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Application of artificial intelligence in the field of autonomous driving

ZhijieZeng

Ganzhou HouDe Foreign Language School, Ganzhou, China

2871664836@qq.com

Abstract: With the advancement of artificial intelligence (AI) technologies, object detection, data processing, and lidar navigation have become increasingly prevalent in autonomous driving, offering convenient transportation solutions. However, challenges such as low obstacle detection accuracy, high error rates, and frequent failures in emergency avoidance persist, necessitating further research into AI applications in autonomous driving. This paper explores the application scenarios of object detection, data processing, and navigation technologies in autonomous driving, compares the advantages and disadvantages of autonomous and human driving, and proposes a solution based on the fusion of data processing, visual navigation, and lidar navigation. The aim is to enhance the intelligence level of autonomous driving and provide theoretical support and practical references for the technology.

Keywords: object detection, data processing, navigation, autonomous driving

1. Introduction

Object detection involves identifying and locating objects of interest in images, determining their categories and positions. It is one of the core challenges in computer vision, centered on answering "what" and "where." [1] Due to variations in object appearance, shape, and posture, as well as interference from factors like lighting and occlusion, object detection remains highly challenging. Key components of object detection include feature extraction, classifier design, region proposal, and non-maximum suppression. The feature extraction capabilities of convolutional neural networks (CNNs) in deep learning enable the processing of complex visual information, making it a current research hotspot.Trends in object detection include lightweight models, multimodal fusion, weakly supervised or unsupervised learning, and the growing application of 3D object detection. Lightweight models reduce computational and memory demands for mobile and embedded devices. Multimodal fusion combines image, text, and audio data to improve accuracy and robustness. Weakly supervised learning minimizes annotation costs, while unsupervised learning explores self-learning and evolution. 3D object detection extends to spatial positioning and pose estimation. Challenges include detecting objects in complex backgrounds, oriented objects, and small-sized objects [2].

Data processing involves cleaning, transforming, fusing, and analyzing raw data collected by vehicle sensors to support environmental perception, route planning, and vehicle control. It ensures the safety and reliability of autonomous driving systems in diverse environments. Classic datasets like KITTI provide sensor configurations and classifications to facilitate dataset construction. Trends include deep learning dominance, BEV perception, end-to-end autonomous driving, multimodal fusion (e.g., lidar-camera fusion), self-supervised learning to reduce annotation dependency, and vehicle-to-everything (V2X) data integration. Positioning systems combine satellite, differential, inertial, and map-assisted methods. Simulation platforms are used for issue identification and scenario replication. Motion sensors include GNSS, IMU, and speed sensors. In order to promote the development of automatic driving technology, this paper systematically combs through the technology and application of data processing in the field of automatic driving, combined with the existing technology to point out the current problems and future development direction [3].Lidar point cloud technology, a critical component of perception, has seen significant breakthroughs [4].

Navigation technology in autonomous driving enables vehicles to safely and efficiently reach destinations in dynamic environments through environmental perception, high-precision maps, path planning, and control decision-making. Satellite navigation provides high-precision positioning, navigation, and timing services [5]. Core tasks include real-time positioning, global and local path planning, and motion control to ensure safety, comfort, and efficiency. Trajectory prediction analyzes dynamic interactions between traffic participants and their environment to inform driving decisions and avoid conflicts

[6].Environmental modeling abstracts physical spaces for algorithmic processing, while path search and smoothing ensure feasible routes. Future challenges include data collection and annotation, algorithm optimization, legal and ethical considerations, and safety reliability.

Autonomous driving refers to a vehicle's ability to operate without human intervention, such as robotic vacuum cleaners. Breakthroughs in intelligent connected vehicles rely on AI models with superior perception, cognition, and decision-making capabilities, supported by advancements in assisted driving, smart cabins, and high-performance chips [7].Multisensor fusion integrates multimodal data (e.g., images and depth sensors) for enhanced performance [8]. Approaches to autonomous driving include single-vehicle intelligence, vehicle-road collaboration, and cloud control. High-precision maps provide lane-level prior information, improving localization and scene understanding. Predictive modules forecast obstacle trajectories, enhancing safety and intelligence.

2. Applications of AI in autonomous driving

As shown in figure1, object detection identifies and locates objects in images, addressing "what" and "where." Challenges arise from object diversity and imaging conditions. Computer vision tasks include classification (identifying objects), localization (determining positions), detection (combining both), and segmentation (pixel-level labeling).

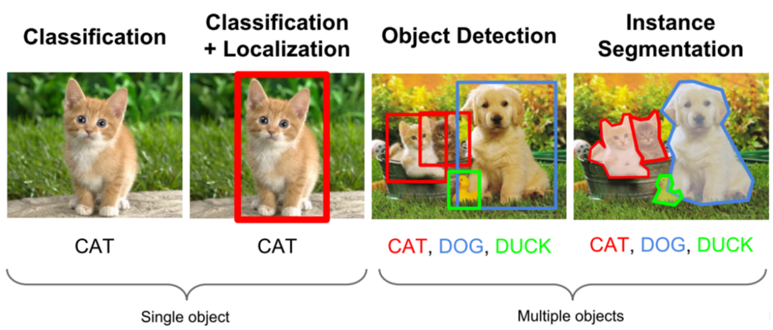

Figure 1. Image recognition task

Table 1. Comparison of object detection and human eye recognition

Detection Method	Speed	Accuracy	Generalization	Anti-Interference Ability
Object Detection	Data-dependent	High (robust)	Adaptive	Strong
Human Eye	Fast	Low (affected by noise)	Poor	Weak

Table 1 compares the difference between target detection methods and human eye recognition, modern target detection is significantly better than human eye recognition in terms of accuracy, generalization and anti-jamming ability, but the speed is constrained by the complexity of the data; although the human eye recognition is fast, but it is susceptible to external interference and poor adaptability.

Autonomous driving integrates data from multiple sources (e.g., lidar, cameras, INS, GPS) into a unified warehouse for analysis and modeling. As shown in Figure 2 traditional vehicle data processing relies on single sensors and structured data for fixed scenarios, while autonomous driving requires multimodal sensors for unstructured data (images, point clouds) in dynamic environments.

As can be seen from Table 2, from the perspective of data processing, traditional in-vehicle data processing is an application based on "single sensor + structured data (numerical or status code)" processing, which is relatively easy to implement when applied to "fixed scenarios". However, for the data processing of autonomous driving, multimodal sensors must be used to process data in a "multi-pronged" manner, targeting unstructured data (images, point clouds), in order to meet the realization of characteristics such as "dynamic and complex environments (urban roads, harsh environments)".

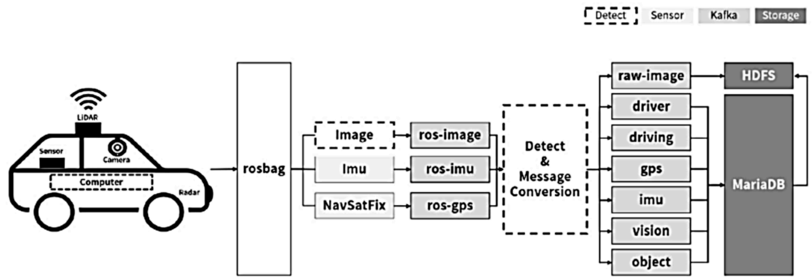

Figure 2. Application of data processing in autonomous driving

Table 2. Traditional vs. autonomous driving data processing

Processing System	Data Source	Data Type	Dynamic Updates	Applicable Scenarios
Traditional GPS	Meter-level	No real-time perception	Offline maps	Structured roads
Autonomous Driving	Centimeter-level	Multisensor fusion	Real-time crowd updates	Complex, dynamic environments

Navigation, as one of the core technologies in autonomous driving, primarily functions to accurately determine a vehicle's position and orientation within a specific coordinate system. Key factors in evaluating navigation performance include precision, robustness, and adaptability to diverse scenarios. For autonomous vehicles to operate reliably under all driving conditions, precise pose information is essential to ensure safety. Currently, mainstream positioning technologies can be categorized into three types (see Figure 3):

1.Radio Signal-Based Positioning: Technologies such as GNSS (Global Navigation Satellite System), UWB (Ultra-Wideband), Wi-Fi, and cellular network positioning (e.g., Cell Phone).

2.Dead Reckoning-Based Techniques: Including IMU (Inertial Measurement Unit), odometry, wheel speed sensors, and similar methods.

3.Environmental Feature Matching: Techniques such as visual positioning, lidar-based positioning, and multi-sensor fusion positioning.

Each of these technologies has its own strengths, providing reliable pose data to support autonomous vehicles in various navigation scenarios.

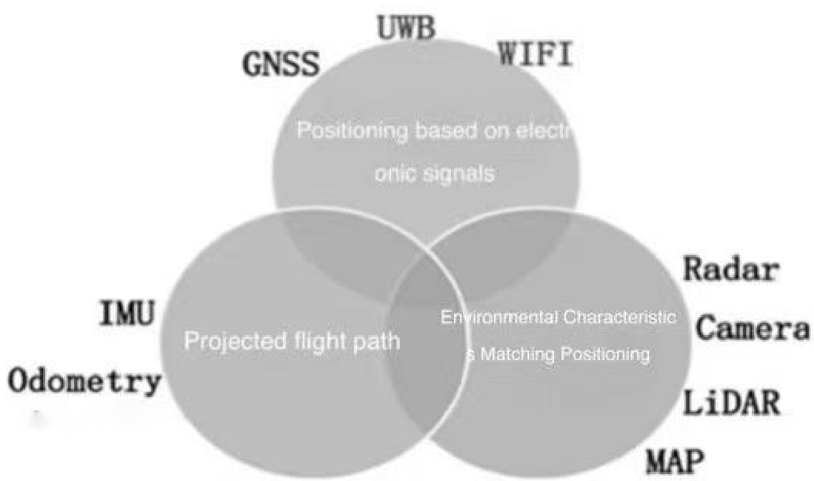

Figure 3. Classification of mainstream positioning technologies

Table 3 compares traditional GPS navigation with autonomous driving navigation: traditional GPS navigation has meter-level positioning accuracy without real-time sensing, while autonomous driving navigation can reach centimeter-level positioning accuracy; and it can realize real-time sensing of the surrounding environment with the help of multiple sensors fusion technology in the car; and at the same time, it can update the map in time with the help of real-time crowdsourcing, and real-time updating of maps can be more adapted to real-time changes in the complex and changeable environment. Traditional GPS navigation cannot meet the complexity of roads other than structured roads.

Table 3. Comparison of traditional GPS navigation and autonomous driving navigation

Navigation System	Positioning Accuracy	Environmental Perception	Dynamic Updates	Applicable Scenarios
Traditional GPS	Meter-level	No real-time perception	Offline maps	Structured roads
Autonomous Driving	Centimeter-level	Multisensor fusion	Real-time crowd updates	Complex, dynamic environments

Artificial intelligence plays a crucial decision-making role in autonomous driving. Vehicles may encounter various challenging conditions during operation, including bumps, vibrations, dust, and even high temperatures - environments where conventional computer systems cannot operate reliably for extended periods.

As shown in Table 4, the autonomous driving software system consists of four key modules:

1.Support Module: Provides fundamental services to upper-layer software modules can be seen in Table 5, including:

• Virtual Communication Module: Facilitates inter-module communication

• Log Management Module: Handles log recording, retrieval, and playback

• Process Monitoring Module: Oversees system operation status, alerts operators and takes automatic corrective actions when abnormalities occur

• Interactive Debugging Module: Enables developer interaction with the autonomous system

2.Perception Module: Utilizes sensors to acquire external environmental data

3.Cognition Module: Employs machine learning techniques to interpret sensor information

4.Behavior Module: Ultimately initiates and controls the movement of the autonomous vehicle's chassis

This modular architecture ensures reliable operation of autonomous vehicles in diverse and challenging driving conditions while maintaining system stability and decision-making capabilities

Table 4. Unmanned driving software system

Unmanned Driving System		
Perception Module	Cognition Module	Behavior Module
Obstacle Recognition Module	DrivingEnvironment ModelingModule	Lateral control module
Traffic Marking Recognition Module	Driving Behavior Planning Module	Longitudinal control module
Traffic Sigmal Light Recogmition Modue	DrivingPath Planning Module	Body electronic control module
Pose Perception Module	Driving Map Module	
Body Information Perception Module	Human-Computer InteractionModule	

Table 5. Support module

Support Module			
Virtual Exchange Module	LogManagement Module	Process MonitoringModule	Interactive Debuging Module

There are differences between intelligent driving and manual driving, as shown in Table 6: The reaction time of manual driving is 1-2 seconds, while autonomous driving has a fast reaction speed in milliseconds; manual driving is restricted by human thinking, psychology and other conditions, and human fatigue, mood and other factors will affect driving; while intelligent driving monitors in all directions (360 degrees) without fatigue, which can minimize the occurrence of accidents and is safer.

Table 6. Comparison between intelligent driving and manual driving

Driving Mode	Reaction Speed	Perception Ability	Safety
Intelligent Driving	Millisecon d level	Multi-sensor fusion, 360-degree (dead-angle-free) monitoring, not affected by fatigue	The theoretical accident rate is low (no drunk driving, fatigue driving)
Manual Driving	1-2 seconds	Limited vision and hearing	90% of driving accidents are caused by humans (such as distraction, speeding)

3. Conclusion

Modern object detection surpasses human vision in accuracy, generalization, and anti-interference but is constrained by data complexity. Traditional vehicle systems suit fixed scenarios, while autonomous driving uses multimodal sensors for unstructured data in complex environments. Traditional GPS offers meter-level accuracy without real-time perception, whereas autonomous navigation achieves centimeter-level precision with dynamic updates. Human drivers react slowly (1–2 seconds) and are prone to errors, while autonomous vehicles react instantly with 360° monitoring and no fatigue. Despite progress, challenges remain in AI applications for autonomous driving, and ongoing technological updates are essential.

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