Project Status 3

Team PSIML

February 2025

1 Overview

During this period, we have successfully implemented sign recognition, enabling our vehicle to detect and interpret road signs accurately. Currently, we are developing a PID controller to improve speed regulation and control. To enhance testing and validation, we have created a simulation environment in Unreal Engine, allowing for more efficient experimentation. Additionally, we have finalized our state machine and selected a physical map for the qualification rounds. Moving forward, our focus will be on refining control mechanisms, integrating all components, and conducting extensive testing to ensure optimal performance.

2 Planned activities

At this phase of the project, our team focused on tasks such as:

- Sign recognition based on YOLO neural network
- Physical testing setup for qualifications
- Simulation in Unreal Engine
- PID controller development
- State machine and decision-making

3 Status of planned activities

- **Sign recognition based on YOLO neural network**
  For our sign detection task, we opted for the newest and smallest Ultralytics YOLO model: YOLO11n, prioritizing real-time performance. To further optimize speed, we focused on a 320x320 region of interest in the top right corner instead of processing the entire image. Our next step was gathering training data. While relevant datasets exist online, we chose to develop our own approach. For our sign detection task, we opted for the newest and smallest Ultralytics YOLO model: YOLO11n, prioritizing real-time performance. To further optimize speed, we focused on a 320x320 region of interest in the top right corner instead of processing the entire image. Our next step was gathering training data. While relevant datasets exist online, we chose to develop our own approach. We generated a synthetic dataset by extracting sign images, removing their backgrounds, and applying random transformations—rotations (-30 to 30°) and resizing (20% to 50%). These modified signs were then placed onto random texture images. To better mimic real-world conditions, we applied additional effects such as Gaussian noise, motion blur, and brightness adjustments to the final images. After testing various transformation parameters and evaluating model performance on smaller datasets, we generated a final dataset of 100,000 images for training. This included 10,000 images per sign and 10,000 without signs to prevent the model from detecting signs in every image. Once trained, the model was tested on real-life footage from both our recordings and previous competition datasets. Satisfied with its performance, we converted it to the NCNN format for efficient deployment on the Raspberry Pi. Initial inference tests showed a processing time of 50-90ms per image, which was well within our requirements.

- **Physical testing setup for qualifications**
  We discovered that the official map was located at another faculty, so due to logistical constraints, we decided to create our own map. Our design follows the guidelines provided by BFMC, ensuring that we can demonstrate all necessary maneuvers for the qualification round. The map is currently in progress.

- **Simulation in Unreal Engine**
  We have developed a custom simulation based in Unreal Engine that fully replicates the competition track. It includes all essential props such as road signs, functioning traffic lights, a ramp and a tunnel. It utilizes advanced rendering features of Unreal to achieve realistic visuals in real-time. The simulation supports communication with both Python and ROS, allowing real-time sensor data streaming and control input reception. This enables efficient testing and refinement of our perception and control algorithms before physical deployment.

- **PID controller development**
  The PID controller has been implemented and integrated into the system, with refinement currently in progress. The input to the PID controller is the angle, which is calculated based on the position of the lane center and the reference angle obtained when the car is perfectly aligned (where the angle is zero).

- **State machine and decision-making**
  We have designed a state machine tailored for the qualification round to handle all required maneuvers, and its development is currently in progress.

4 General status of the project

We have successfully completed several key tasks, including the implementation of sign recognition and the creation of a robust simulation environment. During this period, we encountered some hardware issues that required soldering to resolve, and we also noticed occasional unresponsiveness from the Nucleo board. Despite these challenges, our efforts remain fully focused on preparing for the qualification round, with work on the car being carried out daily. We are optimistic about our progress and committed to pushing forward with dedication and hard work.

5 Upcoming activities

In the upcoming activities, we will focus on refining our previous algorithms, finalizing the state machine, and developing all necessary maneuvers.