

The Application of Artificial Intelligence in Intelligent Transportation System

Yibo Zhao *

College of Transportation Engineering, Chang'an University, Xi'an, China

* Corresponding author: zhaoyibo@chd.edu.cn

Abstract. Intelligent transportation systems are an important research direction in the field of transportation, offering safer, more efficient, and sustainable transportation solutions. AI, as a powerful technological tool, has demonstrated remarkable achievements in various domains. In the context of intelligent transportation, the application of AI is gaining increasing attention and expectation. Its powerful capabilities in data processing, analysis, intelligent decision-making, and autonomous control bring profound changes to the transportation system. The objective of this research is to examine the implementation of artificial intelligence (AI) in intelligent transportation and investigate its potential impact on the transportation system. This study first defines AI in the context of intelligent transportation and identifies AI sub-branches with potential applications in intelligent transportation systems. It then reviews the development of ITS and the challenges they face. Lastly, based on a literature review, an advanced overview of current and possible applications that utilize artificial intelligence in automated driving systems and transportation systems management and operations is provided. The analysis reveals that AI technologies can accurately predict traffic flow, optimize signal control in real time, and achieve highly automated driving. These results demonstrate the potential advantages and application value of AI in intelligent transportation. The application of AI in intelligent transportation systems holds immense potential for providing safer, more efficient, and sustainable transportation solutions. This research provides a new perspective and solution approach to the advancement of ITS. The application of AI in the realm of intelligent transportation can positively impact the operational efficiency, traffic safety, and environmental sustainability of transportation systems.

Keywords: Artificial intelligence application, intelligent transportation system, automated driving.

1. Introduction

With the continuous acceleration of urbanization and the continuous growth of car ownership, intelligent transportation has become an important and urgent issue in modern cities. Traditional transportation systems face increasing challenges such as growing numbers of vehicles, traffic accidents, and congestion, which have had a significant negative impact on urban development and residents' lives. However, with the continuous advancements and popularization of artificial intelligence technology, the field of intelligent transportation has ushered in new hopes and opportunities.

Artificial intelligence (AI), as a powerful technological tool, has already demonstrated remarkable achievements in multiple domains. In the realm of intelligent transportation, the application of artificial intelligence is increasingly attracting attention and expectations. Its powerful data processing and analysis capabilities, as well as its intelligent decision-making and autonomous control characteristics, have brought about a completely new transformation to the transportation system. Transport departments both domestically and internationally are exploring the application of AI in intelligent transportation systems. In March 2022, China's Ministry of Transport and Ministry of Science and Technology released the "Outline for the Technological Innovation Development Plan in the Transportation Sector (2021-2035)", which emphasizes the integration and innovative application of new generation information technologies, including mobile internet, AI, blockchain, cloud computing, and big data, as well as aerospace information technology, with transportation to comprehensively enhance the level of development in intelligent transportation. The focus of the Joint Program Office (JPO) for Intelligent Transportation Systems (ITS) of the US Department of

Transportation is to prioritize artificial intelligence (AI) research. This priority aims to expedite the integration of AI technologies by state and local agencies in handling transportation challenges [1]. In recent years, numerous researchers have actively explored the application of artificial intelligence in intelligent transportation systems. Zhang Xinyu et al. applied artificial intelligence to multi-object detection in autonomous vehicles, achieving precise identification of obstacles [2]. Pei Yueling, et al. proposed the application of deep learning and intelligent big data in areas such as highway license plate and vehicle type recognition, and road network planning, providing theoretical support for traffic network management and planning [3]. Zhang Wensheng et al. proposed applying artificial neural networks to traffic flow prediction of typical road networks such as cities and highways to improve the accuracy of traffic flow prediction [4]. In the past few years, the United States Department of Transportation (USDOT) has made significant progress in exploring artificial intelligence. Some modal administrations of the USDOT, such as the Federal Highway Administration (FHWA) and the Federal Railroad Administration (FRA), are dedicated to applying artificial intelligence technology to address relevant issues. Applications based on AI have been deployed to perform video analysis, anomaly recognition, safety analysis, and data fusion. FHWA is committed to the development of AI technology for collecting a mass of traffic data to discover trends and establish connections among seemingly unrelated data sources. Furthermore, it is employed in video analysis to assist in the assessment of driver conduct across diverse driving situations. FHWA has developed AI solutions for multimodal transportation management [5].

This article aims to explore the application of artificial intelligence in intelligent transportation, two key areas will be explored in-depth, including the AI application in Advanced Driver Assistance Systems and Autopilot Systems, as well as the AI application in Transportation Systems Management and Operations. The subsequent sections of this paper are structured as follows: Section 2 elaborates on the definition of AI in intelligent transportation and the branch technologies of AI that have potential applications in the field of ITS. Section 3 analyzes the overview and current challenges of intelligent transportation systems. Section 4 discusses the application of AI in ITS. Section 5 provides a conclusion of this paper.

2. The Definition and Subfield Technology of Artificial Intelligence in Intelligent Transportation Systems

2.1. Definition of AI in the Context of ITS

The first step in identifying potential artificial intelligence application categories related to ITS is to determine the definition of AI in the context of ITS. 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). Artificial Intelligence (AI) pertains to the progress of computer systems and machines that exhibit the ability to execute tasks and render decisions which traditionally necessitate human intelligence. AI aims to imitate human intelligence and enhance or automate human-like behavior. Artificial intelligence endows systems with the following abilities: perception and perception of the environment, reasoning and analysis of information, autonomous learning and adaptation to new situations, decision-making, communication, and taking action [6]. Then the definition gives some examples of subfields of artificial, including machine learning, natural language processing, and object recognition. The definition also defines machine learning which is a broad subfield of AI and mentions the relative concepts. Finally, the definition places its emphasis on artificial intelligence in intelligent transportation systems and offers illustrative activities and applications within this field [7].

2.2. AI Sub-Fields and Techniques

2.2.1. Machine learning

Machine learning (ML) is an important branch of AI, aimed at enabling computer systems to learn and improve from data without the need for explicit programming. It's a method that allows machines to learn from experience, automatically discovering patterns and patterns from data through training models and utilizing these patterns and patterns to make predictions or decisions. The basic principle of ML is to construct a mathematical model, train the model using input data, and then utilize the trained model to predict or classify new data. Reinforcement Learning is a ML approach. In reinforcement learning, algorithms learn the optimal action strategy through interaction with the environment. It iteratively optimizes strategies through trial and error and reward and punishment mechanisms. Reinforcement learning is often used in decision-making problems such as path planning in autonomous vehicles [8].

Machine learning can be applied to traffic prediction, intelligent traffic signal control, driving assistance systems, traffic accident prediction and prevention, and vehicle recognition and tracking [5]. The application of machine learning can help enhance the efficiency, safety, and sustainability of transportation systems. By analyzing and understanding a large amount of traffic data, machine learning models can provide decision support and intelligent traffic management solutions [8].

2.2.2. Artificial neural network

Artificial Neural Networks (ANN) is a mathematical model that simulates biological neural networks, used to simulate the neural network structure and information processing mechanisms of the human brain. It is the foundation of ML and deep learning. Artificial neural networks are composed of a large number of artificial neurons, which transmit and process information with each other through connections (connecting weights). Each neuron receives multiple input signals, weights the sum of these signals, and generates an output through the activation function. With the rise of deep learning, deep neural networks (DNN) and other models based on artificial neural networks have also achieved many breakthrough results [9].

Artificial neural networks have various applications in the realm of transportation: traffic flow prediction, vehicle detection and tracking, driving behavior recognition, traffic accident prediction and analysis, and intelligent traffic signal control. Artificial neural networks have strong capabilities in processing large amounts of traffic data and pattern recognition and can provide effective decision support and intelligent applications for the transportation field [5].

2.2.3. Deep learning

Deep Learning is a special method in the field of machine learning, based on the concept of artificial neural networks (ANNs), which use multi-layer nonlinear models to learn and model data. It hierarchically extracts high-level features of data and uses these features for learning and decision-making. Compared with traditional machine learning methods, deep learning has several significant features such as multi-layer structure, autonomous feature learning, large-scale data processing, and parallel computing ability [5, 9].

2.2.4. Object and face recognition

Object recognition and face recognition are applications of deep learning in the domain of computer vision. Object recognition is used to automatically detect and classify objects in images or videos, while face recognition is used to recognize and verify facial features. These applications improve accuracy by learning and representing complex features through deep learning models and are widely used in fields such as image search, intelligent monitoring, and facial unlocking [5].

2.2.5. Natural language processing

Natural Language Processing (NLP) is a domain that studies how to enable computers to understand and process human natural language.

The objective of NLP is to enable computers to understand, analyze, and generate human language, and to communicate naturally and fluently with humans. This type of communication can include voice interaction and text interaction. NLP technology covers various tasks, including language comprehension, machine translation, sentiment analysis, text classification, entity recognition, question answering, etc [10]. NLP can be used to process text data related to transportation, such as news reports, social media information, and public transportation announcements, to extract information about road conditions, traffic accidents, traffic congestion, and so on. This information can be used for real-time traffic navigation to help drivers choose the best route [5, 9, 11]. NLP technology can help process a large amount of document data, such as traffic regulations, road planning documents, etc. Through techniques such as text classification and entity recognition, relevant traffic rules and road attribute information can be extracted to furnish support for traffic management and planning [11].

3. Definition and Development of ITS

3.1. Overview of Intelligent Transportation Systems

An intelligent transportation system is a system that utilizes advanced information technology and artificial intelligence technology to raise traffic efficiency, reduce traffic congestion, and enhance traffic safety. It achieves intelligent management and control of traffic flow, traffic lights, traffic facilities, etc. by collecting, processing, and analyzing traffic data. The goal of ITS is to provide more efficient, safe, and environmentally friendly transportation services and enhance the travel quality of urban residents.

Today's transportation systems can furnish up-to-date information regarding various travel methods, empowering commuters to make well-informed choices to minimize travel time and cost. Technology can monitor the flow of vehicles, people, and goods to optimize efficiency while diminishing energy consumption and emissions. In the event of a disaster, transportation operations can be adjusted to facilitate mass evacuations through electronic monitoring, transit, and traffic control. Vehicles can also monitor their surroundings and conditions to alert drivers of weather changes, traffic congestion, and potential hazards. The development of self-driving vehicles aims to eliminate crashes and maximize transportation system capacity. These capabilities are delivered through the integration of various disciplines within the field of intelligent transportation systems (ITS), which strive to provide safe, efficient, and sustainable transportation solutions [12].

The intelligent transportation system consists of multiple components, including traffic perception devices, data communication networks, traffic control devices, and traffic management centers. Traffic perception devices such as sensors and cameras are used to collect traffic data, data communication networks are used to transmit and share data, traffic control devices such as traffic lights and variable information signs are used to optimize and adjust traffic flow and traffic management centers are responsible for analyzing and making decisions on traffic data.

Intelligent transportation systems rely on various key technologies, including artificial intelligence, big data analysis, the Internet of Things, and machine learning. Artificial intelligence technology can provide functions such as traffic flow prediction and congestion warning by analyzing and predicting traffic data. Big data analysis technology can explore patterns and patterns in traffic data, providing support for traffic management and decision-making. The Internet of Things technology can achieve the interconnection and interoperability of transportation equipment, improving the overall efficiency of transportation systems. Machine learning technology can improve the intelligence level of transportation systems by learning and optimizing traffic data [12].

3.2. Current Challenges Encountered by Intelligent Transportation

The current challenges faced by ITS include the following aspects:

Cybersecurity and privacy protection: Intelligent transportation systems rely on extensive data collection and sharing, including vehicle location, traffic flow, and personal information. Ensuring

the security and privacy protection of these data is an important challenge that requires effective protective measures and privacy protection mechanisms.

Technical standards and interoperability: Intelligent transportation systems involve multiple technical fields and participants, including vehicle manufacturers, traffic management agencies, and communication service providers. Ensuring that various technologies are compatible and interoperable with each other to achieve seamless integration and collaborative work of the system is an important challenge.

Infrastructure update and investment: Intelligent transportation systems require advanced infrastructure support, including traffic lights, road sensors, and communication networks. However, updating and upgrading existing infrastructure requires significant investment and resources, which is a challenge.

Legal and regulatory framework: Intelligent transportation systems involve many legal and regulatory issues, including data privacy, responsibility allocation, and security standards. Establishing an appropriate legal and regulatory framework to promote system security and sustainable development is an important challenge.

Faced with these challenges, all parties must work together, including the government, academia, industry, and various sectors of society, to promote the development and application of ITS [12].

4. Artificial Intelligence Applications in Intelligent Transportation Systems

4.1. AI Application in Automated Driving Systems

In recent times, there has been a notable worldwide emphasis on the fast progression of autonomous vehicles (AVs). These AVs show great potential in revolutionizing modern transportation systems and are expected to tackle various longstanding transportation issues such as congestion, safety concerns, parking problems, and energy conservation [13]. AI plays a pivotal role in enabling vehicle automation, encompassing advanced driver assistance systems (ADAS) as well as Automated Driving Systems (ADS). Additionally, AI has the potential to be integrated into emergent driver alert systems and connected vehicle functionalities. Automated Driving Systems can consistently perform the complete range of tasks involved in dynamic driving, and they depend on various forms of AI to facilitate the detection and response to objects and events [5]. The conventional belief surrounding earlier (semi-)automated driving concepts primarily focused on ADAS that aid drivers during the driving process. These systems, such as driveway aberrancy alarming and blind spot alerts, are designed to automate and enhance certain vehicle functions to improve safety by reducing human driver errors [13].

The Automated Driving System is mainly composed of perception, decision-making, and execution subsystems. The system involves key technologies including environment perception, decision-making planning, control execution, and V2X communication, and its structure is shown in Figure 1. Artificial intelligence plays a key role in autonomous vehicles. It can realize autonomous driving of vehicles through perception, decision-making, and control.

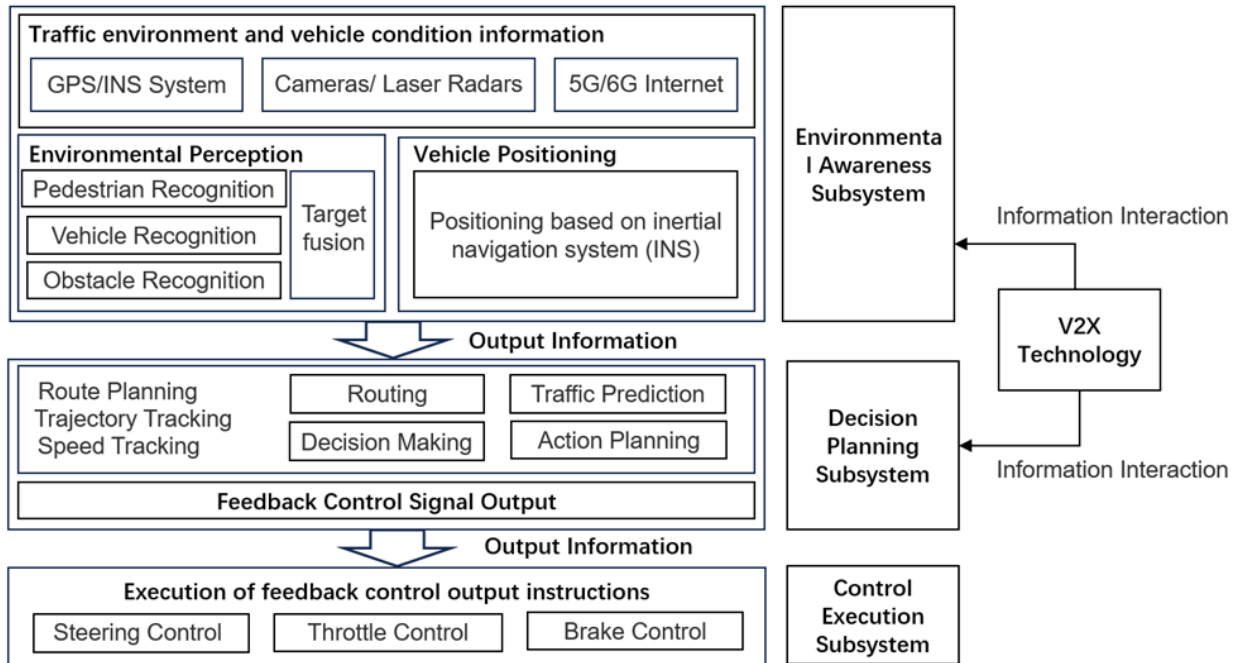


Figure 1. Schematic diagram of autonomous vehicle structure (Picture credit: Original)

Perception: Autonomous vehicles use various sensors (such as cameras, radars, laser radars, etc.) to sense the surrounding environment. Through technologies such as deep learning and computer vision, artificial intelligence can process and analyze sensor data, achieving recognition and tracking of roads, vehicles, pedestrians, and obstacles [5, 13].

Decision making: Based on perception of the environment, artificial intelligence can analyze and infer the optimal driving strategy. It can make reasonable decisions based on factors including current traffic conditions, road conditions, and vehicle performance, such as selecting appropriate lanes, speeds, and steering actions [5].

Learning and optimization: AI can improve the performance and efficiency of autonomous vehicles through continuous interaction and learning with the environment. It can continuously optimize autonomous driving algorithms and decision-making models by learning driving behavior and traffic rules, gradually improving the safety and driving experience of vehicles [13].

In general, the application of AI in autonomous vehicles enables vehicles to more intelligently perceive and understand the surrounding environment, make accurate decisions, and achieve accurate control, to achieve efficient and safe autonomous driving.

4.2. AI application in Transportation Systems Management and Operations

Artificial intelligence (AI) has many applications in transportation system management and operation. This section encompasses the utilization of artificial intelligence (AI) in various applications aimed at enhancing the performance of a multimodal infrastructure. These applications involve the deployment of real-time and dynamic systems, services, and management strategies to optimize capacity, enhance efficiency and productivity, and bolster the security, safety, and reliability of our transportation system.

Traffic prediction and optimization: AI can analyze a large amount of traffic data, including traffic flow, road conditions, and historical data, to predict future traffic conditions. These predictions can help traffic managers make decisions, and optimize traffic signal timing, route planning, and traffic flow scheduling to improve traffic efficiency and reduce congestion. The utilization of deep learning and picture analysis techniques has demonstrated potential in facilitating short-term forecasts of vehicle trajectories on arterials. This is particularly advantageous in situations when there is a scarcity of data.

Intelligent traffic signal control: AI can provide more intelligent traffic signal control by real-time monitoring of traffic flow and optimizing signal timing. This can reduce waiting time, improve traffic mobility, and reduce traffic congestion. The utilization of machine learning and object identification techniques enables the detection of queues and pedestrians, as well as the prediction of vehicle arrivals at crossings. These capabilities may be leveraged to optimize traffic signal timings.

Traffic Management Decision Support: AI can provide decision support tools for traffic managers to help them make smarter decisions. By analyzing and simulating different traffic management strategies, AI can evaluate their effectiveness and provide the best decision recommendations.

Traveler Information and Navigation: AI can provide real-time traffic data and navigation guidance for travelers. By analyzing traffic data and travelers' preferences, AI can provide travelers with the best route selection, updated traffic conditions, and travel recommendations.

These are some applications of AI in transportation system management and operation. With the continuous development of technology, AI is expected to play a greater role in the transportation field, improving traffic efficiency, reducing congestion, and improving the travel experience [5].

5. Conclusion

Artificial intelligence plays a vital role in addressing the numerous challenges faced by traditional transportation systems, making significant contributions to intelligent transportation systems. The development of autonomous driving technology has facilitated vehicles to achieve advanced levels of self-driving capability, unlocking immense potential for future transportation systems. Additionally, by utilizing deep learning and machine learning algorithms to analyze transportation data, accurate traffic predictions and optimizations can be made, effectively alleviating traffic congestion. The application of intelligent traffic signal control further enhances traffic system efficiency and reduces waiting times through smart algorithms and real-time data analysis. In summary, the integration of artificial intelligence into intelligent transportation systems presents substantial opportunities for creating safer, more efficient, and sustainable transportation systems. However, despite the significant breakthroughs achieved in the field of AI in intelligent transportation, several challenges and obstacles must be addressed, including data privacy and security concerns, as well as the establishment and adaptation of appropriate laws and regulations. Therefore, alongside the advancement of AI in intelligent transportation, it is imperative to conduct thorough research, foster collaborative efforts, and develop corresponding policies and standards to ensure safety and sustainable development.

Looking ahead, with the successive progression of technology and the maturation of AI, intelligent transportation systems will undergo iterative improvements and evolution. Expectations include the advancement of more sophisticated and intelligent autonomous driving technology, accurate and real-time traffic prediction and optimization, efficient and intelligent traffic signal control, as well as precise and reliable behavior recognition and accident warning systems. These advancements will further elevate the efficiency and safety of transportation systems, providing residents with an enhanced travel experience.

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