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Application of graph theory in transportation linkage in logistics management and its computer aided model design

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Abstract. Path planning is an important part of logistics management and an important part of intelligent transportation system. The shortest path problem in graph theory is the theoretical basis of path planning. On this basis, this paper studies the application of graph theory in logistics management and transportation linkage and its computer-aided model design. In order to give full play to the advantages of the optimized road network model, this paper adopts the matching path planning algorithm and control strategy. The optimized road network model puts forward a partition method based on data quantity and connectivity principle and realizes the equalization of partition data quantity. Compared with the general road network model, the established road network partition is more reasonable and more in line with the actual requirements of the path planning algorithm. Through the research in this paper, it provides a reasonable and effective solution for practical application, which is innovative and practical.

Keywords: Graph theory, logistics management, transportation path

1. Introduction

Path planning is an important function of GIS and an important part of intelligent transportation system. Its theoretical foundation is the shortest path problem in graph theory. In practical application, although many factors such as distance, time, speed, charging, turning and traffic lights need to be considered, the core problem can be summed up as the shortest path problem with different weights [1]. Because logistics management system is limited by hardware conditions such as storage space and computing capacity, it is necessary to effectively solve the storage and computing problems in path planning, especially in large area wide area path planning. At present, the traditional hierarchical data structure provides an effective solution for the path planning algorithm which divides the hierarchical data structure into the scale of urban road network by vertical and horizontal layers. However, for provincial and even national wide area road networks, there are still problems such as uneven data volume and too many subnetworks. There is a certain gap between the rationality of the path planning and the calculation efficiency [3]. If these problems can be well solved, the path planning will be more effective and

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the planning results will be more scientific and reasonable. The research results can be further applied to logistics distribution, operation management, transportation planning and other application systems, greatly improving the road traffic capacity and transportation efficiency of the entire road network, and reducing operation costs. Therefore, the research of this topic has important theoretical and practical significance [4].

Based on the summary of previous studies, this paper adopts the matching path planning algorithm and control strategy, and the application of graph theory in logistics management and transportation links are studied, designing a computer-aided model. The optimized road network model effectively solves the problems of storage space and calculation efficiency in wide area path planning and calculation, provides a reasonable and effective solution for practical application, and has certain innovation and practicality [24].

The optimized road network model puts forward a partition method based on data quantity and connectivity principle, and the equalization of partition data quantity is realized. Compared with the general road network model, the established road network partition is more reasonable and more in line with the actual requirements of the path planning algorithm. The full text is divided into five parts. The first part is the research background and significance; the second part elaborates the research status of this paper, which lays the foundation for the follow-up study of this paper; the third part is the research methods, mainly introduces the construction and algorithm of the model; the fourth part is A. The model is applied to practical engineering and achieved good results, summing up Marie.

2. Related work

Since the hardware platform adopted by the logistics management system is significantly lower than the PC in terms of computing power and memory size, the path planning in the logistics management system must solve the memory and computational problems [5]. A large number of experts and scholars at home and abroad have made a lot of improved algorithms and new algorithms through in-depth research, involving computational efficiency, data model optimization [21], wide-area massive data storage and many other aspects, which are unique in terms of spatial complexity, time complexity, ease of implementation, and scope of application [6]. However, at present, the research results of wide-area path planning algorithms in China are relatively few; especially the depth of research on data organization technology is inadequate. There is a certain gap between the rationality of planning and the efficiency of computation and practical application. If these problems can be solved well, the path planning results can be more scientific and reasonable, and have important theoretical value for the development of application systems [7]. Path planning is an important function of the logistics management system and an important part of the intelligent transportation system [22, 23]. It can help drivers choose the route with the shortest route or the least time or the lowest comprehensive cost in the crisscrossing road network, which is very convenient for people to travel. Path planning is applied to other application systems such as logistics distribution, operation management, transportation planning, which can greatly improve the road capacity and the transportation efficiency of the entire road network, reduce operating costs, and achieve intelligent transportation and management purposes [8]. Therefore, the research of this topic has important practical significance.

3. Logistics network design and algorithm

3.1. Design of logistics network model based on graph theory

The improvement of the new model in road network layering and partitioning, SD layer establishment, data volume control, and cost parameter pre-existence fully considers the applicability of the path planning application algorithm. Therefore, in the navigation system, the optimized road network model should be used as the basic architecture based on the system operation, and the path planning algorithm suitable for optimizing the characteristics of the road network model should be adopted [9]. According to this idea, a two-way hierarchical path search strategy and a road radiation angle-based control method are adopted to achieve satisfactory requirements for wide-area path planning. The search strategy of the optimization model is mainly implemented in the following three ways. The traditional one-way search method always selects the starting point as the starting point of the search path, adopts the form of tree branch search, and passes the next level node (i.e.,

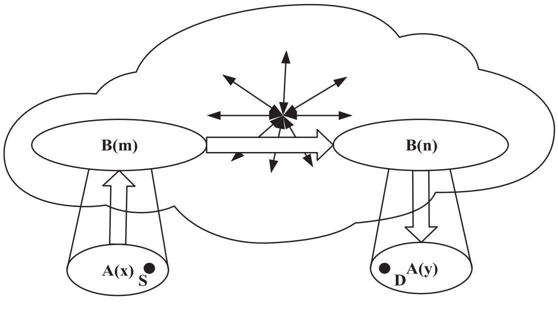

Fig. 1. Schematic diagram of one-way search.

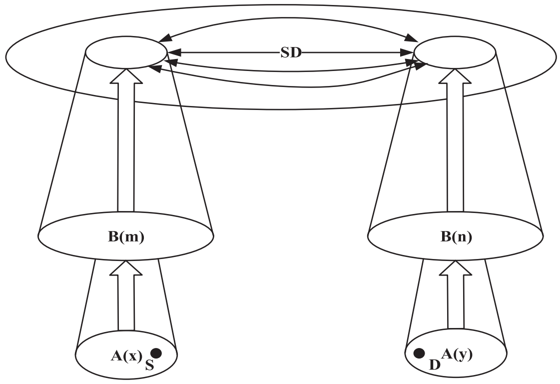

Fig. 2. Schematic diagram of two-way search.

intersection) step by step, selects the next level through the path, and finally reaches the target point. On the basis of this, the optimization model adds a method of retro-tracking from the target point. That is, while adopting the one-point search of the starting point, a feasible entry path is selected from the target point for step-by-step tracing, the searching operations in two directions meet at the target locations of the feasible paths, and a complete path is finally determined [10]. The road network handled in this paper covers several provinces, dozens of cities, hundreds of thousands of roads of various grades, and there are many traffic schemes between nodes. This two-way search method makes full use of the path information in the fan-in/fan-out direction provided for each node in the existing data structure, and the search efficiency is greatly improved compared with the one-way mode by improving the utilization of data. At the same time, by using an algorithm customized for the two-way search method, the path search direction from each node can be limited to a range with a relatively high success rate (i.e., a direction in which the start point and the target point face each other) [11]. In the traditional algorithm, the method for finding the path between the two points S and D in the map is as shown in Fig. 1. Set S as the search starting point, first find the boundary point that it can reach in the partition A(x), map it to the upper partition B(m). Starting from the upper partition, the upper partition B(n) of the underlying partition A(y) containing D is searched; then B(n) is mapped down to the lower partition A(y), and finally the target point D is searched. Let the number of optional paths in A(x) be xl, the number of paths from B(n) to A(y) be x2, and the number of paths to B(m) be x0, then the number of possible paths for all searches is $X = xl*x2*x0$ [12].

In the path planning algorithm for optimizing the road network model, the method for finding the path between the two points S and D is as shown in Fig. 2: set S and D as the starting point and the target point respectively. First find the boundary points that can be reached in the bottom partitions A(x) and A(y), respectively, and map them up to the upper partitions B(m) and B(n) respectively. In the second layer partition, the boundary points of B(m) and B(n) are mapped up to the top layer (SD Layer) respectively; the SD Layer design rules ensure that B(m) and B(n) can exist simultaneously in a single SD Layer partition C(mn), in which possible paths between B(m) and B(n) can be searched. Set the number of optional paths in A(x) be yl, the number of optional paths in A(y) be y2, the number of paths from B(m) to SD be y3, and the number of paths from B(n) to SD be y4. The number of paths in the SD Layer partition C(mn) be y0, then the total number of possible search paths is $Y=(y1*y3 + y2*y4)*y0$.

According to the characteristics of the optimized road network model, (yl*y3 + y2*y4) is of the same order of magnitude as (xl*x2) (because there is a direct correspondence between the lower layer Region and the upper layer SDRegion), and y0 is less than x0 multiple orders of magnitude. Therefore, Y is much smaller than X, that is, the bidirectional search method can significantly reduce the software calculation workload, and greatly improve the computational efficiency [13]. The path network is layered and partitioned. During the search process, the search path can be selectively established in view of the actual situation of the searched path and related nodes. Since the correspondence between the road level and the zoning level has been taken into account in the stratification process, the different levels of zoning correspond to the corresponding level roads (for example, the high-level roads can be directly located in the high-level zoning). Therefore, the search can be performed at

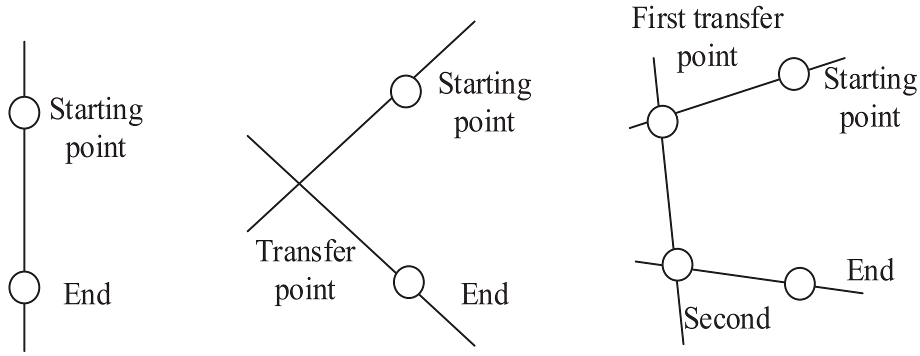

Fig. 3. Various transfer requests at the two site.

different levels for the actual needs of different grades of roads, which not only optimizes the number of objects to be searched (different grades of roads), but also facilitates switching in different levels of search operations.

The hierarchical search method can be described as follows: after two nodes in a given road network are used as the starting point and the target point of the path planning. First, determine whether they belong to the same lowest level partition, and if so, the search path is directly given by calling the corresponding subroutine in the lowest level partition. If they do not belong to the same lowest-level partition, calculate the search path of this level in the partition in their respective underlying partitions, and directly reach the edge node of the underlying partition [14]. Then, find the upper layer (Layer 2) node corresponding to the searched bottom edge node. If the two nodes in Layer 2 belong to the same Layer 2 partition, the search path can be directly given in the partition of Layer 2; otherwise, the search paths of the two points in the respective partitions of Layer 2 are respectively calculated, until the edge node of the layer partition. Since the same partition in which any two nodes are located has been divided in the highest level SD Layer, it can be ensured that the two corresponding nodes of the two Layer 2 partition edge nodes in the SD Layer belong to the same SD partition. And it is guaranteed that a top path connecting the two nodes is searched in the SD Layer [15]. Combined with the paths searched in Layer 1, Layer 2 and SD Layer, a complete access path connecting the starting point and the target point can be finalized. In this process, the data information to be input is: a vectorized hierarchical road network with a topology, a starting point S, and a target point D. The final output is an optimal path between node S and node D. In the process of establishing the optimized road network model, the angle of the road segment has been pre-existed in the road network data as the cost parameter. Therefore, in the search strategy, the control mode based on the road radiation angle can be used to control the direction and range of the path search according to the road auxiliary angle. Thus the initial search direction at the starting node is consistent with the azimuth interval of the target node, which not only ensures the search result is reasonable, but also saves a lot of system resources originally consumed in the unreasonable search direction [16].

3.2. *Logistics transportation path planning algorithm*

The path planning algorithm based on the optimized road network model effectively combines the two-way, hierarchical path search strategy and the control method based on road radiation angle under the overall control system architecture, which can make full use of the characteristics and advantages of the improved optimized road network model to achieve the desired calculation results. The basic functions of the algorithm are as follows: the input and output of the algorithm: Input: The road network established by the optimization model, the starting point S and the target point D are any two nodes specified in the road network. Output: An optimal path between node S and node D [17]. The basic flow of the algorithm is as follows: Initialization: Allocate memory space for the data structure used in the path calculation process, assign initial value, and mainly complete the setting of road network data loading and program running environment. Determine the level of the road network where the nodes S and D are located. If the nodes S and D are already on the high-level road network, go to step (3); otherwise, it must first search for the shortest path from the high-level road network and the corresponding node S' on the high-rise road network in a small area near S [18]. At this point, the search in this area will consider both the high-level road network and the low-level road network. Similar processing is done for node D. In the high-level road network, the node S (or corresponding node S') and D (or the corresponding node D') are called, and the corresponding path planning subroutine is called to perform the shortest path calculation. Through the same layer search, ascending layer search and connection layer search, the data information of many nodes and road segments and related costs are obtained, and the optimal road that meets the path calculation conditions is selected, then an optimal short path between nodes S and D is output comprehensively.

4. Experimental design and analysis

The content of this experiment is: According to the optimized road network model, the wide-area road network data is effectively organized, and two nodes with actual distance greater than 2000 km are selected as the starting point and target point of the path search in the wide-area road network. Calculate according to the priority conditions of the idle speed road, and compare the experimental results with the effects of the traditional method [19]. The purpose is to verify the correctness of the path planning results in the long-distance situation, and verify that the optimized road network model is reasonable and effective for the data organization of the wide-area road network, and the wide-area path planning calculation based on the optimized road network model is accurate and efficient. This experiment takes Tiananmen Square and Shenzhen World Trade Plaza as the starting point S and target point D of the path search. These two nodes are located in two large-scale urban road networks in Beijing and Shenzhen, and the linear distance between the two nodes is greater than 2,000 km. The urban road network data of Beijing and Shenzhen and the wide-area connection road network data between them include the real road traffic rules, road grade, width, road length, and the number of road sections is more than 200,000. Due to the large coverage, complex topology, and many attribute attributes, the data volume of the entire road network is close to 800 MB.

First, the data is organized according to the method of optimizing the road network model, and then partitioned and layered. The unit partition data size is set to 512 KB, which is divided into Layer 1, Layer 2 and SD Layer three-layer structure. The Layer 1 partition is built on the basis of the data-based partitioning method based on the standard MESH, so that the data volume of each partition of Layer 1 is controlled to a suitable range of 512 KB. In the Layer 1 partition, the Layer 3 or higher functional road corresponding to Layer 2 is extracted to form the Layer 2 high-level road network, and then the Layer 2 partition is formed by merging adjacent partitions according to data volume balancing and road network connectivity. Finally, the Layer 2 and above functional roads are extracted from the Layer 2 partition to form an SD layer network. The high-level road network of each pair of Layer 2 and the Layer 2 partitions that may be involved are combined to form their SD partitions. The optimized road network after completion includes: 1727 Layer 1 partitions, 133 Layer 2 partitions, and 8971 SD Layer partitions.

Then, the data is organized according to the traditional road network model, and the data is partitioned and layered. The total number of Layer 1 partitions formed after dividing the road network according to the standard MESH and other areas is more than 8000, the maximum partition data volume is 1590 KB, and the minimum partition data volume is only 2 KB. According to the 8*8 merge extraction high-level road network, more than 120 Layer 2 partitions are formed, and the data volume of the largest Layer 2 partition is 720 KB. Therefore, the path planner corresponding to the traditional road network model allocates a minimum memory space of 2048 KB for a single partition. Finally, for the data organized by the above two road network models, the same path planning algorithm—two-way hierarchical search method and radiation angle control method A* improved algorithm is adopted to compare and theoretically analyze the path planning calculation results based on these two kinds of data, which proves the effectiveness and advancement of the optimized road network model [20]. According to the method of experimental design, the maximum memory space, the time of calculation, the calculation results and the total mileage of the single partition required by the traditional road network model and the optimized road network model are shown in Table 1.

According to the comparison of experimental results, it can be clearly found that the optimized road network model is better than the traditional road network model. The difference between the two is mainly reflected in the memory resource consumption, although the number of partitions on Layer 2 is

Table 1
Comparison of experimental results

Project	Traditional road network model	Optimization of road network model
The maximum memory space required for a single partition	2048 KB	512 KB
Search criteria	Highway priority	Highway priority
Total mileage	2475.471 km	2431.492 km
Total travel time	36 hours and 2 minutes	30 hours and 13 minutes
Time consumed by operation	63.3 seconds	8.6 seconds

Fig. 4. Wide area path planning results using optimized road network model.

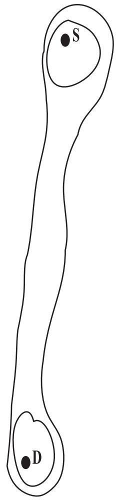

Fig. 5. Schematic diagram for optimizing the search range of road network model algorithm.

basically the same. The difference between the maximum and minimum values of the unit partition data of the traditional road network model is tremendous, and the consumption of memory resources is much larger than that of the optimized road network model. In terms of search range control, by comparing the two diagrams of Figs. 5 and 6, it can be clearly found that: the data organized by the optimized road network model, the path planning only involves two partitions of the starting point S and the target point D on Layer 1, the two corresponding partitions of Layer 2, and one SD partition, for a total of five partitions (see Fig. 5). As the data organized by the traditional road network model, the path planning will involve the two partitions of the starting point S and the target point D on Layer1 and 15 consecutive partitions on Layer 2, for a total of 17 partitions (see Fig. 6, the space search range of the former is much smaller than the latter.

The SD in the optimized road network model is a continuous road network. There is no need to repeat the partition combination and edge processing in the calculation process. However, the traditional road network model has a small number of partitions in Layer 2 (15), since the segment at each edge of the partition is at least a hundred or so. It takes a lot of time to perform the edge processing on these Layer 2 adjacent partitions in the calculation process, and the latter has much longer time expenditure in this respect than the former. Therefore, compared with the two, the efficiency of wide-area path planning based on the optimized road network model is greatly improved, and the requirements for memory space are greatly reduced. This conclusion has also been proved by the above experiments.

Experiment proves that the optimized road network model used in this paper effectively solves the

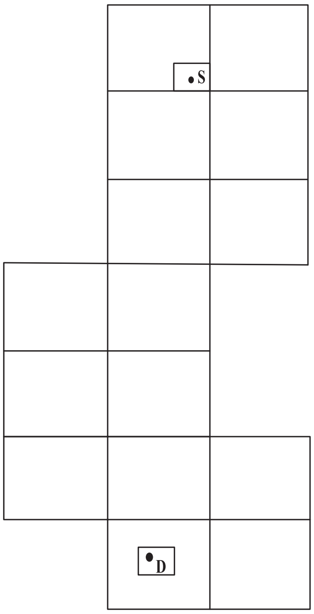

Fig. 6. A sketch map of the search scope of the traditional road network model algorithm.

problem of memory space and computational efficiency in wide-area path planning calculation, providing a reasonable and efficient solution for practical applications. However, the optimization of road network model also has its own limitations in organizational structure and storage format, mainly in the following aspects: due to the close correlation of data in each level and each partition, updating a specific data will cause a large number of related data changes, and road network is difficult to update.

5. Conclusion

The application of graph theory in the transportation link of logistics management is studied, and the computer aided model is designed. The optimized road network model proposes the partition method based on data volume and the principle of connectivity, which realizes the balance of the partition data volume. Compared with the general road network model, the established road network partition is more reasonable and more in line with the actual requirements of the path planning algorithm. Then the model is optimized based on graph theory. The optimization reduces the memory consumption when the algorithm is implemented, so that the wide-area road network data established according to the road network model is easier to apply to the low-end navigation system and products. The experiment proves that the optimized road network model used in this paper effectively solves the problem of memory space and computational efficiency in wide-area path planning calculation, and provides a reasonable and efficient solution for practical applications. However the optimized road network model also has its own limitations in organizational structure and storage format, which is mainly manifested in the following: Due to the close correlation between the data of each level and each partition, the update of a certain data will cause a large number of related data changes, and the road network is difficult to update.

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