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Modeling and Optimization of Interaction Behavior between Right Turning Motor Vehicles and Pedestrians at Signalized Intersections based on Machine Learning

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Abstract

This project first conducted a comprehensive analysis of the interaction process between pedestrians and right turning motor vehicles and its influencing factors through a summary of existing literature and observation of actual situations. On the basis of comprehensive and accurate data, machine learning algorithms were used to model and predict the interaction behavior between pedestrians and right turning motor vehicles. By comparing different algorithms, the optimal models for predicting the yielding behavior of right turning motor vehicles and pedestrian crossing behavior in the current dataset were obtained. According to the model evaluation report, the obtained models have better predictive performance on the test set. And based on the obtained optimal model, the feature importance ranking was carried out for the pedestrian crossing model and the right turn motor vehicle yielding model, and the importance scores of the influencing factors of pedestrian crossing behavior and right turn motor vehicle yielding behavior were obtained respectively. Finally, a comparison was made between the modeling effects of the crossing gap feature group and the speed distance feature group, further clarifying the importance of the speed distance index for right turning motor vehicles in predicting interactive behavior.

Keywords

Machine Learning; Interactive Behavior; Vehicle; Behavioral Prediction.

1. Introduction

As an important hub in urban road environments, signal controlled intersections require pedestrians and vehicles to share the same traffic area. In signal intersections without dedicated right turn phases, the interaction between right turning motor vehicles and pedestrians is very frequent. Poor interaction behavior can lead to traffic conflicts, seriously affecting the safety and efficiency of road traffic. In complex situations, how to accurately simulate the interactive decision-making behavior of pedestrians and motor vehicles at intersections, especially accurately predict their reactions to each other's states, is still a problem that needs to be studied.

2. Research Background

2.1. Research Significance

The safety and efficiency of road traffic have always been an important issue in the field of transportation research. In signalized intersections where complete phase separation between pedestrians and vehicles has not been achieved, pedestrians and vehicles must share the same space, and the interaction between pedestrians and motor vehicles is inevitable. Poor

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interaction behavior can lead to traffic conflicts, seriously affecting the safety and efficiency of road traffic.

With the advancement of technology, autonomous driving technology has received increasing attention, and research has found that optimal autonomous driving behavior can be achieved by designing a system that completes the work of a human driver. But to achieve safe driving of autonomous vehicles in complex urban traffic environments, in addition to precise control of autonomous vehicles and mastery of road traffic rules, it is also necessary to have a deep understanding of the interaction process between human drivers and other road users in complex traffic environments. The interaction between right turning motor vehicles and pedestrians is an important part of the interaction behavior among many road users, so the study of the interaction behavior between right turning motor vehicles and pedestrians can provide effective reference for autonomous driving and driving assistance systems.

In this context, the study of the interaction behavior between pedestrians and right turning motor vehicles has the following theoretical significance and practical value:

1) The prediction and analysis of the interaction behavior between pedestrians and right turning motor vehicles can help to clarify the operating mechanism of pedestrians and motor vehicles at signalized intersections, understand the impact of both parties and the external traffic environment on their respective behaviors, and provide reference for establishing pedestrian safety evaluation indicators and methods at intersections.

2) The comparative analysis of factors affecting the interaction between right turning motor vehicles and pedestrians can provide a more reliable theoretical basis for intersection planning, design, and management.

3) The interaction between right turning motor vehicles and pedestrians is an important component of the interaction behavior among many road users, and the research results can also provide theoretical basis and model foundation for active risk identification in autonomous driving and vehicle networking related scenarios.

2.2. Current Research Status at Home and Abroad

1) Current research status in China

Domestic research on human vehicle interaction mostly focuses on conflict indicators or delays caused by conflicts. Although some papers have focused on the internal mechanisms of pedestrian vehicle interaction and used theories such as social forces and game theory to model and simulate pedestrian and vehicle behavior, there are limitations in obtaining real data and idealizing crossing strategy formulation, which have not yet achieved the effect of accurately and realistically reproducing the interaction process.

2) Current research status abroad

Salmon et al. used a system framework event analysis method to analyze the conflicts between motor vehicles and pedestrians crossing the street, pointing out that the design of intersections has a certain impact on the crossing behavior of motor vehicles and pedestrians, as well as the types of conflicts between the two. Friederike Schneemann et al. used natural driving experiments to obtain the interaction behavior between pedestrians and motor vehicles. They studied the driver's arrival behavior, pedestrian's crossing decision behavior, and driver's yielding behavior in uncertain pedestrian crossing scenarios through three preset scenarios. They analyzed the impact of TTC of 3 seconds and 4 seconds on the interaction between pedestrians and vehicles, and found that the driver's arrival behavior is mainly related to his initial speed. They also pointed out that the speed of the motor vehicle has a significant impact on pedestrian crossing decisions.

In summary, research on human vehicle interaction in China mainly focuses on the study of its conflicts. There are two main aspects to the study of human vehicle conflicts: analyzing the

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factors affecting conflicts using conflict frequency and traffic conflict technical indicators; By utilizing the traffic characteristics of pedestrians and motor vehicles in human vehicle conflicts, the theory of traversable division is adopted to study the traffic delay and safety under traffic conflicts. In addition, some scholars have used game theory, cellular automata, and social force models to model and simulate the interaction process between humans and vehicles. Comparing the research on human vehicle interaction at home and abroad, it can be found that domestic scholars often take the perspective of equal right of way for humans and vehicles, or focus on the efficiency of motor vehicle traffic when studying human vehicle interaction, while foreign scholars generally conduct research on human vehicle interaction based on the premise that pedestrians have priority right of way in the process of human vehicle interaction.

In the study of pedestrian and motor vehicle interaction, many researchers at home and abroad have used the indicator of gap that can be crossed. However, this indicator is indirectly obtained through the speed and distance of pedestrians or motor vehicles. Whether it can truly reflect the response of pedestrians or motor vehicles to the current traffic state remains to be studied. The factors considered when there is interaction between pedestrians and motor vehicles mainly focus on the traffic characteristics of vehicles and pedestrians, such as the speed, headway, and traffic volume of vehicles and pedestrians. There is a lack of consideration for intersection types, daytime or nighttime environmental factors. The current research on the interaction behavior between right turn motor vehicles and pedestrians only focuses on ordinary right turn lanes, lacking consideration for different forms of right turn traffic.

2.3. Development Trends

In recent years, the safety risks of right turning vehicle intersections and pedestrians have mainly focused on public transportation. Guler et al. discussed the impact of limited public transportation city roads on pedestrian safety; Ageldin et al. found that in highly mixed traffic environments, indicators based on pedestrian avoidance behavior are more suitable for evaluating pedestrian crossing safety than time asymptotic indicators; Suwarto et al. used the Time to Accident (TA) metric and incorporated a time-dependent data function to distinguish between minor and severe conflicts; Tageldin et al. proposed a pedestrian avoidance detection method based on Permutation Entropy (PE), which proposed a new extraction method for parameters related to pedestrian vehicle conflict evaluation while avoiding conflicts between people and vehicles; KADALIB. R., VEDGIRI proposed a method for determining the degree of danger in the case of mixed traffic flow between different vehicles and pedestrians at the same intersection.

3. Research Design

3.1. Research Objectives

This project combines domestic and foreign literature and on-site observations, starting from three aspects: traffic characteristics, intersection design, and environmental factors, comprehensively considers the influencing factors of the interaction between right turn motor vehicles and pedestrians. With comprehensive and accurate data support, machine learning algorithms are used to predict and model the interaction behavior of right turn motor vehicles and pedestrians from their perspectives. By comparing the predictive effects of the speed distance feature group and the crossing gap feature group on the test set, the importance of the speed distance index of right turn motor vehicles in predicting interaction behavior is clarified. Based on this, the speed distance characteristics of the interaction between right turn motor vehicles and pedestrians are analyzed. The analysis results can provide effective references for establishing pedestrian safety evaluation indicators and methods at intersections.

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3.2. Main Content

1) Analysis of Interaction Behavior between Right Turning Motor Vehicles and Pedestrians

Clarify the definition of interaction between motor vehicles and pedestrians, identify key time points in the interaction process, analyze the interaction behavior between right turning motor vehicles and pedestrians at signalized intersections, determine the types of interaction behavior between pedestrians and right turning motor vehicles, and preliminarily determine the influencing factors of the interaction between right turning motor vehicles and pedestrians to be considered in this project through observation of actual situations and summary of domestic and foreign literature.

2) Data collection of interaction between right turning motor vehicles and pedestrians at signalized intersections

Based on the analysis of the interaction between right turning motor vehicles and pedestrians, obtain the required signal intersection video, use video processing technology to obtain trajectory data of pedestrians with right turning motor vehicles, automatically extract the position and speed information of pedestrians and right turning motor vehicles during interaction from the trajectory data, and obtain other influencing factor data of human vehicle interaction through manual observation, providing a data basis for model establishment.

3) Modeling, prediction, and feature importance ranking of interaction behavior between right turning motor vehicles and pedestrians

Preliminary screening is conducted on the obtained features to eliminate some features. Different machine learning algorithms are used to model pedestrian crossing behavior and right turning motor vehicle yielding behavior, and the models are evaluated and compared to select the optimal model under the current dataset. On the basis of the optimal model, the importance of the features in the pedestrian crossing model and the right turn motor vehicle yielding model are sorted separately, and the importance scores of each influencing factor on the interaction behavior are obtained.

4) Analysis of speed distance characteristics of interaction between right turning motor vehicles and pedestrians

Comparing the modeling effects of the crossing gap feature group and the speed distance feature group, further clarifying the importance of the speed distance index of right turning motor vehicles in predicting interactive behavior; Using speed distance SVM feature classification based on predictive models, compare the yielding behavior of right turning motor vehicles in different interaction areas; Using speed distance to divide the human vehicle interaction behavior in the early right turn lane, obtain the speed distance range corresponding to the safety interaction decision area and the dispute interaction decision area.

3.3. Innovation Points

(1) A pedestrian vehicle traffic conflict risk level model based on pedestrian crossing classification was proposed, and the COM+port of VISSIM software was used for secondary development. Real time simulation of pedestrian vehicle traffic conflicts was completed and the risk level classification model was verified. Relevant traffic conflict index values were obtained, laying the foundation for the next step of real-time pedestrian vehicle conflict control system.

(2) The optimization of parking and pedestrian crossing positions, the width of zebra crossings at pedestrian intersections, and the consideration of signal light groups for pedestrian signal phases is mainly aimed at further improving the service level of the relevant road network and ensuring that the efficiency of pedestrian and vehicle traffic is improved compared to before the improvement.

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3.4. Project Features

The study of pedestrian and motor vehicle behavior has always been an important part of the transportation field. In signalized intersections where complete separation of pedestrians and vehicles has not been achieved, the interaction between pedestrians and right turning motor vehicles has a significant impact on road safety and efficiency. This project models and analyzes the interaction behavior between right turning motor vehicles and pedestrians, and implements secondary development based on Python. By comparing with the actual situation, relevant evaluation values of traffic conflict risk are obtained to demonstrate the conflict risk level proposed in this project. Finally, based on the distance between the sidewalk and the parking line and the width of the sidewalk, an optimization plan for reducing pedestrian vehicle conflicts related to the intersection is derived.

4. Conclusion and Prospect

The following goals can be achieved through this study:

1) Analyze the safety of geometric parameters and transportation facilities

In the past, the geometric parameters of urban intersections were obtained through measurement and on-site driving, which required a lot of manpower and material resources. This project determined the risk of pedestrian vehicle conflict through functional analysis of road network delays and simulated signal timing facilities, and thus obtained a rough strategy for optimizing intersection parameters. By comparing the simulation results of intersections with the simulation parameters involved in current regulations, relevant methods for optimizing intersections were obtained.

2) Predict the optimized results of traffic safety at urban intersections

In this project, the VISSIM software was used to optimize parameters such as the distance between parking lines and pedestrian crossings, and the optimized results were obtained through simulation. After determining the general planning values for pedestrians and vehicles in the early stage of national spatial planning, VISSIM is further operated to determine the degree of danger of pedestrian vehicle conflicts. Based on the statistics of conflict frequency and vehicle speed, specific measures for intersection simulation optimization are obtained.

3) Provide support for the design and implementation of urban intersections

In the process of intersection design involved in the upcoming urban renovation, the design of intersections mainly relies on determining values according to regulatory guidelines. Simulation software needs to be used to obtain the evaluation of the design effect, which can further provide practical reference opinions for the construction and other specific work of intersections.

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