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Deep learning in driverless: Research results, issues, challenges

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Abstract. As computing and communication technologies continue to evolve, leading technology companies are investing significant resources in self-driving car techniques. With the use of deep learning in driverless driving, driverless cars are enabling them to sense, make decisions and control in complex environments, leading to truly autonomous driving. Deep learning is used for environment perception, which enables driverless cars to understand their surroundings by recognizing information such as road surfaces, pedestrians and vehicles, and also used for decision formulation, by predicting the behavior of other vehicles, pedestrians and identifying the environment around the road conditions to control the driverless car to make the optimal driving decision. But in order to achieve fully autonomous driving, there are still some technical aspects. Therefore, we deep learning in the existing driverless technology is reviewed, mainly discussing the application in the direction of driverless implementation and safety inspection. Through reading a large amount of literature, we discuss the problems that hinder the development of the driverless field, and at the same time, how to solve the problems in the future to promote the breakthrough of the driverless field. The application of deep learning in driverless not only enhances the intelligence level of driverless cars, but also prepares for the commercial application of driverless cars in the future. It enables driverless cars to better identify and adapt to complex traffic environments. Finally, realizing truly autonomous driving.

Keywords: Deep learning, driverless, autonomous driving.

1. Introduction

As technology evolves, transport has played an important role in economy development and people's lives. The corresponding problem is the chaos of traffic and the consumption of a lot of manpower accompanied by fatal traffic accidents resulting in loss of human life. The emergence of self-driving cars offers comfort and safety as an alternative to traditional human drivers. Traditional control algorithms and machine learning algorithms used in recent years have not achieved a complete replacement for human driving, and with the emergence and continuous development of deep learning algorithms, driverless technology is entering a qualitatively new stage. In the evolution of unmanned driving, we need to achieve the technology contains many aspects, unmanned car for the surrounding environment should be very accurate recognition, while making the correct and safe decision-making. But the testing and verification of driverless cars is a complex and time-consuming process. Cruise's self-driving car had a safety accident in a previous test, which led to the suspension of its driverless

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business and a series of adjustments. Due to a number of safety accidents, people greatly distrusted driverless technology.

Deep learning automatically learns the intrinsic laws and representation levels of data by training large amounts of data. This type of learning gives deep learning a significant advantage when dealing with complex data such as images and speech. Driverless cars need to perceive, communicate, make decisions and control in a complex and dynamically changing environment. This requires driverless cars to be able to receive and process large amounts of visual, auditory and tactile information while deep learning can exactly meet this requirement. Meanwhile it is also used to detect and confirm the safety of driverless technology, used to assess whether a driverless car is worthy of being trusted, which in turn will help to solve the problem of people's driverless distrust.

2. Design principles for driverless cars

In the field of driverless car design, the fundamental purpose is to be used for the convenience of human beings (freeing up the driver's needs, more orderly traffic, etc.), in addition to designing driverless cars that need to fulfil four requirements. Firstly and most prominently, to guarantee the safety of the driverless car[1]. the design should ensure the maximum degree of safe driving, for a variety of special events need to have the ability to identify and automatically trigger the safety mechanism. Secondly, efficiency, the driverless car should be able to independently choose the optimal path, including the evaluation of real-time road conditions and traffic flow, so as to improve traffic efficiency. Third, stability and reliability [1], the popularity of driverless cars in future applications requires not only the improvement of driverless car technology, but also the unification of external road design and traffic signal rules. And the system needs to be adapted to diverse road and weather conditions. Finally, compatibility, unmanned vehicles need to achieve synergy with other traffic participants to ensure that each other to operate independently in a secure and organized operation. Yang Li is with the ifab-Institute of Human and Industrial Engineering, Karlsruhe Institute of Technology, Engler-Bunte-Ring 4, Karlsruhe, Germany [2], had proposed that the future shared space consists of self-driving cars and other traffic participants, and information communicated between them is indispensable which will make the interaction more complex for fully autonomous driving (explained below). He proposed a kind of electronic human-computer interface to communicate with other traffic participants, and also explained that being subject to the high complexity of the individual's behavior at this stage, the implementation of deep learning for training data can be misinterpreted in terms of explicit information encoding. But I propose that as deep generative models continue to improve, employing recurrent neural networks and deep convolutional neural networks to extract obvious information from the training data will make the information interaction between autonomous vehicles and other traffic participants effective and accurate.

3. Present state of development of driverless cars

In this section we present the current results in the field of self-driving cars. Rasheed Hussain raised an attractive perspective that the diversity between autonomous car and automated car [3]. The preceding one may require human intervention in the operation of the car during the whole driving process (e.g. emergency braking, route setting and so forth), while the other relies on the system to implement decisions without any human involvement at all. From his viewpoint, I would classify driverless cars into four categories based on their functions:

Driver assistance: Nowadays, many self-driving cars in the society are in this stage, the system itself can only provide limited assistance to the driver. For instance, it can be set in constant speed cruise mode on the motorway, which can help the driver to a certain extent, but it still requires the driver to maintain a high degree of attention to control the vehicle.

Semi-autonomous driving: The system is capable of automatically intervening when the driver receives a warning but fails to initiate action in a timely manner, and is still essentially a driver-operated system that can intervene in the control of the vehicle if necessary. This is not referring to existing emergency protection measures like airbag popping after a collision but rather warning of an impending collision and automatic safety avoidance when the driver fails to act.

Highly autonomous driving: In this stage the car can be fully controlled in almost all scenarios, without human monitoring and interpretation, but still offering the driver the option of driving the car.

Fully autonomous driving: Only the system complete control of the entire car operation, humans can only through the human-computer transmission platform for the control. Such a form is difficult to achieve which need a permanent development of artificial intelligence

4. Relevant Existing Technologies to Achieve Driverless driving

Image processing for the realization of unmanned technology is an indispensable part. The system needs to perceive the surrounding environment in real time and react accordingly. In this process, the system is required to pre-process the obtained images, including denoising, image enhancement to improve the accuracy of the subsequent image processing algorithms. For object detection and tracking, it is necessary to identify obstacles, pedestrians, road signs, signal lights, etc. in the surrounding environment, and track objects in motion, segment the image, locate the content of each region to interpret the information in the region, utilizing sensor data through sensors such as LiDAR to perform 3D modelling. Therefore, processing image, using neural network to learn, so that the vehicle autonomous perception and understanding of the environment, is the prerequisite for the implementation of driverless technology.

4.1. CNN and RNN

Convolutional neural network (CNN) which is a type of neural network widely used in the fields of image recognition, computer vision and deep learning. With the emergence of the innovative Alexnet in 2012, which caused a great sensation in the field of deep learning, CNNs are able to automatically learn the feature representation of the input image and improve the accuracy of the image classification task by retaining information about the spatial structure of the data through convolution and pooling.

The hidden layer state of the RNN is passed on to the next time step at each time step, allowing the network to remember previous information and better understand contextual information when processing the data. The RNN will be integrated with the CNN in a hybrid to take advantage of their individual strengths most of the time.

Convolutional neural networks have many diverse directions of usage in the field of autonomous driving. the following will be based on the various recognition objectives of the existing models are presented. CNN has always been dominant for static objects of research. With the development of time a variety of CNN convolutional models have emerged in recent years and Rongqiang Qian proposed a CNN model for classification based on MPPs, which has improved the recognition rate to 98.86% in 2016 [4]. Reem Abdel-Salam’s team used a network model with a depth of 8 layers, and their RIECNN achieved 99.75% accuracy on GTSRB, while having a short preprocessing time and inference time in 2022 [5]. Currently in the detection of static environmental conditions has reached a high level of accuracy, but it is clear that these are not applied to more complex environmental variables in motion, in recent years, 3D-CNN in the recognition of the performance level of the motion environment has been greatly improved, compared with the two-dimensional CNN, he increased the depth (time). Shuyang Du proposed a 3D-LSTM convolutional model with residual connections solving the problem of gradient vanishing and gradient explosion during deep network training. It can directly transfer gradients, which makes it easier to propagate the gradient signal through the network and contributes to accelerating the training process, allowing the network to converge to an improved result more quickly [6].

4.2. Assessing Trust Level of a Driverless Car

The issue of safety and trust in driverless cars is fundamental to their future ubiquity. With the true reality of the cost of a problem with a driverless system being too much to bear, technology companies need people to trust the vehicles with the most valuable thing of all: their lives.

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Relying on road tests alone does not provide enough evidence to prove the safety of driverless cars. It is essential that the test and evaluation system for driverless cars is improved and complete. The trustworthiness of a driverless car is related to the trustworthiness of the main on-board unit components. Gour Karmakar [7] proposed a DNN-based model that used the four features of vehicle speed, flow rate, phase time, and distance between vehicles to predict the individual on-board unit's trustworthiness so that it can determine whether individual vehicle-mounted units are faulty or not, and they also proposed a simple judgement of whether a vehicle is trustworthy or not based on traffic flow, speed and phase time. However, it is clear that such a simple judgement is too arbitrary, the trustworthiness of the vehicle is also associated with the failure of the system operation. Different failures in system operation have different impacts on the assessment of the overall trustworthiness, so how do we make a complete trust assessment of a vehicle?

Yulin Ma [8] proposes to divide the vehicle behavior indicators into C1-C4, C1 corresponds to the starting and stopping of the car etc., C2 defines speed control, obstacle avoidance etc., C3 refers to following the car, emergency system etc., and C4 correlates to auto-parking, crossroads etc., with corresponding weight coefficients assigned to each traffic terminology condition. In addition, it is also vital to assess the system's security strategy, communication security, data privacy, and so on. Moreover, certification of unmanned systems by government agencies to ensure their compliance with relevant standards and norms.

5. Driverless Dilemmas and Future Directions

5.1. Safety and Reliability

The driverless field is now facing the technical problem of how to improve the visual ability of the car, generally driverless cars used sensors unable to traverse solid obstacles. If there is a pedestrian suddenly appeared in the lane, the scanner is not in time to detect it. Detectors and sensors in harsh environments will face the inability to correctly identify the outside world, while the system must use this information in order to correctly locate the car.

Driverless cars not only need to pay attention to other vehicles in the vicinity, but also must be able to detect the surrounding pedestrians, lanes, traffic signs and lights, stop lines and a series of factors. Even though there are now corresponding algorithms for all aspects of driving technology, how to make the system to improve the accuracy of decision-making, the combination of multiple technologies, how to solve the corresponding priorities, conflicts in order to achieve a truly complete autonomous driving still requires future efforts.

Driverless systems are vulnerable to adversarial attacks. Attackers may mislead the decision making of driverless vehicles by interfering with sensors, tampering with data or spoofing models. How to ensure the security of the on-board network, its ability to withstand attacks, and its capacity to be protected from interference information, and how to make certain that driverless systems are robust and secure against adversarial threats, which also have a significant impact on driverless vehicle trust.

In terms of achieving an acceptable level of trust, one type of approach would be to design a short-term safety system for self-driving cars, which would be able to realize security decisions (e.g. stopping the car in a safe position) in a very short time (within seconds) in the event of various serious failures thus being able to guarantee the safety of life. This would take trust in driverless cars to a huge level, but it is clear that we are still a long way from full realization and that driverless car technology is not yet mature enough to cope with the variety of situations on the road.

5.2. Validation and Testing

Trustworthiness assessment and testing: The safety and reliability of driverless systems need to be thoroughly assessed and tested. Before that, the needs and specifications of driverless systems need to be clarified. As mentioned above, some reasonable and effective definitions have been proposed. In order to achieve driverless promotion in the future, I think it is indispensable for governments to carry out relevant policy specifications to define the system's functionality and performance requirements, traffic rule compliance requirements, and safety strategies. Published by the International Organization for Standardization (ISO) is a functional safety standard for automotive electronic systems, which is also applicable to driverless cars. The standard specifies security requirements and processes for the development of automotive electronic systems aimed at ensuring the stability of driverless cars. NHTSA has published a series of guidelines and regulations on security assessment of autonomous vehicles. However, these are primarily for vehicles with partial autonomous driving capabilities and are based solely on US laws and regulatory structures while not harmonized worldwide.

6. Conclusion

Self-driving cars are developing rapidly with the times and the development and application of many self-driving cars are accelerating globally today. In this paper, we outline the current evolution of driverless cars, where today's driverless technology is still at a low-level stage, while highly automated driving is still subject to strong uncertainties in technology and policy. We also present the current application of deep learning neural networks in achieving the driverless control of the system and examining the safety of the driverless respectively. In addition, we discuss the current bottleneck of the driverless and the direction of the future development. The application of driverless is not only trapped by the advancement of technology, but also will face the related policy challenges. How to improve people's trust in unmanned driving, which is a requisite for the future development of driverless driving. Although self-driving car technology has achieved remarkable results so far, it is still too early to say that self-driving cars are stepping into the commercial stage.

However, no specific data analyses have been provided for the corresponding technologies, and the presentation of specific technologies is rather shallow. We will focus on the field of computer vision and learning to conduct relevant practical research to contribute to breakthroughs in self-driving related technologies in the future.

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