COMBINING ALGORITHM WITH KNOWLEDGE FOR WAY-FINDING

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ABSTRACT:

On the basis of analyzing the advantages and disadvantages of the shortest path algorithm and the problem solving based on knowledge method, it is clearly showed that neither the algorithm, which provides the precise solution nor the common method, which is totally suitable to people's usual finding activities and based on the common sense, can provide us with a satisfactory solution. However, they can be complementary to each other, and this has made the combined use of the two become a necessity. Therefore, in this paper we set forward the combination use of knowledge and algorithm for way-finding. In this combined method, the knowledge is used for retrieving the case and isolating the searching area while algorithm is used for finding out the best solution in the isolated areas. The study shows that although the new approach can not always ensure a most accurate solution, it not only prunes off a lot of search space but also produces routes that meet people's preference of traveling on familiar and major roads.

1. INTRODUCTION

Wayfinding was defined as the processes involved in determining a route between two points and then following that route [Mark et al., 1999]. The final goal is to find the path between the source point and the destination point Human wayfinding can be regarded as a purposive, directed, and motivated activity [Golledge, 1999]. Wayfinding is one of the most important functions among the computer-assisted vehicle navigation system. The optimal path planning can be taken as to find the shortest path within a specific road network[Trimpfet.al.,1992;Car,1998;Raubal,2001;Winter,2002; Trimpf & Kuhn, 2003]. At present there are a lot of studies of the shortest path method, which are based on the algorithms. Most of them are applying the Dijkstra and the A* method. They take the spatial feature of the geographical network into consideration with an aim to optimize the algorithm from the aspects of calculating and data structure and to modify the needs of memory and finally improve the operational efficiency(Lu Feng，2001). These algorithm can ensure the optimal solutions and its efficiency has also been tested by practice. While at the same time the practice also claims that the direct application of the algorithm to wayfinding is not sensible. Most of the routes searched by the algorithms are actually irrelevant as they cannot possibly be part of the solution and using only these algorithms may also produce solutions unsuitable for human drivers, consequently they waste computation.

Wayfinding is also a kind of basic activity in human being's daily life, i.e. the navigation of human beings themselves. People have to do the wayfinding under several circumstances, such as driving across the boundaries, driving around the city or moving through the buildings. People usually use the cognitive maps as the common sense to resolve the problems of wayfinding and relative localization. Successful wayfinding needs the combination of spatial knowledge and different types ofcognitive ability (Raubal&Worboys, 1999). So the method based only on human beings' common sense and geographical knowledge is not efficient enough. The reason lies on that human being have never been a best way-finder, he seldom can figure out the best route unless the distance is quite short. From the above, it can be seen that each individual technique does not provide a good method for wayfinding. However, satisfactory solutions can be obtained by combining knowledge and accurate algorithms.

2. SHORTEST PATH ALGORITHMS

The shortest path is the important problem of traffic network analysis. It is the base of the route optimal problem, such as route design and route analysis. Shortest path problem is modeled as finding path between two nodes in a weighted network $G= (N, A)$ with a node set N and arc set A. In route finding, G is the road network, nodes are road intersections and arcs are road sections. The weight of each arc is the distance, time or cost between two adjacent nodes. Dijkstra algorithm is perhaps one of the most efficient algorithms for this problem. Most of the other algorithms are its variations.

Although various algorithms exist for finding the shortest path, their performance tends to deteriorate as the network size increases (Karimi,1996;Zhan & Noon,1998). These algorithm can ensure the optimal solutions and its efficiency has also been tested by practice. While at the same time the practice also claims that the direct application of the algorithm to way-finding is not sensible. Specific optimization criteria, which are adopted in the rout plan process, are varied as to shortest path, the least time, and the minimum cost. These criteria are seem to be standard criteria for establishing the model of route planning and using in the process problem solving. Behavioral study shows that most drivers don't always choice the optimal path but the suboptimal path based on various factors such as road familiarity, road types and so on (Weng Min, 2006a). Conventional shortest path algorithms don't meet these demands because the knowledge of road network is not considered in the algorithm designing. Conventional network route selection strategies found in most computer models may not accurately reflect the decision making strategies of travelerso while we should not hasten to discard existing models, we should realize that they may be more normative and more precise than we usually assume. So, from the basis of these models, we should improve them by applying people's knowledge of finding routes to make the result more suitable for decision-makes.

3. KNOWLEDGE-BASED METHOD

The knowledge-based method stresses simulating people's ways of solving problems in cyber environment. The knowledge is acquired in the process of resolving real-world problems by human beings. This method emphasizes the use of people's instinct, value sense, experience, judgments and reasoning flexibly. As the situation of finding route for example, if a person wants to go to the city south from the center, probably he will not consider the roads which are to the north. That is to say, the common sense of direction and geographical information will lead people to choose the optimal route in finding a way to the destination. So, if we integrate some people's common sense and geographical information into the algorithm of finding route for computing, data and space redundancy will be reduced and searching speed will be accelerated. And eventually, we will get a better result which is more suitable from the perspective of our daily behaviors.

Behavior study has resulted in some important findings about people's wayfinding(Weng Min,2006a): (1)People prefer to travel on major roads.(2) People's route finding process is characterized by minimizing the angle between the present direction of travel and the calculated direction to the destination.(3) People like to travel on familiar routes.(4) People like to find route in the local area.

Human beings are not efficient route finders. They are seldom able to find the best route unless the distance or travel is very short (Liu & Tay, 1995). Thus, we should not simply copy the human ways of route finding. However, human beings are apt at using the heuristic knowledge, i.e. to divide the road network into parts which contain or not contain the solutions by adopting different kinds of geographical knowledge, while they are not good at finding out the optimal solutions among those parts. In the past, the method based on knowledge was used to solve the problem not effectively solved through the algorithm. However, studies show that the exact mathematic algorithm for the shortest path will produce a more effective solution if it combines with knowledge about road network and human beings cognition

4. A COMBINED METHOD

From the above, it can be seen that each individual technique does not provide a good method for route finding. However, each of them has its advantages in solving the problem. Analysis of their advantages and disadvantages shows that they can easily help each other. Thus, integrating them is the natural solution. In this paper we set forward the combination use of knowledge and algorithm for way-finding. We suppose that a driver plans to arrive at the point *D* from point *S*. According to the behavioral research, he will first search in his memory whether he has ever used this route. If the answer is yes, which means the route is a familiar one to him; he will use the memory to guide his present travel. In addition, if he wants to go the place which is not very far from this familiar place, he will develop the former solution to search for the new one for the new problem. On the basis of this experience and knowledge, we meet drivers' preference for familiar routes by analyzing and storing these typical cases to build the case base and by doing the reasoning of them. If the route has never been used by the driver, he will try to find another one. Starting from point *S*, the driver will fist choose the lower level road from the network which will lead him to the higher level road network, and then he will try to stay long enough on the higher level road. Only when he is approaching point *D* will he use the intermediary lower level roads to reach the destination. Therefore according to this kind of behavioral cognition and the spatial hierarchy structure of the road network, this kind of method can be described as following; if both the points *S* and *D* are of the same higher level network, the algorithm will only be used to the higher level network; if both the two points are of the same lower level network, the algorithm will only be used to a small area around point *S* to help the driver to reach the main road quickly. When he is on the main road, he only has to choose which road can lead him to point *D* most quickly among the main road network. As he is near point *D*, he has to reconsider the searching for the road to point *D* in this small area. Figure 1 illustrates this scenario. Grids are used to show the isolated areas.

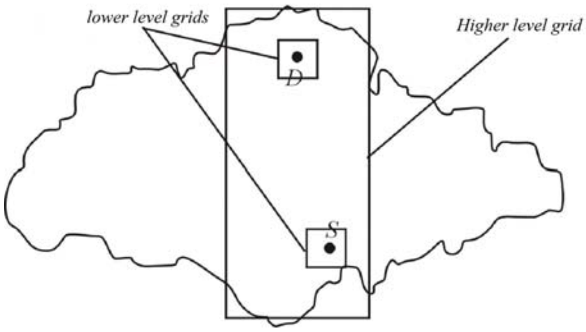

Figure 1. The ideal grids for reducing search space

In the real network of the urban road, Human begins have classified the main road hierarchically, these hierarchies are based the level of the roads, traffic volume or the speed while aiming at different improvement criteria. The hierarchies increase successively from the higher level to the lower one, the higher level is the subset of the lower one. The whole road network is divided by those main roads. When we are reading the road map of each city, we can find that the main roads and express ways form a network, and the main roads divide the whole network into several smaller districts naturally, which we call them natural grid(Weng Min,2006b). As figure 2, thick lines are major roads and thin lines are minor roads.The minor roads in the natural grid are connected with the major roads through the enter/exit nodes. In the grids containing source *O* and destination *D*, the shortest paths *OA* and *DB* are computed by running Dijkstra algorithm. In the network which only includes major roads, the shortest path *AB* between two grids containing *O* and *D* is obtained by running Dijkstra algorithm. The three paths are local shortest path, which form the optimal path from the source *O* to the destination *D*. Obviously, this path does not guarantee the best solution.However, the solution may be good enough as people do prefer to drive on major roads.

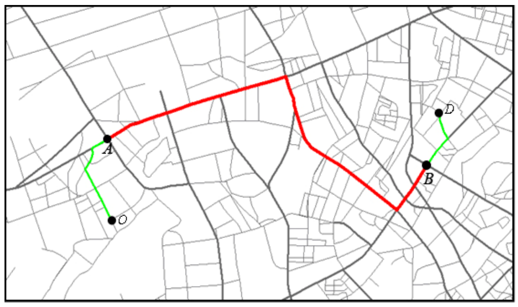

Figure 2. A case of the combined method

In this combined method, the optimal path is computed in the three sub-networks instead of the whole large network. Each sub-network is the small part of the whole network, so the computational time will be reduced obviously. It can be seen from the figure 3, the size of whole network containing minor and major roads is too large, but the search scope *O*-grid and *D*-grid are very small. Though the scope of network which only includes major roads *C1* is the close to the size of whole network, the numbers of the nodes are obviously cut down. Consequently, this will improve the efficiency of algorithm.

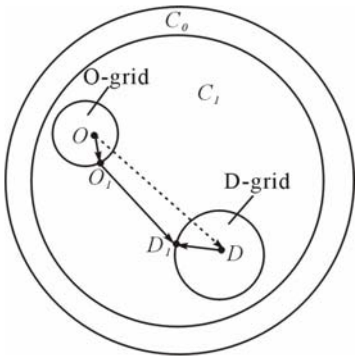

Figure 3. The Comparison between the combined method and Dijkstra algorimth

If the final result is that node *A* is the best exit point of *O*-grid and node *B* is the best entry point of *D*-grid, then *AB* is stored as the case in case base(as figure 4). For planning the new route, if the source point O_1 lies in the *O*-grid and the destination point D_1,lies in *D*-grid, then the shortest path algorithm could be used to compute the shortest path between O_1 and *A* or between D_1 and *B*. Then connecting O_1A—*AB*—*B* D_1 will form the shortest route between O_1 and D_1

Suppose a traveler intend to go from the source *O* to the destination *D*. According to the case base, the procedure of the path planning algorithm is as follows:

(1) Find the *O*-grid containing source *O* and the *D*-grid containing destination *D*

(2) Tell whether there is a case stored in the case base perfectly matching with the path between the *O*-grid and the *D*-grid, if so, retrieve this case and then go to (4); or

(3) Run the shortest path algorithm in the sub-network which only includes major roads to find the shortest path from the best exit/entry point of the *O*-grid to the best exit/entry point of the *D*-grid, and then add the new solution into the case base.

(4) Run the shortest path algorithm separately in both the *O*-grid and *D*-grid to find the shortest path from the source *O* and destination *D* to the best exit/entry point of path in (2) or (3).

(5) Connect path in (2) or path in (3) and two shortest paths in (4), which form the shortest path from the source *O* to the destination *D*.

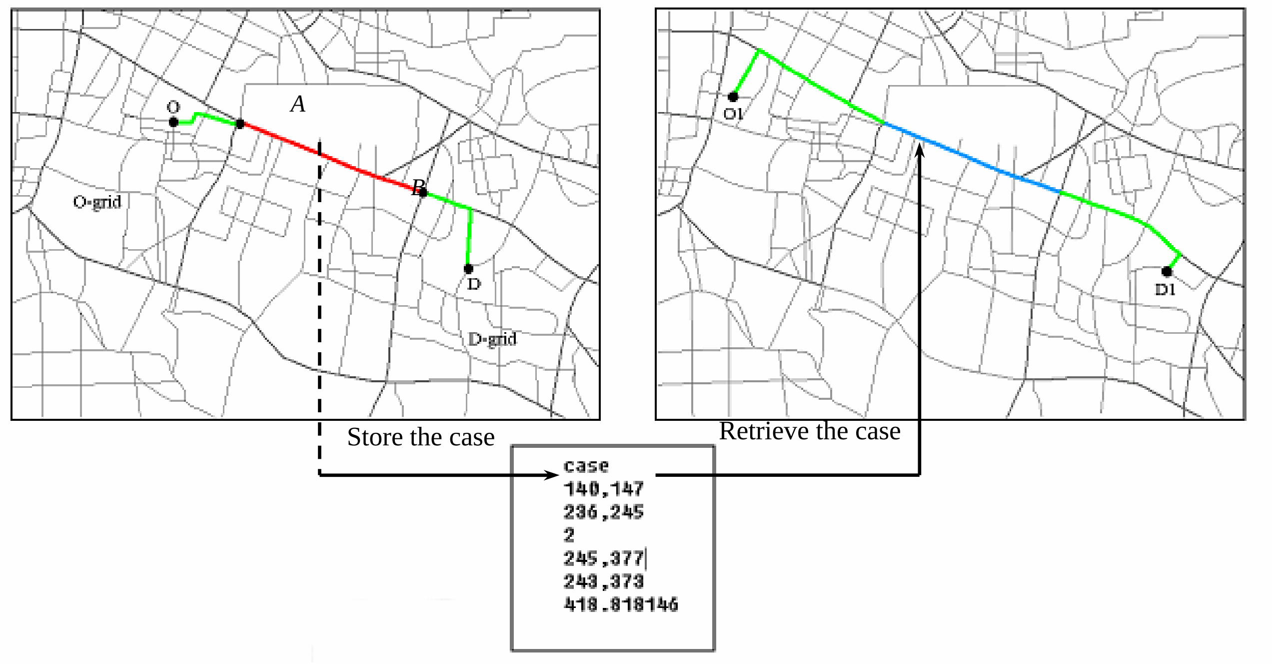

Figure 4. Retrieving the case

From analysis of the algorithm above, when computing the shortest path between the grids, the key of the algorithm is defining the best exit/entry points. Figure 5

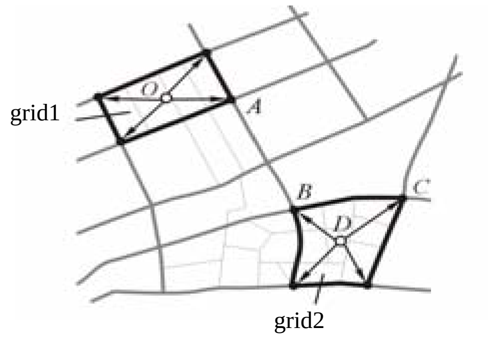

Figure5. The enter/exit node between two grids

Shows the definition of best exit/entry point between two grids. Separately, grid 1 and grid 2 are the grids of source *O* and destination *D* and connecting each exit/entry point between *O* and *D* through pseudo link. And the cost of pseudo link could be substituted for the sum of distance, between the source *O* (destination *D*) and every exit/entry point, and distance, between every exit/entry point and the destination *D* (source *O*). And then find the best exit/entry point through computing the sum of minimum distance.

5. CONCLUSION

On the basis of analyzing the advantages and disadvantages of the shortest path algorithm and the problem solving based on knowledge method, it is clearly showed that neither the algorithm nor the common method can provides us with a satisfactory solution. This paper sets forward the new approach of integrating knowledge and algorithm. In this combined method, the knowledge is used to the separate the search space while the conventional algorithm is applied to find the best solution from this reduced and isolated space. The result which is composed of the local best solution of every part does not guarantee the accurate solution. However, this method not only substantially reduces the time and space required in computation, but also produces acceptable solutions.

The study shows that although the new approach of integrating knowledge and algorithm can not always ensure a most accurate solution, it not only prunes off a lot of search space but also produces routes that meet people's preference of traveling on familiar and major roads.

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