THE UNIVERSITY OF DANANG
**UNIVERSITY OF SCIENCE AND EDUCATION**

## NOVELTY OF PHD DISSERTATION

# RESEARCH DEVELOP SOME SOLUTIONS SUPPORTING THE CONTROL OF AUTONOMOUS VEHICLES

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The overall goal of the dissertation is to study a solution to effectively operate autonomous vehicles through intelligent control, find the optimal route, taking into account legal and ethical factors, in order to support vehicle control safely. The research results of the dissertation can serve as a premise to develop a number of modules on autonomous vehicles to improve performance and safety features during the operation of autonomous vehicles.

Specifically, the dissertation will research and develop some solutions to support safe control as well as ensure legal and ethical factors. Modules are built as motion planning module, control decision support module, motion control support module, motion tracking control module and standby motion planning module.

The proposed solutions for research and development are as follows:

- Proposing a motion planning solution using a sampling technique-based approach to generate the optimal trajectory from the set of orbital candidates. The goal of this solution is to not only improve computational efficiency, but also deal with uncertainty in environmental data.

- Proposing solutions to ensure legal and ethical factors for the operation of autonomous vehicles by establishing motion trajectories and control decision-making models. Based on ethical and legal factors, 02 modules will be built, including a module for setting motion trajectories with a set of constraints of road traffic laws and a control

decision support module with elements of driver ethics to control the operation of autonomous vehicles.

- Proposing a solution to support safe control for autonomous vehicles, including a motion control support module, a motion tracking control module and a contingency motion planning module. In which:

Motion control support module is built with 02 main goals: the first is minimal interference, which means that this motion control support system only applies autonomous control when necessary; the second is safety assurance, i.e. the collision-free state of the vehicle is explicitly enforced through optimal constraints.

The Motion Tracking Control Module is built with the goal of controlling navigation, expecting that the movement of the autonomous vehicle will be precise and stable. This also plays an important role in the task of controlling the movement of the vehicle, especially when the vehicle is operating at high speed.

Finally, the contingency motion planning module aims to ensure the safety of autonomous vehicles by constructing an optimal path based on the mobility assessments of other road users in a certain period of time. It then calculates emergency maneuvers for each trajectory.

The contributions of the dissertation are as follows:

**The first contribution** of the dissertation is to propose a motion planning method using a sampling technique-based approach with the aim of improving computational efficiency and handling uncertainty in environmental data. This technique is simple, effective with information obtained from sensor signals and navigation systems.

**The second contribution** of the dissertation is to build a module to solve the problem of decision support for autonomous vehicles with a set of constraints that are regulations on road traffic laws and drivers' ethics. This control support module includes a solution for setting motion trajectory and control decision-making model as the following:

- The decision support module plays an important role in avoiding collisions and avoiding obstacles in motion. The operational process of this module is separated into two separate parts, including: theoretical model and data collection system.

- Motion trajectory setting module is built based on predictive model control method. To control the forecast for an object, the process needs to perform the following steps: (a) Building a predictive model; (b) defining the objective function and constraints; (c) finally solving the optimization problem. In particular, the set of constraints of this module includes the legal and ethical constraints of the behavior of participating in traffic. This approach is suitable for complex environmental conditions because these constraints can arise from different aspects of motion planning, enhancing obstacle avoidance while ensuring a globally optimal trajectory.

**The third contribution** of the dissertation is to improve the safety features for autonomous vehicles by building a set of modules to support decision making for safe

control including the following modules: the first module is control motion tracking, the second module is for motion control support, and the last one is a contingency motion planning module, specifically as follows:

- Motion tracking control module features navigation control for precise and stable vehicle movement. The solution of this module is to incorporate time-varying uncertainties to moving obstacle predictions into the optimization problem, while also providing constraints for the boundary limit and moving obstacles while maintaining the vehicle's motion plan for a limited period of time.

- Motion control support module to solve the diverse and complex situations that we often encounter in traffic environment conditions. The motion control support solution will create a safe motion trajectory for the vehicle. The design of this control support system has two main goals: the first one is minimal interference, i.e. applying autonomous control only when necessary; the second is safety, i.e. zero state Vehicle collisions are explicitly enforced through optimization constraints. This module is characterized by shortening the motion planning cycle in order to minimize deviations from the forecast input, while ensuring safety according to the motion plan. This driver assistance solution is only implemented in situations where a complex vehicle movement scenario is likely to result in a collision with realistic warning elements.

- The contingency motion planning module is built to perform and promote efficiency in cases of high-speed traffic, the remaining processing time is too short to perform emergency braking level to avoid the obstacles.

The content of the dissertation includes the introduction, the content consisting of 4 chapters and the conclusion, as follows:

**Chapter 1. Overview of autonomous vehicle control**

In this chapter, in order to have a basis for building a control support solution in the operation of autonomous vehicles, in addition to an overview of autonomous vehicles with the process of building, developing and determining the level of hierarchy according to autonomous vehicle operation, I will present the problems that exist and then provide solutions to build support modules. These are the objectives to be achieved of the dissertation.

And to solve the problems proposed by the dissertation, this chapter will present the preparatory knowledge as a theoretical basis to solve the proposed problem, including: building mathematical models, methods of solving problems to be studied and the related research results.

The content of this chapter is in the author's articles 3, 4 and 9

**Chapter 2. Proposed solutions finding the optimal path for autonomous vehicles**

This chapter will present an overview of techniques for setting up paths for autonomous vehicles. Analyze and evaluate the advantages and disadvantages of each technique to serve as a basis for building an optimal path-finding module for autonomous

vehicles using sample-based techniques. This motion planning module solves the problem of generating optimal trajectories, achieving computational efficiency and dealing with uncertainty in environmental data.

The content of this chapter is in the author's articles 9 and 11.

**Chapter 3. Proposed solutions to legal and ethical issues of autonomous vehicles**

This chapter will address legal and ethical issues in the operation of autonomous vehicles with a system of 02 modules, including:

- Motion planning module with constraints set of road traffic laws to solve legal problems when participating in traffic of autonomous vehicles.

Control decision support module with a set of constraints is built from the driver's behavioral characteristics. This module will solve the problem of driver ethics applied to the modular system of autonomous vehicles.

The content of this chapter is in the author's articles 5 and 7.

**Chapter 4. Proposed solutions to support safe control of autonomous vehicles.**

Based on existing problems with solutions, set goals, along with theoretical basis and mathematical tools presented in chapter 1, this chapter will build a set of modules to improve efficiency. and support safe control of autonomous vehicles, with a system of 03 modules, including:

- Motion tracking control module will solve the problem of navigation control with the desire that the vehicle's movement is accurate and stable.

- Motion control support module solves diverse and complex situations commonly encountered in traffic environment conditions.

- The contingency motion planning module solves situations that ensure vehicle safety when participating in high-speed traffic.

The content of this chapter is summarized based on the research results of the author's articles 1, 2, 6, 8 and 10.

The last part are some conclusions of the dissertation.

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