Explore the Impact and Key Role of AI Technology in Autonomous Driving

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Abstract: Artificial intelligence technology in today's world is in a stage of exponential explosive growth, and the time of technology iteration is getting faster and faster, so artificial intelligence will soon penetrate into every industry. It is obvious that driverless technology is developing more and more rapidly with the support of artificial intelligence. For example, Google's driverless project, Tesla's Autopilot, and China's Baidu's Carrot Travel are rapidly affecting people's travel methods. At the same time, it is very clear that more and more technology companies are pouring into the research and development of driverless technology like a flood. This paper will discuss the key role and impact of artificial intelligence in driverless technology, introduce the sensors of self-driving cars, describe the significance of sensor fusion strategies, and analyze the deep learning models used in data processing. At this stage, AI has become a hot spot in the development of world science and technology. The research object of this paper is about the key role of AI in the field of autonomous driving.

1 INTRODUCTION

First of all, in real life, many people may not know the true meaning of self-driving cars (AVs), which can sense the external environment through the car's sensors, and then transmit the data to the car's interior for analysis and then predict and plan the next operation of the car. Driverless cars rely on technologies such as Global Positioning systems (GPS), lidar and radar to take the surrounding environment and transmit the data to the next part of the vehicle to determine the direction and speed of the vehicle, as well as to predict the behaviour of other road users, such as cyclists and pedestrians walking on the road. (Isaac, 2016). For centuries, since the invention of the automobile, many scientists have dreamed of enabling cars to drive themselves. The concept of self-driving cars dates back to the 16th century, when Leonardo Da Vinci designed a small, three-wheeled self-propelled car with a small pre-programmed steering system and parking brakes combined with a series of propulsion springs, which is amazing because it provides humanity with the earliest blueprint for future self-driving cars.

The early modern autonomous car experiments were led by Carnegie Mellon University (CMU) and Delphi University (DELCO), using simple sensors and algorithms. By the 1990s, Carnegie Mellon's Navigation Laboratory (Navlab) developed early prototypes of autonomous vehicles using computer vision and sensor fusion. In the past 20 years, autonomous driving technology has continued to mature, and many technology giants have launched their own autonomous driving systems, such as Google and Tesla. Although they are not fully autonomous, their advanced driver assistance systems (ADAS) functions demonstrate the potential of AI in car driving.

Today, more and more companies have joined in and achieved a series of technological breakthroughs: advances in deep learning, computer vision, sensor technology (such as lidar) and high-precision map technology have made driverless cars more reliable in various complex environments.

In recent years, more and more scholars have been studying how AI can enhance driverless technology, indicating that AI is still promising in enhancing traffic safety and improving traffic efficiency. According to research, about 1.35 million people die

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in traffic accidents every year in the world, and about 90% of these accidents are caused by human error. However, driverless technology with the support of AI can well reduce the probability of human error, because AI can predict and avoid potential dangers and reduce the incidence of accidents by analyzing sensor data in real time.

In addition, AI also optimizes vehicle path planning and traffic management, which can reduce traffic congestion and improve overall transportation efficiency. AI can also continuously optimize the vehicle's self-diagnosis and maintenance prediction functions through machine learning and big data analysis, and improve the reliability of the system (Bhardwaj, 2024).

However, it is worth noting that although AI can rapidly promote the development of driverless technology, it still has shortcomings in some aspects. For example, when driverless cars face some complex road conditions, the system may not have processed similar data before and make wrong decisions. In addition, when facing some extreme weather conditions, AI processing data will also make similar mistakes.

Therefore, exploring smarter AI models and finding better sensors to achieve the future AI can quickly analyze some unknown data sets and make correct decisions efficiently during driving under some disadvantageous conditions. This paper focuses on summarizing what relevant models and algorithms AI will use in driverless technology, and will point out what kind of profound impact the arrival of AI will have on society, and how governments should take the right measures to prevent the harm caused by AI in the face of these problems.

2 THE KEY ROLE OF AI IN DRIVELESS TECHNOLOGY

The AI can play a key role in the field of driverless driving, so what specific key roles can it play? First, AI can enable self-driving vehicles to perceive the surrounding environment through advanced sensors, cameras, radar, lidar, GPS and other equipment, and make real-time decisions. Secondly, AI can improve the safety of autonomous driving through algorithms, especially methods based on deep learning, which have made significant progress in key components such as vehicle perception, object detection and planning.

An Intel report revealed that self-driving technology will reduce users' commuting times and save hundreds of thousands of lives over the next decade. For example, the first self-driving vehicle using neural networks in 1988 was able to generate control commands from camera images acquired by a laser rangefinder. Finally, and more importantly, since the decision-making process of autonomous driving systems is opaque to humans, explainable AI (XAI) is needed to provide transparency in the decision-making process, enhance user trust in the system, and meet regulatory requirements (Shahin et al., 2024).

The main way for humans to perceive the outside world is through various senses. Similarly, cars perceive the outside world mainly through various sensors that act as the "senses" of the car to perceive changes in the external environment. Sensors play an extremely important role in the process of autonomous driving and are the key to the decision-making process of autonomous vehicles.

The data they collect has heterogeneous and multimodal characteristics, and these data are further integrated to form effective decision-making rules. In the autonomous driving system, they are the basis for perceiving the surrounding environment of the vehicle. In addition, they can also provide detailed information about objects around the vehicle, roads and traffic conditions.

Sensors can detect obstacles, identify road signs, measure vehicle speed and position, etc., which greatly improves driving safety. Sensors are divided into short-range, medium-range and long-range according to the transportation range of wireless technology. Specific sensor types include cameras, millimetre wave radar (MMW-Radar), GPS, inertial measurement unit (IMU), lidar, ultrasonic and communication modules. Each sensor has its own characteristics. For example, cameras can be widely used for environmental observation and can produce high-resolution images, but are affected by lighting and weather conditions. LiDAR can estimate distance and generate point cloud data by emitting laser pulses and measuring the time it takes to reflect back, but it is expensive. By comparison, so each sensor has its advantages and disadvantages (Ignatious et al., 2022).

It is obvious that a powerful sensor system is needed to truly realize unmanned driving, so perform sensor fusion to complement the advantages and disadvantages of each sensor and achieve efficient operation. Sensor fusion is the combination of data from multiple sensors to obtain more accurate and reliable environmental information than a single sensor. Scholars have studied many sensors fusion strategies. This paper mainly discusses three important fusion levels. (1) Low-level Fusion (LLF):

Driverless cars improve the accuracy of obstacle detection by integrating the lowest level of sensor data, also known as raw data, and retaining all the data. (2) Intermediate Fusion (MLF): The car fuses the corresponding sensor data, such as colour information extracted from radar and lidar images or position features. (3) High-Level Fusion (HLF): Each sensor independently executes the target detection or tracking algorithm, and then combines the results together to work together to achieve the same goal. In addition to the fusion of the three levels of sensors, algorithmic fusion is also carried out, such as the fusion of convolutional neural networks (CNN) and recurrent neural networks (RNN) (Yeong et al., 2021).

3 THE ROLE OF MACHINE LEARNING AND DEEP LEARNING IN AUTONOMOUS DRIVING TECH

Machine learning is a branch of artificial intelligence that enables systems to learn data from fixed problems and train the data so that analytical models can learn on their own. Automatically constructing problems and autonomously learning to solve related tasks, ML enables computers to discover hidden insights and complex patterns without explicit iterative programming to learn from training data for specific problems. Deep learning is a conceptual network (artificial neural network) of machine learning based on artificial nerves.

For many applications, DL models outperform shallow ML models and traditional data analysis methods. In addition, DL is able to process large amounts of high-dimensional data such as text, images, videos, speech, and audio data by using deep neural network architectures. Deep learning is a subset of machine learning that focuses on using deep neural networks to improve learning capabilities.

DL models typically contain multiple hidden layers and are able to automatically discover high-level feature representations of data (Janiesch et al., 2021). For driverless technology, ML and DL play an important role in four main aspects: environmental perception, decision making, predictive modeling, and real-time processing.

3.1 The Role of Convolutional Neural Networks in Autonomous Driving

The architecture of a CNN, including input layers, convolutional layers, pooling layers, and fully connected layers. The key role of a convolutional neural network is to detect objects on the road while the car is driving. By training artificial neurons, CNN can analyze different road scenarios, such as collisions, open roads, traffic, etc., and send appropriate instructions to the car based on these scenarios, such as braking, accelerating, or decelerating. In convolutional neural networks, the You Only Look Once (YOLO) algorithm is particularly worth mentioning.

It is a prediction technique that can provide accurate results with fewer background errors. It has excellent learning capabilities and can learn representations of objects and apply them in object detection (Mishrikotkar, 2022). YOLO is designed for real-time applications and can achieve fast detection speeds while maintaining high accuracy. The network structure of YOLO includes several main substructures, such as convBnLeaky, bottleneck, bottleneckCSP, and SPP (Spatial Pyramid Pooling), which are reused throughout the network to extract image features.

In addition, YOLO can also efficiently extract image features through its convolutional layers and specially designed modules (such as CSPNet), and gradually reduce the spatial dimension of the feature map while increasing the feature depth (Liu et al., 2021). Nowadays, many deep learning architectures are aimed at target detection, but recently there is a new study that uses deep networks for vehicle control, which is called an end-to-end architecture. The input source of this architecture is a deep network composed of different sensors, and the weight parameters are trained based on the training signal input of the vehicle. As shown in Figure 1, a small remote control car can pass obstacles in a controlled real environment through a CNN network. This neural network uses 7 convolutional layers and 4 fully connected layers to map the steering angle training signal to the raw pixel input from the front RGB camera (Cameron Wesley Hodges et al., 2019).

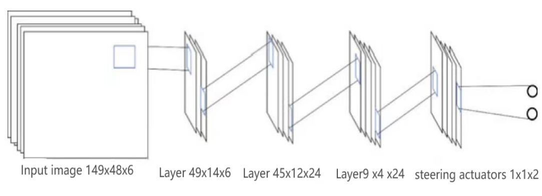

Figure 1: Five-layer convolutional neural network (Cameron Wesley Hodges et al., 2019).

3.2 The Role of Recurrent Neural Networks in Autonomous Driving Technology

RNN is different from the general neural network architecture in that it introduces a recurrent layer, which is the core of the RNN and can process sequence data. The recurrent layer has a memory function that can capture the dynamic features in the time series. For unmanned driving technology, the recurrent layer can learn the movement pattern of the vehicle at different time steps. In addition, there is a mixed density network output layer (MDN). Unlike the traditional single output, the MDN can output a probability density function to represent the uncertainty and multimodality of the prediction. Then the main role of RNN in the process of unmanned driving is to predict the trajectory. The recurrent neural network can process sequence data, which enables them to identify the behavior patterns and intentions of drivers at intersections.

Through the mixed density network output layer, RNNs can provide a probability distribution of predicted trajectories instead of a single deterministic prediction, which helps to deal with uncertainty in the real world. In order to enable the unmanned driving system to select the most likely trajectory to respond, the researchers introduced a clustering algorithm that can extract a set of possible trajectories from the probability distribution and sort them according to their probabilities, which can effectively achieve this goal (Zyner et al., 2019).

Studies have shown that the RNN framework can classify the activities of objects on the road, and the activity classification system can effectively identify specific dangerous situations. RNN can use the temporal information of the upper and lower parts to map the input sequence to the output sequence, but problems arise when the input information decays or grows exponentially during the recursive connection process of the network. Long short-term memory (LSTM) is a structure of RNN that can solve this kind of problem well. For example, as shown in Figure 2, the vanishing gradient replaces the storage unit of each node of the network. The storage unit is to remember and accumulate cells, and the forget gate determines what proportion of cell memory should be kept in the next step. The input gate determines whether the input should be allowed, and the output gate determines whether the output of the block should be sent. Unlike general RNN, the back propagation error in LSTM does not disappear exponentially over time, and the data is easy to train (Khosroshahi et al., 2016).

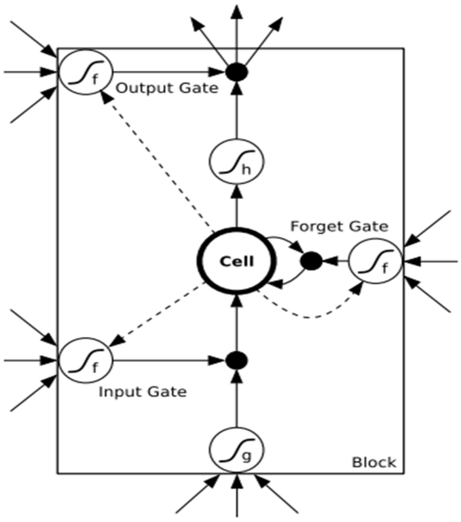

Figure 2: An LSTM Memory Cell (Khosroshahi, et al., 2016).

3.3 The Role of Deep Reinforcement Learning Neural Network in Autonomous Driving Technology

When a car is driving on the road, it is often not smooth sailing. In the face of some complex road sections, traditional supervised learning is difficult to cope with the complex and changing driving environment. Deep reinforcement learning can effectively solve this problem by training machines through interaction with the environment and learning from mistakes.

The framework of deep reinforcement learning consists of spatial aggregation, attention model, temporal aggregation, and planning. This framework integrates RNNs and uses RNNs to integrate information on time series. RNNs can remember previous state information and combine current observations to infer the true state of the environment. The attention mechanism is used to process relevant information and reduce computational complexity.

The spatial bureau aggregation network contains sensor fusion and spatial features. This network can process data collected from multiple sensors (such as cameras and lidars) and extract spatial features through CNNs. In addition, Bayesian filter algorithms, such as Kalman filters, are used to process sensor readings and infer the true state of the environment. Finally, reinforcement learning planning is performed through a deep Q network (DQN) or a deep deterministic policy gradient (DDAC) algorithm. Studies have shown that the framework was tested on the open source 3D racing simulator TORCS (which provides complex road curvature and simple interaction scenarios), and the experimental results show that the proposed framework is able to learn to drive autonomously in these complex scenarios (Sallab et al., 2017).

4 CHALLENGES OF AI IN THE FIELD OF AUTONOMOUS DRIVING AND FUTURE SOLUTIONS

Looking back at history, any emerging product will face challenges in a certain era. For example, the textile machines that appeared in the first industrial revolution replaced workers, causing many workers to lose their jobs. Similarly, driverless technology will face similar situations in modern times.

Driverless cars will replace taxis. Especially with the support of AI technology, driverless technology will advance by leaps and bounds, which will make people feel more and more uneasy. It will inevitably face many challenges in the future.

4.1 Challenges of AI in Autonomous Driving

4.1.1 The challenge Comes from AI Itself

AI systems must ensure that they can make safe decisions in all situations. However, even though driverless technology is gradually maturing with the help of AI, it is still impossible to guarantee the safety of road driving 100%, which highlights the lack of AI's ability to understand and process complex traffic environments. In addition, when in harsh environments, it is difficult for sensors to obtain real-time road conditions, resulting in AI being unable to process data in a timely manner. At the same time, improving the safety of AI systems requires a large amount of data for training.

The cost of obtaining and processing data is sometimes too high, and the manufacturing and maintenance costs of autonomous vehicles are high. Costs need to be reduced before they can be popularized. When obtaining user data, many people also say that their privacy rights are violated. AI systems are very likely to be attacked by cyber attacks, and there is currently no strong network security protection system to maintain the safety of AI autonomous driving.

4.1.2 The Challenge Comes from Society

AI driverless cars will face serious challenges in society, especially ethical challenges. First of all, people will not trust their lives to a machine to manage, and many drivers cannot overcome the psychological barriers brought by AI driverless cars. In addition, driverless taxis are slowly squeezing the living space of human drivers.

For example, China's Turnip Express has 6,000 orders every day in Wuhan, triggering a technological ethics crisis. People are afraid that drivers will lose their jobs after full popularization (Nair, 2024). The most important thing is that the government does not have a fair and transparent regulatory framework and legal documents for AI driverless cars.

Each country has a very different way of regulating driverless technology. For example, Japan allows Level 4 autonomous vehicles, provided that they comply with strict safety standards, while the United States adopts a state-by-state approach. Some states such as Arizona are very open to autonomous vehicle testing. Faced with such a complex regulatory chaos, it is a problem for some multinational travelers (US, 2024).

4.2 Suggestions for Future AI Driverless Technology

First, in the face of a complex regulatory environment, governments need to communicate and implement unified regulatory standards, including who will supervise and how government officials will supervise. A clear legal system needs to be established. When faced with a car accident, the legal responsibilities of both parties need to be quickly clarified.

The government needs to formulate relevant laws and regulations to ensure that people's living standards are not negatively affected by AI in order to deal with the moral and ethical dilemmas of social personnel. Secondly, the privacy of user data needs to be adequately protected so that users do not have to worry about their personal information being stolen while experiencing unmanned driving (West, 2016).

Finally, researchers should be committed to innovation, research more powerful sensors to improve Ai's ability to process data in extreme climates, and improve the efficiency and performance of large AI models, especially for the optimization of deep learning neural networks, such as research on lightweight neural network structures such as MobileNet and EfficientNet, so that they can run efficiently on vehicle hardware (Oranim, 2024).

5 CONCLUSIONS

AI has made great achievements in the field of driverless cars. By processing the data from the sensors of driverless cars, AI can help vehicles make correct decisions quickly on the road. With the reinforcement of sensor fusion strategies, AI can process the obtained data better and faster. AI is mostly based on deep learning frameworks in machine learning, such as convolutional neural networks, recurrent neural networks, and deep reinforcement learning frameworks, to process the environment perception, behavior prediction, road planning, etc. of cars.

Although driverless technology has achieved a rapid leap with the support of AI, and safety has been guaranteed to a certain extent, what follows is that society has doubts about whether AI will have a negative impact on people's living standards, and faces serious moral and ethical challenges. In the future, the government and enterprises need to work together to deal with this thorny problem.

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