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Research Article

Mathematical Modeling Methods and Their Application in the Analysis of Complex Signal Systems

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Mathematical models are effective means of answers established by humans to solve real-world problems. Complex wireless communication can establish information interaction between vehicles, in order to reduce the delay time of the coordination control optimization timing scheme in coordination delay time. For smart car driving, a complex signal system, this study first establishes a relevant mathematical model. It is used to compare three mathematical models commonly used today. The results obtained under the same conditions show that the mathematical model is better in dealing with the complex signal system in terms of transmission accuracy in all segments. A number of vehicles in different states of the traffic system are selected, and the relevant data are collected to plot ROC curves using the mathematical model. It can be concluded that the freer and more complex the movement behavior of the vehicle, the greater the load it imposes on the road and the system. The results of the confusion matrix show that the model can effectively reduce the pressure on the road and the signal system. With the starting objective of smooth operation of public transportation, the target values are optimized by layering, and finally, the regional roadway capacity is effectively converged. Then, the mathematical model optimization of complex wireless systems and intelligent transportation networks is quantitatively evaluated. The optimized timing scheme through coordinated control achieves the expected effect in coordinated control of delay time and also reduces the average delay time of all intersections of the road network.

1. Introduction

Mathematical modeling is to establish a mathematical model according to actual problems, solve and calculate the mathematical model, and then solve the actual problems in life according to the calculated results. The essence of a mathematical model is a dynamic simulation, not a fixed way of thinking. It is the use of mathematical symbols, mathematical formulas, languages, graphics, etc., to abstract, summarize, and describe the essence of the problem, so as to explain some objective phenomena and development laws in life. Mathematical modeling requires people to flexibly use the relevant knowledge of mathematics, as well as to carefully observe and analyze the real problems in life, abstract from the problems, and extract the mathematical model, which is called mathematical modeling. Since mankind began to tie ropes, mathematics, as the foundation of all disciplines, has developed significantly along with the progress of human technology. Every century of mankind has been the century of mathematics, and mathematics has emerged and developed throughout the history of human civilization [1]. In this century, mathematics has once again demonstrated its irreplaceable power because of the rapid development of computer technology, which has ushered in digitalization in all industries. Mathematics represents absolute rationality, which removes the pretense of things and represents their essence abstractly yet intuitively. That is why numbers have found deeper and wider application in many fields and joint disciplines such as biomathematics, financial mathematics, and physical mathematics have emerged [2]. And mathematical modeling, as the most useful form in the field of science and social life, has become a necessary way to apply mathematics in the context of big data [3].

Mathematicians of different eras and countries defined mathematical models slightly differently, and there are obvious differences in the way they are expressed, but the essence is largely the same. British mathematicians considered that in a broad sense, all mathematical concepts and basic algorithms can be called mathematical models. French scientists have defined mathematical models in detail in both the broad and narrow senses. They considered that in the broad sense, all concepts in mathematics are abstractions and generalizations of real prototypes and therefore belong to the original mathematical models. In a narrow sense, a mathematical model refers specifically to a structure of mathematical relations that reflects only a specific system or a specific problem. The definition of a mathematical model given by the well-known Chinese mathematician Jiang Qiyuan is that it is a mathematical structure that makes the necessary simplifications for a specific object or purpose in the real world according to its intrinsic laws and later expresses it by applying appropriate mathematical tools [4–7]. From the above descriptions, it can be seen that different mathematicians have defined mathematical models in terms of their types, modeling processes, and modeling methods. In this study, these definitions are summarized to obtain a definition of mathematical models that is applicable to a broader scope. A mathematical model is a mathematical structure that abstractly represents a system or event using mathematical language. This mathematical structure consists of two main parts, the first part is numbers, letters, and symbols, and the second part is mathematical formulas, algorithms, diagrams and laws, etc. [8]. Simple ones such as functions, derivatives, geometry, and physical-chemical equations are mathematical models, and complex ones such as operations research, statistics, and optimal solution problems are also typical mathematical models.

In recent years, with the increasingly proficient use of mathematics, mathematical models have penetrated a wide range of industries. Together with the rapid rise of related technologies such as the Internet, deep learning, artificial intelligence, and big data, the application of mathematical models in complex signaling systems has also received increasing attention from the general public and related practitioners [9]. As the most popular means of transportation nowadays, the automobile not only carries the work of human transportation but also is the basis of the modern transportation industry. And the traditional automobile industry introduces new and high technology and carries out technological substitution, and upgrade to become a smart car is a typical complex signal system [10]. The concept of a smart city has been proposed for more than a decade, and nowadays, the intelligent transportation system is one of the first projects to be realized on the ground. And the vehicle wireless communication network has already achieved regional coverage on the city roads and highways of several large cities, which has laid a solid foundation for the popularization of the intelligent transportation network system [11]. The simultaneous development of wireless signal systems and intelligent vehicles has positive implications for enhancing road safety, reducing environmental pollution, improving traffic efficiency, and reducing manpower waste. The application of mathematical modeling in this complex signal system is very important and irreplaceable, which reflects the practical significance and great economic value of this study.

The contribution of research innovation is that the mathematical model developed in this research has better transmission accuracy in all segments when processing complex signal systems. In this study, a mathematical model is established based on the Doppler effect caused by signal propagation during vehicle operation. With the increase in the number of signal seeds in the system, the signal accuracy of the mathematical model is generally improved, which indicates that the more the number of tree layers generated for the actual transmission of signals, the higher the propagation accuracy. However, the phenomenon of a slight decrease after reaching the critical value may be due to the overflow of tree nodes caused by the excessive depth of the generated tree, resulting in the reduction of signal propagation accuracy. As the information exchange capacity of the mathematical model in this study is enhanced, the congestion during the peak commuting period is greatly reduced. The mathematical model implemented in this section next quantifies the optimization of complex wireless systems and intelligent transportation networks. The results show that the area surrounded by the yellow area is smaller than the area surrounded by the blue line, which means that the timing scheme optimized by the coordination control achieves the expected effect on the coordination delay time control and reduces the average delay time of all intersections in the road network.

2. Mathematical Model Flow and the Type of Signal Used

The process of mathematical modeling is the presentation of a way of thinking from abstraction to figuration, which is realized in the actual modeling process with numbers, letters, and conformity [12]. In the process of mathematical modeling and solving practical problems with it, there is a division of levels and hierarchical requirements, the basic flow chart of which is shown in Figure 1.

As you can see from Figure 1, when a problem is encountered in real life, it is abstracted into a mathematical problem and modeled. Compared with the oneness of other mathematical courses, mathematical modeling courses involve a wide range of knowledge. When using AHP to analyze problems, first, analyze and deal with the problems according to the principle of “organization and hierarchy” to construct a hierarchical structure model. Under this model, the complex problem is divided into several elements, which form several levels according to their attributes and relationships. The analytic hierarchy process can be roughly divided into four steps: (1) establish the hierarchical structure model, (2) construct a judgment (paired comparison) matrix, and (3) test consistency. A relative scale shall be adopted to minimize the difficulty of comparing various factors with different properties, so as to improve accuracy. After the model is built, the problem is solved by substituting it into the model, and the result is checked after the solution is obtained. If it is applicable to reality, the problem is solved. If it is different from reality or partially problematic,

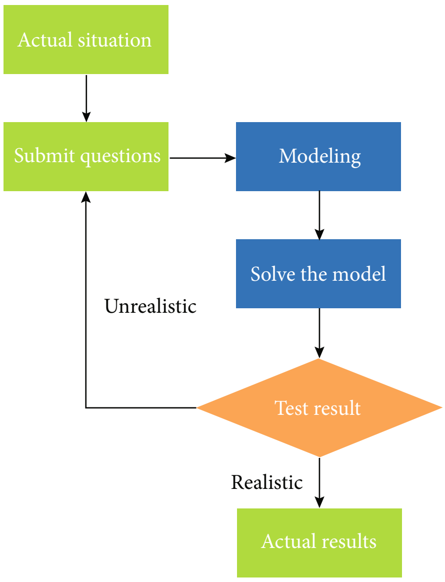

Figure 1: The basic process of mathematical modeling activities.

the model is modified and the process is cycled until the final correct solution is obtained [13]. Complex wireless communication is able to establish information interaction between vehicles and vehicles or even any physical object that can affect the operation of the vehicle, essentially IoT applications in the transportation industry.

Figure 2 represents the communication principle of a vehicle in a complex wireless information system. As a practical application of the Internet of Things in the field of transportation, the complex wireless signal system uses wireless sensing technology in communication to realize real-time interaction between the vehicle and the road and the surrounding environment information. And the collected data can be processed and shared quickly by modern sophisticated mathematical modeling and wireless communication technology, thus interconnecting the vehicle and many physical objects in the surrounding area within a certain range [14]. With the landing of 5G communication base stations worldwide, 5G wireless signals based on cellular networks have become the main technological hallmark of smart vehicles and their communication and the direction of automated driving and traffic optimization industries in the current and future decades [15]. As shown in Figure 2, there are four main types of wireless complex signal-based networked communications in the industry today. Vehicle-to-vehicle communication (vehicle-to-vehicle, V2V), vehicle-to-pedestrian or cyclist communication (vehicle-to-pedestrian, V2P), vehicle-to-infrastructure communication (vehicle-to-infrastructure, V2I), and vehicle-to vehicle-to-network (V2N) [16]. Previously, when vehicles were on the road, they usually got the latest road conditions through traffic broadcasts and other forms, while V2V communication enables vehicle-to-vehicle information exchange. It omits intermediate steps and allows all vehicles in the network to get timely information such as road congestion and traffic accidents. It also allows vehicle collision warning by transmitting and receiving sound waves, which greatly reduces the probability of traffic accidents [17]. V2P communication provides interaction between vehicles and pedestrians or cyclists, and vehicles send collision warning messages to pedestrians or cyclists when they are too close to each other, and pedestrians and cyclists can send information such as road congestion and traffic accidents to vehicles as well as between vehicles [18]. V2I communication is an enhancement of the basic traffic network information, which enhances the information interaction and sharing between vehicles and roadside infrastructure (Road Side Unit, RSU) [19]. In recent years, with the popularity of navigation APPs, V2N communication has also developed, which realizes real-time interaction between vehicles and the core network of traffic command, making it possible to plan driving routes, real-time road condition inquiries, severe weather warnings and network cloud services, and other functions developed based on modern computer technology, which greatly improve the probability of safe driving and travel efficiency of vehicles [20].

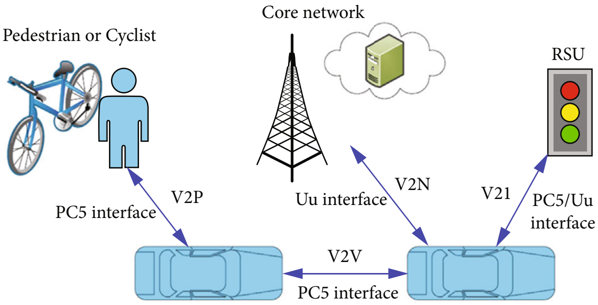

Figure 2: Schematic diagram of vehicle networking communication types and their basic flow charts.

3. Mathematical Modeling of Intelligent Vehicle Signaling System

To achieve real-time communication between intelligent vehicles, a variety of suitable anti-interference methods should be selected. The intermediate medium for communication between different groups of unmanned vehicles is the cloud server. The vehicle communication between each group can be carried out through the internal LAN. In order to ensure smooth communication between vehicles, it is generally necessary to define the data structure of vehicle information storage on the cloud server in advance. The cloud server is communicatively connected to a plurality of unmanned vehicles through a network. The cloud server may maintain a data structure or database to compile and store vehicle information of the unmanned vehicle. Some of the vehicle information may be received from the driverless vehicle while other information may be compiled and generated at the server based on the updated information received from the driverless vehicle. At present, the methods commonly used in the industry include the execution power control method, the rational allocation of resources, and the signal mode selection method. The selection of these methods has a great impact on the quality of signal transmission between intelligent vehicles. Unlike the traditional location-fixed point-to-point cellular communication, the biggest problem to be faced by the complex signal system of intelligent vehicles is that the vehicles in the network are moving at a relatively high speed. Signal propagation between vehicles at high speed will produce Doppler effect; it refers to the wave source, and the observer has relative motion, the observer receives the frequency of the wave, and the frequency of the wave source is not the same phenomenon. The sound of a train whistle coming from afar becomes sharp and thin (i.e., the frequency becomes higher and the wavelength becomes shorter), while the sound of a train whistle leaving us becomes low (i.e., the frequency becomes lower and the wavelength becomes longer), which is the phenomenon of the Doppler effect. This phenomenon was first discovered by Austrian physicist Doppler in 1842. The Dutch meteorologist Barot had a team of horn players stand on an open train speeding past from near Utrecht, Netherlands, in 1845 and blew, and he measured the change in pitch on the platform. The Doppler effect has been used by astronomers to measure the apparent velocity of stars since the second half of the 19th century. It is now widely used to corroborate observations of the motion of celestial bodies and artificial satellites. In intelligent vehicle networking wireless complex communication systems, this phenomenon is called Doppler shift, which refers specifically to the relative motion of the transmitter and receiver causing a shift in the signal at the carrier frequency of unidirectional propagation, which then triggers distortion and rapid changes in the channel in time. If the propagation is multidirectional, it causes more kinds of Doppler shifts, which in turn makes the wireless complex signal propagation cause more errors. Because of the generation of Doppler shifts, the signal coherence time of the complex system decreases, which eventually leads to the evolution of wireless communication into time- and frequency-selective fading communication, often called instantaneous fading communication. In instant fading communication, the response on each signal transmission channel changes rapidly with time. And there is the problem of prediction delay and feedback delay in real communication, and the three together will cause a large error, and the mathematical modeling needs to focus on how to eliminate this error. A communication delay estimation algorithm is proposed for wireless sensor networks using the CSMA/Ca communication mechanism. A combined link model is established to predict link reliability based on the time and space correlation of link quality. The simplified collision probability model is used to predict the channel contention delay, and the communication delay is obtained by combining the predicted link reliability. The overhead of the algorithm is analyzed, and the channel contention delay prediction algorithm is simulated on the simulator. The results show that the prediction algorithm can accurately predict the contention delay of the network.

First, assume that the fading of all signal channels in a complex wireless signal system contains not only large-scale fading but also small-scale fading, starting with the on-board interference channel, the expression of which is

$$g_{i,j} = \left|h_{i,j}\right|^2 L_{i,j}, \tag{1}$$

where L denotes large-scale fading and h denotes small-scale fading; the overall obeys the log-positive-terminus distribution. Since the large-scale fading changes more slowly, it can be accurately estimated by the signal base station at each change interval. The small-scale fading, on the other hand, needs to be determined based on the actual situation and cannot be relied on by the signal base station for a more accurate prediction.

After that, the small-scale fading can be predicted assuming that the transmitter and receiver of the signal are relatively stationary and there is no Doppler effect if they are not moving. The small-scale fading obeys independent distribution, and its mean is zero and variance is one, which is typical of the complex Gaussian distribution. In this study, the model is defined as the ideal model, which is applicable to the time period of road congestion, when the vehicles are usually stationary or moving very slowly compared to the propagation speed of the signal. In such a scenario, the in-vehicle interference channel is given by

$$g_{i,j} = G\beta_{i,j}\varsigma_{i,j}d_{i,j}^{-\alpha}. \tag{2}$$

In the above equation, G is the loss constant of the signal in the propagation path and α is the path loss exponent. However, excluding the congestion during the peak commuting period, most of the cases are not modeled as ideal. Therefore, the next step is to model the case where both the transmitter and the receiver of the signal undergo relatively high speed motion. This situation occurs more often when vehicles and pedestrians or cyclists carry out signal transmission and is referred to as a nonideal model in this study. In this case, the small-scale fading cannot be accurately predicted, so the small-scale signal fading is modeled using a Markov process as follows:

$$h_{i,j} = \varepsilon\tilde{h}_{i,j} + \sqrt{1-\varepsilon^2}\,e_{i,j}. \tag{3}$$

The estimation errors obey independent identical distribution, and the small-scale fading preview errors and estimation errors in the Eq. are independent and uncorrelated with each other.

When the intelligent vehicle user uses the spectrum resource k on the idle signal channel, its transmitted data is no longer interfered with by other users, and at this time, the signal of the vehicle at the receiving end can be expressed as

$$y_{i,k} = \sqrt{p_{i,k}^{V}L_i}\,h_i s_i + n. \tag{4}$$

The corresponding signal-to-noise ratio is

$$\xi_{i,k}^{V} = \frac{p_{i,k}^{V}g_i}{\sigma^2}. \tag{5}$$

The signal transmission rate in a complex wireless system is then calculated by the formula

$$r^V_{i,k} = X \log_2 (1 + \xi_{i,k}), \tag{6}$$

where the mean of n is 0 and X is the variance, which is calculated as follows:

$$X = \arg\min \left\{ \sum_{i=1}^{N} \sum_{j=1}^{N} x_{i,j} c_{i,j} \right\}. \tag{7}$$

When two transmission modes share the same spectrum resources, the signal interference phenomenon occurs. Considering this situation, the signals received by the vehicle are

$$y_{i,j} = \sqrt{p^V_{i,j} L_i} h_i s_i + \sqrt{p^C_{i,j} L_{i,j}} h_{i,j} s^C_{i,j} + n. \tag{8}$$

It corresponds to a signal-to-noise ratio of

$$\xi^V_{i,j} = \frac{p^V_{i,j} g_i}{p^C_{i,j} g_{i,j} + \sigma^2}. \tag{9}$$

The expression for the rate at which the signal is transmitted between is

$$r^V_{i,j} = X \log_2 \left(1 + \xi^V{}_{i,j} \right). \tag{10}$$

Assuming that the interference signal caused by transmitting is 1, the transmitting power increases for a larger number of users in a multiplexed cellular network, calculated as

$$\xi^C_j = \frac{p^C_j g_{i,B}}{\sigma^2}. \tag{11}$$

The transmission rate corresponding to the signal it generates is

$$r^C_j = X \log_2 \left(1 + \xi^C_j \right). \tag{12}$$

In this complex wireless signal system, the transmit power expression for multiplexing cellular users is as follows:

$$\eta^C_{i,j} = \frac{p^C_{i,j} g_{j,B}}{p^V_{i,j} g_{j,B} + \sigma^2}. \tag{13}$$

It has a transmission rate of

$$v^C_j = X \log_2 \left(1 + \eta^C_j \right). \tag{14}$$

Combining the above multiple scenarios, then the mathematical modeling ensemble formula for maximizing the utility function of smart car users in this study is as follows:

$$(X*, P*) = \arg \mathrm{MAX} \left\{ \sum_{i=1}^{N} \sum_{j=1}^{M} x_{i,j} u(p)_{i,j} \right\}. \tag{15}$$

Finally, an activation function is selected for the mathematical model established, because if the activation function is not included in the mathematical model established in this study, then it is only equivalent to a linear regression model and cannot handle the logic of more complex signal systems. The introduction of the activation function into the dynamic system changes the monotonic processing model into a nonlinear one, which can represent and calculate more complex smart car signal transmission situations. ReLU has sparsity, which enables the sparse model to better mine relevant features and fit the training data. In the region of $x > 0$, the gradient saturation and gradient disappearance will not occur. The calculation complexity is low, and the exponential operation is not required. The activation value can be obtained as long as there is a threshold value. The main monotonic functions commonly used today are the Sigmoid function and the ReLU function, and their respective function diagrams are shown in Figure 3.

The choice of different activation functions applied to complex wireless signal systems can have an impact on training and prediction, which in turn can sway the computational results. When using the Sigmoid function to compute large-scale data, it generates large errors, while using the ReLU activation function can converge quickly, achieving computational savings and improving training efficiency. Moreover, for dynamic deep music models, the gradient of the ReLU function is constant, and there is no gradient disappearance as in the case of the Sigmoid function. As mentioned above, therefore, the ReLU function is finally chosen as the activation function for mathematical modeling in this study.

4. Application of Mathematical Modeling in the System

The mathematical model developed in this study has a high recall value and will have a strong predictive power when calculated using positive class samples, which can be used in complex wireless signal systems for smart cars. To verify the signal transmission accuracy of the mathematical model developed in the previous section, it is used to compare with three mathematical models commonly used in traffic systems today. These three models are the BinOCT model, CART model, and C4.5 model, and the results obtained from the tests conducted under the same conditions are shown in Figure 4.

A comparison with three commonly used mathematical models shows that the mathematical model established in this study has a better transmission accuracy in all segments in dealing with complex signal systems. When the number of signal leaf nodes is in the interval of 25 to 30, the signal

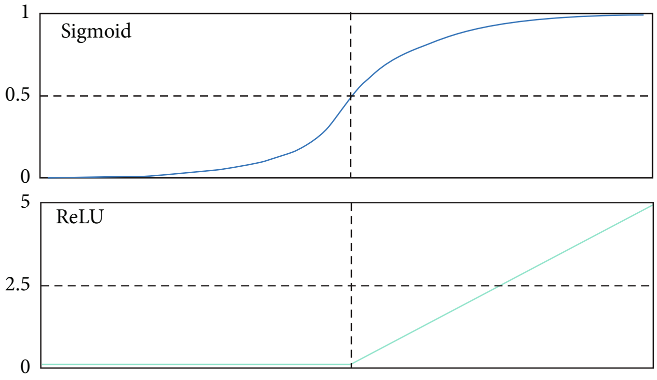

Figure 3: Schematic diagram of Sigmoid function and ReLU function.

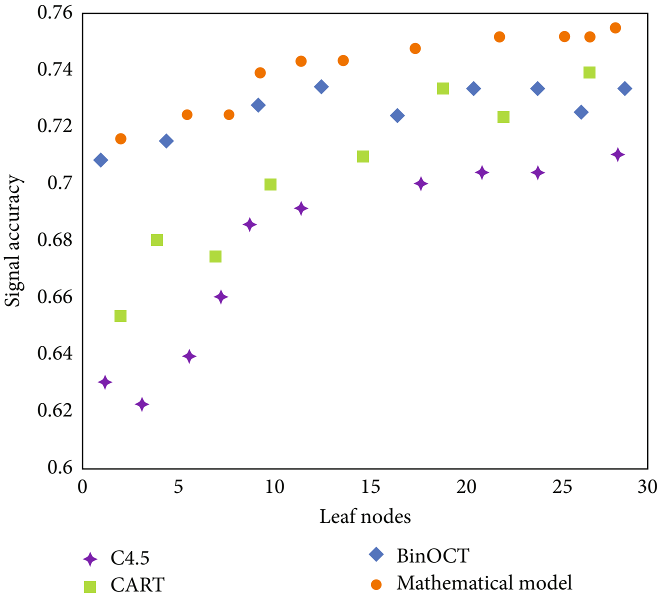

Figure 4: Comparison of signal transmission accuracy with three common mathematical models.

transmission accuracy is even the highest at 75.6%. This indicates that the use of branch boundary constraints reduces the search space and also achieves high classification prediction accuracy. In the interval 0 to 10, where the number of signal leaf nodes is small, the mathematical model developed in this study also shows good accuracy. This indicates that the model has good performance in maintaining sparsity without weakening its signal transmission accuracy.

This experiment next selects the variation of the accuracy of the mathematical model with the number of signals in the three signal patterns for different values of the number of random signals in the smart car communication system. The obtained results are shown in Figure 5.

The overall increase in signal accuracy of the mathematical model for the three signal modes with the number of seeds of the system signal indicates that the more layers of the tree generated for the actual transmission of the signal, the higher the accuracy of the propagation. However, the phenomenon decreases slightly after reaching a critical value. This may be because too much tree depth will generate overflow tree nodes, resulting in a decrease in signal propagation accuracy. Therefore, the maximum tree depth is the optimal solution for the three signal propagation modes. Then observing one by one, it can be found that the vehicle-to-vehicle signal transmission mode V2V has the highest accuracy, and the accuracy increases as the number increases. This is due to the fact that the mathematical model in this study focuses on eliminating the Doppler effect caused by signal transmission between vehicles. The V2P mode between vehicles and pedestrians or cyclists and the V2N mode between vehicles and the central network, although the signal transmission accuracy is lower than V2V2, reach a minimum of more than 85% at a signal leaf number of 11, which can fully meet the demand in practical use. The above test results show that the mathematical model established in this study can propagate signals more accurately in the case of all three signal modes, which is scientific and reliable.

A number of vehicles in different states of the traffic system are selected, and the relevant data are collected to draw

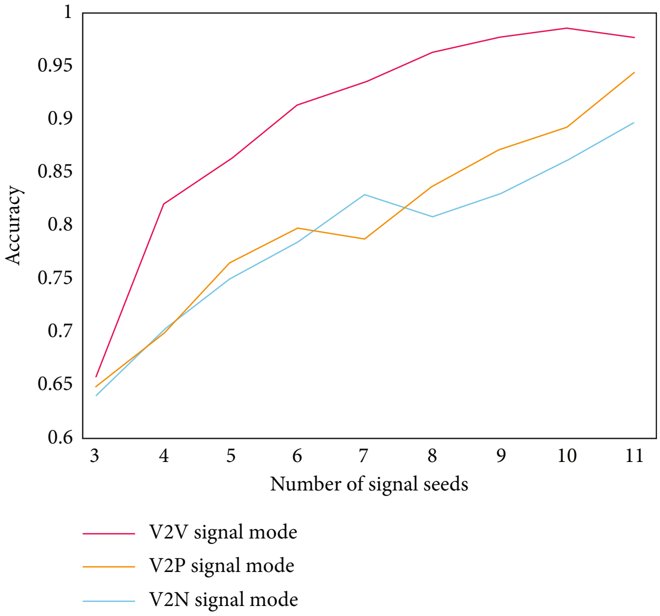

Figure 5: A line graph of the accuracy of the mathematical model in three signal modes as a function of the number of signals.

ROC curves using a mathematical model. The three main modes of vehicles on the road are selected: waiting state, free driving state, and slow driving state. Therefore, the aggressiveness of vehicles and the vulnerability of roads will be analyzed as indicators also in the field of transportation. In this study, the ROC curve and confusion matrix are used to characterize these two measures, respectively, and the results are shown in Figure 6.

The four ROC curves in Figure 6(a) reflect the degree of damage caused by the attack of the vehicles on the road in different states and also the load they impose on the complex wireless signal system that assumes the role of scheduling and communication in traffic in different states. It can be seen that the freer and more complex the movement behavior of the vehicle, the greater the load it causes to the road and the system. The initial increments in all three states are rapid and have a large slope, and this trend slows down considerably when a certain point is reached. The possible reasons for this are that the mathematical model developed for this study requires a large amount of kinetic energy to process the initial signal data, but once the system is operating smoothly, the signal data can be collected, analyzed, and transmitted in a stable manner. The results of the confusion matrix show that the rational use of the mathematical model, proper guidance and scheduling of vehicles, and keeping the vehicles informed of their surroundings can effectively reduce the pressure on the road and the signal system.

The mathematical model also allows for scheduling optimization of traffic flows during peak traffic periods. From the collected data hierarchy strategy, it is clear that the parameters to be iterated are the peak traffic period, peak traffic section, and announcement traffic distribution. Therefore, the existing registered vehicles are first processed in the model according to the splitting strategy to aggregate them. Then, using the feature that the number of vehicles passing the target road section in one day and night must be nonconsecutive positive integers, the interval time of vehicles is used as a reference to achieve loss-free iteration using the mathematical model. Taking the smooth operation of public transportation as the starting target, the target value is gradually optimized through layer-by-layer drawing, and finally, the regional road section passing capacity is effectively converged. Based on the improved mathematical model, to calculate the road throughput capacity of the iterative data map is shown in Figure 7.

After using the improved mathematical model to optimize the traffic flow of a road section, the throughput capacity of the road section for vehicles is significantly improved. And thanks to the enhanced information exchange between vehicles, between vehicles and pedestrians or cyclists, and between vehicles and the core network by the mathematical model in this study, the congestion during the peak commuting period is also greatly reduced.

The mathematical model conducted in this section next quantifies the optimization of complex wireless systems and intelligent transportation networks in the assessment. The use of radar plots enables a more detailed demonstration of the computational performance of the mathematical model established in this study in multiple dimensions. In this paper, the vehicle delay times at each intersection are selected as the raw data, and the resultant plots obtained after processing are shown in Figure 8.

In Figure 8, a total of six main roads correspond to six intersections with signalized groups in the target road network. They are arranged in a clockwise manner, and the average delay time of intersections without coordinated control optimization is enclosed by a blue straight line, while the average delay time of intersections after coordinated optimization is enclosed by a yellow straight line. The area enclosed by the blue straight line in Figure 8, i.e., the result of the data without optimization, has sharper edges, with the data at

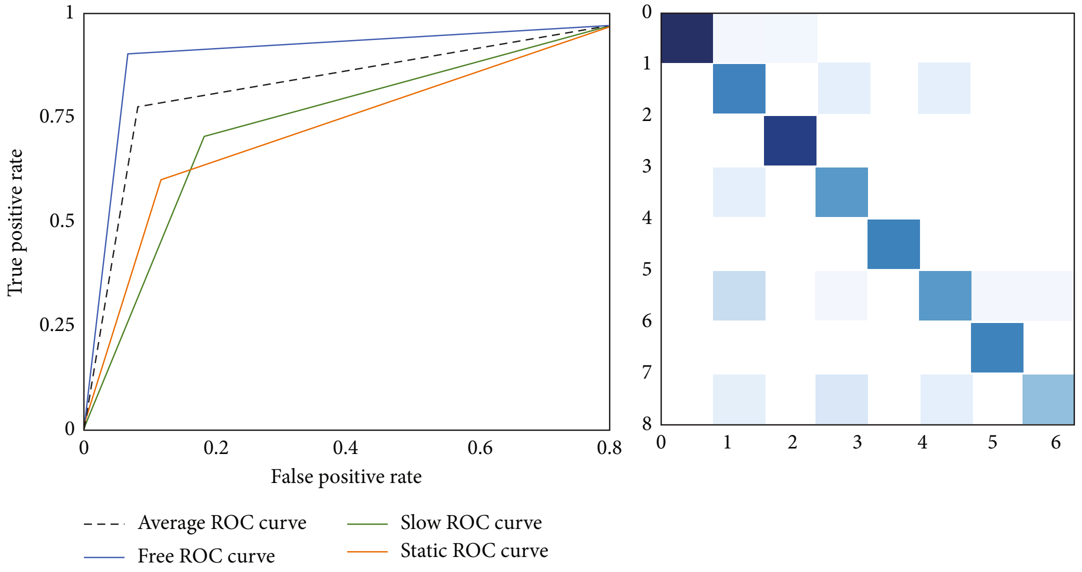

Figure 6: ROC curves and confusion matrix plots for three vehicle modes.

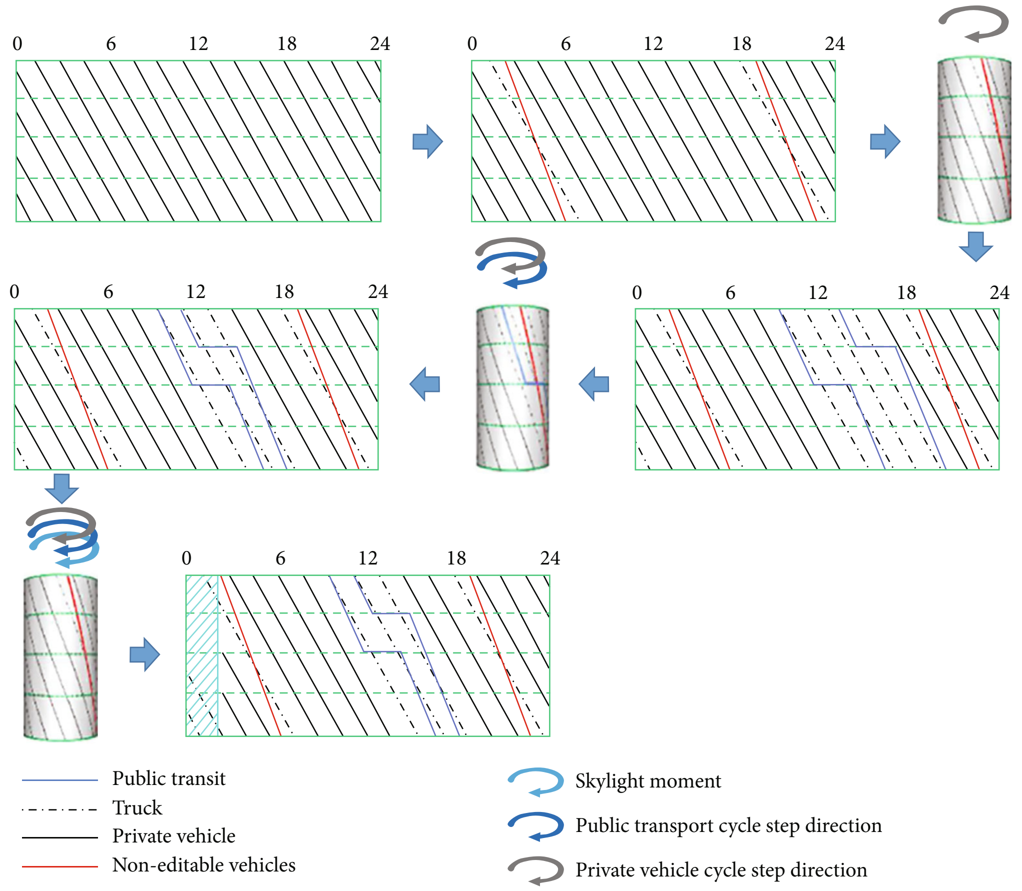

Figure 7: Calculation of vehicle passing ability data map of regional road sections based on improved mathematical model.

dimensions I18 and T16 being the most distant from the center point and the data at I3 being the closest to the origin. The graph formed by the area enclosed by the yellow lines is relatively rounded, mainly thanks to the data at I3 being enlarged, while the data at dimensions I9, T16, and I18 are significantly reduced. It is also obvious that the area enclosed by the yellow area is smaller than the area enclosed by the blue line, which means that the coordinated control

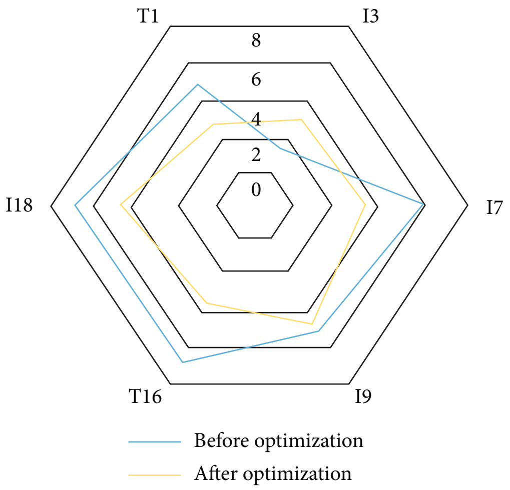

Figure 8: Mathematical model for congested road traffic optimization before and after the extension time radar map.

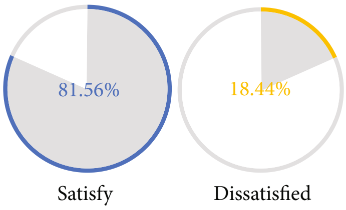

Figure 9: Satisfaction survey results of tested smart car drivers.

optimized timing scheme achieves the desired effect in coordinating the delay control and also reduces the average delay of all intersections in the network.

This mathematical model was added to the traffic network system for a three-month trial run. Then, a satisfaction questionnaire was distributed to 80 smart car drivers using the traffic complex wireless signal network, and the results are tallied in Figure 9.

The questionnaire results show that 81.56% of the smart car drivers are satisfied with this mathematical model, which again indicates that the results of this study and the mathematical model are scientifically valid in complex wireless signal systems. And still, 18.44% of smart car users made an unsatisfactory evaluation of this mathematical model. Collecting the details of the questionnaire revealed that the main points of their dissatisfaction were mainly insufficient signal strength in urban suburbs, the signal received during traffic congestion would be noisy, and sometimes, there would be no timely feedback about the presence of pedestrians next to the vehicle. To address these issues, this study will follow up and target to improve and optimize the mathematical model.

This chapter examines the full range of the established mathematical model, from the accuracy of signal transmission to the variation of the number of different signal leaves. The traffic of the three main modes of vehicle operation is also computed, and based on this, the target value is gradually optimized by laying out layer by layer with the starting objective that public transportation can operate smoothly. These relevant and necessary experimental groups have led to valid conclusions, and the results show that the mathematical model developed in this study is scientific and valid in complex wireless signal systems. The combination of the above experiments and their results is the only way to obtain excellent results with more than 80% satisfaction from the users.

5. Conclusion

In this study, a mathematical model is established based on the Doppler effect caused by signal propagation during vehicle operation. In order to verify the signal transmission accuracy of the developed mathematical model, it is compared with the three mathematical models commonly used in today's transportation system. The test results under the same conditions show that the mathematical model developed in this study has better transmission accuracy in all segments when processing complex signal systems. The mathematical model developed in this study also shows good accuracy in the interval 0 to 10 where the number of signal leaf nodes is small. This shows that the model maintains sparsity without reducing its signal transmission accuracy and has good performance. In the selected intelligent vehicle communication system, among the three signal modes with different random signals, the accuracy of the mathematical model changes with the number of signals. With the increase in the number of signal seeds in the system, the signal accuracy of the mathematical model is generally improved, which indicates that the more the number of tree layers generated for the actual transmission of signals, the higher the propagation accuracy. However, the phenomenon of a slight decrease after reaching the critical value may be due to the overflow of tree nodes caused by the excessive depth of the generated tree, resulting in the reduction of signal propagation accuracy. Select multiple vehicles in different states of the transportation system, collect relevant data, and draw ROC curves using mathematical models. Select three main modes of vehicles on the road: waiting state, free driving state, and slow driving state. It can be concluded that the more free and complex the motion behavior of the vehicle, the greater the load it exerts on the road and the system. The results show that the timing scheme optimized by coordination control achieves the expected effect on coordinating delay time control and reduces the average delay time of all intersections in the road network. However, the mathematical model of signal propagation has defects and needs further improvement. There is also the risk of data leakage. Smart car drivers and relevant practitioners should use the results obtained from the analysis wisely.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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