Computers and Artificial Intelligence；Vol.2, No.2; 2025
E-ISSN: 3006 -3728 P-ISSN：3006-371X
DOI: https://doi.org/10.70267/cai.25v2n2.2936
Published by: Zeus Press

# Autonomous Driving Driven by Artificial Intelligence: Development Status and Future Prospects

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## Abstract

This paper aims to explore the current status and future development trends of artificial intelligence technology in the field of autonomous driving. By analyzing the application of artificial intelligence technologies such as computer vision, deep learning and reinforcement learning in autonomous driving, this paper shows that autonomous driving is currently a hot topic in society. At present, L2 and L3 autonomous driving systems have been launched. In the future, autonomous driving may develop in the direction of vehicle–road collaboration and L4 unmanned delivery. In addition, we still face many challenges, such as the accuracy attenuation of computer vision algorithms in extreme weather and the proportion of responsibility between car companies and users in autonomous driving accidents.

### Keywords

artificial intelligence, computer vision, deep learning, reinforcement learning, autonomous driving, vehicle–road coordination

## 1. Introduction

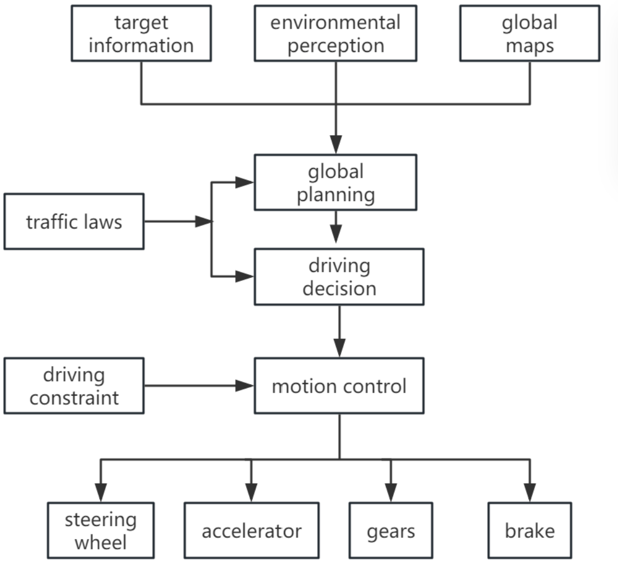
In recent years, with the rapid development of artificial intelligence technology, autonomous driving technology has become one of the most concerning frontier directions after the deep integration of the field of transportation and artificial intelligence. With the development of the automobile industry, people not only need a comfortable driving environment but also increasingly look forward to intelligent driving. The development of autonomous driving technology represents the future development trend of the automotive industry. With the gradual maturity of this technology, autonomous driving has moved from the laboratory to actual road tests and has gradually entered commercial application operations in many regions of the world. With the advancement of technology and improvements in laws and regulations, the application scenarios of autonomous vehicles will further expand. With the gradual popularization and application of advanced information technologies such as 5G and the Internet of Things, autonomous driving systems will be more closely integrated with other traffic participants to establish a more intelligent and collaborative traffic environment.

This study aims to explore the industrialization of autonomous driving vehicles after the deep integration of artificial intelligence and the transportation field. It adopts the framework of "technology analysis-current situation analysis-thinking analysis" and analyzes artificial intelligence technologies such as computer vision, deep learning and reinforcement learning. Combined with the autonomous driving vehicles currently in production, such as Tesla, Xiaopeng Motors, and Mercedes-Benz, this article further considers the development trend and feasibility of autonomous driving vehicles.

## 2. Application of Artificial Intelligence Technology in Autonomous Driving

Artificial intelligence technology is gradually making autonomous driving possible. As shown in Figure 1, according to the target information set by the driver, the automatic driving system obtains the environmental state information through cameras, radar, lidar and other sensors; takes traffic rules and necessary vehicle driving constraints as constraint conditions; and generates global vehicle path planning and automatic driving decisions from the starting point to the end point. Then, the steering wheel and throttle receive the corresponding control signal to achieve control of the vehicle speed and steering angle, avoid obstacles, and safely reach the target location. (Wang, 2024)

*Figure 1: Diagram of the automatic driving system*




The application of artificial intelligence technology in automatic driving is reflected in three main aspects: computer vision, deep learning and reinforcement learning. Computer vision technology involves the "eyes" of self-driving cars; captures information about the surrounding environment through cameras; and uses image recognition and processing algorithms to detect and recognize targets such as roads, vehicles, and pedestrians. Deep learning technology provides autonomous driving systems with powerful data processing and learning capabilities, enabling them to extract features from massive amounts of driving data and continuously optimize decision-making models. Reinforcement learning technology provides intelligent decision-making ability for autonomous driving and enables the system to independently learn the optimal driving strategy by simulating the driving environment and reward mechanism. (Du, 2025)

### 2.1 Computer Vision

Computer vision involves simulating the human visual system, using cameras to capture images or videos, and then using algorithms to process and analyze the image to extract useful information.

In autonomous driving, convolutional neural networks (CNNSs) are mainly used for environmental perception tasks, such as target detection, lane recognition, semantic segmentation, and traffic sign recognition.

A CNN extracts features such as edges, shapes and textures from images through convolutional layers. Object detection models (YOLO, SSD, and Faster R-CNN) predict the locations and categories of objects through a regional suggestion network (RPN) or an anchor point mechanism on the basis of a CNN. The output results include the bounding box and category label of the target. This principle can be used to detect dynamic targets such as vehicles, pedestrians and bicycles in front of them, as well as to identify static targets such as traffic signs and signal lights. The CNN extracts the features of the lane lines (such as color, shape and direction) through the convolutional layer. Semantic segmentation models (such as U-Net and DeepLab) classify each pixel of an image on the basis of a CNN to distinguish the lane lines from other areas. The output results include the position and shape of the lane lines. This principle can be used to identify lane lines on highways and urban roads and assist vehicles with lane keeping and automatic lane change functions. The CNN extracts local features of the image through the convolution layer and restores the size of the feature map through the deconvolution layer or upsampling operation. The output result is a segmentation map with the same size as the input image, and each pixel corresponds to a category label. This principle is used to distinguish navigable areas from obstacles. A CNN uses a convolutional layer to extract the features of traffic signs (such as shape, color and pattern). Classification models (such as ResNet and VGG) classify traffic signs on the basis of CNNs, and the output results include the categories and locations of traffic signs. The above principle is used to identify speed limit signs, parking signs and yield signs. Helping autonomous vehicles comply with traffic laws.

The most typical example is Tesla's HW4.0 visual solution. Compared with those of HW3.0, the camera pixels of HW4.0 have increased from 1.2 million pixels to 5 million pixels, and the maximum visual detection distance has increased from 250 meters to 424 meters, allowing for farther and clearer vision.

## 2.2 Deep Learning

Deep learning is an important branch of the field of artificial intelligence, which involves obtaining fitting functions from input and output data and samples and adjusting the weight ratio of parameters to obtain the most suitable model; that is, the automatic driving system makes choices in many situations through independent learning and mastery of human driving behaviors and habits.

By processing the data of different sensors through deep learning models (such as CNNs and RNNs) and then using fusion algorithms (such as Kalman filters) to integrate the data of cameras, radar, lidar and other multisensors, this principle can help autonomous vehicles improve the accuracy of target detection and distance estimation to ensure the safety of autonomous vehicles. Time series models (such as LSTM and transformer) are used to analyze the historical trajectory of the target and predict the future trajectory and behavior of the target (such as vehicle lane changes and pedestrian crossings). This principle can predict the behavior of the vehicle in front of the pedestrian, avoid the collision of the autonomous vehicle, and better assist the vehicle in driving safely in a complex urban environment.

Xpeng Motors' second-generation intelligent assisted driving system, XNGP (Navigation Guided Pilot), has been launched. It is based on the first-generation XPilot system and adds full-range intelligent assisted driving functions under urban road conditions (urban NGPs) and enhanced functions of high-speed NGP and VPA memory parking. The XNGP system is composed of two laser radars, a dual Orin chip supercomputing platform, 13 cameras, 12 ultrasonic radars, 5 millimeter-wave radars and 1 in-car camera. The computing power of the dual Orin chips reaches 400 TOPS, which can process 30 trillion operations per second, providing powerful data processing and decision-making capabilities for the autonomous driving system.

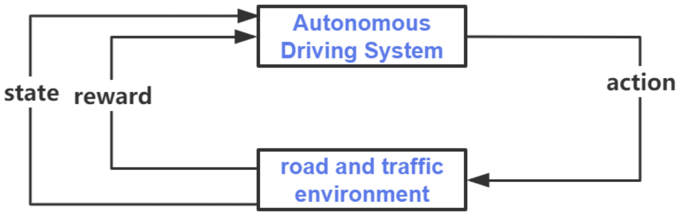
## 2.3 Reinforcement Learning

Reinforcement learning is an important branch of machine learning that allows agents to autonomously learn optimal strategies through trial and error and reward mechanisms.

In automatic driving, the agent of reinforcement learning is the automatic driving system, the environment is the road and traffic environment where the vehicle is, the state may be the position, speed, surrounding vehicles, etc., the action may be acceleration, deceleration, steering, etc., and the reward is the feedback obtained after the automatic driving system completes the action, such as safety and comfort.

The current state of the vehicle and the environment (such as location, speed, surrounding vehicles, etc.) is represented as a state vector, and then the actions that the vehicle can perform (such as acceleration, deceleration, steering, etc.) are defined. The reward function is designed again to consider factors such as collision avoidance, compliance with traffic rules, and reduction of energy consumption. Finally, the optimal strategy is learned through a reinforcement learning algorithm (such as Q-learning). This principle can help the autonomous vehicle plan the optimal path of the vehicle and assist the vehicle in changing lanes and avoiding obstacles in complex scenes. The running state of the vehicle (speed, acceleration, etc.) is represented as a state vector, and the control actions of the vehicle (steering angle, throttle, brake, etc.) are defined. Then, the reward function is designed, and the optimal control strategy is learned through the policy gradient (PPO) algorithm considering tracking error, acceleration change, collision risk, etc. Through this principle, autonomous vehicles can achieve accurate steering and speed control of the vehicle, improving the safety of autonomous driving.

*Figure 2: Automatic driving under the reinforcement learning mechanism*




The Mercedes-Benz Drive Pilot is the first and only Level 3 autonomous driving system certified by the Economic Commission for Europe. When the driver presses the button on the edge of the steering wheel and the green light comes on, Drive Pilot starts to work. The system works when the speed is under 60 km/h, on a sunny day with good lighting conditions, on a highway with identifiable markings, with a centimeter-level high-precision map in the car, and the navigation data need to be approved by the local government. The system uses the SAC algorithm to optimize the throttle and brake control, and the distance error when following a car is less than 0.5 m, controlling the movement of the vehicle.

## 3. Development Status of Autonomous Driving Technology

### 3.1 Technology Classification and Application

The recognized rating standard for automated driving was developed by SAE (Society of Automaton Engineers International) (Chen & Liu, 2025), and by definition, automated driving is divided into six levels:

*Table 1: Level of automatic driving*

| Level | description | Whether manual intervention is required |
|---|---|---|
| L0 | No automation | Driver's sole responsibility |
| L1 | Assisted driving (e.g. adaptive cruising) | require |
| L2 | Partial automatic driving (e.g. automatic lane change) | require |
| L3 | Conditional autonomous driving (e.g. highway driving) | might require |
| L4 | Highly automated driving (no manual required in certain environments) | no requirements |
| L5 | Full autopilot (no steering wheel) | no requirements |

At present, in practical applications, L2-level automatic driving has become mainstream and has been widely used in many mass-produced models; specific applications include automatic parking and adaptive cruising. Level 3 autonomous driving, such as Audi's traffic jam assistance app, is beginning commercialization. Level 4 autonomous driving is piloted in some closed parks and other restricted areas. The actual verification of these applications provides valuable test run data for the next step of the optimization and improvement of autonomous driving technology. The development status of autonomous driving is still very impressive. (State Administration for Market Regulation & Standardization Administration of China, 2021)

### 3.2 Main Technical Routes

At present, the development routes of autonomous driving technology can be divided into two main types: progressive routes and radical routes. There are significant differences between the two approaches in terms of technology implementation, commercialization strategy and goal setting. (Yan et al., 2018)

### 3.2.1 Progressive Route

The progressive route of autonomous driving emphasizes the gradual upgrading of the level of autonomous driving, gradually moving from a low level (e.g., L1--L2) to a high level (e.g., L3--L4). Focus on the safety and reliability of the technology, through the gradual accumulation of data and experience, and eventually achieve fully autonomous driving.

This route starts with driver assistance features (such as adaptive cruising and lane keeping) and gradually adds automation. By deploying low-level autonomous driving systems on a large scale, actual road data can be accumulated, algorithms and models can be optimized, and data can be gradually accumulated. Moreover, the security of the technology is strictly tested and verified at each stage to ensure the reliability of the system in various scenarios. The progressive approach is typified by Waymo. Waymo technology developed from early self-driving test projects (such as Google's self-driving car), gradually improved the level of technology, and finally, L4 self-driving taxi services were launched. The path of traditional car manufacturers such as Audi, BMW and Mercedes-Benz is also to gradually introduce L2- and L3-level automatic driving functions and gradually promote the upgrade of automatic driving technology.

Each stage of the progressive route is rigorously tested, so it is characterized by a gradual upgrade of technology, effectively avoiding safety accidents caused by immature technology. Therefore, technology maturity is relatively high, and the risk is controllable.

### 3.2.2 Radical Route

The autonomous driving radical route emphasizes the rapid advancement of the application of autonomous driving technology through the large-scale deployment of low-level autonomous driving systems (such as L2), the accumulation of data and the acceleration of technology iteration to achieve fully autonomous driving (L5).

This approach focuses on data-driven and rapid innovation. By deploying low-level autonomous driving systems on a large scale, massive amounts of actual road data are collected for training and optimization algorithms. Data are used to quickly improve technology and shorten development cycles. Moreover, the system performance is continuously optimized through user feedback and actual usage data. Tesla is a typical representative. Although its autopilot and fully self-driving (FSD) functions still belong to the L2 level, through large-scale deployment, Tesla has accumulated massive amounts of actual road data and continuously optimized the algorithm. Tesla's goal is to quickly achieve fully autonomous driving. Gm's Cruise also takes an aggressive approach, accelerating technology iteration through large-scale testing and deployment.

The radical route is characterized by fast, rapid accumulation of actual road data through large-scale deployment and then data-driven, rapid improvements in algorithms and models. If the progress is smooth, commercial landing of the technology may be realized more quickly in the future.

## 4. Future Development Trends and Challenges of Autonomous Driving

Artificial intelligence technology has been applied to autonomous driving, and its future development is very promising. The future development of autonomous driving technology has both opportunities and challenges. In particular, with the development of new technologies, car-road collaboration, 5G integration, and artificial intelligence are highly coordinated, automatic driving will achieve more commercial landing, and automatic driving will be more popular in ordinary people's homes. However, to achieve fully automated driving, many challenges, such as technology, legal regulations, ethics, and social acceptance, remain.

### 4.1 Future Development Trends

### 4.1.1 Technological Development

The future of automated driving depends on the development of various technologies in the future.

First, the development of 5G networks has led to a high degree of adaptation to autonomous driving. The 5G network is known for low delay, high bandwidth, and wide connection, and its low delay characteristics provide strong technical support for automatic driving, realizing high-speed real-time information interaction between vehicles and vehicles and between vehicles and roads, facilitating real-time interactive processing of various environmental conditions that may be encountered on the road, and greatly improving the safety and efficiency of automatic driving. Driving safety is the primary factor in cars.

Second, vehicle–road collaboration has become an important development direction. Through intelligent road-supporting infrastructure and the coordination of vehicle autonomous driving, a capable and efficient traffic system has been constructed. To ensure safe driving at the same time, the traffic efficiency of automatic driving should be improved to improve the speed of automatically driven vehicles after countless data are accumulated and trained and to gradually meet the requirements of modern people's fast-paced lives.

The development of edge computing technology can drive itself. A large number of data computing tasks are distributed to the nearest vehicle or roadside to reduce the dependence on the network and cloud, which can effectively reduce the time consumption caused by network transmission, achieve rapid processing of sensor data, make quick decisions, and improve real-time reliability.

Finally, the development of multimodal fusion is also critical. The application of multisource data such as visual, radar, and LiDAR data can effectively improve the accuracy of environmental perception (for example, the fusion of camera and liDAR data can accurately identify pedestrians and obstacles), and then, it is possible to expand from a specific scene to a wider range of urban roads and finally realize the commercial application of autonomous driving.

### 4.1.2 Commercial Application

The commercial application of automatic driving will first be applied to shared travel, logistics distribution, public transportation, private car travel and other aspects.

In terms of shared travel, autonomous taxis and shared cars will become an important part of future urban transportation, which is conducive to further reducing travel costs and improving transportation efficiency. Baidu Apollo has launched self-driving taxi services in several cities.

In terms of logistics distribution, at present, closed parks have partially realized driverless logistics vehicles and automatic AGV warehousing and pick-up. In the future, autonomous logistics vehicles have broad application prospects in industrial parks and urban distribution scenarios, which can further reduce logistics costs and improve distribution efficiency.

In terms of public transport, several cities in Singapore and China have begun testing self-driving buses. Wuxi, for example, has implemented driverless buses in a small number of relatively independent areas, but the operation speed is relatively slow. In the future, self-driving buses are expected to gradually land in specific areas (such as airports and university campuses) and gradually promote urban transportation, providing efficient and safe urban bus services.

## 4.2 Challenges

The popularization of autonomous driving technology still faces many practical challenges. For example:

First, in extreme weather (such as haze, rain and snow) or complex scenes (such as bright light, night), the performance of artificial intelligence models may decline, and there may be problems related to the reduced safety of automatic driving.

Second, how autonomous systems make ethical decisions (such as protecting passengers or pedestrians) in an unavoidable accident is an ethical dilemma.

Third, in the event of an autonomous vehicle accident, how to assign blame—whether it is the manufacturer, the software provider, or the driver—is a complex issue.

Fourth, social acceptance is low, and many users believe that self-driving cars have safety issues.

Fifth, it can easily cause social problems, and automatic driving technology can cause some drivers to lose their jobs.

Sixth, the cost of sensors and computing equipment for autonomous vehicles is high, and it is difficult to popularize autonomous driving on a large scale.

## 5. Further Thinking on Autonomous Driving

Although autonomous driving technology is not fully mature, it is bound to be a future trend. Personally, the development of autonomous driving, in the future, first, to gradually improve the maturity of technology and gradually achieve the perfect realization of vehicle–road coordination and vehicle–vehicle coordination, the future is bound to integrate progressive routes and radical routes, the data-driven method of radical routes and safety and reliability tests of progressive routes. Moreover, it is necessary to promote the development of technology and the combination of multiple modes. At the same time, social acceptance should be improved, and the relevant laws and regulations system should be gradually improved.

### 5.1 Improvement Measures

(1) Establish clear rules for determining liability and clarify the responsibilities of manufacturers, software providers and drivers.

(2) Strengthen public education and improve publicity methods to improve the public's recognition and acceptance of autonomous driving technology.

(3) Provide career transition skills training for drivers who may be unemployed to minimize driver loss.

(4) Reducing the cost of sensors and computing equipment through technological advances and large-scale production.

(5) The fusion of multisensor data such as camera, radar and lidar data improves the perception ability of the automatic driving system in complex environments, thereby improving the safety and reliability of the system.

(6) Build a "people-oriented" fault tolerance mechanism, adopt preregulatory behaviors such as prior supervision to premanage risks, and comprehensively guarantee the safe development of automatic driving.

### 5.2 Specific Case Analysis

#### 5.2.1 Accident Process

In May 2023, a Mercedes-Benz S-Class sedan equipped with DRIVE PILOT (L3) turned on the automatic driving mode on the highway. It encountered heavy rain, and the lidar failed. The system did not ask the driver to take over in time. The vehicle lost control and crashed into the guardrail, causing serious injuries to the people in the car. This triggered social thinking, such as whether Mercedes-Benz did not design a redundant system for extreme weather. Is the control transfer mechanism of the L3 system compliant?

#### 5.2.2 Judgment Result

Mercedes-Benz bears 70% of the responsibility for system design defects (failure to achieve sensor redundancy and timely transfer of control) and compensates for medical and vehicle losses of approximately 1.2 million euros; the driver bears 30% of the responsibility for not paying attention to weather changes in time.

## 6. Conclusion

Artificial intelligence technology is the core technology used to promote the development of automatic driving; although automatic driving technology is currently only at the partial automatic driving level (L2 level), I believe that with the introduction of 5G technology, car and road collaboration and other new technologies, automatic driving will develop faster and more stably and eventually achieve fully automated driving.

## References

Cai, L. (2025). From "control" to "facing uncertainty": A jurisprudential perspective based on the trolley problem in autonomous driving. *Zhejiang Academic Journal,* (01), 88-97. https://doi.org/10.16235/j.cnki.33-1005/c.2025.01.016

Chen, B., & Liu, Y. J. (2025). Ethical governance and legal response: The safe development of autonomous driving. *Study and Practice,* (2), 45-52. https://doi.org/10.19624/j.cnki.cn42-1005/c.2025.02.008

Du, X. Y. (2025). Research on the application of artificial intelligence and electronic information integration in intelligent driving systems. *Times Automobile,* (3), 184-186.

State Administration for Market Regulation, & Standardization Administration of China. (2021). *Classification of driving automation for vehicles*. Ministry of Industry and Information Technology.

Wang, Y. M. (2024). *Research on intelligent vehicle trajectory control based on deep reinforcement learning* [Master's thesis, Shenyang University of Technology]. CNKI. https://link.cnki.net/doi/10.27322/d.cnki.gsgyu.2024.000549

Yan, X. W., Zhu, Z. Z., Zhou, K., & Peng, B. (2018). Application analysis of artificial intelligence in autonomous driving systems. *Journal of Hubei University of Automotive Technology, 32*(1), 40-46.

## Funding

This research received no external funding.

## Conflicts of Interest

The authors declare no conflict of interest.

## Acknowledgment

This paper is an output of the science project.