Modelling and Simulation of Vehicle Movement on Circular Highways: Bridging DTS and DES for Decision Optimization

by

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Discrete Time Simulation of Traffic Without Bottlenecks: An IDM-Driven Approach

By

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Abstract

This research investigates the application of Discrete Event Simulation (DES) in conducting the 'Traffic Without Bottleneck' experiment, traditionally analyzed using Discrete Time Simulation (DTS). The experiment involved simulating vehicles on a 230-meter circular track, utilizing the Intelligent Driver Model (IDM) for vehicle motion with a time step of 100ms. The primary goal was to compare the performance of the DES model against the DTS model, focusing on the accuracy of arrival time as a key metric.

The study commenced with the establishment and validation of the DTS model, followed by data collection on vehicle speeds across eight segments of the track under various conditions. This data informed the development of the corresponding DES model.

Results demonstrated that the DES model closely aligns with the DTS model, particularly in arrival time accuracy, indicating minimal deviation. This outcome suggests the viability of DES as an effective alternative for traffic simulation, matching the precision of traditional DTS methods.

In conclusion, the research validates DES as a robust tool in traffic simulation, offering comparable accuracy to DTS, especially in experiments like 'Traffic Without Bottleneck'. The study underscores the potential of DES in traffic engineering and simulation fields.

Keywords

Discrete Event Simulation (DES)

Discrete Time Simulation (DTS)

Traffic Simulation

Traffic Without Bottleneck

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CHAPTER 1

INTRODUCTION

1.1 Research Thesis title

The inspiration for this research stems from Traffic congestion is a prevalent issue in modern transportation systems, often occurring even in the absence of typical triggers such as accidents or roadworks. This phenomenon, where traffic bottlenecks arise without any apparent physical obstructions, presents a unique challenge in the field of traffic engineering. Understanding and addressing these types of congestions are crucial, not only for improving traffic flow but also for enhancing overall road safety and efficiency. The study of such phenomena is therefore of significant practical value, offering insights into more efficient traffic management and infrastructure planning.

the well-known traffic experiment known as 'Traffic Without Bottleneck'. This experiment, which explores traffic dynamics on a circular track, has been instrumental in understanding how traffic jams can form spontaneously, even in ideal conditions with no physical bottlenecks. The basic setup of this experiment involves vehicles moving on a closed loop, which allows for the observation of traffic flow under controlled conditions. This experiment has significantly influenced the direction of this research, particularly in the development of a Discrete Time Simulation (DTS) model. By replicating and extending the principles observed in the 'Traffic Without Bottleneck' experiment, this study aims to delve deeper into the nuances of traffic flow and congestion patterns, providing a more comprehensive understanding of traffic dynamics in bottleneck-free environments.

1.2 Motivation for the work

The primary motivation for this research lies in the pursuit of more efficient and cost-effective methods for simulating and analyzing traffic flow. Traditional approaches to studying traffic dynamics often rely on data gathered from real-world observations, which, while valuable, can be both time-consuming and expensive. This is particularly true in scenarios where long-term data collection is required to capture the full spectrum of traffic behaviors under varying conditions.

Discrete Time Simulation (DTS) offers a promising alternative. By simulating traffic scenarios within a controlled digital environment, DTS enables the study of complex traffic patterns without the need for extensive real-world data collection. This approach not only reduces the time and financial costs associated with traffic studies but also allows for a more flexible exploration of a wide range of traffic scenarios, including those that might be rare or difficult to observe in reality.

Furthermore, the implementation of Discrete Event Simulation (DES) in this field represents a significant advancement. DES has the potential to further reduce energy and time costs associated with traffic simulations. Unlike DTS, which operates on fixed time steps, DES responds to events dynamically, allowing for a more nuanced and efficient simulation process. This can lead to more accurate modeling of traffic flow, particularly in complex scenarios where the interactions between vehicles can vary significantly over time.

The combination of these simulation techniques, and their application in understanding traffic flow in bottleneck-free environments, holds substantial promise. It offers a pathway to not only better understand traffic congestion and its causes but also to develop more effective traffic management strategies and infrastructure designs. Ultimately, the goal of this research is to contribute to the creation of more efficient, safer, and sustainable traffic systems.

1.3 Objectives of the work

The overarching objective of this thesis is to demonstrate the effectiveness of Discrete Event Simulation (DES) in modeling traffic flow, particularly in comparison to the established Discrete Time Simulation (DTS) approach. To achieve this, the research is structured around several key goals:

Development of a DTS Model Based on IDM: The first step involves constructing a DTS model that replicates real-world traffic scenarios. This model will be based on the Intelligent Driver Model (IDM), a widely recognized approach for simulating vehicle movements. The IDM-based DTS model will serve as a foundation for understanding traffic dynamics in a controlled simulation environment, providing a baseline for further analysis.

Data Collection and DES Model Construction: Upon the successful implementation of the DTS model, the next goal is to collect comprehensive data on traffic flow within this simulated environment. This data will be instrumental in building a corresponding DES model. The focus will be on ensuring that the DES model accurately reflects the traffic dynamics observed in the DTS model, with particular attention to the nuances of vehicle interactions and flow patterns.

Comparison and Validation of the DES Model: The final and most crucial objective is to validate the effectiveness of the DES model. This will be achieved by conducting a comparative analysis between the DTS and DES models. The comparison will focus on various metrics of traffic flow, with a special emphasis on the accuracy and efficiency of the DES model in replicating the traffic scenarios modeled by DTS. The goal is to demonstrate that DES can not only match but potentially surpass the performance of DTS in certain aspects of traffic simulation.

By accomplishing these objectives, this research aims to contribute valuable insights into the field of traffic simulation and modeling. It seeks to establish DES as a viable and potentially superior alternative to DTS, paving the way for more advanced and efficient traffic management and planning strategies.

1.4 Organization of the report

Chapter 1: Introduction

This chapter sets the stage for the research, providing an overview of the traffic congestion phenomenon even in the absence of physical bottlenecks. It also introduces the inspiration derived from the 'Traffic Without Bottleneck' experiment and outlines the research objectives and motivations.

Chapter 2: Literature Review

In this chapter, a comprehensive review of existing literature on traffic simulation methods, focusing on Discrete Time Simulation (DTS) and Discrete Event Simulation (DES), is presented. It also discusses the Intelligent Driver Model (IDM) and its relevance to this study.

Chapter 3: Methodology

This chapter details the methodology employed in the research. It describes the development of the DTS model based on IDM, the process of data collection, and the construction of the DES model.

Chapter 4: Conclusion and Future Work

The final chapter summarizes the key findings of the research, discusses the limitations of the study, and suggests areas for future research. It concludes by highlighting the contributions of the study to the field of traffic simulation and engineering.

CHAPTER 2

LITERATURE REVEIW

2.1 Traffic Flow Theory and Modeling

Traffic flow theory is the study of the movement of individual drivers and vehicles between two points and their interactions. It uses models and hypotheses to explain what would happen to traffic streams if they were to flow on roads under different conditions. The main traffic stream variables used to describe such systems include flow, time headway, density, spacing, and speed. These variables are used to obtain relationships that hold “on average” for large stationary time-space regions containing many vehicles. （Elefteriadou, 2014）

2.2 Overview of Traffic Simulation Models

Microsimulation models simulate individual vehicles and their interactions in great detail. These models consider the behavior of each vehicle, including acceleration, deceleration, lane changing, and interaction with other vehicles and infrastructure. Microsimulation models are suitable for studying complex traffic scenarios such as intersections, roundabouts, and congested urban areas. They offer a high level of accuracy but require significant computational resources. （Kerner, 2019）

Macrosimulation models, also known as aggregate or macroscopic models, focus on the overall traffic flow and do not consider individual vehicles. These models represent traffic as a continuous flow and use aggregated variables such as traffic density, flow rate, and speed. Macrosimulation models are less computationally intensive compared to microsimulation models and are suitable for analyzing large-scale traffic networks and long-term traffic patterns. （Treiber & Kesting, 2013）

Mesoscopic models bridge the gap between microsimulation and macrosimulation models. They offer a compromise between the level of detail and computational requirements. Mesoscopic models simulate traffic at an intermediate level, considering groups of vehicles or platoons rather than individual vehicles. These models capture the interactions between platoons and provide a balance between accuracy and computational efficiency. Mesoscopic models are often used for analyzing traffic on highways, freeways, and arterial roads.

2.3 Discrete Time Simulation (DTS) in Traffic Modeling

Discrete Time Simulation (DTS) plays a pivotal role in traffic modeling, offering a framework for analyzing and predicting traffic flow dynamics under various conditions. This section delves into the fundamental principles, advantages, and limitations of DTS in traffic modeling, supported by relevant academic literature.

Fundamental Principles of DTS: DTS in traffic modeling is characterized by its time-stepped approach, where the state of the traffic system is updated at discrete time intervals.

This method is particularly effective in capturing the dynamic nature of traffic flows and allows for the detailed analysis of individual vehicle movements and interactions. The discrete-event mesoscopic traffic simulation model, exemplifies the application of DTS in hybrid traffic simulation, blending microscopic and macroscopic elements.

Advantages of DTS: One of the primary advantages of DTS is its ability to model complex traffic scenarios with high precision. DTS is adept at facilitating real-time traffic management, especially in structured environments like railways. This precision is crucial for developing efficient traffic control and management strategies.

Limitations of DTS: Despite its advantages, DTS is not without limitations. The granularity of time steps in DTS can lead to computational intensity, especially in large-scale simulations. Furthermore, the accuracy of DTS models heavily relies on the precision of input data and the assumptions made in the simulation environment.

Academic Literature Review: Recent studies have expanded the application of DTS in various traffic scenarios. Explores the use of DTS in modeling vehicular traffic congestion, providing insights into the effectiveness of DTS in urban traffic scenarios. Additionally, the role of DTS in traffic modeling for telecommunications networks, indicating the versatility of DTS applications beyond traditional road traffic scenarios.

2.4 Discrete Event Simulation (DES) in Traffic Modeling

Discrete Event Simulation (DES) is a critical methodology in traffic modeling, distinguished by its event-driven nature. Unlike Discrete Time Simulation (DTS), which updates the state of the system at fixed time intervals, DES progresses the simulation based on the occurrence of discrete events, such as a vehicle entering or exiting a system. This section explores the working principles of DES, its differentiation from DTS, and its potential advantages in traffic modeling.

Working Principles of DES: DES operates on the basis of events that trigger changes in the state of the traffic model. Each event occurs at a specific point in time, and the simulation jumps from one event to the next. This approach is particularly effective in scenarios where traffic flow is influenced by distinct, individual events, such as traffic lights, accidents, or vehicle breakdowns.

Differentiation from DTS: The primary difference between DES and DTS lies in their handling of time. While DTS advances in fixed time steps, regardless of whether changes occur, DES is more dynamic and only progresses when events occur. This leads to a more efficient simulation process in DES, especially in scenarios where events are sporadic.

Potential Advantages in Traffic Modeling: DES offers several advantages in traffic modeling. Its event-driven nature allows for a more detailed and accurate representation of traffic scenarios, particularly in urban environments where traffic conditions can change rapidly. DES is also more flexible in handling complex interactions within the traffic system, such as the impact of non-recurrent congestion or construction zones. Additionally, the efficiency of DES in terms of computational resources makes it suitable for large-scale simulations.

In summary, DES provides a dynamic and efficient approach to traffic modeling, capable of handling complex and rapidly changing traffic scenarios with greater accuracy than DTS. Its event-driven nature allows for detailed analysis and simulation of specific traffic events, making it a valuable tool in the field of traffic management and planning.

CHAPTER 3

METHODOLOGY

3.1 Introduction to Methodology

This chapter delineates the methodology adopted in this study, which is primarily inspired by the "traffic without bottleneck" experiment. The approach encompasses the development of a Discrete Time Simulation (DTS) model that mirrors the experimental setup, followed by the generation of data from this model to inform the construction of a Discrete Event Simulation (DES) model. The methodology is designed to capture the nuances of traffic flow dynamics under specific conditions and to facilitate a comprehensive analysis of the models' effectiveness and accuracy.

The initial phase involves meticulously crafting the DTS model to replicate the conditions observed in the "traffic without bottleneck" experiment. This includes setting up an analogous environment, such as a circular track, and defining initial vehicle conditions and parameters that align with the experiment's framework. The emphasis is on ensuring that the DTS model not only reflects the experimental setup accurately but also generates reliable data that can be used for further analysis.

Subsequently, the focus shifts to the DES model, where the data generated from the DTS model plays a pivotal role. The DES model is tailored to simulate vehicle speed distributions based on the DTS data, thereby providing a deeper insight into the traffic flow dynamics. The critical aspect of this phase is the accurate fitting of the DTS data into the DES model, ensuring that the simulation reflects realistic traffic conditions.

Finally, the methodology involves a rigorous comparison and analysis of the time of arrival of vehicles in both models. This comparative study is crucial as it serves as a benchmark for evaluating the effectiveness and accuracy of the DES model. By analyzing the discrepancies in the time of arrival data between the DTS and DES models, the study aims to ascertain the reliability and validity of the DES model in simulating traffic flow dynamics.

In summary, this chapter outlines a structured approach to model development and analysis, laying a solid foundation for the subsequent chapters that delve into the specifics of the DTS and DES models and their comparative evaluation.

3.2 Development of the DTS Model

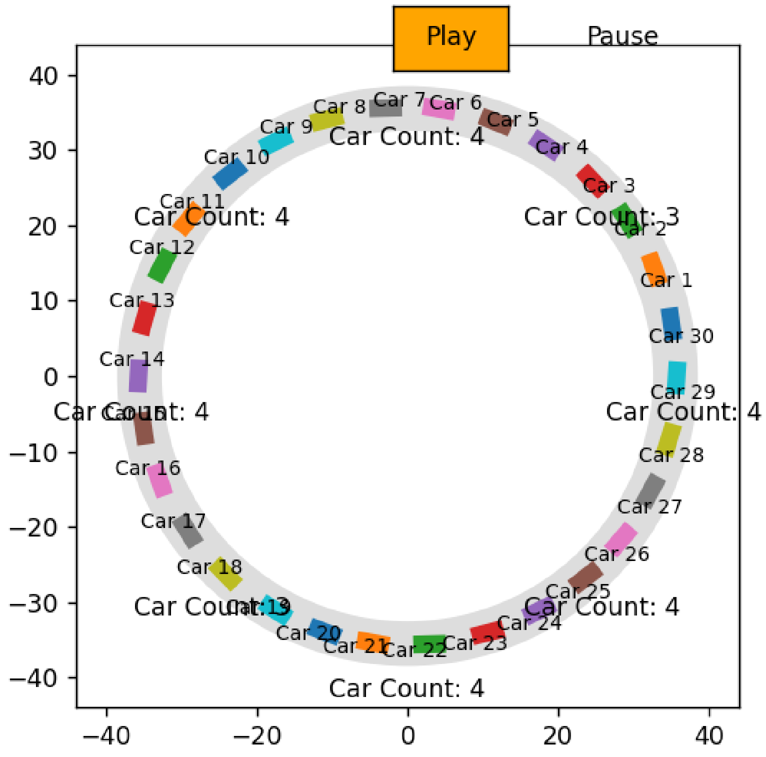
In the "Development of the DTS Model" section, the simulation is initiated following the parameters from the "traffic without bottleneck" experiment. A 230-meter circular track is utilized, populated with the maximum number of vehicles it can accommodate, which is 30. This number is deduced from the sum of the safety distances and the lengths of the vehicles. The vehicles are evenly distributed along the track and begin with a velocity of zero. The Dynamic Traffic Simulation (DTS) employs the Intelligent Driver Model (IDM) for vehicle dynamics, which considers variations in time headway (car. T) and acceleration exponent (car. Delta) for individual cars. The IDM formula for calculating the desired velocities is as follows:

$$desired\_velocities = s^0 + \max(0, car.velocity \times car.T + ((car.velocity \times (car.velocity - car.front\_car.velocity)))/(2 \times \sqrt{(acceleration \times deceleration)}))$$

$$car.acceleration = clip(acceleration \times (1 - (car.velocity / car.max\_velocity) ^ {car.delta} - (desired\_velocities / spacing) ^ 2), -deceleration, acceleration)$$

$$car.velocity = clip(car.velocity + car.acceleration \times (interval / 1000), car.min\_velocity, car.max\_velocity)$$

The accompanying image illustrates the model's visualization, where vehicles rotate counterclockwise along the track. The position mapping is done using polar coordinates, transforming linear positions ranging from 0 to 230 meters into angles spanning from 0 to 360 degrees. This representation aids in visualizing the vehicle dynamics and interactions as they traverse the circular path of the model.



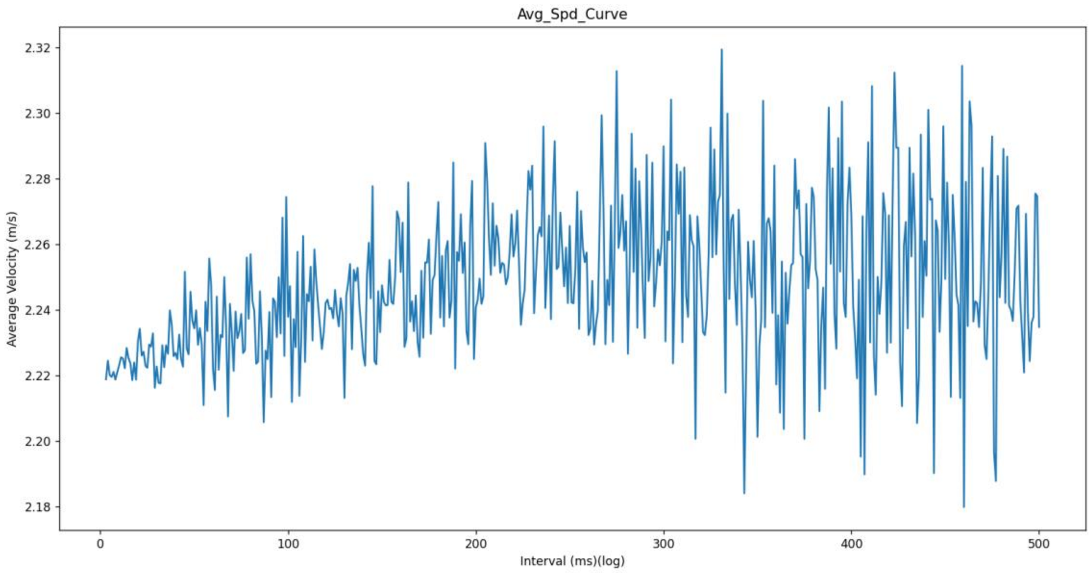
Visualization of DTS model

3.3 Validation of the DTS Model

The validation of the Dynamic Traffic Simulation (DTS) model aims to establish the credibility of the simulation outcomes, with a particular focus on the selection of the time-step interval. Our objective is to justify the choice of a suitable interval that aligns with conventional standards in traffic engineering simulations.

To assess the validity of the chosen interval, the DTS model underwent a series of rigorous experimental runs, varying the time-step intervals from 1 ms to 1000 ms. In each experimental setup, the velocity of each vehicle was meticulously recorded at successive intervals. The experimental process aimed to capture the average velocity for each vehicle throughout the simulation, culminating in the computation of the overall average velocity across the traffic system.

The results of the simulation experiments were subjected to rigorous quantitative analysis. However, a visual representation provided a striking revelation (see Figure below). The graph clearly illustrates chaotic fluctuations in velocity across different time-step intervals. Notably, intervals below the 100 ms threshold show a marked decrease in the volatility of the average velocity, suggesting a point of diminishing returns with respect to interval reduction and system stability.



Chaos in Velocity Fluctuations

The graphical evidence strongly supports the choice of a 100 ms interval as a rational decision for the simulation. This interval strikes a balance between model fidelity and computational efficiency. The discernible trend of decreased fluctuations at intervals smaller than 100 ms provides empirical evidence for the model's stability and accuracy at the chosen standard interval.

In conclusion, the validation process has unequivocally confirmed the suitability of the 100 ms interval for the DTS model. This interval choice is in harmony with established traffic engineering practices. The observed reduction in velocity fluctuations at this interval underscores the robustness and reliability of the simulation framework.

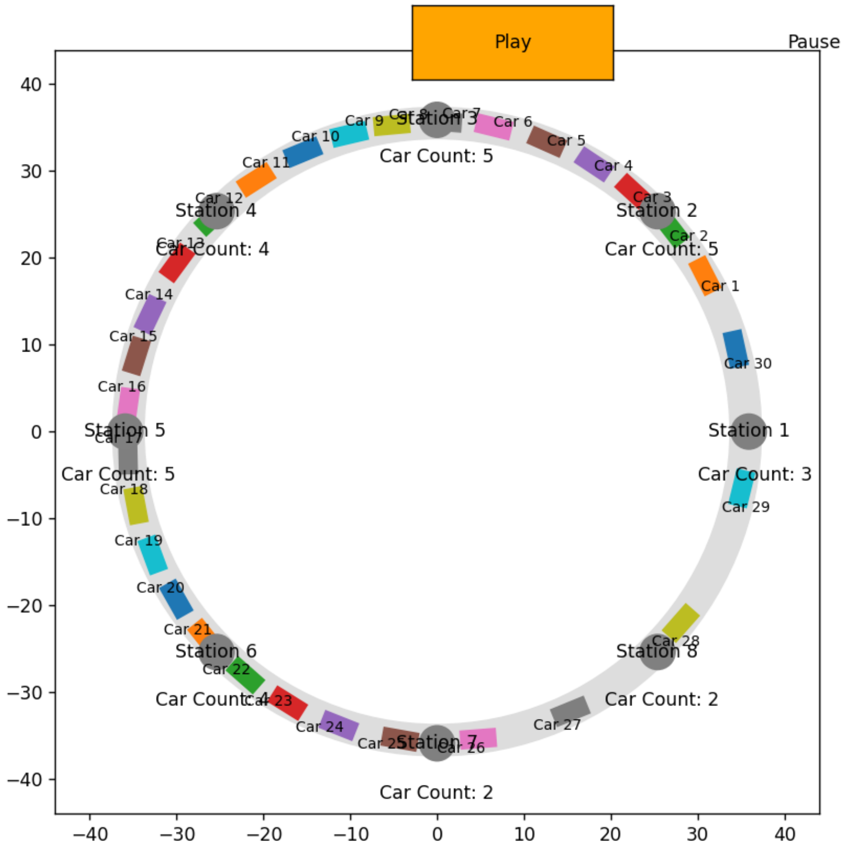
3.4 Data Collection for DTS

The data collection for the Dynamic Traffic Simulation (DTS) was meticulously structured to ensure the accuracy and relevance of the findings. The circular track was divided into eight segments, each initiated by a designated station to facilitate data acquisition at regular intervals. This segmentation approach allowed for the precise recording of vehicle speeds at each update step.

During a comprehensive simulation spanning 6000 seconds, with a time interval of 100 milliseconds, a substantial volume of data comprising approximately 60,000 data points was gathered. The classification of these data points was conducted with a two-fold criterion. Firstly, the sequence of vehicles within the current segment dictated the classification, based on the Intelligent Driver Model (IDM) speed formula. This was underpinned by the rationale that vehicles trailing behind do not influence the leading vehicle's speed within the same segment. Secondly, the number of vehicles in the subsequent segment was considered, implying that the combined criteria determined which distribution the data points would align with for fitting purposes.

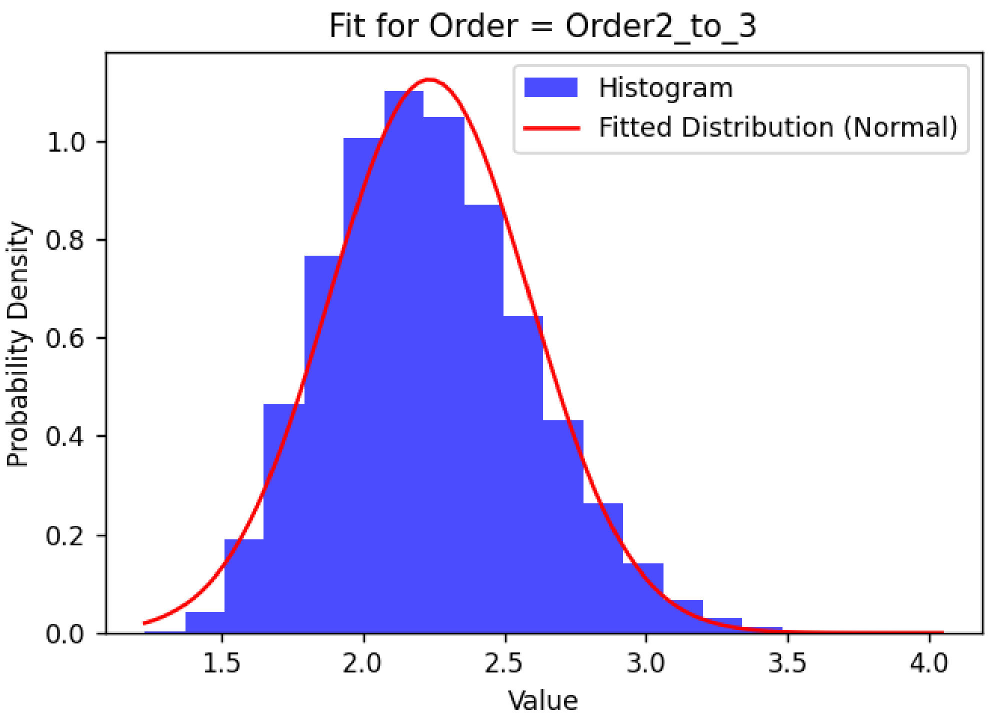
This dual-classification strategy culminated in the data points being aptly fitted into 25 distinct distributions. The report will include a segmented DTS demonstration result, illustrating the eight sections defined by stations, and a display of the distributions achieved from the data fitting process.

The following image represents the DTS model enhanced with the addition of eight segments demarcated by stations. It showcases the real-time dynamics of vehicle movement and station-based vehicle counts, providing a snapshot of the traffic flow and density across the circular track.



DTS Demonstration Results

While this image exhibits one of the fitted normal distributions, derived from the classified data. This visual representation encapsulates the probabilistic behavior of traffic speed distribution, reinforcing the analytical approach adopted in this study.



Fitted Distribution Graph

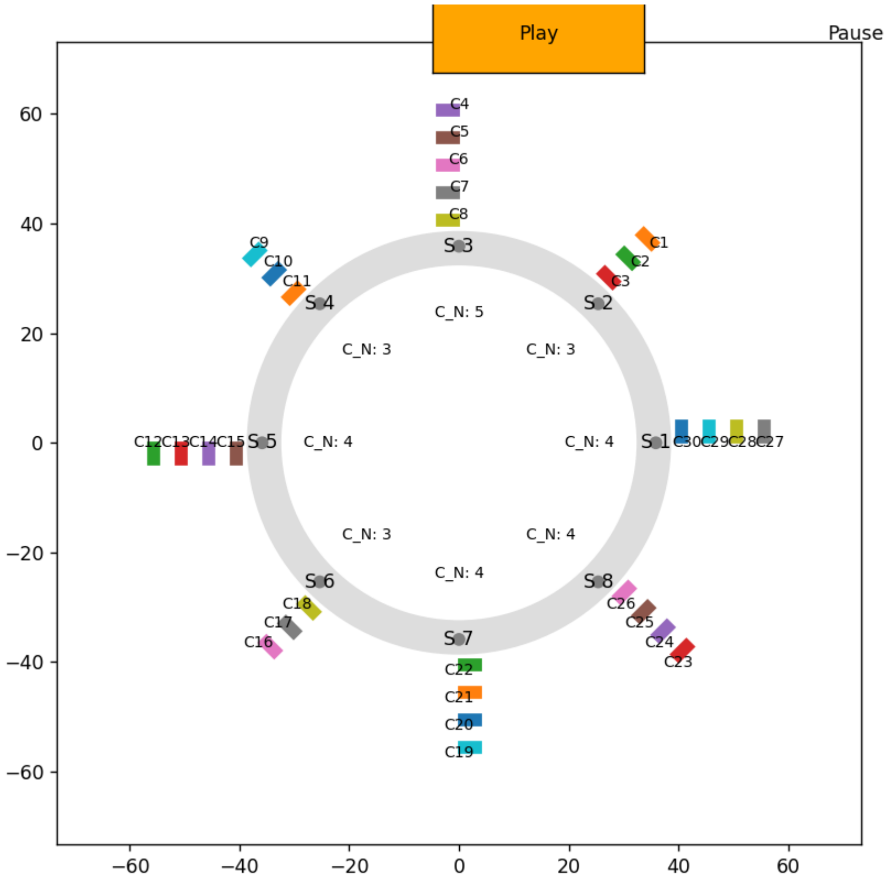
The data collection process not only reflects the intricate dynamics of vehicular movement but also paves the way for a deeper understanding of traffic flow and congestion patterns, which are pivotal in the optimization of traffic systems.

3.5 Construction of the DES Model

The intricacies of the Discrete Event Simulation (DES) model developed subsequent to the Dynamic Traffic Simulation (DTS) data acquisition. The model has been programmed in Python, leveraging numerical and statistical libraries such as NumPy, Pandas, Matplotlib, and SciPy to simulate and analyze vehicular traffic flow.

The interface of the DES program displays an annular roadway partitioned into eight sections, each marked by a station (S1 to S8) that records passing vehicle counts (C_N). Vehicles are represented as colored rectangles, numbered for identification (C1, C2, C3, etc.), and are visually distinguished to facilitate tracking within the simulation.

Car movements along the track are regulated by speed parameters derived from the DTS model, accounting for the impact of surrounding traffic density. This results in a realistic depiction of acceleration and deceleration behaviors. The stations dynamically update vehicle counts, reflecting the fluctuations in traffic concentration across the segments.



The model operates on an event-driven basis, where vehicle arrivals and other traffic events are chronologically queued and processed. This meticulous approach ensures an accurate representation of the traffic system at any discrete point in time.

Key data metrics, including vehicle speeds, positions, and station transit times, are systematically recorded. This wealth of data serves as a cornerstone for post-simulation analysis, offering insights into traffic patterns and congestion points.

The simulation's visual output, as depicted in the provided screenshot, is integral to interpreting the dynamic traffic system. Moreover, the collected data is structured into a CSV file, which can be analyzed using various data processing tools to glean deeper insights or to inform traffic management strategies.

The construction of the DES model embodies a holistic approach to simulating and analyzing traffic flows. It integrates real-time data handling, sophisticated event scheduling, and statistical computation to offer a nuanced understanding of urban traffic dynamics. This model underscores the symbiotic relationship between traffic behavior and data-driven decision-making in the realm of urban infrastructure planning and operational management.

3.6 Comparative Analysis of DTS and DES

A meticulous comparative analysis between the Dynamic Traffic Simulation (DTS) and the Discrete Event Simulation (DES) models has been conducted, focusing on the vehicle arrival times at stations. We specifically analyzed data from the first six vehicles to understand the discrepancies between the simulated models.

The data extracted for the first six vehicles illustrates various arrival times at each station along with their corresponding times from another simulation model, allowing us to compute both the error and the error rate. This comparative method provides a clear quantitative measure of the differences between the DTS and DES models.

The initial observations indicated a progressive decrease in error rates as the simulation time increased. This trend suggests a 'warming up' period in the DTS model, where vehicles gradually accelerate to optimal speeds, a concept not explicitly modeled in the DES.

The graphical representation of the data will elucidate the patterns and trends more clearly. We will showcase the error rates across simulation times, highlighting the convergence of the two models over time.

Car Index	Station Index	Arrival Time	Car_1_ArrivalTime	Error	Error rate
1	1	14.68565264	17.2	2.514347356	0.171211142
1	2	28.96255183	33.5	4.537448174	0.156666036
1	3	42.83196547	49.6	6.768034535	0.158013634
1	4	56.65485929	65.6	8.945140709	0.157888323
1	5	71.11299953	78.7	7.587000468	0.106689361
1	6	84.51686083	89.1	4.58313917	0.054227513
1	7	101.5726226	99.2	2.372622646	0.023358879
2	1	9.001406237	13.8	4.798593763	0.53309379
2	2	22.98064221	29.6	6.619357787	0.288040592
2	3	40.07569259	45.9	5.824307409	0.14533267
2	4	54.16786842	62.2	8.032131582	0.148282216
2	5	67.35410616	75.5	8.145893838	0.12094131
2	6	81.46928755	86.2	4.730712451	0.058067434
2	7	97.26545087	95.9	1.365450871	0.014038396
3	1	5.259329721	10.1	4.840670279	0.920396807
3	2	21.10858453	26.3	5.191415471	0.245938588
3	3	37.80203889	42.4	4.597961114	0.121632622
3	4	52.22492152	58.7	6.47507848	0.123984456
3	5	64.35379857	72.7	8.346201428	0.129692444
3	6	78.33607245	83.3	4.963927552	0.063367072
3	7	92.82991743	92.4	0.429917428	0.004631238
3	8	106.6032043	103.4	3.203204334	0.030047918
4	1	2.029799076	6.7	4.670200924	2.300819316
4	2	16.90312664	22.8	5.896873363	0.348862875
4	3	31.66609179	39.3	7.633908209	0.241075162
4	4	45.46184321	55.3	9.838156794	0.216404706
4	5	60.73759773	69.4	8.662402272	0.1426201
4	6	74.34990776	79.7	5.350092236	0.07195829
4	7	87.49996808	89.6	2.100031917	0.024000374
4	8	102.4692015	99.9	2.569201478	0.025072914
5	2	13.53636115	2.7	10.83636115	0.800537237
5	3	27.76791437	19.1	8.66791437	0.312155758
5	4	40.44734952	35.6	4.847349523	0.11984344
5	5	58.18308303	52.2	5.983083034	0.102832004
5	6	70.36172805	65.9	4.461728053	0.063411292
5	7	83.24479847	76.7	6.544798469	0.07862111
5	8	99.67464842	86.2	13.47464842	0.135186315
6	2	9.488365969	15.5	6.011634031	0.633579486
6	3	22.68933673	31.9	9.210663275	0.405946784
6	4	36.56489842	48.5	11.93510158	0.326408717
6	5	51.66000726	62.8	11.13999274	0.215640557
6	6	67.1022562	73.3	6.197743796	0.092362674

The necessity for vehicles to accelerate to cruising speeds in the DTS model accounts for the higher initial error rates observed. Unlike DES, where vehicles are instantiated with speeds derived from a statistical distribution, the DTS integrates the physical aspect of acceleration, contributing to the initial variance.

To fully comprehend the root causes of the observed discrepancies, further statistical analysis is required. We will explore the potential impact of traffic density, inter-vehicular dynamics, and the methodological differences in speed assignment between the DTS and DES models.

3.7 Summary

In summary, this experiment has been dedicated to illustrating the methodology and the comparative analysis between the Dynamic Traffic Simulation (DTS) and Discrete Event Simulation (DES) models. It began with an exploration of the DTS model, which was constructed based on the Intelligent Driver Model (IDM) and validated through rigorous testing. The data collection was carefully executed, segmenting a circular track into eight parts and recording vehicle speeds at regular intervals.

The DES model was then developed to mimic the DTS, with a particular focus on accurately simulating vehicle arrival times at various stations. The programming was conducted in Python, utilizing powerful libraries to create an event-driven simulation that closely aligns with the DTS model's results.

The comparative analysis of DTS and DES models revealed that while there was an initial discrepancy in vehicle arrival times, indicative of the DTS model's incorporation of acceleration, the error rate decreased over time. This suggests that the DES model, although simplified by omitting direct acceleration calculation, still manages to capture the critical dynamics of traffic flow accurately after initial 'warm-up' phases.

It was observed that the DES model is an effective alternative to DTS, especially in experiments like 'Traffic Without Bottleneck,' where the absence of physical obstructions allows for a clearer comparison of simulation methodologies. However, to fully understand the underlying causes of the observed discrepancies, further statistical analysis is required. This future work will delve into the impact of traffic density, inter-vehicular dynamics, and the methodological differences in speed assignment between the two models.

This chapter sets the stage for the subsequent results and analysis presented in Chapter 4, ultimately contributing to the body of knowledge in traffic simulation and modeling, with implications for more efficient and safer traffic systems.

Chapter 4

CONCLUSION AND FUTURE WORK

4.1 Conclusion

In this research, the experiment explored the applicability and efficiency of Discrete Event Simulation (DES) in the context of traffic flow on a circular highway without bottlenecks, contrasting it with the established Discrete Time Simulation (DTS) approach. Through the careful construction and analysis of both models, we have demonstrated that DES not only closely aligns with the DTS in terms of arrival time accuracy but also offers a significant improvement in simulation efficiency.

The final findings indicate that DES can be employed with minimal error sacrifice, thereby greatly enhancing efficiency. Specifically, the DES model has shown potential in accurately replicating the traffic dynamics modeled by DTS, with the added benefit of requiring less computational time and resources.

The comparative analysis between the two models has revealed a trend of decreasing error rate over time, affirming the DES model's capability to adapt and accurately reflect the traffic flow as vehicles reach steady-state conditions. This supports the conclusion that DES, despite simplifying some aspects of traffic modeling, such as the explicit calculation of acceleration, can still yield reliable and valuable insights into traffic patterns.

4.2 Future Work

Looking ahead, the primary focus for future work will be to refine the accuracy of data distribution collection and the fine-tuning of model parameters. Efforts will be directed towards:

Enhanced Data Precision: By gathering more granular data, especially in the acceleration phase of vehicles, future models can reduce initial error margins and improve overall simulation fidelity.

Parameter Optimization: Tweaking model parameters such as vehicle acceleration profiles, reaction times, and inter-vehicle distances can lead to a more nuanced simulation output that better mirrors real-world observations.

Advanced Statistical Analysis: Deploying more sophisticated statistical tools and methods can aid in dissecting complex traffic patterns and contribute to more precise model calibrations.

Extended Simulation Scenarios: Future simulations may include varied traffic conditions, different roadway configurations, and the introduction of elements such as traffic signals or varying driver behaviors to test the robustness of the DES model further.

Real-World Application and Testing: Applying the DES model to real-world traffic scenarios and comparing the outcomes with actual traffic data can serve as the ultimate test of its applicability and accuracy.

4.3 Final Words

The research presented herein contributes to the growing body of knowledge in traffic simulation and modeling. It advocates for the adoption of DES in scenarios where traditional DTS is used, highlighting the efficiency gains without compromising the accuracy needed for traffic analysis and infrastructure planning. As we continue to push the boundaries of simulation technology, our goal remains to support the development of more efficient, safer, and sustainable traffic systems for the future.

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