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Design of Vehicle Unmanned Driving Navigation System

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Abstract. This paper studies the design of unmanned vehicle navigation system, aiming to improve the autonomous navigation capability of unmanned vehicles in complex environments. Based on multi-sensor information fusion technology, combined with positioning navigation algorithm and dynamic path planning method, a high-precision and high-real-time unmanned navigation system is constructed. During the system design process, key technologies such as visual SLAM, inertial navigation and GPS fusion positioning are studied, and a target recognition and environment perception module based on deep learning is designed to realize the autonomous decision-making and path planning of vehicles in dynamic environments. Through testing and verification in actual scenarios, the system performs well in navigation accuracy, obstacle avoidance ability and path planning efficiency in complex environments. The research results show that the proposed unmanned navigation system has good adaptability and reliability in scenarios such as urban roads and highways. What's more, this paper shows that there are more and more theoretical support and practical reference for the application of unmanned driving technology in the future.

1 Introduction

1.1 Background and significance

Although the traditional human driving method is flexible, it has many limitations. The judgment ability of human drivers in complex environments is limited by physiological and psychological factors, and they are prone to traffic accidents due to fatigue, distraction or wrong decisions. However, unmanned driving technology can achieve accurate perception, real-time analysis and autonomous decision-making of the vehicle's surrounding environment through multi-sensor fusion and intelligent algorithms, thereby significantly improving driving safety and efficiency. The rise of this technology not only provides new

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ideas for solving urban traffic congestion and reducing traffic accidents, but also lays the foundation for future intelligent transportation.

The rise of driverless technology is one of the most significant signs of technological development in recent years. Behind it is the unremitting pursuit of human society for a more efficient, safer and smarter transportation system. With the rapid development of artificial intelligence, sensor technology and computing power, driverless technology has gradually moved from laboratory research to practical application, becoming an important force for change in the field of modern transportation.

In recent years, the rapid development of unmanned driving technology has benefited from a variety of key technological innovations. For example, the advancement of visual SLAM (simultaneous localization and mapping) technology enables vehicles to achieve autonomous positioning and navigation in unknown environments; the fusion positioning technology of inertial navigation systems and GPS further improves the positioning accuracy of vehicles in complex environments; the introduction of deep learning algorithms has made a qualitative leap in target recognition and environmental understanding capabilities. The combined effect of these technologies provides solid technical support for the realization of unmanned driving systems.

The navigation system plays a vital role in unmanned vehicles and is one of the core technologies for achieving autonomous driving of vehicles. Unmanned vehicles need to complete autonomous navigation from the starting point to the target point in a complex dynamic environment, and this process is inseparable from an efficient navigation system. The navigation system not only needs to perceive the environment in which the vehicle is located in real time, but also needs to analyze and process environmental information to provide support for the vehicle's path planning and behavior decision-making [1]. The role of the navigation system runs through the entire operation process of the unmanned vehicle, and its performance directly determines the navigation accuracy, path planning efficiency and overall safety of the unmanned vehicle.

1.2 Current research status

The development of foreign unmanned driving navigation systems can be traced back to the 1980s. With the advancement of computer technology and the innovation of sensor technology, unmanned driving technology has gradually moved from laboratory research to practical application. In recent years, foreign research in the field of unmanned driving navigation systems has made significant progress, especially in the fields of multi-sensor fusion, path planning algorithm optimization, and vehicle-road cooperative technology, forming a relatively mature technical system. In the technological development of unmanned driving navigation systems, foreign research institutions and enterprises have played an important role. For example, Google's Waymo project has focused on the research and development of unmanned driving technology since 2010. Its navigation system uses a combination of high-precision maps, laser radar (LIDAR) and visual sensors to achieve centimeter-level positioning accuracy and efficient path planning. At the same time, Tesla combines visual SLAM technology with deep learning algorithms through its Autopilot system to achieve autonomous navigation capabilities in complex urban environments. The technological breakthroughs of these companies have not only promoted the technological progress of unmanned driving navigation systems, but also provided important references for subsequent research.

Domestic research in the field of unmanned navigation systems started relatively late, but in recent years, with the strong support of national policies and the rapid development of enterprise technology, my country has made significant progress in the research and application of unmanned navigation system technology. Domestic research mainly focuses on multi-sensor fusion positioning, visual SLAM technology, path planning algorithm optimization, and vehicle-road collaborative technology, forming a technological innovation and application model with Chinese characteristics [1].

1.3 Paper structure

The research goal of this paper is to improve the autonomous navigation capability of unmanned vehicles in complex environments, and to design and implement a high-precision, high-real-time unmanned navigation system based on multi-sensor information fusion technology. This study aims to build an efficient and safe unmanned navigation system that can adapt to various scenarios such as urban roads and highways by comprehensively using key technologies such as visual SLAM (simultaneous localization and mapping), inertial navigation and GPS fusion positioning, combined with deep learning target recognition and environmental perception modules.

Chapter 1 is the introduction, which mainly introduces the research background, significance and current research status of unmanned navigation system at home and abroad.

Chapter 2 is the design and implementation of the unmanned driving navigation system, which mainly discusses the overall architecture, key technologies and implementation methods of the navigation system.

Chapter 3 studies the multi-sensor fusion positioning method, which mainly focuses on the key issues of high-precision positioning technology in unmanned navigation systems.

Chapter 4 is about environmental perception and target recognition based on deep learning, which mainly discusses the key technologies and implementation methods of environmental perception and target recognition in unmanned navigation systems.

2 Overview of autonomous driving technology

As an important research direction in the field of intelligent transportation, the core of unmanned driving technology is to realize the autonomous perception, decision-making and execution of vehicles. The key technologies of unmanned driving mainly cover four core modules: environmental perception, path planning, vehicle positioning and behavior control. The coordinated work of these technologies is the key to realize the autonomous navigation of unmanned vehicles.

Environmental perception technology is the cornerstone of the unmanned driving system. It realizes real-time perception of the vehicle's surrounding environment through the collaborative work of multiple sensors. Environmental perception technologies mainly include visual perception, lidar perception and millimeter-wave radar perception. Visual perception technology obtains image information of the surrounding environment through cameras, and combined with deep learning algorithms, it can realize the recognition and classification of roads, lane lines, traffic signs, pedestrians and obstacles. For example, the object detection algorithm based on convolutional neural network (CNN) has been widely used in the environmental perception system of unmanned vehicles, which can detect and identify pedestrians, vehicles and other obstacles around the vehicle in real time.

Path planning technology is one of the core modules for unmanned vehicles to achieve autonomous navigation. The path planning algorithm needs to calculate an optimal path based on the real-time environmental information provided by the environmental perception module, combined with the vehicle's current positioning information and target point. Commonly used path planning algorithms include Dijkstra algorithm, A* algorithm and RRT (Rapidly-exploring Random Tree) algorithm.

Vehicle positioning technology is another key technology in unmanned navigation systems. Its core goal is to achieve high-precision positioning of vehicles in the global coordinate system. Traditional single GPS positioning technology cannot meet the high-precision positioning needs of unmanned vehicles in complex environments due to problems such as low positioning accuracy and signal susceptibility to interference. Therefore, modern unmanned vehicles usually adopt multi-sensor fusion positioning solutions, such as combining GPS with inertial navigation systems (INS) and visual SLAM (Simultaneous Localization and Mapping) technology [2].

Behavior control technology is the final execution link for unmanned vehicles to achieve autonomous driving. Its goal is to adjust the vehicle's driving behavior in real time based on the results of path planning and environmental perception. Behavior control technology mainly includes speed control, steering control and emergency braking control. Speed control achieves vehicle acceleration and deceleration operations by adjusting the throttle and brake; steering control achieves vehicle steering operations by adjusting the steering wheel angle; emergency braking control automatically triggers the emergency braking function when a potential collision risk is detected to ensure the safety of the vehicle.

At the same time, the application of machine learning in unmanned navigation systems is one of the key technologies for achieving efficient and intelligent navigation. With the rapid development of deep learning, navigation methods based on machine learning have gradually become a research hotspot, providing a new technical path for autonomous navigation of unmanned vehicles in complex environments [3]. In unmanned navigation systems, machine learning technology is mainly used in multiple key links such as environmental perception, path planning, behavioral decision-making, and multi-sensor data fusion, achieving intelligent understanding and autonomous decision-making of complex environments in a data-driven way.

In terms of environmental perception, machine learning technology uses deep learning models to extract features and recognize patterns from sensor data, significantly improving the accuracy and robustness of environmental perception. For example, the target detection algorithm based on convolutional neural network (CNN) can identify key information such as pedestrians, obstacles, and traffic signs around the vehicle in real time, and classify and locate these targets.

In terms of path planning, machine learning technology has achieved intelligent path planning in dynamic environments through methods such as deep reinforcement learning. Traditional path planning algorithms are usually based on static environment assumptions and cannot adapt to real-time changes in complicated dynamic environments.

In terms of behavioral decision-making, machine learning technology simulates the decision-making process of human drivers through deep neural networks to achieve intelligent response to complex traffic scenarios. For instance, the driving strategy model based on deep learning can select the optimal driving behavior, such as lane keeping, lane changing, overtaking, etc., based on real-time environmental information and vehicle status. This data-driven decision-making method can effectively deal with the uncertainty in complex traffic scenarios and significantly improve the autonomous decision-making ability of unmanned vehicles. For example, Tesla's Autopilot system achieves intelligent decision-making in complex traffic scenarios through deep learning algorithms, and can achieve autonomous lane changing and overtaking on highways.

3 Research on multi-sensor fusion positioning method

Multi-sensor fusion positioning technology can achieve complementarity and optimization in different environments by combining multiple positioning methods such as GPS, inertial navigation system (INS), and visual SLAM (Simultaneous Localization and Mapping). For example, when the GPS signal is good, the system mainly relies on GPS to provide high-precision global position information; when the GPS signal is weak or lost, the inertial navigation system can provide high-precision position updates in a short time by measuring the acceleration and angular velocity of the vehicle; and visual SLAM technology can further improve the accuracy and stability of positioning by sensing environmental characteristics in real time. This multi-sensor fusion positioning solution not only overcomes the limitations of a single sensor in complex environments, but also significantly improves the robustness and adaptability of the system [4].

The core of multi-sensor fusion technology lies in how to efficiently and accurately integrate the information of multiple sensors. In unmanned navigation systems, commonly used multi-sensor fusion methods include fusion methods based on Kalman filtering, fusion methods based on particle filtering, and fusion methods based on deep learning.

The path planning algorithm is one of the core modules in the unmanned driving navigation system. Its goal is to calculate an optimal driving path based on the vehicle's current position, target point and environmental information. The performance of the path planning algorithm directly affects the navigation efficiency and safety of unmanned vehicles in complex environments. The design of the path planning algorithm needs to comprehensively consider factors such as the optimality, real-time performance, safety and environmental dynamics of the path, so as to provide reliable path planning support for unmanned vehicles.

Path planning algorithms can be divided into two categories: global path planning algorithms and local path planning algorithms. Global path planning algorithms are mainly used to find the optimal path from the starting point to the target point in a global range under a known map environment. This type of algorithm is usually based on graph search methods, such as the Dijkstra algorithm and the A* algorithm. The Dijkstra algorithm calculates the shortest path from the starting point to the target point by constructing a graph model, which is suitable for path planning in a static environment. However, in a dynamic environment, the real-time performance of the Dijkstra algorithm is insufficient and it is difficult to meet the real-time path planning requirements of unmanned vehicles. The A* algorithm introduces a heuristic search strategy based on the Dijkstra algorithm. By evaluating the heuristic distance from the node to the target point, the most promising nodes are expanded first, thereby significantly improving the efficiency of path search. The A* algorithm is widely used in path planning for unmanned vehicles due to its simple and efficient characteristics.

Local path planning algorithms are mainly used for real-time path adjustment of vehicles in dynamic environments. By combining the real-time environmental information around the vehicle, the driving path is dynamically adjusted to avoid dynamic obstacles. Local path planning algorithms are usually based on sampling methods, such as the RRT (Rapidly-exploring Random Tree) algorithm and the RRT* algorithm. The RRT algorithm can quickly search for a feasible path in a complex environment through random sampling and tree structure expansion methods. It is suitable for scenes with high-dimensional space and many dynamic obstacles. The RRT* algorithm introduces an optimization strategy based on RRT, which can dynamically adjust the path during the search process to obtain a better path planning result.

In recent years, multi-sensor fusion methods based on deep learning have gradually become a research hotspot. By extracting and fusing multi-source sensor data through deep neural networks, more efficient multi-sensor data integration can be achieved, significantly improving the system's perception and positioning capabilities. For example, multi-sensor fusion methods based on deep neural networks can simultaneously process data from visual sensors, LiDAR, and inertial sensors to achieve high-precision estimation of vehicle position and environmental characteristics. This method can not only overcome the limitations of traditional fusion methods, but also automatically extract high-order features from sensor data through end-to-end learning, significantly improving the fusion effect [5].

4 Environmental perception and target recognition based on deep learning

Combined with deep reinforcement learning technology, the training model can make smarter decisions in real-time environments and enhance the system's autonomous decision-making capabilities. By interacting with the environment, the path planning strategy is optimized to further improve the system's intelligence level.

The system has shown good environmental adaptability and navigation capabilities in different scenarios such as urban roads, highways and rural roads. In complex traffic environments, severe weather conditions and low-structured road environments, the system's environmental perception, positioning and path planning capabilities are excellent, and it can quickly respond and adjust driving strategies in scenarios with dense dynamic obstacles and frequent lane changes.

High-precision map construction is a key link in unmanned navigation systems, aiming to provide vehicles with detailed environmental information and ensure their accurate navigation in complex scenarios. The following are the main steps and methods for building high-precision maps. High-precision map construction relies on data from multiple sensors, including laser radar (LiDAR), cameras, GPS, and inertial navigation systems (INS). These sensors provide three-dimensional point clouds, images, position, and attitude information, respectively. The preprocessing stage involves removing noise, calibrating sensor data, and performing coordinate alignment to ensure data accuracy and consistency. Key features such as road boundaries, lane lines, obstacles, and road signs are extracted from the preprocessed data. Feature extraction usually uses deep learning algorithms such as convolutional neural networks (CNN) to improve recognition accuracy and robustness. Feature matching achieves accurate positioning of the vehicle by comparing real-time sensor data with features in high-precision maps. Multi-sensor fusion techniques such as Kalman filtering or particle filtering are used to integrate information from different sensors to improve the accuracy and reliability of positioning. For example, GPS provides global location information, INS supplements high-precision short-term positioning when the GPS signal is weak, and visual SLAM technology further optimizes the positioning results by perceiving environmental features in real time [6-10].

The system's high-precision positioning capability, efficient path planning algorithm, and stable real-time response capability provide reliable technical support for autonomous navigation of unmanned vehicles in complex dynamic environments. However, the system still has room for improvement in terms of real-time and robustness of multi-sensor fusion technology. Future research can further improve the aggregate performance of the system by optimizing the multi-sensor fusion algorithm, introducing more advanced deep learning algorithms, and improving the processing power of the computing platform.

5 Conclusion

The multi-sensor information fusion technology, the high-precision positioning method combining visual SLAM and inertial navigation, and the target recognition and environment perception module based on deep learning proposed in this study provide important theoretical support and technical reference for the optimization design of unmanned navigation systems. These technological innovations not only significantly improve the positioning accuracy, path planning efficiency and environmental adaptability of the system, but also lay a solid technical foundation for the autonomous navigation capabilities of unmanned vehicles in complex dynamic environments. From the perspective of social and economic benefits, the design of the unmanned navigation system proposed in this study can not only improve traffic efficiency and safety, but also bring more convenience to people's lives. For example, in the field of intelligent transportation, unmanned vehicles can achieve efficient and safe traffic management, reduce traffic congestion and accidents; in the field of logistics and transportation, unmanned vehicles can achieve efficient cargo transportation, reduce labor costs and transportation risks; in the field of emergency rescue, unmanned vehicles can achieve fast and accurate material transportation and personnel rescue, and improve rescue efficiency and safety.

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