

# Research on Autonomous Driving Control Methods for Smart Vehicles

Qingbo Su

*(Sichuan City Vocational College, Chengdu 610000, China)*

**Abstract:** With the continuous advancement of technology, autonomous driving in smart vehicles has gradually become a research hotspot in the automotive industry. Traditional driving relies on human drivers for operation and decision-making, but this approach involves uncertainties and errors due to human factors, which can easily lead to traffic accidents and congestion. The emergence of autonomous driving offers new solutions for improving traffic safety, reducing accidents, and enhancing travel efficiency. This paper introduces autonomous driving in smart vehicles, analyzes its current development status and existing challenges, and explores autonomous control and execution mechanisms to effectively enhance the control capabilities of smart vehicle autonomy, thereby promoting the sustainable development of intelligent vehicle technology.

**Keywords:** smart vehicles; autonomous driving; driving control

## 1 Introduction

A smart car is an automobile integrated with advanced technologies and equipment, enabling functions such as autonomous driving, intelligent navigation, smart traffic management, and vehicle-to-everything (V2X) connectivity through the use of sensors, artificial intelligence, and automatic control systems. The development of smart cars marks a significant shift in the automotive industry toward greater intelligence, digitization, and sustainability, and represents one of the key directions for future transportation systems. In smart vehicles, the development and application of autonomous driving can reduce human errors and lapses, thereby enhancing driving safety and comfort [1]. In the future, the smart car market will continue to expand, offering broad prospects and significantly influencing both transportation methods and lifestyles.

## 2 The Connotation and Development Significance of Intelligent Vehicle Autonomous Driving

### 2.1 Connotation

Autonomous driving in smart vehicles primarily relies on computer control technology and connected vehicle technology, enabling the vehicle to perceive its surrounding environment and make control decisions based on preset driving trajectories. Specifically, smart cars are equipped with environmental perception technologies that can detect real-time information about roads, other vehicles, pedestrians, and more. Based on this sensory data, the vehicle can perform basic operations such as speed adjustment, overtaking, lane changing, and evasive maneuvers to ensure safe travel along the predefined route. Additionally, during operation, the vehicle can dynamically adjust and make decisions [2] according to its ongoing perception of the surrounding environment.

### 2.2 Development Significance

First, enhancing driving safety. During autonomous driving, intelligent vehicles can use sensors, cameras, and radar to perceive road conditions, traffic signs, other vehicles, and pedestrians in real time. By analyzing this data with advanced algorithms, they make more accurate and reliable driving decisions, effectively reducing or eliminating human errors such as drowsy driving and distracted driving, thereby significantly lowering the incidence of traffic

accidents and improving overall driving safety.

Second, improving driving comfort. Autonomous driving reduces the driver's workload, eliminating the need for prolonged concentration while operating a vehicle. Particularly during long trips, drivers can switch the car to autonomous mode, freeing up time and energy for other meaningful activities such as resting, relaxing, or conversing with passengers. This enhances driving comfort, making long-distance travel more relaxed and enjoyable.

Third, accelerate the process of societal intelligence. The widespread adoption of smart vehicles can reduce energy consumption and exhaust emissions, thereby lessening their negative impact on the environment [3]. This not only promotes sustainable development of social resources but also drives intelligent advancement across related industries. For instance, integrating autonomous driving into smart vehicles can foster innovation and development in areas such as high-precision mapping, sensors, and artificial intelligence algorithms, helping to propel society as a whole toward greater intelligence.

### **3 Development Status and Existing Issues of Autonomous Driving in Smart Vehicles**

#### **3.1 Development Status**

Today, with continuous technological advancements and the development of the automotive industry, autonomous driving is gradually becoming practical and widespread. An increasing number of Chinese automakers are researching and exploring intelligent vehicles and their related components, aiming to achieve the early popularization of autonomous driving. Autonomous driving involves multiple key technologies, such as control and positioning systems, making it a complex operational process that requires intensified research into these core technologies. This not only enhances the safety of autonomous driving but also facilitates its broad application.

The realization of autonomous driving relies on in-vehicle sensing devices. These sensors play a crucial role in autonomous driving systems by collecting comprehensive vehicle data and location information, enabling the system to make intelligent decisions and plan driving routes. In the process of intelligent decision-making and route planning, autonomous systems primarily use data fusion technology to gather, organize, and analyze data from vehicle perception devices, then employ intelligent decision-making algorithms to scientifically and rationally plan driving paths, ensuring vehicles can reach their destinations quickly and safely. At the same time, the system continuously monitors the vehicle's status in real time, thereby enhancing the safety, efficiency, and accuracy [4] of autonomous driving.

The quality of autonomous driving systems significantly impacts the overall performance of smart vehicles, and this influence is profound. Relying on various sensors and corresponding algorithms, autonomous systems can collect and analyze data from the vehicle's surroundings, enabling real-time determination of optimal driving routes and avoiding congested or hazardous areas to ensure efficient travel. In the future, there will be substantial room for development in autonomous driving, and it is already being applied in certain specialized fields. For instance, applying autonomous technology in agriculture enables automated farming operations, improving agricultural productivity and reducing farmers' labor burdens. Similarly, its application in freight and logistics allows for unmanned transportation, enhancing delivery efficiency and lowering operational costs.

#### **3.2 Existing Problems**

##### *3.2.1 Privacy Issues*

While the development of autonomous driving in smart vehicles enhances travel convenience, it also raises certain privacy concerns. For instance, sensors and cameras can record data such as a vehicle's travel routes and driving habits. If hackers gain access to a vehicle's or network system, they could obtain or alter users' personal information, using it for fraud, theft, or other illegal activities. This not only disrupts users' daily lives but also leads to financial and security losses. Therefore, privacy protection has become a critical issue, requiring enhanced security measures and the establishment of relevant regulations to ensure the safety and privacy of autonomous driving systems, thereby

providing drivers with a secure and reliable travel environment [5].

### *3.2.2 Inadequate development of intelligent infrastructure*

Currently, intelligent infrastructure in some regions remains underdeveloped, failing to meet the demands of autonomous driving for smart vehicles. For instance, the coverage of intelligent traffic signals is limited, and traditional signal systems still prevail, making it difficult to effectively address traffic congestion and optimize traffic flow, thus perpetuating low transportation efficiency and persistent traffic jams. Moreover, the coverage of vehicle communication networks is insufficient, preventing comprehensive connectivity and interoperability among vehicles, which restricts information exchange and coordination between them, thereby hindering the efficient operation of intelligent transportation systems.

### *3.2.3 High cost and rapid technological obsolescence*

Autonomous driving requires a large number of devices and facilities to support its operation, such as sensors, communication equipment, and data processing systems. The procurement and installation costs of these devices and infrastructure are relatively high, making the deployment and widespread adoption of autonomous driving systems challenging. For some car owners and consumers, the cost of autonomous driving technology may exceed their affordability, thereby affecting their willingness to embrace it. At the same time, new technologies and equipment continue to emerge [6], replacing older ones, which makes some users hesitant about adopting autonomous driving technology.

## **4 Intelligent Vehicle Autonomous Driving Control and Execution**

### **4.1 Control Method**

#### *4.1.1 PID Control Method*

The PID control method is an automatic control approach based on linear, non-dynamic systems, primarily consisting of three components: proportional control (P), integral control (I), and derivative control (D). It calculates the controller's output signal by comparing the difference between the system's actual output and the desired output, thereby achieving system control. Although the PID method is simple, easy to use, and widely applied, it has certain limitations and struggles to effectively adapt to complex nonlinear and dynamic systems. In real-world driving scenarios, the PID control method often fails to meet requirements for system response speed, stability, and robustness. Therefore, in the field of autonomous driving, it is necessary to combine other control methods to achieve higher-level control performance.

#### *4.1.2 Fuzzy Control Method*

Fuzzy control is a method based on fuzzy logic theory that simulates human thinking to achieve control in complex environments and scenarios. In practical control processes, a fuzzy controller uses current input information to generate a fuzzy output through fuzzy inference and matching with fuzzy rules. This fuzzy output is then converted into specific control commands—such as steering angle or acceleration—via defuzzification. The advantages of fuzzy control include its ability to handle nonlinear and complex control problems with relatively low requirements for system modeling. It can flexibly deal with various uncertainties and ambiguities, and different control needs can be accommodated by adding or adjusting fuzzy rules [7].

#### *4.1.3 Neural Network Control*

Neural network control methods are primarily based on neural networks and are used to solve complex control problems. In the automotive field, these methods can be applied to autonomous driving, vehicle stability control, and intelligent transportation systems. Among them, convolutional neural networks (CNNs) are a special type of neural network mainly used for image processing and pattern recognition tasks. By using high-speed cameras to capture real-time images of the road ahead, these images serve as input data for building a neural network model. The network uses its prior training experience and learned knowledge to analyze and predict the current driving scenario, then

generates optimal control commands such as steering angle, wheel rotation, and vehicle speed. For example, when a CNN receives an image of a curved road, it can recognize the pattern and output the appropriate steering angle. In emergency situations—such as encountering obstacles or other vehicles ahead—the neural network can quickly respond based on visual information, adjusting both speed and steering to ensure safe driving.

#### **4.2 Longitudinal and Lateral Control**

Longitudinal control refers to managing a vehicle's motion along the forward-backward direction, primarily involving operations such as acceleration, deceleration, and braking. It is essential for enabling vehicle following and maintaining safe distances. In longitudinal control, intelligent vehicles typically use sensors to gather environmental information, such as the distance and speed of obstacles ahead. Based on this data, the vehicle can implement appropriate longitudinal movements using corresponding control methods. During execution, the intelligent vehicle calculates the required control inputs according to the chosen method and then activates actuators—such as the throttle, brakes, and transmission—to perform acceleration, deceleration, or braking. At the same time, real-time sensor data is continuously monitored and used to adjust the longitudinal control, ensuring safe and stable driving.

Lateral control primarily refers to the regulation of a vehicle's lateral motion, including steering, lane keeping, and vehicle position adjustment. In intelligent vehicles, lateral control is mainly achieved through electronic stability programs (ESP) and autonomous driving systems. ESP uses sensors to detect the vehicle's attitude and road conditions, then automatically controls braking and steering as needed to maintain stability and safety. Autonomous driving systems, on the other hand, utilize sensors and map data to identify the vehicle's current lane and position, and automatically adjust steering and positioning accordingly to ensure the vehicle remains within its lane. The key to effective lateral control lies in vehicle localization and environmental perception. Vehicle localization can be accomplished using global positioning systems (GPS) and inertial navigation systems (INS) to determine the vehicle's current position and orientation. Environmental perception relies on sensors such as radar, cameras, and lidar to gather information about the surrounding environment—including vehicles, pedestrians, and obstacles—enabling the lateral control system to make appropriate decisions and adjustments.

#### **4.3 Vehicle Control Platform**

The vehicle control platform is a core component of the autonomous driving control system in intelligent vehicles, consisting of two parts: the vehicle electronic control unit and the communication bus. The former is responsible for controlling and computing the vehicle's operational status by receiving data from various sensors—such as radar and cameras—analyzing it, and performing calculations to enable autonomous driving control. The latter connects the vehicle electronic control unit with other vehicle systems, including the engine, braking system, and steering system, enabling data transmission and communication. Through the communication bus, different modules can exchange data and control instructions in real time, facilitating coordinated operation and ensuring system reliability. Additionally, real-time information about vehicle performance and road conditions is provided to the driver, allowing them to better understand the vehicle's status and surrounding environment, thus making appropriate decisions and actions.

#### **4.4 Simulation Test**

Simulation testing is a crucial method for evaluating the performance and safety of autonomous driving systems in intelligent vehicles. In simulation tests, the first step is to define the test objectives and evaluation metrics, such as vehicle driving stability, path tracking accuracy, and obstacle avoidance capability. Next, appropriate control algorithms and strategies should be designed based on these metrics and validated within a simulation environment. Commonly used control methods include fuzzy PID control, model predictive control, and neural network control. By adjusting the parameters of the control algorithms, the vehicle's control performance can be optimized—for example, tuning the parameters of a PID controller can improve both motion stability and response speed. Additionally, simulation tests enable comparison of different control methods to identify the most suitable approach. Through simulation, various driving scenarios and unexpected situations—such as sudden obstacles or changing road

conditions—can be modeled to assess the autonomous system’s responsiveness. During testing, key parameters such as vehicle trajectory, speed, acceleration, as well as the execution and effectiveness of the control algorithms, can be monitored to ensure safe operation of the intelligent vehicle.

## 5 Conclusion

The development of autonomous driving in smart vehicles is a significant trend in the automotive industry, enhancing both safety and comfort in driving, and playing an important role in advancing societal intelligence. However, during this development process, challenges remain, such as privacy concerns, inadequate infrastructure, high costs, and rapid technological obsolescence. To effectively address these issues, relevant authorities, enterprises, and all sectors of society must work together to create synergies and promote the healthy advancement of smart vehicle technology.

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