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Evaluation of Microscopic Traffic Modeling using the Application of Artificial Intelligence

[1]Pwaviron Kennedy Gambiye
School Of Engineering
Department Of Civil Engineering
Adamawa State Polytechnic

[2]Emmanuel Nicholas Jesman
Department Of Physical Planning
And Development
University Of Abuja

[3]Aliyu Yazid
Department Of Civil Engineering
Modibbo Adama University Adamawa State

Abstract:- Effective traffic management is essential for addressing the critical problem of traffic congestion in urban areas, and the development of accurate and reliable traffic models plays an important role in this process. Microscopic traffic models that simulate individual vehicle behaviour have gained popularity in recent years. However, the development of these models can be challenging due to the complex interactions between vehicles and the environment. In response, artificial intelligence (AI) has emerged as a promising approach to traffic modelling. This paper covers the review of microscopic traffic models that use artificial intelligence (AI) techniques, such as modeling based on intelligent transport system, microscopic car-following and lane-changing models, and driver behaviour models. The review is divided into three sections, each section discusses several papers that propose new models, methodologies, or algorithms, and provides a brief overview of their contributions, methodology, and simulation results. Specifically, the paper discusses the advantages of AI-based traffic models, such as their ability to handle large datasets and complex traffic scenarios, improved accuracy and increased efficiency. Additionally, the paper highlights the limitations of AI-based traffic models, such as their reliance on the accuracy of the data that is used in developing the models, their computing intensity, and their inability to completely replace human drivers. Overall, this review highlights the potential of AI to revolutionize the field of traffic modelling and offers insights into the challenges and opportunities of AI-based traffic models.

***Keywords**:- Microscopic Traffic Models, Artificial Intelligence, Traffic Flow, Intelligent Transport Systems, Traffic Management.*

I. INTRODUCTION

Urbanization has made traffic congestion an issue because of the rise in the number of cars on the road.To address this issue, most countries expand the existing roadways. However, this approach comes with the challenge of having to demolish older roads which leads to significant economic and environmental costs. Although these measures are taken to improve the road infrastructure, it is clear that the rate of vehicle acquisition has surpassed the rate of new infrastructure development(Hawi et al., 2015). The development of accurate and reliable traffic models requires effective traffic management that can simulate traffic flow, predict patterns, and optimize traffic management strategies. As a result, artificial intelligence is used to improve the accuracy and efficiency of these models.

Microscopic traffic models have become popular in recent years due to their ability to simulate individual vehicle behaviour and provide a detailed understanding of traffic dynamics. However, the challenge in developing accurate and reliable microscopic traffic models is the complex interactions between vehicles and the environment.

Incorporating artificial intelligence (AI) into traffic modelling has shown great potential in improving the accuracy of traffic predictions and enabling better traffic management strategies. In this vein, traffic congestion can be reduced by AI-powered management systems which can help optimize the use of existing road infrastructure and in turn improve traffic flow. In this way, the application of artificial intelligence in traffic modelling can significantly address the challenges caused by traffic congestion in urban cities. Therefore, this review aims to provide an overview of microscopic traffic models using artificial intelligence techniques and how they can be used to improve traffic management and reduce traffic congestion in urban areas. In general, using artificial intelligence in microscopic traffic models has several advantages that can help improve traffic management and transport systems.

A. Microscopic Traffic Models

There are three types of traffic flow models that are categorized based on their level of detail: microscopic, mesoscopic and macroscopic traffic models focus on the specific intricacies of traffic flow, simulating individual vehicle –driver units. Macroscopic traffic models, on the other hand, assume a significant number of vehicles on a road, allowing the treatment of each vehicle stream as a flowing tube or stream.Mesoscopic traffic model analyze vehicle groups instead of individual vehicles.(Popping, 2013)

Microscopic traffic models are simulation models that simulate the behaviour of individual vehicles in traffic. They consider the dynamic interactions between vehicles and their surrounding environment, including other vehicles, traffic signals, road geometry, and weather conditions.(Toledo et al., 2005)There are several types of microscopic traffic models, including car-following models, lane-changing models, and gap-acceptance models. Traditional microscopic traffic models have limitations in handling complex traffic scenarios and predicting traffic patterns accurately."Microscopic models describe information about the behaviour of each single vehicle. For this reason, they can be applied mainly to narrow-range transportation systems with a much higher level of detail."(Mardiati et al., 2014)

B. Artificial Intelligence in Traffic Modeling

Artificial intelligence (AI) refers to the ability of a computer or computer-controlled robot to perform tasks that typically rely on human intelligence and judgment."AI refers to methods and approaches that mimic biologically intelligent behaviour in order to solve problems that so far have been difficult to solve by classical mathematics"(Sadek, 2007).

AI has revolutionized many fields, including transportation. AI techniques such as machine learning and deep learning have shown great potential in traffic modelling, offering the ability to learn from large datasets and handle complex traffic scenarios. AI-based traffic models can learn from data to improve their accuracy and provide more accurate predictions of traffic patterns. However, AI-based traffic models require large amounts of training data and can be challenging to interpret.

Artificial intelligence can be applied to intelligent traffic systems to improve the efficiency of vehicle scheduling and communication.

C. Background of Microscopic Traffic Model Using Artificial Intelligence

- Microscopic traffic flow modeling deals with the interaction between vehicles and the behaviour of individual vehicles.
- Traffic simulation makes use of computer software and applications which is a mathematical modelling of traffic dynamics.
- In microscopic simulation, the behaviour and interactions of each driver is described in a traffic system, as a result a more detailed modelling for each movement of the vehicle is obtained.
- Microscopic traffic models gives the details of traffic flow and the interactions within it.

D. Advantages of Microscopic Model Using Artificial Intelligence

- Tracking of a single vehicle on the road, which gives a more detailed analysis of traffic behaviour and patterns can be achieved through microscopic traffic modelling.
- The interaction between vehicles can be reflected in terms of traffic performance indicators (vehicle travel time and delay).
- The most effective strategies for reducing congestion and improving traffic flow can be identified through the use of different traffic management strategies.
- The animation interface of the simulator in the microscopic model helps to visualize the impact of a specific parameter on the traffic.
- Microscopic traffic models are an excellent starting point for understanding traffic operating status under various traffic demands.

E. Disadvantages of Microscopic Model Using Artificial Intelligence

- The models may not be able to account for all factors that affect traffic behavior, such as weather conditions and road construction, which can limit their accuracy in certain situations.
- When the training data is incomplete or incorrect, the models will not produce the desired outcome; therefore, their accuracy depends on the data quality.
- They require significant processing power due to their intensive computations and this can limit their scalability and practicality for real-time traffic management systems.
- Because these models are programmed, they have limitations due to their fixed set of rules and lack of creativity, which prevents them from improving with experience or adapting to unexpected situations on the road.
- AI-based microscopic traffic models cannot replace human drivers. Human drivers are unpredictable and can make sudden decisions that are difficult to model accurately.

II. LITERATURE REVIEW

This section provides a comprehensive review of microscopic traffic models that use AI techniques. AI-based gap-acceptance models, car-following models, and lane-changing models are reviewed.

A. Simulation Based on Intelligent Transport System

- "A viscous continuum traffic flow model with consideration of the coupling effect for two-lane freeways" by Dihua&Guang-Han: The paper proposes a new traffic flow model for two-lane freeways that considers the coupling and lane changing effects of vehicles on two adjacent lanes. The proposed model is a higher-order continuum model that integrates the Taylor series expansion of the viscous continuum traffic flow model into the multi-lane model. The paper also provides a linear stability analysis and obtains the neutral stability condition. Finally, the paper investigates issues related to lane changing, shock waves, rarefaction waves, local clustering, and phase transition through a simulation experiment. The simulation results show that the proposed model is effective in describing the non-anisotropic behavior of multi-lane traffic.(Dihua & Guang-Han, 2009).
- "Evaluation of Transportation Infrastructure Management Strategies Using Microscopic Traffic Simulation" by Stirzaker&Dia: The paper uses a traffic simulation model to evaluate the impacts of different infrastructure management strategies on road infrastructure utilization. The model is calibrated using two independent sets of data to ensure its validity. The study investigates the benefits of treating additional road capacity as a bus lane, a high occupancy vehicle lane,

and a general traffic lane open to all vehicles.(Stirzaker & Dia, 2007).

- “Comparative Analysis of Intelligent Transportation Systems for Sustainable Environment in Smart Cities” by Balasubramaniam et al.,:The paper performs a short analysis of existing sustainable transportation methods in the Internet of Vehicles (IoV) and analyzes various characteristics of sustainability and the advantages and disadvantages of existing transportation systems. It then provides a clear suggestion for effective sustainable transportation planning aimed at the maintenance of an eco-friendly environment and road traffic safety through intelligent transportation systems.(Balasubramaniam et al., 2017).

B. Modeling Based on Microscopic Car Following and Lane Changing

- “Analysis of Distribution and Calibration of Car-Following Sensitivity Parameters in Microscopic Traffic Simulation Models” by Schultz &Rilett: The paper discusses a methodology to introduce and calibrate a low parameter distribution for car-following sensitivity factors in microscopic traffic simulation models. The approach is applied to IH-10 in Houston, Texas, with the CORSIM model and subsequently calibrated with an automated genetic algorithm methodology to examine the effectiveness of the distribution alternatives.(Schultz & Rilett, 2004).
- “Lane Changing Model Based on Finite State Automaton” by Zhang et al.,:The paper proposes a vehicle moving framework based on finite state automaton to model both discretionary and mandatory lane changing. The model considers the driver's state and decision-making process and analyzes critical lead and follow gaps for safety. A traffic simulator was developed to validate the model in a two-lane road. The results show that the model can regenerate the realistic macroscopic characteristics of traffic flow and the microscopic characteristics of lane changing.(Zhang et al., 2008).
- “Lane-Changing Decision Model for Heavy Vehicle Drivers” byMoridpour et al.,:The paper presents a fuzzy logic lane-changing decision model for heavy vehicle drivers on freeways. The model is based on 2 and 3 fuzzy sets and aims to improve the accuracy of heavy vehicle lane-changing maneuvers and their impact on traffic flow. The accuracy of the model was examined by comparing the estimated number of lane-changing maneuvers and traffic flow measurements with the observed values through microscopic traffic simulations. The results show that the fuzzy logic heavy vehicle lane-changing model can better estimate the number of lane-changing maneuvers of heavy vehicles and their impact on traffic flow compared to traditional models.(Moridpour et al., 2012).

C. Modeling Driver Behaviour

- “Development of a Cognitive-Emotional Model for Driver Behavior”by Maag et al.,:The paper presents a cognitive-emotional driver model that focuses on anger and its validation through a driving simulator study. The model takes into account cognitive and emotional mechanisms involved in driving behavior and can be used to enhance road safety and assist the driver. The methodology used by the authors includes a literature review of cognitive and emotional mechanisms involved in driving behavior and a driving simulator study involving 30 participants. The study showed that the model was able to predict anger-related driving behavior with a high degree of accuracy.(Maag et al., 2010).
- “Identification of a Longitudinal Human Driving Model for Adaptive Cruise Control Performance Assessment” by Lee &Peng: The paper aimed to develop a human driving model that can accurately evaluate the performance of adaptive cruise control systems. The authors evaluated six driver models based on selected data from two vehicle motion databases. The Gipps' model was found to be the most promising, and a modified version of the model was suggested and evaluated. The modified model was implemented in a microscopic traffic simulator and was found to produce results that agree with macroscopic traffic behavior. The paper developed a longitudinal driver model suitable for the design and evaluation of Adaptive Cruise Control systems.(Lee & Peng, 2002).
- “A game theoretical model of traffic with multiple interacting drivers for use in autonomous vehicle development” by Oyler et al.,:The paper proposes a game theoretical model of traffic where multiple drivers interact with each other. The model is developed using hierarchical reasoning and reinforcement learning to provide a computationally tractable solution to the problem of finding a policy for a Partially Observable Markov Decision Process. The simulation results demonstrate that the resulting driver models provide reasonable behavior for the given traffic scenarios.(Oyler et al., 2016).

III. RESULTS AND DISCUSSION

The literature review provides an overview of microscopic traffic models that utilize Artificial Intelligence (AI) techniques. The review covers different types of gap-acceptance models, car-following models, and lane-changing models, and focuses on how AI has been used to improve these models. The paper discusses two types of approaches: simulation-based and modeling-based. It also focuses on how artificial intelligence techniques, like finite-state automata, fuzzy logic, and game theory, are used in traffic modeling. The review also covers various driver behavior models, such as cognitive-emotional models and longitudinal human driving models, that have been used to improve traffic simulations. Table 1 outlineeach paper reviewed, including the research problem/question, methodology and key findings/results.

Table 1: Overview of microscopic traffic model studies using artificial intelligence

S/N	TITLE OF THE PAPER	AUTHORS	RESEARCH PROBLEM/QUESTION	METHODOLOGY	KEY FINDINGS/RESULTS
A	**Simulation Based on Intelligent Transport System**				
1	A viscous continuum traffic flow model with consideration of the coupling effect for two-lane freeways	Sun Di-Hua, PengGuang-Han	How to develop a traffic flow model that considers the coupling and lane-changing effects of vehicles on two adjacent lanes.	The authors propose a new traffic flow model for two-lane freeways that integrates the Taylor series expansion of the viscous continuum traffic flow model into the multi-lane model and investigate its effectiveness through a simulation experiment.	The proposed traffic flow model for two-lane freeways is capable of explaining various traffic phenomena observed in real-world traffic flow.
2	Evaluation of Transportation Infrastructure Management Strategies Using Microscopic Traffic Simulation	CallanStirzaker, Hussein Dia	How to evaluate the benefits of transportation management strategies for maximizing road infrastructure utilization using a traffic simulation approach.	The authors used two independent sets of data to calibrate and validate their traffic simulation model. One set was used for calibrating the model parameters, and the other for running and validating the calibrated model. An independent data set of field travel times between selected intersections on Coronation Drive and Milton Road was used to validate the model's performance.	The simulation results showed that a bus lane would produce the best travel time benefits for buses but at the expense of reduced benefits to other road users.
3	Comparative Analysis of Intelligent Transportation Systems for Sustainable Environment in Smart Cities	AnandkumarBalasubramaniam, Anand Paul, Won-Hwa Hong, HyunCheolSeo, Jeong Hong Kim	How to establish an effective sustainable transportation planning system for an eco-friendly environment and road traffic safety.	The authors perform a short analysis of existing sustainable transportation methods in the Internet of Vehicles (IOV) and provide a clear suggestion for effective sustainable transportation planning aimed at the maintenance of an eco-friendly environment and road traffic safety.	The paper suggests that sustainability in the Internet of Vehicles (**IoV**) can be achieved not only by the use of pollution-free vehicular systems but also by the maintenance of road traffic safety or prevention of accidents or collisions. The study provides a clear suggestion for effective sustainable transportation planning aimed at the maintenance of an eco-friendly environment and road traffic safety, which, in turn, would lead to a sustainable transportation system.

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S/N	TITLE OF THE PAPER	AUTHORS	RESEARCH PROBLEM/QUESTION	METHODOLOGY	KEY FINDINGS/RESULTS
B	**Modeling Based on Microscopic Car Following and Lane Changing**				
1	Analysis of Distribution and Calibration of Car-Following Sensitivity Parameters in Microscopic Traffic Simulation Models	Grant G. Schultz, L. R. Rilett	How to introduce and calibrate a low parameter distribution for car-following sensitivity factors in microscopic traffic simulation models.	The methodology used in this paper involves introducing and calibrating a low parameter distribution for car-following sensitivity factors in microscopic traffic simulation models using measures of central tendency and dispersion.	The key findings of this paper are that the distribution of car-following sensitivity parameters can be modelled in microscopic traffic simulation models, and the lognormal and normal distribution alternatives are effective at replicating observed conditions and representing the full distribution of car-following sensitivity factors.
2	Lane Changing Model Based on Finite State Automaton	F. A. Zhang, XuanHui-Yu, Zhao Qiao-Xia	How to model lane changing efficiently using a vehicle moving framework based on finite state automaton.	The paper proposes a vehicle moving framework based on finite state automaton to model both discretionary and mandatory lane changing. The model considers the driver's state and decision-making process and analyzes critical lead and follow gaps for safety. A traffic simulator was developed to validate the model on a two-lane road.	The proposed vehicle moving framework based on finite state automaton can efficiently model both discretionary and mandatory lane changing, and the traffic simulator developed to validate the model shows that it can regenerate the realistic macroscopic characteristics of traffic flow and the microscopic characteristics of lane changing.
3	Lane-Changing Decision Model for Heavy Vehicle Drivers	Sara Moridpour, MajidSarvi, Geoff Rose, EhsanMazloumi	How to improve the accuracy of heavy vehicle lane-changing maneuvers and their impact on traffic flow using a fuzzy logic lane-changing decision model.	The paper presents a fuzzy logic lane-changing decision model for heavy vehicle drivers on freeways. The model is based on 2 and 3 fuzzy sets and aims to improve the accuracy of heavy vehicle lane-changing maneuvers and their impact on traffic flow. The accuracy of the model	The key finding of this paper is that the fuzzy logic heavy vehicle lane-changing model can better estimate the number of lane-changing maneuvers of heavy vehicles and

S/N	TITLE OF THE PAPER	AUTHORS	RESEARCH PROBLEM/QUESTION	METHODOLOGY	KEY FINDINGS/RESULTS
				was examined by comparing the estimated number of lane-changing maneuvers and traffic flow measurements with the observed values through microscopic traffic simulations.	their impact on traffic flow compared to traditional models. The model can also help improve traffic safety by reducing the risk of accidents caused by heavy vehicle lane-changing maneuvers.
C	**Modeling Driver Behaviour**				
1	Development of a Cognitive-Emotional Model for Driver Behavior	Christian Maag, Christian Mark, Hans-Peter Kruger	How to develop a cognitive-emotional driver model that takes into account anger and its effects on driving behaviour, and how to validate this model through a driving simulator study.	The paper presents a cognitive-emotional driver model focusing on anger. The model is based on a literature review of cognitive and emotional mechanisms involved in driving behaviour. The authors also conducted a driving simulator study to validate the model. The study involved 30 participants who drove in a simulated environment while their physiological responses were measured. The results showed that the model was able to predict anger-related driving behaviour with a high degree of accuracy.	The key finding of this paper is the development of a cognitive-emotional driver model that focuses on anger and its validation through a driving simulator study. The model can be used to enhance road safety and assist the driver by taking into account cognitive and emotional mechanisms involved in driving behaviour. The study showed that the model was able to predict anger-related driving behaviour with a high degree of accuracy.
2	Identification of a Longitudinal Human Driving Model for Adaptive Cruise Control Performance Assessment	Kangwon Lee, HueiPeng	How to identify the most accurate human driving model for evaluating the performance of adaptive cruise control systems.	The paper used two vehicle motion databases, the SAVME database and the ICCFOT database, to evaluate six driver models. The 4000 longest car-following cases were identified and used to represent the "driver population" under normal driving conditions. The selected data were plotted and analyzed to modify Gipps' model, which was found to be the most promising. The modified model was implemented in a microscopic traffic simulator to produce	The paper found that Gipps' model was the most promising among the six-driver models evaluated. The modified model exhibited stop-and-go behaviour, which was not present in the original Gipps' model. The paper developed a longitudinal driver model suitable for the design and

S/N	TITLE OF THE PAPER	AUTHORS	RESEARCH PROBLEM/QUESTION	METHODOLOGY	KEY FINDINGS/RESULTS
				results that agree with macroscopic traffic behaviour.	evaluation of Adaptive Cruise Control systems.
3	A game theoretical model of traffic with multiple interacting drivers for use in autonomous vehicle development	Dave W. Oyler, YildirayYildiz, Anouck R. Girard, Nan I. Li, Ilya V. Kolmanovsky	How to model the collective behaviour of vehicles in traffic by microscopic modelling of human drivers using game theory and reinforcement learning.	The paper uses hierarchical reasoning and reinforcement learning to develop a game theoretical model of traffic where multiple drivers interact with each other. The model provides a computationally tractable solution to the problem of finding a policy for a Partially Observable Markov Decision Process. Simulation results are reported to demonstrate the effectiveness of the proposed approach.	The paper presents a game theoretical model of traffic that uses hierarchical reasoning and reinforcement learning to provide a computationally tractable solution to the problem of finding a policy for a Partially Observable Markov Decision Process. The simulation results demonstrate that the resulting driver models provide reasonable behaviour for the given traffic scenarios.

IV. CONCLUSION

In conclusion, this review provides an overview of microscopic traffic models that make use of AI techniques. The review shows that using these models can greatly optimize traffic flow. However, it is important to note there is no universally applicable model capable of encompassing all traffic scenarios. Factors like the environment, traffic management, and road facilities must also be considered.

The studies reviewed in this paper shows how traffic flow can be improved by using AI in traffic simulation, which can help transportation engineers and urban planners make informed decisions regarding transportation infrastructure management and sustainable transportation planning. Furthermore, the review emphasizes that AI-based traffic models have the potential to improve safety, reduce congestion, and enhance transportation system efficiency. However, further research is necessary to create more reliable and accurate AI-based traffic models that consider the intricate and ever-changing nature of traffic flow.

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