Team 7 Project Proposal: Road Sign Navigation of Unknown Multi-Path Environment

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I. Introduction

Our final project will focus on real-time road sign detection and reacting without global map, which is similar to the real human driving situation. To achieve our goal, we need to collaborate the depth camera with decision making system and our controller. The basic pipeline consisted by four parts, detection-decision-planning-action. The main problem is how to efficiently combine these parts on a F1TENTH car.

II. Problem Overview

Autonomous vehicles can struggle with navigating through unmapped environments that are designed for humans to easily navigate. At busy city intersections and in construction sites, drivers have to be able to follow road signs and other clues to understand how to navigate in a novel environment where multiple paths may exist but only can safely be followed.

Our project emulates these conditions by forcing the car to navigate blind through a diverging path without a clear path defined outside of the road signs that it can use to navigate the environment. For this project, we will set up a race course with diverging paths. At each intersection, we will have road signs that indicate where the ”safe” path is. The car is tasked with following the road signs to navigate through the course smoothly.

There are a few elements of this problem that makes it challenging. First, any processing and decision making needs to happen in real-time. Since we are attempting to smoothly navigate the course, the car needs to be able to make decisions without slowing down significantly or stopping. Second, the car also needs to understand its environment well enough so it only turns when the path is there even if the car reads the sign earlier. Overall, he difficulty for this project comes from translating signs in a real unknown environment to actual trajectories that the car follows.

III. Background and Previous Work

In the field of real-time road sign detection for autonomous vehicles, researchers and engineers have explored various methods to improve detection accuracy and speed. Below are some approaches that have been tried:

LLTH-YOLOv5 is a framework designed for traffic sign detection in low-light scenarios. It includes a low-light enhancement stage that adjusts the input image at the pixel level and an object detection stage that uses a transformer-based detection head for better accuracy in small target detection [1]. Multi-Scale Detection is an optimization strategy based on the YOLOv4 network was proposed, which includes an improved triplet attention mechanism in the backbone network and a bidirectional feature pyramid network (BiFPN) in the neck network. This enhances feature fusion and improves the detection of small-scale traffic signs [2]. Researchers have also developed novel lightweight methods that utilize vehicle cameras and edge computing devices to identify and detect traffic signs in real-time [3].

These methods aim to provide key information for autonomous vehicles' decision-making to ensure safe driving.

IV. Goal

A. Base Goal

Our base goal for this project is to achieve real-time road sign detection via RealSense depth camera alongside a smooth, collision-free car trajectory without stops. Our preliminary road sign dataset will consist only of right turns, left turns, and stop signs. We will also be using a vanilla YOLOv8 model with minimal parameter fine-tuning as a baseline for our project performance. For the motion planning aspect of this project, we will use a Pure Pursuit controller as a starting point.

B. Reach Goal

After achieving our base goal, we will aim to complete a number of extensions onto the existing object-detection and localization pipeline. The first change we plan to make is to diversify the road sign dataset by adding ”no right turn” and ”no left turn” signs in addition to a ”U-turn” sign to test the precision of our controller and the speed of our object-detection model. We also plan on using an MPC controller to optimize the trajectory and improve on the overall performance compared to a Pure Pursuit controller. Regarding our object-detection model, we will also add more pictures to the dataset and further fine-tune the model’s parameters to improve its accuracy.

V. Timeline

In the next week, we plan on completing the training of our YOLOv8 object-detection model tailored for road sign detection. We also aim to complete integration of the vision model with the rest of the ROS pipeline. In the second week, we aim to have a working decision model that translates the output of the object-detection into a working trajectory. This is also when we would have the pure-pursuit version complete. The final week would involve refining the performance of the project, and integrating reach goals like using an MPC controller, and adding additional signs.

References

[1] Sun, X., Liu, K., Chen, L. et al. LLTH-YOLOv5: A Real-Time Traffic Sign Detection Algorithm for Low-Light Scenes. Automot. Innov. 7, 121–137 (2024).

[2] Wang X, Guo J, Yi J, Song Y, Xu J, Yan W, Fu X. Real-Time and Efficient Multi-Scale Traffic Sign Detection Method for Driverless Cars. Sensors. 2022; 22(18):6930.

[3] Luo, Y., Ci, Y., Jiang, S. et al. A novel lightweight real-time traffic sign detection method based on an embedded device and YOLOv8. J Real-Time Image Proc 21, 24 (2024).