1 Introduction

This report outlines the key activities carried out by **TEAM COSS** during the preparation for **the Bosch Future Mobility Challenge**, including team collaboration efforts, changes encountered during the project, and the progress made.

Particular Activities

Initial Odometry Generation: obtaining initial odometry from a predefined starting position to enable position feedback using Iterative Closest Point.
ICP-Based Localization: Implemented ICP to align BEV lane data with a cropped region of the global map for precise vehicle localization.
MPC development: Implemented model predictive control for precise vehicle control.
Parrallel Parking and Overtaking: Parking and overtaking path generation and tracking using MPC.

Team Spirit

Team members conducted development by setting up an appropriate development environment that suited their roles and situations.

Changes

- We changed to MPC, a more advanced control approach than Pure Pursuit, enabling precise longitudinal and lateral control for parking and overtaking missions.

These activities and the spirit of collaboration played a crucial role in achieving the initial project goals. The team responded to challenges with flexibility and a proactive approach, ensuring steady progress.

2 Planned activities

1) Optimization and Deployment of initial Odometry
Details Task:

- **Noise Filtering and Position Estimation:** Velocity sensor data visualization was used to identify noise patterns, leading to an improved fusion process with IMU data and the integration of Kalman filtering for more accurate localization.

Outcome: Improved position accuracy, enabling consistent localization feedback.

2) ICP-Based Localization Implementation
Details Task:

- **BEV and Cropped Map Alignment:** We extracted BEV lane information from the camera image. And we generated a Cropped Map from the Global Map based on initial odometry. We applied ICP to align BEV lane points with the Cropped Map and obtain a transformation matrix(T_total)
- **Global Coordinate Mapping:** We derived T_map to express the Cropped Map in the Global Map frame. And the following is equation for the final vehicle position.

$$\mathbf{P}_{\text{global}} = T_{\text{map}} \times T_{\text{total}} \times \mathbf{P}_{\text{BEV}}$$

Outcome: Successfully mapped BEV-based vehicle position to Global coordinates.

2) MPC-based path tracking
Details Task:

- **MPC development:** We developed a nonlinear MPC controller using a kinematic bicycle model for real-time path tracking. And Designed cost function and constraints to minimize position and yaw errors.
- **Parrallel Parking:** We used graph search (Dijkstra) and cubic spline smoothing to generate feasible parking paths. And adjusted MPC constraints for safe and accurate parking. We used depth camera as lidar to detect free parking spot.
- **Highway Overtaking:** we detected obstacle with camera and identified the nearest changeable node for lane switching and generated a smooth transition path.

Outcome: Successfully implemented parking and overtaking algorithm with MPC.

3 Status of planned activities

Activity	Status	Description	Difficulties
Odometry Generation	Completed	1. Successfully integrate velocity sensor and IMU data 2. Significantly reducing velocity sensor noise using kalman filtering	N/A
ICP-Based Localization	In progress (75%)	1. Successfully implemented ICP-based BEV-to-Cropped Map alignment 2. Derived T_total, T_map for accurate coordinate mapping	Hard to apply in real-time
MPC-Based path tracking	In progress (95%)	1. Successfully detect free parking zone and park without collision with other cars. 2. Vehicle can detect the obstacle and overtake without collision.	More Parameter tuning is needed for applying in real world.

4 General status of the project

Our team has implemented all the necessary functions for autonomous driving and is currently in the process of applying them.

Localization via initial Odometry: Successfully implemented initial odometry and position feedback mechanism.
Localization via ICP: Initial odometry and ICP-based localization successfully integrated. And Real-time stability issues identified and under investigation.
MPC-based path tracking: Successfully implemented all control methods for path tracking.

5 Upcoming activities

For the final, we will focus on developing control methods using localization without GPS.
1) Development of real-time Localization via ICP

Objective: We will refine localization performance under varying environmental conditions. And we will enhance position accuracy and reduce drift in long-duration tests, and ensure smooth and reliable localization by mitigating instability in dynamic conditions.

Detailed Tasks:

- Apply low-pass filtering or adaptive Kalman filtering to smooth ICP Updates and implement outlier rejection for sudden position jumps.

- Use previous frame′s estimate as a prior to stabilize updates and introduce sliding window averaging to reduce oscillations.
- Improve lane feature extraction for ICP matching and ensure robust feature selection to minimize misalignments.