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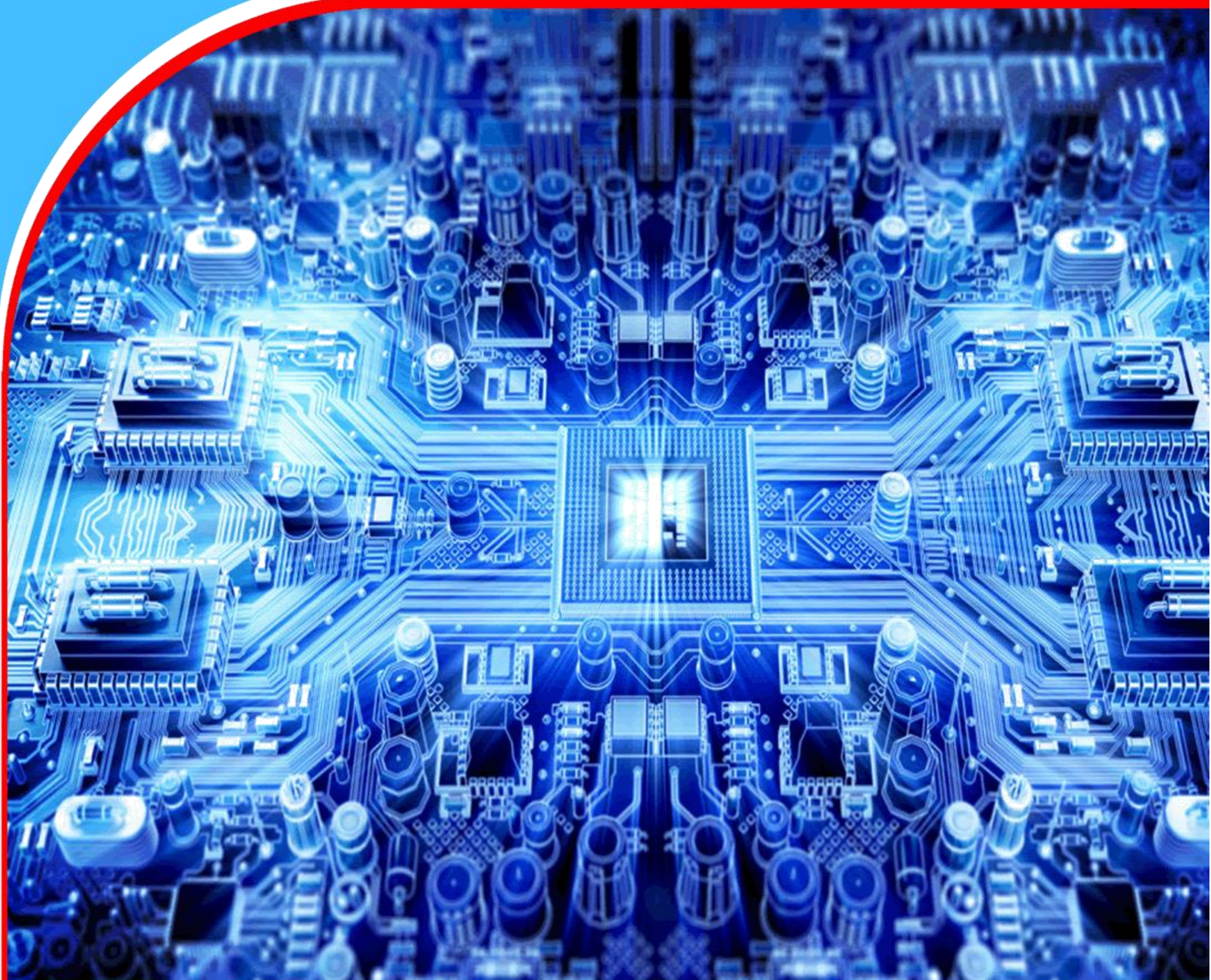

Artificial Intelligence in Transportation Systems A Critical Review

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Abstract

Purpose: The purpose of the research is to investigate the role of machine learning (ML) and artificial intelligence (AI) in the growth of smart cities. It aims to understand how these technologies are being used to manage expanding metropolitan areas, boost economies, reduce energy consumption, and improve the living standards of residents. The study also aims to analyze the information flow associated with ICT in smart cities.

Methodology: The methodology involves conducting a survey to identify the typical technologies used to support communication in smart cities. It also involves a systematic evaluation of current patterns in publications related to ICT in smart cities. The research utilizes ML and AI techniques to analyze and interpret the collected data.

Findings: The findings of the study indicate that ML and AI play a significant role in various aspects of smart cities, particularly in the field of intelligent transportation systems. These technologies are utilized for tasks such as modeling and simulation, dynamic routing and congestion management, and intelligent traffic control. The research also reveals the application of ML and AI in other forms of transportation like air, rail, and road travel.

Recommendations: Based on the findings, the study suggests that the agent computing paradigm is a powerful technology for the development of large-scale distributed systems, particularly in the context of geographically dispersed and dynamic transport systems. The research emphasizes the interoperability, flexibility, and extendibility of agent-based traffic control and management systems. It concludes by suggesting potential future research directions to effectively integrate agent technology into traffic and transportation systems.

Keywords: *Urban Mobility; Digitalization, Connected Environment Intelligent Transportation System Connected Automated Vehicles Cyber-Social-Physical Spaces Vehicle-Infrastructure.*

1.0 INTRODUCTION

Urban mobility has seen a significant adjustment recently. In addition to become more complicated, the usual home-work-home travel pattern is no longer the norm. Nowadays, trips frequently connect several locations in an irregular fashion. The capacity to recognize typical "home-work/school-home" travel patterns and design the transportation system appropriately has transformed the approaches to transportation planning and operation. The conventional method has been to forecast, plan, and deliver before carrying it out. But there are also significant changes taking place in the conventional transport sector.

Though urban areas occupy just 3% of Earth's land, 75% of the natural resources are consumed and 60% to 80% of world greenhouse gas emissions are produced. The urban population will rise to 70% by 2050 instead of more than 50% of the global amount of urban population. The rapid urbanization of countries will drastically impact the environment, security, and management of the urbanized cities. Many countries like the US, EU, Japan, etc. have been proposed the concept of smart cities to reduce optimized energy consumption and natural resources. Many countries worldwide have developed and adopted intelligent city programs to address future problems efficiently. Innovative approaches are needed to improve production quality and sustainability and to reduce costs for intelligent production systems. It is important to note that in the 1990s, the father of artificial intelligence (AI), John McCarthy, described artificial intelligence as 'the science and engineering of smart machines, especially smart computer programs. The word "AI" is used in general when a computer simulation works, like thinking and problem solving, which humans associate with another human mind. Artificial intelligence is divided into 16 different parts namely knowledge representation, natural language understanding, a theory of computation, reasoning, genetic algorithm, machine learning, artificial neural network (ANN), systems, expert systems, data mining, artificial life, programming, distributed artificial intelligence, theorem proving, belief revision and constraint satisfaction. Today, AI has become a field of research that is necessary to expand globally in the engineering field, education, law, science. AI disciplines including machine learning, processing of natural languages, image processing, and data mining are now a major theme for modern technology leaders. ML is now very fast growing as an AI branch. The usage has gone to relevant disciplines, including digital learning machines, smart cities, medical science, agriculture, archaeology, sports, business, etc. A general thoughtful of AI & ML work and their variants have been provided in this article. This paper provides useful ideas and opportunities for undertaking AI and ML work.

These transformations have made urban mobility become less predictable, whereby it follows a fuzzier pattern, with urban mobility acting as an "active organism", changing and adapting to new circumstances and patterns. This is partly due to the fact that the solutions being offered to consumers are being replaced rapidly, with new options becoming obsolete over much shorter periods than previously. Furthermore, when solutions are understood to be problematic or inefficient, they are easily abandoned. For example, a few years ago, Segway's seemed to be the answer for short-distance urban travels, but these have now been quickly replaced by electric bicycles and/or electric scooters, at a much lower cost and higher convenience to users. In terms of urban mobility, all these changes in transportation planning and transport systems, together with the inherit complexity of all the system, has raised several new challenges at different levels. For example, with regards to travel payment, the typical model of a monthly pass vs. a one-travel ticket can no longer meet the demand of less stable patterns with regards to transport utilisation, as the payment system needs to integrate different modes and mobility solutions. There is a growing need for an integrated system that enables the use of different modes, without the need for different physical tickets. However, dynamic information systems are also required—which facilitate the sharing of revenue between the distinct modes and operators.

Artificial Intelligence (AI) in transportation systems:

Fully Autonomous Vehicles

The development of fully autonomous vehicles is a significant focus for the future. AI algorithms, combined with advanced sensor technologies and deep learning techniques, will enable vehicles to navigate complex traffic scenarios and handle all driving tasks without human intervention. This achievement has the potential to revolutionize transportation by improving road safety, reducing traffic congestion, and increasing overall efficiency.

Enhanced Traffic Prediction and Management

AI will continue to advance in predicting and managing traffic patterns. By analyzing vast amounts of real-time data from various sources, including sensors, GPS systems, and social media, AI algorithms will provide accurate and up-to-date traffic predictions. This will enable better traffic management, including dynamic routing, congestion prevention, and optimized traffic signal control, resulting in smoother and more efficient transportation systems.

Intelligent Infrastructure and Connectivity

AI will enable intelligent infrastructure systems that communicate with vehicles and provide real-time information. For example, smart traffic lights can dynamically adjust signal timings based on traffic conditions, optimizing traffic flow. Additionally, AI-powered vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communication systems will enhance safety, coordination, and efficiency on the roads.

Personalized Mobility Services

AI will play a vital role in providing personalized mobility services to users. By analyzing individual preferences, travel patterns, and real-time data, AI algorithms will offer customized transportation solutions, such as on-demand ride-sharing and multimodal journey planning. This will enhance the overall travel experience, improve accessibility, and reduce the reliance on private vehicles.

Sustainable Transportation Solutions

AI will contribute to the development of sustainable transportation systems. Machine learning algorithms can optimize energy consumption, promote eco-friendly driving behaviors, and facilitate the integration of electric and autonomous vehicles into transportation networks. AI-powered logistics and routing systems will also prioritize environmentally friendly options, reducing carbon emissions and promoting sustainable mobility.

Advanced Safety Systems

AI will continue to advance safety systems in transportation. Enhanced object detection and recognition algorithms, combined with AI-powered collision avoidance systems, will improve vehicle and pedestrian safety. Additionally, AI will assist in identifying potential maintenance issues in vehicles and infrastructure, allowing proactive maintenance and minimizing the risk of accidents caused by mechanical failures.

Current Trends in Intelligent Transportation Systems

Congestion, accidents, and pollution issues due to transportation are becoming more severe because of the tremendous increase in various travel demands, including vehicular traffic, public transportation, freight, and even pedestrian traffic. To resolve such issues, ITSs have been developed that are able to integrate a broad range of systems, including sensing, communication, information dissemination, and traffic control. Three essential components are necessary for any IT'S to perform its function(s): data collection, data analysis, and data/information transmission. Data-collection components gather all observable information from the transportation system (e.g., traffic flow at a particular point of the road network, average travel time for a particular road section, number of passengers boarding a transit line, etc.) for further analysis of the current traffic conditions. Traditionally, inductive loop detectors, which detect the presence of vehicles based on the induced current in the loop with passing vehicles, and pneumatic tubes, which detect the presence of vehicles based on pressure changes in the tube, have been used to collect basic traffic information such as traffic volume and spot speed. However, because of their high implementation cost and impact on traffic during implementation, these methods are becoming less popular, especially in congested areas.

Due to advances in sensing and imaging technology, video cameras and radio-frequency identification (RFID) scanners are increasingly being considered for use in traffic data collection. Cameras can be installed at different locations in the network to collect traffic videos. The videos are then analyzed using specifically designed image processing software (e.g., Autoscope) to determine information such as traffic flow, speed, vehicle types, etc. In this context, automatic license plate recognition is one crucial area of research, as through the recognition and matching of license plates, it can provide additional information such as selected paths and travel times. On the other hand, radio-frequency identification data (RFID) can commonly be obtained at locations that accept contactless payment (e.g., Autotoll and Octopus systems in Hong Kong), or for freight transport. Through the matching of unique RFID, different traffic-related information, such as path choice and travel time, can be extracted.

With these basic components, ITSs can be categorized into one of two categories based on their functionalities. These are Advanced Traveler Information Systems (**ATIS**) and Advanced Management Systems (**AMS**). The details of each are presented below.

Advanced Traveler Information Systems

ATISs aim to help travelers make travel decisions (e.g., mode choice, route choice, departure time choice, etc.) by providing various types of information (e.g., travel time, wait time, available parking). Of the various implementations, travel time estimation/prediction, and route guidance systems are the most commonly studied areas as they can affect travelers' choices directly, especially route choice. With the advancement of the data-collection methods and communication technologies described above, travel time and route guidance information provided can be in a more accurate and real-time manner. With the additional sources of data (e.g., GPS data, mobile phone data, etc.), other real-time information is also available to travelers. For example, analysis of road-condition images from drivers taken automatically from smartphone applications can be used to determine available roadside parking in real time. Another example is the prediction of bus arrival time from information transmitted by bus passengers through mobile phone signals across different cell towers.

Advanced Management Systems

AMSs aim to control or manage different infrastructures and operators within the transportation system under different situations to ensure the efficiency and safety of the transportation system. In the literature, such control/management methods are applied to arterials, freeways, freight transport, transit services, and incident/emergency situations. With enriched data sources, improved data resolution, and enhanced information dissemination methods, more real-time and detailed management is possible. For example, Fu and Yang proposed bus-holding control strategies based on real-time bus location information to regulate bus headway at specific stops. Although these researchers have only validated their models in simulation experiments, they provide good insight into how new sources of information could be used in transit management. Kurkcu et al. provide another example by using open data sources and social media data for incident detection, which is the crucial first step of incident-management procedures.

Smart Cities and Related Artificial Intelligence Techniques

The ITSs introduced in the previous section aim to solve transportation-related issues and improve the overall efficiency of transportation systems. These ITSs fall under the category of smart mobility within the framework of smart cities, which is gaining its concerns in the recent decades. In the literature, there is not yet consensus as to what constitutes a smart city, and there are diverse definitions. For example, Hall suggested that a smart city would monitor its components (e.g., roads, buildings, etc.) to better optimize its resources, plan preventive maintenance activities, and monitor security, while maximizing services to its citizens. Lombardi et al, on the other hand, proposed that smart cities are those that use information and communication technology (ICT) on human capital, social and relational capital, and environmental issues. The definitions also depend on the background of stakeholders and the focus of the government. For instance, academia considers improving quality of life to be the major goal of a smart city, while stakeholders in a private company might opt for efficiency as the primary goal [42]. Despite this diversity of definitions, using advanced electronic/digital technology (e.g., ICT), embedding ICT or other electronic hardware into city infrastructure, and improving stakeholders' interests in different aspects of the system are the three common characteristics or dimensions of the smart city.

Artificial neural networks (ANN), with the ability to perform non-linear mapping between inputs and outputs through the consideration of hidden layers and sufficient training, are suitable for addressing transportation problems in which the parametric relationships among variables are not well-understood. In the literature, ANNs are commonly adopted in state estimation/forecasting, incident detection, traffic/infrastructure control, and behavior analysis. Similar to ANN, support vector machines (SVM) are supervised learning models that analyze input data, but are more focused on the classification of stages/scenarios. As a result, although SVMs have been applied to other transport-related problems, they are mainly used for problems like incident detection and accident prediction in the context of ITS. Unlike ANN and SVM, which are solely data-driven, Bayesian networks are a type of statistical model that considers the probabilities and conditional dependencies of the control variables. In the ITS literature, Bayesian networks have been used for various transportation problems, but are mainly used when the focus is traffic forecasting and incident/accident-related issues.

Artificial Intelligence (AI) in transportation systems refers to the integration of AI technologies and techniques to enhance and optimize various aspects of transportation. It involves the application of machine learning, computer vision, natural language processing, and other AI methodologies to improve efficiency, safety, and sustainability within transportation networks.

AI can play a significant role in multiple areas of transportation, such as:

Autonomous Vehicles

AI enables self-driving cars and autonomous vehicles by utilizing sensors, computer vision, and machine learning algorithms to navigate, perceive the environment, and make decisions without human intervention.

Traffic Management

AI can optimize traffic flow and reduce congestion by analyzing real-time data from traffic sensors, cameras, and historical patterns. This information helps in predicting traffic patterns, optimizing signal timings, and suggesting alternative routes to improve overall transportation efficiency.

Predictive Maintenance

AI techniques can be used to monitor and analyze data from vehicles and infrastructure to predict maintenance needs. This allows for proactive maintenance and reduces unexpected breakdowns, increasing reliability and reducing downtime.

Smart Logistics and Supply Chain Management

AI can optimize logistics operations by analyzing large datasets, optimizing routes, predicting demand, and managing inventory more efficiently. This leads to cost savings, faster deliveries, and improved resource utilization.

Intelligent Transportation Systems (ITS)

AI technologies are used in ITS to monitor and manage transportation networks. This includes real-time incident detection, dynamic routing, adaptive traffic signal control, and providing traveler information to enhance safety and efficiency.

Passenger Experience

AI-powered virtual assistants and chatbots can enhance the passenger experience by providing real-time information, personalized recommendations, and assistance throughout the journey.

The integration of AI in transportation systems has the potential to revolutionize the way we travel, making it safer, more efficient, and sustainable. However, it also raises concerns such as ethical considerations, cybersecurity, and the impact on employment. These factors need to be carefully addressed to ensure the responsible and beneficial implementation of AI in transportation.

2.0 CONCLUSION AND RECOMMENDATIONS

Conclusion

In conclusion, the integration of Artificial Intelligence (AI) in transportation systems holds great potential for revolutionizing urban mobility and improving various aspects of transportation. By leveraging AI technologies such as machine learning, computer vision, and natural language processing, transportation systems can become more efficient, safe, and sustainable. AI plays a crucial role in autonomous vehicles, enabling self-driving cars and autonomous transportation by utilizing sensor data, computer vision, and machine learning algorithms. This technology allows vehicles to navigate, perceive the environment, and make decisions without human intervention, leading to safer and more efficient transportation.

Furthermore, AI contributes to traffic management by analyzing real-time data from sensors, cameras, and historical patterns. This analysis helps optimize traffic flow, reduce congestion, and provide alternative routes, ultimately improving overall transportation efficiency. Predictive maintenance is another area where AI can make a significant impact. By monitoring and analyzing data from vehicles and infrastructure, AI techniques can predict maintenance needs, enabling proactive maintenance and reducing unexpected breakdowns. This leads to increased reliability, reduced downtime, and improved transportation services.

Recommendations

Adoption of Agent Computing Paradigm

The study recommends the use of agent-based technology for the development of large-scale distributed systems, specifically in geographically dispersed and dynamic transport systems. Agent-based traffic control and management systems offer interoperability, flexibility, and extendibility, making them suitable for smart cities' transportation needs.

Emphasis on Interoperability and Extendibility

The research highlights the importance of ensuring interoperability and extendibility in agent-based traffic control and management systems. These systems should be able to seamlessly integrate with existing infrastructure and future technologies, allowing for efficient communication and coordination among various transportation entities.

Integration of AI and ML in Traffic and Transportation Systems

The study suggests further research to effectively integrate AI and ML technologies into traffic and transportation systems. This integration can enhance the capabilities of intelligent transportation systems, including modeling and simulation, dynamic routing and congestion management, and intelligent traffic control.

Development of Personalized Mobility Services

AI algorithms should be leveraged to provide personalized mobility services to users. By analyzing individual preferences, travel patterns, and real-time data, transportation solutions can be customized to meet the specific needs of users. This can include on-demand ride-sharing, multimodal journey planning, and other innovative mobility options.

Focus on Sustainable Transportation Solutions

AI can contribute to the development of sustainable transportation systems. Machine learning algorithms can optimize energy consumption, promote eco-friendly driving behaviors, and facilitate the integration of electric and autonomous vehicles into transportation networks. Additionally, AI-powered logistics and routing systems can prioritize environmentally friendly options, reducing carbon emissions and promoting sustainable mobility.

Advancement of Safety Systems

AI should continue to be utilized to advance safety systems in transportation. Enhanced object detection and recognition algorithms, coupled with AI-powered collision avoidance systems, can improve vehicle and pedestrian safety. Additionally, AI can assist in identifying potential maintenance issues in vehicles and infrastructure, allowing for proactive maintenance and minimizing the risk of accidents caused by mechanical failures.

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