Advancements and Challenges in Intelligent Driving Technology: From Evolution to Future Prospects

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Abstract: This paper provides an overview of the current challenges and advances in intelligent driving technology, focusing on the rapid developments in the fields of computer technology, artificial intelligence, and machine learning that are driving the development of self-driving cars. The emergence of advanced processors, sensors, and data processing capabilities has greatly enhanced the performance of intelligent driving systems. This paper also explores the benefits of smart driving technologies in improving road safety, reducing traffic congestion and optimising transport efficiency. It highlights global efforts to promote smart driving through supportive policy and regulatory frameworks, and provides support for automotive companies to access growth opportunities in the field. Further, the article traces the evolution of autonomous driving technology between its early conception in 1969 and actual testing in the late 20th century, categorised into different levels of automation. The article also examines some of the self-driving cars available in the market and their related technologies such as connectivity solutions, machine learning processors, and sensor fusion technologies, and provides insights into various applications such as semantic segmentation, target detection, and obstacle avoidance based on deep learning approaches in automated navigation scenarios, which are important in enhancing driving safety and navigation functions. By discussing the limitations of intelligent driving technology and future prospects including complex road conditions, legislative issues, liability and interpretability challenges, this paper highlights the need for continued research and development in this area and summarises areas where future research and progress may be involved.

1 INTRODUCTION

Intelligent driving technology refers to the use of advanced computer technology and perception systems thereby enabling autonomous vehicle navigation and driving. With the rapid advancement of computer technology, artificial intelligence and machine learning, a variety of high-performance advanced processors, sensors emerge one after another, supplemented by large-scale data processing and analysis capabilities, so that intelligent driving technology has been greatly developed. Secondly, with the continuous improvement of the overall economic strength of the nation and the demand for people's daily travelling means of transport, the number of private cars has increased dramatically. Intelligent driving technology can reduce the risk of accidents caused by human driving errors by monitoring real-time road conditions, and indirectly optimise road traffic to reduce traffic jams. Nowadays, countries are also trying to promote the development of smart driving, and have introduced many welfare policies and regulatory frameworks that facilitate the development of car companies. This is an opportunity for automakers to gain national support.

The concept of self-driving technology was introduced in 1969, and the earliest practical tests date back to the end of the 20th century, when the Navlab project at Carnegie Mellon University in the US first realised self-driving vehicles on city roads in 1995. The 2016 U.S. Policy Guidelines for Self-Driving Vehicles categorizes self-driving technology into six levels as one of the standards to assess the level of autonomous driving technology. Currently, the applied self-driving cars in the market belong to the partially automated stage, incorporating a very wide range of technologies. For example, Qualcomm Technologies can provide connectivity for

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autonomous driving with modems and Snapdragon processors that enable vehicles to interconnect and continuously learn from each other. It is also provided to perform heterogeneous processing1 for machine learning, human-computer interaction, intelligent safety and sensor sensing. Based on the prevalence of sensors in vehicles, Global Navigation Satellite System (GNSS) solutions have been proposed to combine image sensors and inertial sensors in vehicles as the primary means of determining road conditions, which is particularly important for self-driving cars at Level 3 (Herrmann, 2018). Bimbraw et al. reviews the evolution of self-driving car technology from radio-controlled vehicles to basic electronic-guided systems in modern automobiles to fully self-driving cars of the future. Autonomous driving technology has gone through several stages of development, including vision-guided, network-guided, and lane-keeping systems. Some of the semi-autonomous driving functions found in contemporary vehicles include adaptive cruise control, lane-keeping assistance, and automatic emergency braking, are based on these systems. In the future, self-driving cars will enable safe and comfortable transportation, but there are also challenges such as interaction with human-driven vehicles, software reliability and preventing terrorists and criminals from using self-driving cars (Bimbraw, 2015). Yurtsever et al. presents the classification of automated driving systems, interfaces, communications, end-to-end driving, and driving behavior assessment, and carries out the views of several car companies on the classification of automated driving and their respective standards for automated driving technology (Yurtsever, 2020).

The rest of this paper is organized as follows: Section 2 provides a description of related methods in this domain Section 3 provides a discussion about the current limitations and future prospects. The conclusions of this work are provided in Section 4.

2 METHOD

2.1 Semantic Segmentation

Manikandan et al. describes the remarkable progress of deep learning in the field of semantic image segmentation and illustrates its wide application in the realm of autonomous driving. The field of autonomous driving covers mediated perception paradigm, behavioral reflection paradigm, and intermediate paradigm. Among them, the intermediate paradigm utilizes semantic segmentation modules to provide affordance metrics for autonomous driving scenarios to guide final driving decisions. This research delves into the significance of semantic segmentation in autonomous driving, reviews related research, and proposes directions for future research. Deep semantic segmentation methods are mainly divided into four categories: classical methods, convolutional neural networks, structural models, and spatio-temporal models. The deep semantic segmentation problem in autonomous driving is relatively simple, and the model building can be simplified by many a priori constraints. Future research can focus on how to estimate depth and semantics simultaneously in the network to solve the problems of computational constraints, the need for large labeled datasets, and complex outputs faced by autonomous driving technology, and solutions such as multi-task learning, end-to-end learning, and modular end-to-end learning are proposed. The paper delves into the field of deep learning-based autonomous driving, focusing on the application of fully convolutional networks and their variants in semantic segmentation, as well as the role of structural models and spatio-temporal characteristics in the segmentation issue (Manikandan, 2023).

Another study mentions that in July 2016, a Tesla ModelS was involved in a fatal accident while in autopilot mode, the first known fatal accident involving a self-driving vehicle. The researchers used a deep learning network to detect hidden parts of the vehicle to help prevent accidents. The study proposes a target detection based on deep learning and image restoration method called DID-Alliance (DIDA), which effectively detects the hidden parts of large vehicles through a six-step process. The experimental results verify the effectiveness of the algorithm, which provides a new approach for the safety of autonomous driving systems and is supported by the National Natural Science Foundation of China and other organizations (Siam, 2017).

2.2 Object Detection

Fang et al. introduces a deep reinforcement learning (DRL)-based navigation system for self-driving vehicles, which utilizes an RGB-D camera to acquire depth information, an adaptive obstacle avoidance algorithm and a DRL decision-making algorithm to achieve lane detection, object detection and navigation functions. The system is realized with ArduinoUNO controller, MPU9250IMU sensor and IntelRealsenseD435 depth camera. The experimental results indicate that the D3DQN algorithm performs better in detecting road obstacles and pedestrians, and successfully navigates an autonomous vehicle using RGB-D inputs to reach a maximum speed of 30km/h in the city. Meanwhile, the study also explores the use of convolutional neural networks for pedestrian detection and navigation in real-time environments, which provides new ideas and methods for the field of future autonomous driving (Fang, 2003).

Aiming at the target detection problem of self-driving vehicles, this article proposes an improved model CSPDarknet45_G based on YOLOv4. The model introduces stochastic regularization and GELU activation function, which enhances the model's nonlinearity and generalization ability. The experimental results are superior to LeakyReLU and Mish by the inclusion of Database Generation (DBG) modules. The enhanced ResNet and CSP architecture is constructed upon the DBG modules, leading to improved model performance. CSPDarknet45_G comprises five CSP_ResBock_Body blocks, with each CSP block containing N Resunit residual modules. The initial AnchorBox size is determined using the K-Means++ algorithm to enhance model stability. Experimental results demonstrate that the upgraded YOLOv4 model exhibits enhancements across all performance metrics and excels in various categories (Xu, 2019).

2.3 Deep Learning–Based Obstacle Avoid

This paper proposes an approach called IVERSE, which aims to improve driving safety and is divided into active and passive systems. The article focuses on the impact of driver information processing, including visual sensors, knowledge, expectations and other factors on driving behavior. To detect changes in the driving environment, the study proposes a computational model-based approach and develops a change detection system based on this model. This system consists of three components: perceptual, perceptual and conceptual, and is capable of dealing with a wide range of environmental changes, such as shadows, precipitation, reflections and lane markings. In addition, the study introduces a computational model of a functional analyzer based on cognitive processing to improve the model's ability to handle complex tasks (Yu, 2021).

Ramos et al. proposes a deep learning-based method for detecting small unexpected obstacles on roads, which overcomes the limitations of traditional methods by learning the shape, size, and appearance context information of objects through deep convolutional neural networks. Combining the deep learning detection method with a stereo image fusion system improves the detection accuracy and reduces the false positive rate. Concentrating on identifying small, common, and unforeseen obstacles in driving situations, a stereo camera-based setup is used to focus on generic obstacles in 3D space. A 3D obstacle representation was generated by two main detection methods, UON and FPHT. Experimental results show that the OR fusion and probabilistic fusion algorithms exhibit the best detection performance over a range of distances, while UON-Stixels and FPHT-Stixels perform well at longer distances. Future plans include enhancing the system's robustness by increasing the amount of training data and integrating the probabilistic fusion scheme directly into the learning system (Ramos, 2017).

3 DISCUSSIONS

As shown in Figure 1 (Muhammad, 2020), this is the Highway Traffic Safety Administration in the United States has proposed a formal five-level classification system for autonomous driving. As early as 1920, foreign countries, especially the United Kingdom, the United States and Germany, have begun to carry out research on driverless cars, and has made great progress in feasibility and practicality. In Europe, especially Belgium, France, Italy and other countries have already planned to adopt driverless cars to operate the transport system, and Germany even allows experimental self-driving cars to go on the road. This shows that the supporting infrastructure for autonomous driving in these countries is relatively complete and the scope of application of autonomous driving is very wide. However, although the market for autonomous driving in China is expanding and the pace of commercialization is accelerating, it is still at Level 2. China's road conditions are very complex, and autonomous driving in different terrains and different environments will have very differentiated performance. This leads to a significant reduction in the general usability of autonomous driving models. For the time being, most autonomous driving tests and applications are conducted on terrains like plains that do not have particularly harsh environments. For example, assisted driving, as one of the categories of intelligent driving, most people will use it only on uncongested straight highway sections, and it will be relatively useless in terms of congested urban commuting, as there are many emergencies on urban roads, such as pedestrians running red lights, and assisted systems similar to cruise control can lead to traffic accidents instead. During the day, the sensor's

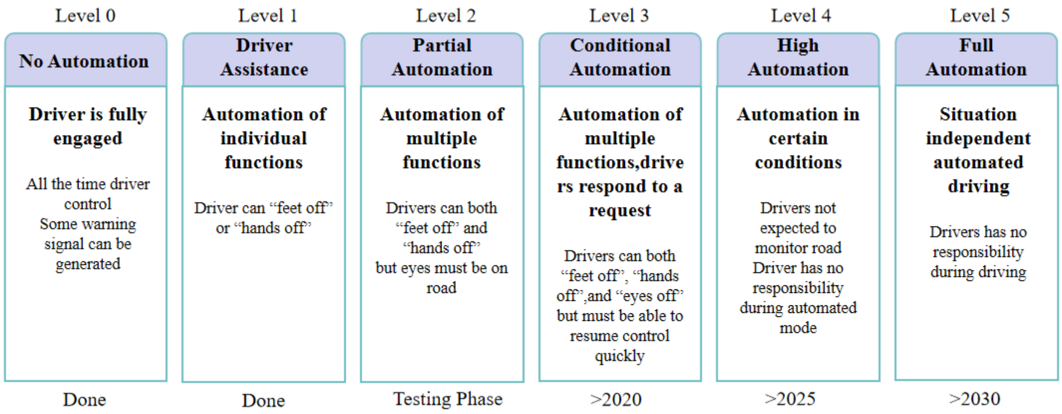

Figure 1: Automatic driving technology classification and evaluation standards (Photo/Picture credit: Original).

field of view is better, and the accuracy of the self-driving system in the recognition and decision-making process becomes higher. But at night, when other conditions on the same road have not changed significantly, the difference between the data read by the sensors and that of the daytime is significant, it reflects the applicability of the autonomous driving model is not enough. Some advanced solutions should be considered in the future (Csurka 2017; Qiu, 2022).

In addition, the legislation on intelligent driving is not sound enough. Laws and regulations are too lagging behind. Intelligent driving technology is developing at a fast pace, so existing traffic regulations are often unable to cover and regulate the problems and challenges posed by the brand-new technology. Before self-driving vehicles can enter the market, they need to undergo real road tests. However, most of the current road test standards are still for conventional vehicles, and the relevant road test standards and specifications for self-driving vehicles have yet to be supplemented. The most important point, which is also directly related to the level of autonomous driving, is the issue of liability when people drive autonomous vehicles. If an accident occurs during the process of autonomous driving, how to define the attribution of responsibility is currently a major controversial problem. At present, especially in China, there are still very big flaws in the self-driving technology. The interpretability of autonomous driving technology is also one of the current challenges. Even if the automatic driving system finally makes a decision, but people cannot understand its internal decision-making process and logic, and its own interpretation of the decision is not necessarily reasonable. And the lack of explanation of the decision-making process of the self-driving technology model may affect people's trust in the self-driving technology, as such decisions may be directly related to the lives of the drivers in the vehicle.

4 CONCLUSIONS

In this work, an overview of intelligent driving was provided. This paper considered the harsh environment that may be faced in the process of automatic driving, observed the decision-making mode and decision-making ability of deep learning and sensor technology in the automatic driving system for current vehicle problems, and then analyzed the impact of algorithms such as neural network, convolutional neural network and recurrent neural network used by them on the decision results. Based on discussions, there are still huge challenges in the field of intelligent driving, for example, the safety of the people in the car cannot be guaranteed during the autonomous driving process. The automatic driving system is not enough to deal with complex road conditions, and cannot make logical explanations for its own decisions, and its interpretability is not high, and people cannot fully trust it. The focus has been placed more on the advancements and results from the algorithmic side of academia rather than on the product side of industrialized applications. Therefore, future research aims to incorporate these elements into the system to provide a more comprehensive overview.

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