# Research Status of Autonomous Vehicle Path Planning

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**ABSTRACT:** In recent years, many companies have been developing path planning algorithms and hardware for autonomous vehicles. This paper mainly introduces the latest research and applications of path planning algorithms and related hardware for autonomous vehicles. The introduced algorithms include improvements to Traditional Algorithms, Intelligent Optimization Algorithms, Reinforcement Learning Algorithms and Hybrid Algorithms, such as improving algorithm running speed, path planning ability, and environment learning speed. In terms of hardware research and application, due to the rise of sensor technology and 5G mobile communication technology, this paper mainly introduces the research and application status of multi-sensor, 5G mobile communication technology and lidar, including improving the measurement accuracy of sensors and the ability of sensors to identify surrounding areas.

## 1. INTRODUCTION

With the improvement of computer and Internet of Things technology, the desire for intelligent driving to replace ordinary driver tasks is about to come true. At present, many large auto companies, scientific research institutions and universities are actively exploring the field of unmanned driving and making breakthroughs continuously. This paper mainly introduces the new research and applications of autonomous vehicle path planning algorithms and related hardware in recent years. The introduced algorithms include improvements to traditional algorithms, intelligent optimization algorithms, reinforcement learning algorithms, and hybrid algorithms, such as improving the algorithm's operating speed, path planning ability, and environment learning speed, etc. In terms of hardware research and application, with the development of sensor technology and 5G mobile communication technology, this paper mainly introduces the research and application status of multi-sensor, 5G mobile communication technology and lidar, including improving the accuracy of sensors and the accuracy in recognizing the surrounding environment. accuracy of changes. In terms of research and application, it is closer to the current development status and has more practical significance.

## 2. RESEARCH STATUS

### 2.1. Current Status of Research in China

Chinese companies such as Huawei and Baidu are exploring the field of autonomous driving.

Huawei is only researching and developing driverless technology, not manufacturing complete vehicles. The autonomous driving network project is Huawei's reform attempt in the direction of high automation and intelligence in the entire life cycle of data center networks, especially in the field of intelligent recommendation and automatic implementation of network changes, focusing on active fault perception, rapid positioning, and intelligent self-healing capabilities. aspects of construction. By building a digital twin network and an open programmable network, it provides a service-oriented network with customized business intentions. At the same time, the project realizes fault-speed intelligent sensing, positioning and modification in 75 typical scenarios, making network operation and maintenance faster and more accurate.

The Apollo autonomous driving platform built by Baidu integrates sensing and computing equipment such as electric police, bayonet, radar, fisheye, and edge computing to perform edge-side fusion of video, radar, and signal control data in millisecond-level computing, non-motor vehicles, pedestrians, signs, markings, traffic events and other full-time, all-element, digital accurate perception. The perception ability is more accurate to achieve full access to the base data of the transportation infrastructure, integrate and apply Internet data, public opinion data, high-precision map data, parking data and other refined traffic management data to realize the full-cycle management and service of traffic big data. Based on "Paddle-Paddle", the only deep learning open source framework in China, it builds an autonomous driving and vehicle-road collaboration engine, and improves AI capabilities such as planning, analysis, judgment, prediction, optimization, and iteration.

### 2.2. Research Status in Other Countries

Developed countries have started research and exploration

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in the field of unmanned driving since the 1980s.

In Europe, BMW and Audi have begun researching driverless technology and are working to commercialize the technology. BMW has been working on autonomous driving for more than 10 years. Back in 2006, a BMW 3 Series "self" lapped the Hockenheim circuit, while the self-driving prototype has been on the road since 2011 on the A9 motorway between Munich and Nuremberg. In 2014, a BMW driverless prototype drifted for the first time at the Las Vegas Speedway, showing the possibilities of autonomous driving at the limit of performance. Now, self-driving vehicles can already park themselves (self-parking) with simple gestures. In 2018, the BMW Group set up an autonomous driving campus near Munich, which also promoted the further development of BMW's self-driving car mass production. Audi is promoting its driverless technology in the unveiling of the Aicon concept car. When people enter the car, they only need to enter the destination, and the navigation will start to automatically plan the route and send the passenger to the designated place.

In the US, Google is also exploring this field. Google's research and development in artificial intelligence has laid a solid foundation for its current research on driverless technology, and has established a research laboratory dedicated to driverless smart cars. Google is also mainly engaged in the research and development of core technologies related to unmanned driving, rather than manufacturing the whole vehicle, but only modifying the software and hardware of the whole vehicle to achieve its purpose of unmanned driving. Today, Google has achieved fruitful results in the field of driverless cars, and has gradually completed tens of thousands of kilometers of road tests. Its subsidiary Waymo is also preparing to enter the driverless taxi industry. In addition, Ford and the Massachusetts Institute of Technology (MIT) are also working on unmanned systems, and mainly on sensors. The main current applications are pre-collision assist with automatic emergency braking, etc.

# 3. ALGORTHIM APPLICATION ANALYSIS

## 3.1. Classification of Path Planning Algorithms

Now commonly used path planning algorithms mainly include Traditional Algorithms, Intelligent Optimization Algorithms, Reinforcement Learning Algorithms and Hybrid Algorithms. Traditional Algorithms such as: A* Algorithm, Rapidly-exploring Random Trees (RRT) Algorithm, etc. Intelligent Optimization Algorithms such as: Ant Colony Optimization (ACO) Algorithm, etc. Reinforcement Learning Algorithms such as: SARSA Algorithm, Q-learning Algorithm, etc. Hybrid algorithms such as: Combination of Firefly Algorithm and Genetic Algorithm, Combination of Reinforcement Learning Algorithm and Particle Swarm Optimization (PSO) Algorithm, etc.

## 3.2. Algorithm Introduction:

### *3.2.1. Introduction to Traditional Algorithms*

Traditional algorithms have been the most frequent and stable algorithms that have been used by researchers for many years. The principle of the algorithm is relatively simple, and it is relatively easy to carry out simulation experiments. Such as: Rapidly-exploring Random Trees (RRT) algorithm, etc.

### *3.2.2. Introduction to Intelligent Optimization Algorithms*

The intelligent optimization algorithm is based on the behavioral laws of natural organisms, so that the intelligent vehicle can have the functions of autonomous learning and autonomous decision-making. Such as: Ant Colony Optimization (ACO) Algorithm, etc.

### *3.2.3. Introduction to Reinforcement Learning Algorithms*

Reinforcement learning is when a smart vehicle can continuously identify what is going on in its environment through its own sensors. Such as: SARSA Algorithm, etc.

### *3.2.4. Introduction to Hybrid Algorithms*

The combination of the two algorithms can achieve complementary advantages and optimize the function of the algorithm. Such as: the combination of Reinforcement Learning Algorithm and Particle Swarm Optimization (PSO) algorithm, etc.

# 4. RESEARCH STATUS OF PATH PLANNING ALGORTHIM APPLICATION.

## 4.1. Application of Traditional Algorithms.

H.Q Sang, Y.s You, X.J Sun, Y. Zhou, F. Liu [1] applied the improved A* Algorithm to get the best travel route, which reduced the amount of computation and time and ensured the safety of the path.

Y. Zhou, E.D Zhang, H.L Guo, Y.H Fang, H. Li [2] applied an improved RRT algorithm to reduce the path planning time and improve its quality

## 4.2. Application of Intelligent Optimization Algorithms.

Q. Luo, H.B Wang, Y. Zheng, J.C He [3] applied the improved ACO Algorithm to study the path planning problem, which improved the overall optimal search ability and convergence speed.

L.F Wu, H.S Zha, C.J Xiu & Q.J He [4] applied the Dobbins curve and Whiskers Algorithm to obtain local paths with obstacle avoidance and better vehicle handling.

### 4.3 Applications of Reinforcement Learning Algorithms

V.N Sichkar [5] applied two algorithms, SARSA and Q-learning, to plan paths for the movements of the two robots, which accelerated the learning speed.

A. Maoudj, A. Hentout [6] applied the improved Q-learning algorithm, which has been improved in the length of the robot's path planning, the time required for the calculation and the safety.

### 4.4 Application of Hybrid Algorithms

T.W Zhang, G.H Xu, X.S Zhan, T. Han [7] used the Genetic Algorithm to analyze the best “Firefly”, thereby improving the accuracy and performance of the Firefly Algorithm, and improving the robot's response ability and computing ability in path planning.

X.H Liu, D.G Zhang, T. Zhang, J. Zhang, J.X Wang [8] used the Reinforcement Learning Algorithm to improve the adaptability of the optimal particle of the PSO Algorithm and correct the optimal position for more efficient path planning

## 5. HARDWARE RESEARCH OF AUTONOMUS VEHICLE

### 5.1. The Application of 5G Mobile Communication Technology

S. Ansari, J. Ahmad, S.A Shah, A.K Bashir, T. Boutaleb, S. Sinanovic [9] proposed a 5G wireless network architecture, which makes the vehicle's security information identifier algorithm meet the transmission requirements and greatly improves the speed of the algorithm.

### 5.2. Applications of LiDAR

S. Lee, D. Park [10] improved the problem of excessive power consumption of traditional LiDAR sensors and realize efficient control of autonomous vehicles.

J.D Choi, M.Y Kim [11] proposed a sensor system that uses thermal sensors and lidar sensors to accurately locate and identify objects even in low-visibility environments such as fog and rain, improving the accuracy of vehicle identification.

## 6. CONCLUSION AND OUTLOOK

At present, the application technology for Traditional Algorithm has been relatively perfect, and the application of combining Intelligent Optimization Algorithm and Reinforcement Learning Algorithm should be the future development trend. First of all, the traffic situation in real life is changing anytime, anywhere. When the intelligent optimization algorithm is combined with the reinforcement learning algorithm, the sensor of the car will immediately feel the changes in the surrounding environment, and the intelligent optimization algorithm can make changes to the changes. The countermeasures can respond in time and change the planned route, which greatly improves the safety of the route. If you want to achieve the expected effect, but also have higher requirements on the speed of the optimization algorithm and the sensitivity of the sensor, it is also necessary to improve the search ability and obstacle avoidance of the intelligent optimization algorithm and the reinforcement learning algorithm in the future. Including improving the computing power of the chip, the chip is also a shortcoming of the current technical level. The development of chip technology enables it to perform calculations in a short time, and driverless driving also has higher requirements for the stability of the chip. At present, Huawei's 5G technology is still in the world's leading position. 5G technology should be used in unmanned driving to improve the accuracy of algorithm processing. At the same time, relevant regulatory authorities should also improve relevant laws and policies, such as accident liability determination, to reduce social resistance to the development of this technology.

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