Robust Trajectory Planning for Autonomous Vehicle

AL FARES Hassan[1,2], TALJ Reine[1,] CHERFAOUI Véronique[1], AIOUN Francois[2], GUILLEMARD Franck[2]

[1] *Heudiasyc, University of Technology of Compiegne, Compiègne, France*

[2] *Stellantis, Poissy, France*

hassan.al-fares@hds.utc.fr

hassan.alfares@stellantis.com

reine.talj@hds.utc.fr

Veronique.Cherfaoui@hds.utc.fr

francois.aioun@stellantis.com

franck.guillemard@stellantis.com

Autonomous vehicles (AVs) have made significant advancements in recent years, yet their full deployment remains limited. The Society of Automotive Engineers (SAE) classifies AV capabilities into six levels, from Level 0 (no automation) to Level 5 (full automation). Achieving full autonomy requires overcoming significant technological and challenges, including developing systems capable of analyzing complex environments, making appropriate decisions, and ensuring safety under all conditions [3]. The general architecture of the processing system for autonomous vehicles consists of three main modules: perception, tactical, and control. The perception module, processes raw data from sensors into refined, actionable information, identifying navigable space, obstacles, and traffic participants, and estimating their positions and velocities. It also performs data fusion to enhance detection reliability and provides uncertainty estimates to inform decision-making. The tactical module, including main functions of decision and planning, determines the appropriate vehicle behavior in its environment, using processed data to interpret driving context, infer traffic rules, and plan maneuvers. Once a maneuver decision is made, a planned path and speed profile are implemented to ensure safety such as obstacle avoidance, maintain vehicle stability, and passenger comfort. The control module operates the vehicle's actuators, translates the tactical decisions into actionable commands for the vehicle's actuators, divided into lateral control, which guides the vehicle's direction, and longitudinal control, which manages speed.

The focus of our research is on the tactical module, particularly on the trajectory planning function, specifically within the context of local planning. The trajectory planning function in an autonomous driving system involves determining the temporal trajectory—a path combined with a speed profile over time—that the vehicle should follow. This process is based on a set of decisions, such as the decision path, acceptable maneuvers domain, speed constraints, and a set of predictions regarding the dynamics of surrounding participants in the environment [1] [2].

This work introduces a robust speed adaptation method designed to respond effectively to dynamic obstacles by operating within the s–t (position–time) domain. The approach generates curves that describe the vehicle's position over time, ensuring smooth speed profiles while proactively avoiding obstacles. The collision matrix in the $s - t$ space is defined as a grid with dimensions corresponding to the length of the trajectory, with a discretization between each point, and over a specific prediction time, corresponding also to the prediction time for other obstacles. On this grid, collision zones can be identified based on the predicted trajectory of the obstacles. These zones represent the positions occupied by the obstacle over a specific interval of time. Overall, this generic obstacle avoidance technique in the s–t space enabling effective speed adaptation in complex, dynamic environments.

Références :

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