

Research on the Application of Artificial Intelligence Technology in the Field of Intelligent Transportation Systems

Chenyu Yu *

Department of Faculty of Urban Construction BJUT, Beijing University of Technology, Beijing, China

* Corresponding author: yuchenyu@emails.bjut.edu.cn

Abstract. This research report provides a comprehensive investigation into the application of artificial intelligence (AI) in the context of autonomous driving technology within Intelligent Transportation Systems (ITS). Firstly, it offers an analysis of the technical aspects of autonomous driving technology. It then focuses on the development and research status of Intelligent Transportation Systems (ITS), with a particular emphasis on vehicle-to-vehicle (V2X) communication as a major AI application in connecting vehicles. The goal is to explore and evaluate the current application of AI technology in connected vehicles. The research investigates existing literature, research directions, methodologies, and case studies to assess the progress, challenges, and potential future developments in this field. Through this study, one can gain a comprehensive understanding of the research progress and practical applications of AI in various domains within the ITS context. This helps uncover the strengths, challenges, and future directions of AI technology in the ITS field, providing valuable insights and guidance for further research and advancements.

Keywords: Artificial intelligence, vehicle-to-everything, intelligent transportation systems.

1. Introduction

Over the past few years, there has been rapid growth in China's urban areas. To tackle the challenges of urban traffic congestion, enhance people's mobility, and enhance the overall urban transportation landscape, it becomes imperative to intensify the implementation of artificial intelligence technology and establish intelligent transportation systems within cities.

The USDOT Intelligent Transportation Systems Joint Program Office (ITS JPO) research team established a suggested definition that puts artificial intelligence (AI) into the context of Intelligent Transportation Systems (ITS). The process of defining AI involves several steps. Firstly, a list of reputable definitions was compiled through an extensive online search. Secondly, new definitions were crafted through brainstorming sessions within the internal team. Next, natural language processing (NLP) and unsupervised machine learning techniques were utilized to compare and cluster the 77 definitions. Lastly, four criteria - relevance, clarity, inclusivity, and simplicity - were used to prioritize the definitions. The final recommended definition was created by combining the top two definitions. The recommended definition is as follows [1].

Artificial Intelligence (AI) encompasses procedure that enable systems to substitute or enhance no-automated tasks, or empower new capabilities that are beyond man-made capacity. AI empowers systems to (1) perceive and understand their surroundings by using sensors, cameras, and other data sources. It can analyze visual, auditory, and other sensory inputs to make sense of the world. (2) reason and analyze vast amounts of data. It uses algorithms and machine learning techniques to identify patterns, extract insights, and draw conclusions from complex datasets, (3) learn from experience and improve their performance over time. Through machine learning and deep learning algorithms, AI can gather knowledge, recognize patterns, and adapt its behavior to new and changing circumstances. (4) make autonomous decisions based on the information they have analyzed. They can communicate with humans or other systems through natural language processing or other interfaces. Additionally, AI systems can take physical or virtual actions based on their decision-making processes. AI encompasses various examples, including machine learning, natural language processing, and object recognition. Machine learning (ML) is a subfield of AI that involves the use

of algorithms and statistical models. Through ML, computers can learn from data, identify patterns, and make decisions without human intervention. Natural language processing enables computers to understand and interact with human language, while object recognition allows AI systems to identify and classify objects in images or videos. The field of machine learning (ML) can be broadly classified into supervised, semi-supervised, unsupervised, and reinforcement learning. In the domain of Intelligent Transportation Systems (ITS), AI has the potential to replace or enhance the capabilities of various components such as field, handheld, and remote sensing devices. It can also augment the functionalities of connected and automated vehicles, traffic management center (TMC) operators, transit and freight operators, decision-makers, and travelers. By leveraging AI technologies, ITS can achieve improved efficiency, enhanced safety, optimized traffic flow, and better decision-making processes across the transportation ecosystem. For instance, AI can be employed to perform tasks such as object and image recognition, speech and audio recognition, processing massive amounts of data to identify patterns, learning from experience, and adapting to new environments. These capabilities enable AI systems to predict traffic phenomena, provide situational awareness, optimize transportation routes, improve traffic management, enhance driver assistance systems, and facilitate intelligent decision-making in the field of transportation. This definition consists of three main elements. Firstly, it acknowledges that AI can substitute or enhance human tasks and offers broad examples of AI applications. Secondly, it defines machine learning and includes references to related concepts. Lastly, it specifically emphasizes the role of AI in Intelligent Transportation Systems (ITS) and provides specific examples of activities and applications within this field.

2. Concept and Development of Artificial Intelligence Technology and Intelligent Transportation Systems

2.1. Artificial Intelligence Technology and ITS Development Situation

2.1.1. The concept of artificial intelligence

The technology is based on theories related to human intelligence and involves appropriate simulation, extension, and expansion of these theories. It is an advanced modern scientific and technological field. Artificial intelligence technology regroups various disciplines and professions, including psychology, computer science, linguistics, and others. Research in artificial intelligence technology should focus on the development of systems and intelligent devices, to simulate human-related activities. Currently, artificial intelligence primarily encompasses areas such as intelligent search, and natural language.

2.1.2. The development situation of artificial intelligence

The field of artificial intelligence (AI) has experienced significant advancements in recent years. One prominent area of AI is machine learning (ML), which allows computer systems to learn from data without explicit programming.

ML encompasses various techniques such as supervised, unsupervised, and reinforcement learning. In the context of traffic-related applications, ML has been successfully applied in areas like traffic prediction, intelligent traffic signal control, and driving assistance systems [2].

Another key component of AI is artificial neural networks (ANNs), which simulate biological neural networks and serve as the foundation for ML and deep learning. ANNs have found extensive use in traffic flow prediction, vehicle detection and tracking, and traffic accident prediction [3].

Furthermore, deep learning (DL) builds upon ANNs by utilizing multi-layer nonlinear models for learning and decision-making. DL hierarchically extracts high-level features and has proven to be highly effective in object and face recognition applications [4]. This technology enables the automatic detection and classification of objects in images or videos, as well as the recognition and verification of facial features. Natural Language Processing (NLP) is another important aspect of AI that empowers computers to understand and process human language. NLP has been employed in diverse tasks such as language comprehension, machine translation, sentiment analysis, and question-

answering. In the context of transportation, NLP can extract information about road conditions and support real-time traffic navigation [5]. Computer vision and imagery analysis play a crucial role in understanding, analyzing, and processing image and video data. Computer vision techniques enable object detection, scene understanding, and action recognition, while image analysis performs tasks like object tracking and segmentation. These technologies find applications in traffic monitoring, traffic safety, and pedestrian and vehicle recognition [6]. The advancements in AI have enabled systems to possess a wide range of functions. They can now sense and perceive the environment, reason, and analyze information, learn from experience, adapt to new situations, make decisions, and communicate and take actions [7]. This integration of AI into various domains has led to innovative research outcomes and practical solutions for real-world problems.

In conclusion, the development of AI technologies, such as ML, ANNs, DL, NLP, computer vision, and imagery analysis, has revolutionized the field of transportation. These advancements have been driven by the contributions of numerous experts and scholars who have published influential papers in the area. Their research has paved the way for significant innovations in traffic prediction, intelligent traffic signal control, object and face recognition, natural language processing, and computer vision applications, to name just a few. As AI continues to evolve, it holds tremendous potential to further enhance transportation systems, improve road safety, and contribute to the efficient mobility of people and goods.

2.2. Intelligent Transportation Systems and ITS Development Situation

2.2.1. The concept of intelligent transportation systems

ITS, which stands for Intelligent Transportation Systems, is a comprehensive concept that encompasses the integration of advanced technologies and communication systems to optimize the efficiency, safety, and sustainability of transportation networks. It leverages a wide range of cutting-edge tools including sensors, communication devices, data analytics, and control systems to collect and analyze real-time information about traffic conditions, enabling effective management of traffic flow and providing intelligent solutions to address transportation challenges.

2.2.2. The development situation of intelligent transportation systems

Intelligent transportation systems (ITS) have witnessed significant progress in recent years with the integration of artificial intelligence (AI) technology into transportation infrastructure. The use of AI in smart transportation has effectively addressed various challenges in urban traffic while promoting the advancement of AI technology itself. According to a study by Li and Zhang [8], the integration of AI techniques in traffic management and flow has resulted in enhanced efficiency and safety in transportation systems. By leveraging information technology, smart transportation systems connect people, vehicles, and roads, allowing for better coordination and optimization of traffic operations. This integration has led to improvements in traffic flow management and control, such as optimizing signal timings, lane configurations, and congestion pricing using AI algorithms. One key aspect of intelligent transportation is the acquisition and processing of traffic information. Using sensors and AI algorithms, data on traffic patterns can be collected and analyzed to provide valuable insights for traffic planning and management. This enables authorities to make informed decisions regarding road infrastructure and traffic policies.

Moreover, the integration of autonomous driving and smart vehicles is another area of development in ITS. AI technologies are being utilized to develop self-driving cars and enable vehicle-to-vehicle communication, which enhances traffic efficiency and safety. Self-driving cars, equipped with AI systems, can make real-time decisions based on the traffic situation, minimizing accidents, and improving overall traffic flow.

Safety and emergency management are also prioritized in the development of intelligent transportation systems. AI-based accident risk detection systems can analyze real-time data and detect potential risks, allowing for timely safety alerts and effective emergency response [8]. This contributes to the overall enhancement of traffic safety.

3. Research and Analysis of AI Technology Applications in Intelligent Transportation Systems

3.1. The Applications of AI in Intelligent Transportation Systems

AI technology has significantly transformed the Intelligent Transportation Systems (ITS) field, bringing about remarkable changes in various transportation aspects. By harnessing advanced algorithms and machine learning techniques, AI has facilitated intelligent traffic management, enhanced safety measures, and improved overall efficiency. Notably, two prominent applications of AI in ITS include:

Firstly, in traffic flow optimization, AI algorithms analyze historical data encompassing traffic patterns, weather conditions, and special events to predict traffic flow. This valuable information is then utilized to optimize urban road networks for efficient traffic management. For example, AI can dynamically adjust signal timings at intersections based on real-time traffic conditions, thus reducing congestion, and enhancing traffic flow. By optimizing routing and resource allocation, AI helps alleviate traffic congestion, thereby improving the commuting experience in cities.

Secondly, V2X (Vehicle-to-Everything) communication heavily relies on AI to enable seamless communication between vehicles and their surroundings. V2X encompasses communication among vehicles (V2V), infrastructure (V2I), pedestrians (V2P), and networks (V2N). AI algorithms analyze data from diverse sources, including onboard sensors, traffic cameras, and cloud-based systems. This analysis facilitates real-time decision-making and communication between vehicles and their environment. V2X communication allows vehicles to exchange critical information such as road conditions, traffic congestion, and potential hazards, ultimately enhancing road safety. Through AI-enabled V2X systems, vehicles can make informed decisions, proactively respond to changing traffic situations, and avoid accidents.

3.2. Autonomous Driving Technology

Autonomous driving vehicles rely on the application of artificial intelligence technology and computer systems to operate automatically without human intervention. These vehicles utilize support from global positioning systems (GPS) and artificial intelligence technology. By intelligently applying computer vision technology, they can effectively plan to drive routes, ensuring that vehicles can operate autonomously according to predetermined procedures, thereby promoting smooth traffic flow and reducing the probability of accidents. Currently, autonomous driving technology can be divided into two main categories, which can be seen in Table 1.

Table 1. Two categories comparing

Parameters	Autonomous	Automated
Definition	It's a type of vehicle that is capable of operating itself and performing essential vehicle functions without any human intervention. The vehicle is also capable of sensing the environment to perform necessary maneuvers.	An automated vehicle utilizes the automated driving system to enable it to respond to external conditions without any human intervention. There are different levels of automation.
Working	An autonomous car can decide on the most efficient route. It can control the lane movement as well.	An automated vehicle can only follow orders about the destination and route. It can adopt automated driving concepts such as lane assist, adaptive cruise control, etc.

From the current development situation of intelligent transportation in China, fully autonomous driving vehicles have not been widely deployed and are still in the research stage. However, as research on this technology deepens and it becomes more mature, it is increasingly practical. Semi-autonomous driving vehicles, on the other hand, have been widely adopted in the market. The development of autonomous driving technology holds significant importance, as its application in the field of intelligent transportation can effectively alleviate traffic congestion in urban areas.

Autonomous driving technology can be applied not only to passenger cars but also to public transportation, industrial vehicles, logistics, and other fields. By applying this technology appropriately, transportation efficiency can be improved. Moreover, it can partially address the challenges faced by vulnerable groups in accessing transportation, providing safe and convenient travel options for the elderly, disabled, pregnant women, and those with medical conditions. The concept of autonomous driving aligns with China's commitment to sustainable development. It can reduce environmental damage caused by vehicle operation, decrease energy consumption, and improve traffic congestion in cities. The obstacle avoidance and emergency braking capabilities of autonomous vehicles can assist drivers in making correct judgments, helping to avoid accidents caused by human error and enhancing safety during vehicle operation.

The application of artificial intelligence technology in autonomous driving has shown promising results. For example, AI-based autonomous driving systems can coordinate the movement of multiple trucks in proximity, enabling them to brake, move forward, and perform other operations simultaneously. In a convoy, the first truck can be controlled by a driver, while the other trucks do not require active driving and only need to be supervised in case of emergencies. The specific implementation method is illustrated in Figure 1.

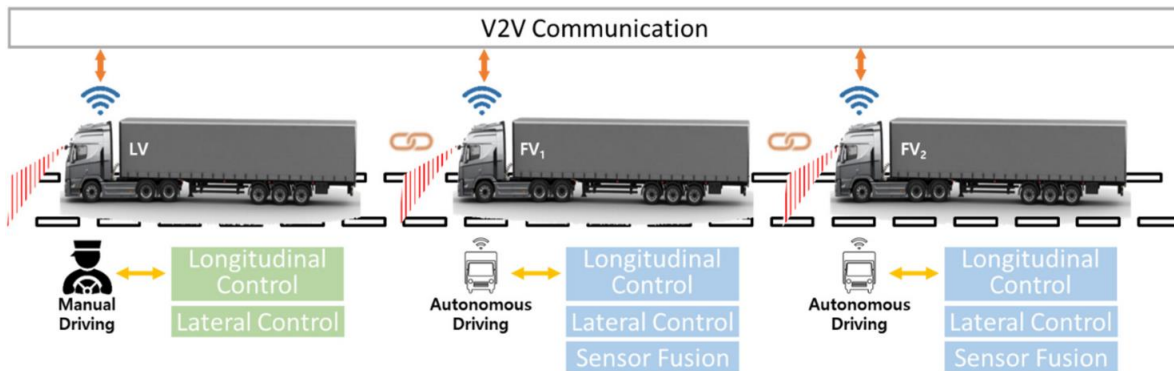


Figure 1. Overall architecture of truck platooning system [9].

3.3. Traffic Flow Prediction and Optimization

Compared to traditional localized optimization control strategies, the AI-enabled traffic network prediction and optimization system is a platform with broader control capabilities. It provides more powerful computing power, allowing for traffic flow analysis of large-scale traffic networks and the ability to simultaneously generate solutions that address multiple issues.

Yuantong intelligent transportation system was launched by “Xi Yue” (A private enterprise focused on the construction of smart cities). Like this application, it has functions such as understanding pedestrian control, road condition perception, calculating pedestrian density, and recognizing road signs. This intelligent transportation system can be seen in Figure 2.



Figure 2. Yuantong intelligent transportation system [10]

Systems that include AI bring the idea of outcome-oriented learning to applications that were traditionally static. When a system is capable of learning from both its successes and failures, and consistently adjusting algorithm parameters to achieve improved results, it can become more flexible and generate greater advantages. A control optimization experimental research platform can be seen in Figure 3.



Figure 3. Guangzhou Internet plus signal light control optimization experimental research platform [11]

It has features such as intersection congestion alerts and excessive vehicle flow density warnings. It quickly feeds these data back to the system for calculation, which then optimizes traffic conditions through signal light optimization and traffic police adjustment instructions.

4. Conclusion

As a result of major strategic initiatives such as promoting a strong transportation nation, transitioning to new energy sources, and achieving energy conservation and emission reduction, the concept of green transportation will increasingly be applied. Therefore, in urban transportation development plans, the government should fully consider the requirements of public transportation and the importance of developing green transportation. Policy measures should be appropriately tilted towards public transportation, establishing a sound management system and robust regulations for public transportation. Special attention should be given to the construction of sidewalks and bicycle systems, enabling green public transportation to effectively improve the safety level of urban roads and promote normal traffic conditions in cities.

At the same time, the government needs to strengthen policy guidance for green public transportation while building modern, green, and healthy cities. Ultimately, it is essential to have a mindset of serving the people and gradually guide the transformation of urban service from being vehicle-centric to people-centric. Encouraging and mobilizing active participation from the public in urban public transportation construction will help create an environmentally friendly living environment.

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