: Compare IMU data from the P1 with that of the Artemis
- Week 9: Learn how to fuse razor IMU with LIDAR Livox MID360 to enable odometry
- Week 10 Complete Project Report and finalize collecting all data

Key Milestones

The first milestone of this project is to successfully fuse the IMU and GNSS in the Atlas system to create the MVP. Testing will be conducted incrementally until the feature is successfully implemented and all necessary data is collected. The deliverable for this milestone will be a report containing the test data, as well as results from larger scale vehicle tests with the project's system integrated. The target completion date for this milestone is Week 6.

The second milestone involves completing testing on the IMU/GNSS Fusion on both the Artemis Board and P1 SDK Board, and comparing the findings of all three using test data and quantifiable comparisons. The milestone will be completed once testing involving the different hardware is complete and a report is submitted. The target completion date for this milestone is Week 8.

The third milestone is to fuse the Razor IMU with LIDAR Livox MID360 to enable odometry on the vehicle. Research will be conducted on LIDAR and odometry prior to testing, and a report containing test data and results will be submitted in my final project report as the deliverable for this milestone. Video footage can also be included in all three milestones.