1 Introduction

The present report summarizes the technical progress of the LH - CDC team in the Bosch Future Mobility Challenge 2025 up to December 16, 2024. In particular, the activities planned from November 18 to December 16 and the current situation as well as upcoming activities are briefly described.

2 Planned activities

The planned activities during the aforementioned period, additionally to the team members in charge for each activity are shown below:

- Perception
  - Lanes detection and analyze road boundaries
    @Cường & Phong
  - Traffic Sign Detection
    @Phong & Huy
  - Maintained the car kit from last year and re-operated the car
    @Huy & Phong
  - Intersection detection and find the next place to go [Early implementation]
    @Cường
  - Obstacle detection and tracking [Early implementation]
    @Cường & Phong
- Control
  - Lane Following [Early implementation]
    @Phong & Huy
- Working tools
  - Track design and test design of track models for model racing
    @Huy

3 Status of planned activities

3.1 Lanes detection and analyze road boundaries [Done]

3.1.1 Goals

- Develop an algorithm to detect two lane lines using OpenCV's API.
- Enhance the algorithm to recognize curved and dashed lane lines while ensuring stable FPS performance.

3.1.2 Implementation

The lane detection algorithm was developed using the robust Python OpenCV APIs. As the physical vehicle model and test map were not yet available, we utilized video sources from the Internet to test and refine the algorithm during the initial development phase.

1. Initial Deployment Process:
   - Image Preprocessing: Input images were converted to grayscale to reduce noise and optimize subsequent processing steps.
   - Boundary Detection: The Canny Edge Detection algorithm was applied to accurately detect lane boundaries.
   - Lane Line Identification: The Hough Transform algorithm was employed to detect and draw straight lane lines based on the identified edges.
2. Enhancements and Optimization

- To improve accuracy and performance in real-world scenarios, we plan to:
  - Apply a Region of Interest (ROI): A trapezoidal ROI will be implemented to focus on the area directly in front of the vehicle, minimizing interference from irrelevant regions.
  - Integrate Deep Learning Models: We aim to incorporate a trained lane recognition model with real-world data, enabling better detection of curves, dashed lanes, and consistent performance under complex lighting conditions.
  - Optimize Preprocessing Parameters: Parameters such as edge detection thresholds, kernel sizes, and Hough Transform configurations will be fine-tuned to adapt to diverse driving environments.

3.1.3 Issues

In the lane recognition process, the system generally performs well in recognizing lanes and processing steering commands. However, when there are variations in input data or video conditions, such as changes in lighting, frame rate, or viewing angle, the recognition module tends to become misaligned, resulting in failure to detect lanes accurately. Despite multiple adjustments and fixes, the system's performance has improved only marginally in handling certain road conditions. The primary challenge lies in the fact that the racetrack has not yet been fully developed, and the car kit is still pending delivery. This has made it difficult to finalize the algorithm and fine-tune the model for optimal performance.

We aim to address these issues by prioritizing the completion of the racetrack and refining the algorithm. Our focus will also include preparing the system to handle unfavorable conditions to ensure greater robustness and reliability.

3.2 Traffic Sign Detection [Done]

3.2.1 Goals

We have successfully completed the recognition of nine traffic signs provided by Bosch and have also integrated traffic light recognition to support decision-making processes. To optimize system performance, efforts were made to increase calculation speed and avoid running multiple models simultaneously.

3.2.2 Implementation

1. Initial Implementation
   - To address misidentification and reduce noise, we expanded the training dataset and augmented it to enhance the model's learning capability.
   - The image processing pipeline includes preprocessing, noise filtering, and feature extraction before passing the data through the recognition model to generate the final results.

3.2.3 Issues Encountered

1. Dataset Challenges:
   - The primary issue lies in the dataset itself, which contains a significant number of noisy or unauthenticated images. This affects the accuracy and reliability of the recognition system.
2. End-to-End System Development:
   - A significant obstacle is the lack of a standardized dataset captured by the vehicle's onboard camera. Without such a dataset, it is challenging to validate the algorithm's performance in real-world conditions. To overcome this, we decided to prioritize building the model and collecting preprocessing data as the foundation for further refinement.
   - Through these efforts, we aim to achieve a robust and efficient traffic sign detection system that integrates seamlessly into autonomous vehicle operations.

3.3 Activities under [Development]

1. Intersection detection and find the next place to go: Use lane detection and traffic signals to identify intersections and decide the next move.
2. Obstacle detection and tracking: Deploy object tracking (OC-SORT/MOSSE) and trajectory prediction for safe navigation.
3. Lane Following: Calculate lane distances to dynamically adjust steering and speed.
4. Track design and test design of track models for model racing: Create tracks with diverse features and test under varying conditions for robustness.

4 General status of the project

In summary, we have successfully completed the lane detection and traffic sign recognition modules, laying the foundation for integrating these features into the vehicle's decision-making process. All functions have been tested using data from the competition and the vehicle kit retained from BFMC-2024. In addition, the ROS environment has been set up on the team members' PCs to support development and testing. Currently, we are working on the development of a powerful End-To-End algorithm designed to enhance the vehicle's autonomous navigation capabilities.

5 Upcoming activities

The upcoming activities from December 16, 2024, to January 20, 2025, are as follows:

- Perception Integration
  - Intersection Detection and Next Destination Identification [Simulation and Finalization]
  - Obstacle Detection and Tracking [Simulation and Finalization]
- Control
  - Implementing an Upgrade of Intersection Navigation
  - Implementing Automatic Handling of Dangerous and Unrecognized Lane Situations.