

Research on the application of autonomous driving technology in port

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Abstract. Automatic driving technology is one of the most popular emerging technologies at present. It has been preliminarily applied in the field of transportation, especially in the automatic container terminal of the port. Automated guided vehicles for freight container (AGV), intelligent container truck (ICT) and intelligent guided vehicle for container (IGV) applying automatic driving technology in the port are briefly introduced. ICT and IGV are especially suitable for the automation transformation of traditional container terminals, and have gradually become the main force of horizontal transportation equipment in automatic container terminals. The main problems existing in the port application of automatic driving technology are emphatically analyzed, and the key research direction is put forward.

Keywords: Automatic driving; Port; Automatic container terminal; Automation transformation

1. Introduction

In recent years, under the background that China and the transportation industry support the development of smart ports, China's automated terminals are in a stage of rapid development. The most typical example of an automated terminal at this stage is an automated container terminal. With the use of three fully automated container terminals in Xiamen Yuanhai Terminal, Qingdao Xinqianwan Terminal and Shanghai Yangshan Port Phase IV, there has been a boom in the construction of automated container terminals around the world. Especially in China, there have been many new and renovated automated container terminals. Tianjin Port, Tangshan Port and Guangzhou Port are promoting the construction of automated container terminals, and inland river terminals represented by Anhui Wuhu Port are also actively promoting the construction of automated container terminals [1-3]. China is now rapidly developing port intelligent construction represented by automated container terminals.

2. Application of autonomous driving technology in ports

Autonomous driving technology means that vehicles can automatically realize path planning, behavior decision-making and motion planning, and vehicles rely on their own capabilities to achieve automatic driving like robots [4]. According to the recommended national standard "Automotive Driving Automation Classification" (GB/T 40429-2021) released by the Ministry of Industry and Information Technology, China's classification standards for autonomous driving technology are similar to SAE. According to the degree of automation of the vehicle handling system, autonomous driving technology is divided into 0-5 levels. Autonomous driving at level 4 and above means that operating systems can replace human drivers.

At present, there are six main application scenarios of autonomous driving technology in the field of cargo transportation: ports, logistics, mining areas, airports, trunk transportation, and terminal transportation. In the port scenario, the current level 4 autonomous driving technology is mainly used to realize the automation of horizontal transportation in automated container terminals. The complexity of the scene is one of the key factors for the practical application of autonomous driving technology. The impact of scenarios on the realization of autonomous driving technology is usually

considered from 8 factors, including simple traffic signs in ports, low pedestrian interference, low vehicle interference, few static interferences, low route complexity, low-speed driving, and infrastructure completion. Comprehensive assessment of the feasibility of promoting the application of autonomous driving technology in port scenarios. The autonomous driving technology in Chinese ports is mainly used in container automated guided vehicles (AGV), intelligent container trucks (ICT) and container intelligent guided vehicles (IGV) [5].

2.1 Container Automated Guided Vehicles

Container automatic guided vehicle (AGV) is a container transportation vehicle with automatic navigation function. Since the world's first automated container terminal was put into operation in 1993, AGV has been the only choice for all automated container terminals for nearly 30 years. AGV uses the "magnetic nail + sensor" method for positioning and navigation. The ground needs to be pre-embedded with magnetic nails, which requires high ground foundation and requires a large investment.

2.2 Intelligent container trucks

Intelligent container truck (ICT) is a container trailer that is equipped with a vehicle-mounted driverless system and meets the needs of container transportation operations without manual driving. ICT adopts "satellite + intelligent sensor" method for positioning and navigation, which is the latest research direction of horizontal automatic transportation of container terminals in Chinese ports in the past two years. ICT can be divided into two types according to different structures: First, on the basis of the existing manned truck, it is equipped with an on-board driverless system and transformed into a driverless truck. Its shape is exactly the same as that of a manned truck, and it still retains the cab. Generally, it can switch between manned and unmanned modes. The other is to cancel the cab on the basis of the human-driven truck, but it still consists of two parts: the tractor and the truck.

2.3 Intelligent guided vehicle

The container intelligent guided vehicle (IGV) is similar to the AGV in shape and structure, but the IGV generally adopts the positioning and navigation method of "satellite and intelligent sensor". Its working principle and control method are also more complicated than AGV. The requirements of terminal infrastructure and investment for are also lower.

AGVs are basically used in the horizontal transport equipment of automated container terminals at home and abroad that have been put into operation in the early days. However, AGV has high requirements on the terminal infrastructure. It adopts the magnetic nail navigation technology, which has high requirements on the flatness of the terminal surface, requires a large investment, and cannot be used for traditional terminals and man-machine mixed operation terminals. In addition, due to its high degree of customization and low output, the price is much more expensive than that of ordinary container trucks. In recent years, with the breakthrough of autonomous driving technology, low-speed autonomous driving technology in enclosed areas has gradually entered the stage of practical application. Unmanned trucks and IGVs are especially suitable for the automation transformation of traditional container terminals, and have gradually become an important development direction of automated horizontal transportation tools in port container terminals. They have been operated on a small scale in multiple areas, significantly reducing labor costs and improving safety. The production level has achieved good economic and social benefits of the port [6].

At present, many Chinese ports have achieved rapid development. For example, unmanned trucks have been successfully applied in Tianjin Port, Rizhao Port, Tangshan Port, Shanghai Port, Zhuhai Port, Ningbo Port and other ports. Intelligent guided vehicles are also rapidly being applied in Guangzhou Port Nansha Phase IV and Tianjin Port Beijiang Section C Automated Container Terminal. China's Westwell Technology, ZPMC, TuSimple, TruckTech, Tage IDriver, PLUSDRIVE, China waterborne Transpot research institute and other innovative enterprises and scientific research units have provided technical support for the application of autonomous driving technology in ports.

3. The main problems existing in the application of autonomous driving technology in ports

3.1 Inadequate ability of self-driving vehicles to adapt to port work environments

Due to the special geographical location of the port, for example, there will be strong winds, heavy fog, snow, continuous high temperature, continuous low temperature, etc. Autonomous vehicles need to operate continuously throughout the day, but vehicles have low adaptability to complex environments. It is also necessary to strengthen research on technologies such as environmental perception and intelligent decision-making for autonomous vehicles, and complete the testing of autonomous vehicles in various port environments.

3.2 The positioning accuracy of autonomous vehicles needs to be improved under the interference of external environment and other equipment

Since autonomous vehicles have high requirements for positioning accuracy when interacting with other loading and unloading equipment, port metal containers and large infrastructure equipment will interfere with the positioning accuracy of autonomous vehicles, causing vehicles to repeatedly reposition, which reduces operational efficiency.

3.3 The port autonomous driving test system is incomplete

The survey found that the country has carried out a lot of research work on the automatic driving test technology, method and evaluation in the real road environment, and has a typical test demonstration area. However, there is a big difference between the road environment and the port. There is a big gap in the types of obstacles, the diversity of motion states, the type of road structure and the complexity, so the test environment cannot be replaced.

3.4 The level of large-scale dispatch management of autonomous vehicles needs to be improved

The operating efficiency of a port is not determined by the normal operation of individual vehicles. It requires the coordinated operation of all vehicles in the port under the control of the TOS system, which can realize the efficient and orderly operation of the port. At present, the integration of self-driving vehicles with port operation processes is still low, and the ability to dispatch and control self-driving vehicles is low. It is difficult to realize the simultaneous operation of dozens of vehicles, or even hundreds of vehicles. The dispatch management level of autonomous vehicles needs to be improved, and the overall efficiency of the port needs to be improved.

3.5 Cybersecurity protection for autonomous vehicles needs to be improved

Network security is the core element of autonomous driving. For example, common equipment such as satellite navigation, cameras, lidar, and millimeter-wave radar can be interfered by hackers and thus affect the judgment and normal driving of autonomous driving, which poses a greater security risk. In addition, the current communication network of autonomous vehicles is a specific network, usually a security firewall designed by the equipment supplier. Due to the lack of unified standards, it is easy to cause network security problems.

4. Key research directions to support the application of autonomous driving technology in ports

Autonomous driving is one of the latest technologies, and it has been initially applied in the field of transportation, especially in the field of ports. But now there are fewer applications of autonomous driving technology, and legal, regulatory, safety, testing and evaluation issues have arisen. Moreover, the port infrastructure is insufficient, and relevant standards and specifications are few. Therefore, in

order to more effectively support the application of autonomous vehicles in ports, key research should be carried out in the following aspects.

4.1 Form a well policy environment and safety supervision mechanism

Form a policy on the operating conditions and management methods of autonomous vehicles, and clarify the relevant management requirements for autonomous vehicles in ports. For example, clarify the safety supervision departments of different types of port autonomous vehicles, and clarify the responsibility for the safety accidents of autonomous vehicles and manned vehicles. At the same time, actively carry out the safety assessment of autonomous driving technology in ports, strengthen network security protection and supervision, and promote the top-level design and construction of autonomous driving network security.

4.2 Guide and regulate the infrastructure construction of port autonomous driving technology

Carry out research on construction requirements for port network infrastructure, security infrastructure, road infrastructure, equipment infrastructure, etc. Form a guide for the construction of port infrastructure supporting autonomous driving, and guide and standardize the construction of port infrastructure for the application of autonomous driving in ports.

4.3 Establish a complete evaluation method and testing system

Actively build typical scenarios for autonomous driving in ports, study testing technologies and conditions, establish test sites that meet complex autonomous driving scenarios in ports, promote the evaluation of the technical performance and safety performance of autonomous driving vehicles in ports, and effectively ensure the safety, reliability, and safety of autonomous driving technologies in ports.

4.4 Establish a standard system for port autonomous driving technology

To guide and promote the application of autonomous driving technology in ports, it is necessary to carry out research and formulation of relevant regulations and standards on port autonomous driving technology, port autonomous driving operating environment, and technology and equipment. And establish an automatic driving standard system for ports, consisting of national standards, industry standards and group standards.

5. Summary

With the research and resolution of the maturity, testing technology methods, port-vehicle cooperation, network security protection, standard layout and formulation of the port autonomous vehicles, the large-scale application of autonomous driving technology in ports and the industrialization of port autonomous driving technology will be realized.

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