Research on intelligent system of expressway service area based on ant colony algorithm

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Abstract

In the process of urban construction and development, the comprehensive application of intelligent transportation system to solve the increasingly serious traffic problems in the expressway service area is the focus of the international community at present. Among them, optimal path planning is one of the most critical problems in intelligent transportation system, which can be handled by intelligent optimization algorithm at present, but there are still shortcomings in it. Therefore, some scholars have studied and proposed the application of ant colony algorithm, which can improve the applicability of problem solving and lay a solid foundation for the construction of high-quality intelligent system of expressway service area. In order to understand the construction and development status of intelligent system in expressway service area at home and abroad, this paper mainly studies the mathematical model of optimal path planning problem in intelligent transportation system, analyzes the ant colony algorithm and its simulation experiment research results, thus proving the application advantages of the algorithm in the system.

Keywords

ant colony algorithm, Highway, Service area, Intelligent system

1 Introduction

With the increase of highway mileage in our country and the low efficiency of highway operation more and more obvious contradiction, intelligent and information technology has become the inevitable trend of highway construction and development, and the state has also begun to encourage and support the intelligent development of highways in policy and other aspects. The process of urbanization has prompted the country's demand for intercity

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transportation infrastructure to gradually increase [1]. According to the National highway network plan, the national highway network will connect all provincial cities, large cities with an urban population of more than 500,000, and medium-sized cities with an urban population of more than 200,000. Covering more than 1,000,000,000 people in the country. With the continuous expansion of highway investment and construction scale, the demand for intelligent systems will also increase, the future development of highway network and the improvement of vehicle ownership will lead to more and more traffic pressure and traffic accidents, which will promote the government's investment in the field of intelligent transportation, laying a solid foundation for the innovation and development of the industry [2.3].

In the context of modern economic development, intelligent transportation system is a new research field proposed based on the development of information technology. It integrates artificial intelligence, cloud computing, big data and other technical means to closely link the three elements of vehicles, roads, people or things with transportation, and finally forms a harmonious and stable unity. Thus, a transportation management system with greater scope, higher efficiency, real-time accuracy can be built. From the long-term perspective of urban construction and development, the construction and promotion of intelligent system in expressway service areas is an effective strategy to solve traffic problems in the new era, especially in easing traffic squeeze, reducing traffic accidents, and steadily developing related industries such as automobile communication. Nowadays, the construction and research of intelligent system in expressway service area mainly achieve the following goals: First, solve the transportation problem. Transportation has a direct impact on social and economic development, so related problems can also hinder economic construction and innovation. For example, traffic accidents will cause a large number of deaths and economic losses, and road construction will affect the stability of the surrounding ecological environment [4]. These problems all prove that in the new era of rapid development of expressways, transportation problems have not been fundamentally solved. The construction of intelligent system can provide new ideas to solve the above problems, such as reducing the driving burden of drivers, effectively coordinating the management of transportation, and providing users with safe and comfortable travel modes. It can also make full use of the energy of the expressway service area to reduce the emission of transportation vehicles by increasing the traffic flow and other ways. To solve increasingly serious ecological and environmental problems; Second, create entirely new industries. Considering the current global economic growth and business development direction, the construction of intelligent system plays an important role in economic innovation and development. At present, it has occupied an important position in the travel information

service system, electronic toll collection system and automobile navigation system, and also provided new development ideas for the data communication industry and the automobile industry. Finally, comprehensively promote the information and engineering communication industry. With the continuous development of social economy and science and technology, people have higher and higher requirements for the travel environment. The construction of intelligent transportation system can not only effectively manage the transportation industry, but also build an advanced and effective information and telecommunication framework, which lays the foundation for the technological development and research and innovation of related industries. At present, the United States has made excellent achievements in the construction and application of intelligent transportation systems, and is one of the more successful countries. Its development planning, application status and investment have gained rich theoretical and practical experience. In the face of increasingly severe urban traffic congestion and safety problems in China, local governments have also increased the relevant construction investment, in Beijing, Shanghai, Guangzhou and other coastal areas began to pilot promotion, although the relevant construction theory has been initially developed, but the central and western regions because of the economic development is relatively backward, the application of more common is the highway toll system. There are few researches on the construction of traffic service area. Therefore, with the rapid development of social economy, it is necessary to strengthen the construction research of intelligent system in expressway service areas in the future, pay attention to showing the application advantages of intelligent algorithms, and scientifically solve the problems faced by system construction and application [5].

2. The development of transportation big data and transportation cloud platform

With the development of the transportation industry and the continuous innovation of information technology, the application of big data in the field of transportation has become increasingly important. Big data not only helps relieve traffic pressure and improve traffic efficiency, but also promotes the development of information consumption industry and improves urban residential satisfaction [6.7].

In the integration and analysis of traffic big data, it is necessary to consider its unique characteristics, such as heterogeneity, variety, dynamic change, large spatio-temporal scale span, locality, high randomness and limited life cycle. At the same time, because traffic big

data is closely related to People's Daily travel, it also has high requirements for real-time and accuracy of data.

For these features, here are a few possible solutions and suggestions:

1. Data integration and standardization: Establish a unified data standard and integration platform, so that various heterogeneous data can be effectively integrated and fused, and provide a unified data basis for subsequent analysis.

2. Real-time data processing: The use of cloud computing and edge computing and other technologies to efficiently process and analyze the traffic data generated in real time to meet the requirements of high timeliness [8].

3. Dynamic analysis and prediction: Through the analysis and modeling of dynamically changing traffic big data, the prediction and early warning of future traffic situation can be realized, providing scientific basis for traffic management and decision-making.

4. Privacy protection and data security: In the process of data collection, storage, transmission and use, it is necessary to strictly abide by the relevant laws and regulations on privacy protection and data security to ensure the security and legality of data.

5. Intelligent transportation system construction: Combining big data technology with intelligent transportation system to realize intelligent scheduling of traffic signals, intelligent navigation of vehicles and intelligent monitoring of traffic safety, so as to improve the level of intelligence and automation of traffic [9].

In short, the integration and corresponding analysis of traffic big data is of great strategic significance for realizing intelligent transportation, improving traffic efficiency and people's travel quality. In the future, we need to further strengthen the research and application of big data technology to provide strong support for the sustainable development of the transportation industry.

High timeliness of big data processing and multi-scale convergence computation

The need for high timeliness of big data processing: In the field of transportation, real-time data is crucial for traffic management and decision-making. Therefore, it is necessary to develop time-efficient big data processing methods that can quickly process and analyze real-time traffic data to provide timely and effective information for traffic managers.

Multi-scale convergence calculation: Considering the diversity and complexity of traffic data, it is necessary to adopt multi-scale convergence calculation method to effectively integrate and calculate data from different sources and different scales to extract more comprehensive traffic information [10].

New methods and theories: In order to meet the needs of high timeliness and multi-scale convergence computing, new big data processing methods and theories need to be proposed. For example, a distributed computing framework based on cloud computing or edge

computing can be developed to improve data processing efficiency using technologies such as parallel computing and stream processing. At the same time, the data fusion method based on graph theory or topology can be studied to realize the effective convergence of multi-scale data. Implicit knowledge mining and evolution model in multidimensional space. The importance of tacit knowledge mining: there is a lot of tacit knowledge in the traffic system, which is hidden in the high-dimensional space, and it is very important to understand and explain the traffic phenomenon. Therefore, advanced data mining and machine learning methods are needed to mine this tacit knowledge. The coupling relationship of the closed space of multi-dimensional ecosystem: there is a complex coupling relationship between traffic subject, situation, behavior, environment and road network topology. In order to study these relationships, a closed space model of multi-dimensional ecosystem can be constructed to simulate the operation and evolution process of traffic system by mathematical or simulation methods [11]. Sequential mining and evolution of tacit knowledge: When mining tacit knowledge, it is necessary to pay attention to the sequential and evolutionary nature of knowledge. In other words, we should not only discover the static tacit knowledge, but also study the law of the change of these knowledge with time and space. For this reason, methods such as time series analysis and dynamic graph theory can be used to explore and describe the evolution of tacit knowledge. Forecasting mechanism and control strategy of traffic situation. Prediction mechanism of traffic situation: The prediction of traffic situation needs to consider various factors such as environment, management, network topology, traffic demand, etc. To accurately predict traffic conditions, a predictive model based on machine learning can be built, using historical and real-time data to train the model and predict future traffic conditions. At the same time, simulation technology and optimization method can be combined to verify and optimize the prediction results. Formulation of control strategies: Based on the predicted traffic situation, corresponding control strategies can be formulated to optimize the operation of the traffic system. Regulation strategies can include traffic signal control, traffic guidance, traffic restriction measures, etc. In order to formulate effective control strategies, it is necessary to consider various factors such as traffic demand, road conditions and environmental factors, and verify and optimize them through simulation or experimental methods [12]. To sum up, in order to meet the needs of traffic big data processing, multi-dimensional tacit knowledge mining and traffic situation prediction and regulation, it is necessary to comprehensively apply various technologies and methods such as data analysis, data mining, machine learning and simulation optimization, and constantly innovate and improve relevant theories and method systems.

3. Method

3.1 Intelligent system

Based on the construction of expressway service area, the basic functions of intelligent system include the following contents: First, traffic information service system. This module is mainly used to provide location and other information services. It mainly uses transmission equipment and sensors to transmit real-time traffic information to the center. After analysis and processing, real-time transfer information, traffic information, weather information and parking lot information are provided. Second, traffic management system. This module mainly has the scientific management concept, which is mainly used for highway control, highway detection and highway traffic management, and provides communication methods between road transportation, vehicles and drivers. Third, the public transport system [13]. This module can realize data sharing, use professional software to show the location of vehicle transportation in real time, and use TV or computer to provide relevant information to the public, so as to facilitate users to choose convenient travel methods and routes; Fourth, the vehicle control system. This module can realize the highly intelligent goal of highway vehicle transportation, and can help drivers effectively control the vehicle, such as danger warning, obstacle avoidance, etc. Fifth, freight management system. This module is designed based on logistics theory, integrated use of network technology, satellite positioning and geographic information system, etc., can not only improve the efficiency of cargo transportation, but also ensure the safety and effectiveness of cargo transportation. Sixth, emergency rescue system. This module uses telephone, SMS, network and other ways to understand the trajectory and specific location of vehicle transportation in real time, and deals with vehicle theft, traffic accidents and other problems according to relevant information in an orderly manner, which can provide convenient services for road transport users. From the perspective of system operation, it contains three elements, and the relationship between them is shown in Figure 1 below: [14]

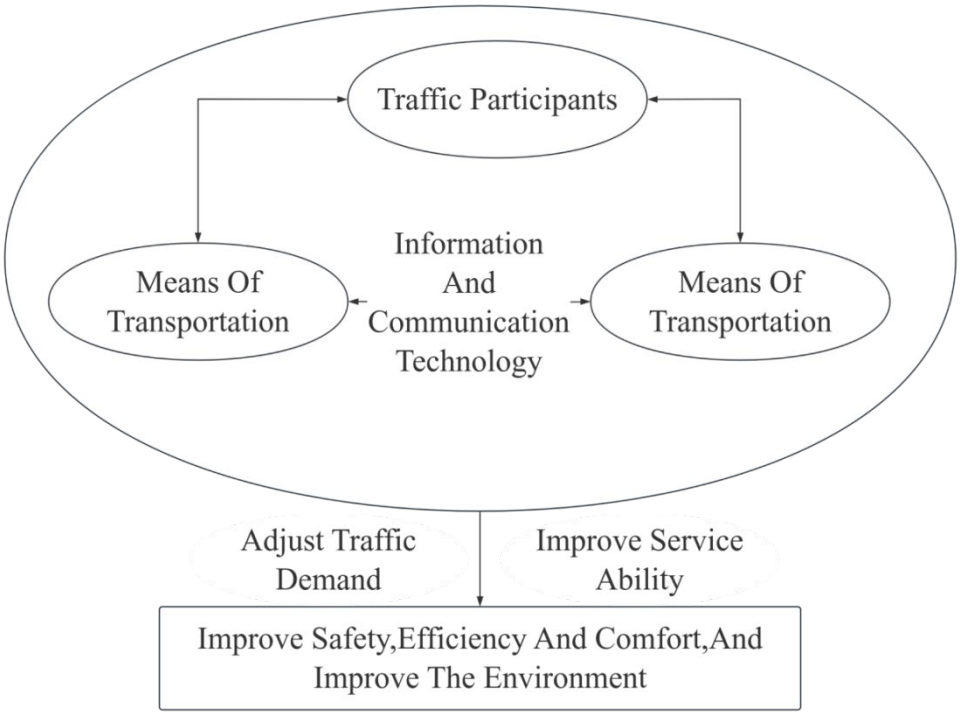

Figure 1: Structure diagram of elements of intelligent system.

3.2 Ant colony algorithm

After defining the intelligent system structure of expressway service area, some scholars put forward the so-called cluster intelligence when studying the data modeling of autonomous behavior. In the early 1990s, an Italian scholar proposed a new intelligent optimization algorithm of ant system based on the behavior characteristics of animals in nature. This algorithm was first successfully used to solve the famous traveling salesman problem and achieved good results. In the mid-1990s, ant colony algorithm attracted the attention of more scholars in the academic circle, and some scholars proposed new and improved algorithms according to their own experience, and ant colony algorithm was also widely used in other fields.

From a theoretical point of view, ant colony algorithms mainly follow the following rules:

First, foraging rules. Based on the structural diagram shown in Figure 2, it can be seen that ants will first perceive food, choose a route according to the result and forage for food; in another case, ants will choose a route according to the intensity of pheromone. Where the concentration is strong, ants will choose the direction and route of travel, and they will adopt the same rule when returning to the nest [15].

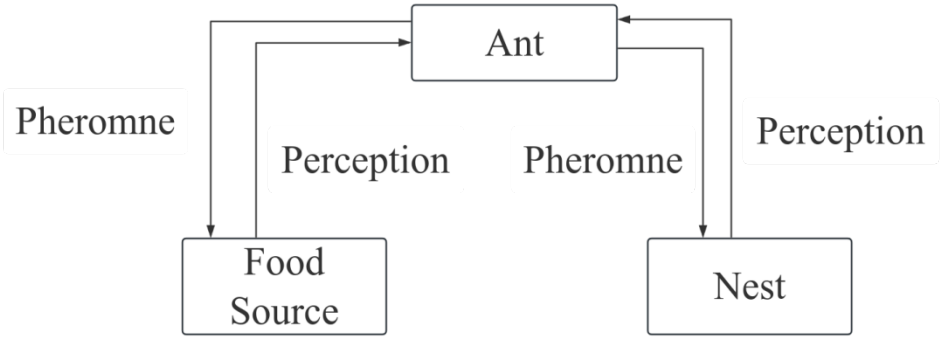

Figure 2: Structure of foraging rules.

Second, the rules of movement. Individual ants will move in the direction of more pheromones during movement, and when there is no pheromone smell around, ants will always move in the original direction, and will not change direction easily. This is because, in the process of movement, although the direction of movement may be randomly disturbed, the individual ant will record the points it has walked to prevent it from turning in circles, and if the next point to go has been recorded, then he will choose another point to ensure that the direction of movement will not change.

Third, obstacle avoidance rules. When an individual ant moves, if there is an obstacle to the next point that the ant wants to move, so that the ant cannot pass, and there is no pheromone to guide it, the individual ant will randomly choose another direction to move. If pheromones are present, then individual ants will act according to foraging rules, thus choosing the best foraging route.

Fourth, the pheromone rule. The pheromone concentration of individual ants is not average when they move, and the pheromone concentration is the highest when they just reach the nest or 15:00, and the concentration will decrease with the increase of the moving distance. In other words, individual legacy pheromone concentrations will continue to decrease with increasing distance.

The idea of ant colony algorithm is as follows: firstly, according to the complexity of solving the problem, the number of ants is determined, and the ant colony is regenerated; Then, the individual ant constructs a feasible solution or a part of a feasible solution through the path exploration, and regards it as the initial solution; After the initial solution is determined, the ant colony algorithm is carried out to randomly select several initial nodes and place ants on this point. The ants will start from the initial node, select the next point as the moving target point according to the heuristic information or pheromone concentration

on the path, and repeat this choice until they find a feasible solution, which is the overall solution process. The flow of ant colony algorithm is shown in Figure 3 below:

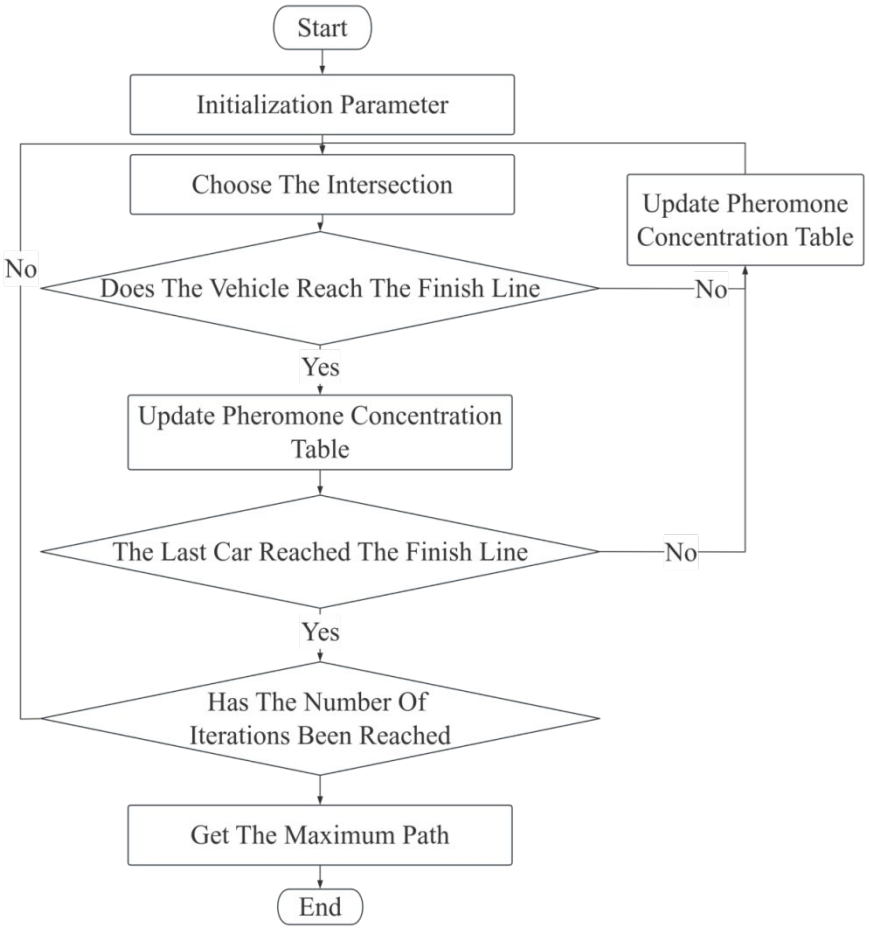

Figure 3: Flow chart of ant colony algorithm

4. Result analysis

The construction of intelligent system in many cities is regarded as the research goal, and the concentration of sex hormone and heuristic factors are selected to verify and analyze in the simulation study. Among them, pheromone concentration refers to the amount of information released by ants, which directly affects the positive feedback ability of the algorithm and determines the efficiency of finding the optimal solution. Specific results are shown in Table 1 below:

Table 1

Comparative results of the influence of pheromone concentration

Pheromone concentration q	Optimal path length
100	15602
300	15602
500	15584
700	15602
900	15620

The results of heuristic factors are shown in Table 2 below:

Table 2

Comparison results of influence of heuristic factors

Pheromone heuristic factor	Optimal path length
100	15602
300	15602
500	15584
700	15602
900	15620

Based on the analysis of the above table, it can be seen that the reasonable range of parameter selection and the final operation result of the ant colony algorithm can be clarified by using the basic ant colony algorithm model for solving and analyzing, which provides a reference for the optimal route selection of vehicles in the field of intelligent transportation in the new era. From the perspective of long-term development, although there are still many problems in the research and promotion of intelligent system, the application of basic algorithms and other heuristic solving strategies for comprehensive research, reasonable selection of ant colony algorithm parameters, can lay a solid foundation for the construction of high-quality highway service area intelligent system. Therefore, future scholars should continue to explore the structure and application function of intelligent system of expressway service area based on ant colony algorithm.

5. Conclusion

In summary, as the focus of urban development in the new era, the research on the construction of expressway service area should reasonably apply ant colony algorithm to solve various problems in the construction of intelligent system, clarify the application advantages and technical defects of the algorithm, and pay attention to the establishment of

a reasonable mathematical model according to the required conditions, so as to better serve the social and economic development. Finally build a system architecture that meets the needs of residents.

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Reference

[1] W. Li, “Research on location selection of expressway concrete Mixing Plant based on Ant colony Algorithm,” Journal of Wenzhou University: Natural Science Edition, vol. 44, no. 2, pp. 47-54, 2023.
[2] Z. Wei, “Research on path planning Algorithm based on improved Ant Colony Algorithm,” High-speed Railway Technology, vol. 5, pp. 69-74, 2023. (in Chinese)
[3] C. Ma, R. Yang, J. Yu, et al., “Research on Powder Metering System of Continuous Asphalt Mixing Equipment based on Ant Colony Algorithm,” Construction Machinery, vol. 009, pp. 053, 2022.
[4] W. Zhang, “Path planning of self-propelled fertilizer spreader in irrigation area based on ant colony algorithm,” Modern Agricultural Equipment, vol. 43, no. 3, pp. 7, 2022.
[5] W. Sun, W. Li, “Path planning of Mowing robot: Based on improved ant colony algorithm and computer vision,” Agricultural Mechanization Research, vol. 44, no. 1, pp. 5, 2022.
[6] H. Xu, X. Chen, M. Hou, et al., “Research on material distribution in Modern war -- Ant colony algorithm model based on multi-objective optimization,” Computer Science and Applications, vol. 14, no. 2, pp. 9, 2024.
[7] X. Yin, “Research and design of location privacy Protection Intelligent Transportation System based on Ant colony algorithm,” Journal of Leshan Normal University, vol. 38, no. 8, pp. 40-45, 2023. (in Chinese)
[8] T. Qu, “Research on distributed web crawler system based on ant colony algorithm,” Information and Computer, vol. 35, no. 12, pp. 88-91, 2023. (in Chinese)
[9] M. Liu, S. Zhang, H. Sun, “Research on Adaptive Vehicle-Road Cooperation Message Transmission based on Ant Colony Algorithm,” Automotive Technology, vol. 3, pp. 35-41, 2023. (in Chinese)
[10] Y. Yang, “Research on Optimal Route of Intelligent Transportation based on Ant Colony Algorithm,” Shihezi Science and Technology, vol. 1, pp. 56-58, 2023.

[11] W. Tong, Q. Huang, “Research on fire hazard perception and intelligent evacuation decision model based on improved ant colony algorithm,” Microcomputer Applications, vol. 003, pp. 038, 2022.
[12] J. Wang, “Research on dynamic shortest time path calculation based on Ant colony algorithm,” Wireless Internet Technology, vol. 20, no. 10, pp. 141-143, 2023. (in Chinese)
[13] J. Liu, X. Gu, L. Chen, et al., “Research on grazing path optimization based on improved ant colony algorithm,” Computer Simulation, vol. 40, no. 7, pp. 305-310, 2023. (in Chinese)
[14] C. Xu, Q. Gong, “Research on robot path planning based on improved ant colony algorithm,” Journal of Henan University of Urban Construction, vol. 32, no. 4, pp. 91-96, 2023. (in Chinese)
[15] X. Shen, Y. Shi, Y. Huang, et al., “Path planning based on bidirectional ant colony algorithm,” Journal of Harbin Engineering University, vol. 44, no. 5, pp. 865-875, 2023. (in Chinese)