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Method of Path Selection in the Graph - Case Study

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ABSTRACT: This paper presents a different perspective on the Dijkstra algorithm. In this paper algorithm will be used in the further analysis to find additional paths between nodes in the maritime sector. In many cases, the best solution for a single criterion is not sufficient. I would be the search for more effective solutions of the starting point to use for subsequent analysis or decision making by the captain of the ship. Using cutting-edge thinking mechanisms, it is possible to create a decision support system based on known Dijkstra's algorithm.

1 INTRODUCTION

Rapid and accurate calculation of the estimated time of arrival at the port of destination of the ship at sea, is of great importance in many areas of the ocean shipping industry. For example, the route and schedule of ships on a day to day, it is important to know when the ship reached the port of destination and to be available for new loads. Estimated time of arrival can also be important in the planning of port operations. Give a reliable estimated time of arrival for ships entering the port, planning port operations, such as work assignments, loading/unloading equipment and harbours for ships can be more efficiently done.

The traditional way is to base the estimate of estimated time of arrival on ships. However, the new technology of satellite position reporting combined with electronic map allows users to land to check weather or update the master's estimated time of arrival at regular intervals, not interfering with the crew of the ship at all hours.

The paper presents an efficient algorithm for determining the estimated time of arrival in port the ship is at sea. The algorithm is implemented in a decision support system in planning the operation of ships, one of which is installed and used by several owners. By calculating the distance of the route between the ship and the port of destination, estimated time of arrival can be estimated by dividing the distance by the speed sailing. Calculating the distance between the ship and the port of destination may be considered to determine the shortest path between two points in the presence of polygonal obstacles, where one point corresponds to the vessel and the other end to the port of destination. Sections defining polygons are obstacles coast. Estimated time of arrival accuracy can be improved by defining special network structures in areas with limited speed, or are waiting for the pilots [3].

The vehicle routing problem lies in the design of optimal routes for a fleet of vehicles, usually in order to minimize operating costs or the number of vehicles used. Several variations of this problem has been extensively studied in the literature optimization as efficient routing of vehicles have a great impact on logistics costs [8].

2 THE PROBLEM

Given that the total linear programming model of a simplified version of the problem of routing the vessel presents an unacceptable solution times for a typical daily planning process, taken a heuristic approach, deciding on your hand. Author decided on this approach for its implementation relatively simple calculation, as well as its record of good results with similar problems to the present.

There are several algorithms such as Dijkstra's algorithm, which is a single source-single destination shortest path algorithm, the Bellman-Ford algorithm to solve the shortest path algorithm with a free hand, A* algorithm solves the single pair shortest path problems using a heuristic algorithm and Floyd Warshall algorithm to find all pairs of Johnson-perturbation and the shortest path algorithm to find the shortest path locally. Genetic algorithms are also used to finding shortest path [1]. In this paper to calculation will be used Dijkstra algorithm.

2.1 *Model input*

Inputs to the model record ship characteristics, movement report data and numerical weather prediction data: the model will integrate consumption curves, speed reduction curves, ship class, ship wind and weather sea borders, movement report speed, maximum allowed speed, movement report trace data to include waypoints, latitude and longitude. In addition to data related to the movement of the vessel it is necessary to the description of the environment. Especially important is the description of the possible routes between the point's start and end.

2.2 *Dijkstra's algorithm*

For a given source vertex (node) in the graph, the algorithm finds the path with lowest cost (ie the shortest path) between that vertex and every other vertex. It can also be used for finding the shortest cost path from one vertex to a destination vertex by stopping the algorithm is determined by the shortest path to the destination node. For example, if the vertices of the graph represent the city and are the costs of running paths edge distances between pairs of cities connected directly to the road, Dijkstra's algorithm can be used to find the shortest route between one city and all other cities. As a result, the shortest path algorithm is widely used routing protocols in a network, in particular the IS-IS and Open Shortest Path First.

Short characteristic of Dijsktra algorithm [2].

- The input of the algorithm consists of a weighted directed graph G and a source vertex s in G
- Denote V as the set of all vertices in the graph G.
- Each edge of the graph is an ordered pair of vertices (u,v)
- This representing a connection from vertex u to vertex v
- The set of all edges is denoted E
- Weights of edges are given by a weight function w: $E \rightarrow [0, \infty)$
- Therefore w(u,v) is the cost of moving directly from vertex u to vertex v
- The cost of an edge can be thought of as (a generalization of) the distance between those two vertices
- The cost of a path between two vertices is the sum of costs of the edges in that path
- For a given pair of vertices s and t in V, the algorithm finds the path from s to t with lowest cost (i.e. the shortest path)
- It can also be used for finding costs of shortest paths from a single vertex s to all other vertices in the graph.

2.3 *Model output*

It is determined based on the input data and the shortest time path by Dijkstra's algorithm, is calculated: range, bearing, and time (hours) for transit between each waypoint, total distance and duration, network least time "shortest" path in latitude / longitude positions, the fuel consumption for network path, cost of fuel.

The calculation determines the feasibility of arrival time given how many hours of time at the beginning and / or late, the ship can reach its destination. If the arrival time of a network path beyond the allowable range of time of arrival of the model calculates the recommended increase in speed based on the distance of at least during the path model and the latest and earliest times, depending on the case. The user can then enter the recommended speed and run the model. If you need to increase the speed greater than the maximum allowable speed, and then prompt the user model that other options should be considered redirection path. Depending on the point on the axis of the transit time, these options are: delay in the port speed reduction without changing the track or storm evasion.

2.4 *Proposed to use*

As indicated above, the algorithm is well known and widely used. Finding the shortest path between two vertices in graphs is not difficult. But not always the shortest path is the best. It is proposed to fast search method inferior alternatives. In such situation, decision maker can choose one of the alternatives and take all the consequences.

After finding the shortest path is proposed to remove from the graph piece belonging to the founded path. Disposal should be carried out as long as there is a lot of segments in the founded path. For each new graph is necessary to find the shortest path. Founded new path should be saved to an array of solutions.

The proposed scheme is shown in figure 2. Provides an overview of the optimal path, the removal of all further edges.

Resulting array can contain many of the same tracks. It is therefore removed from the same tracks. Of course, such removal is not a problem.

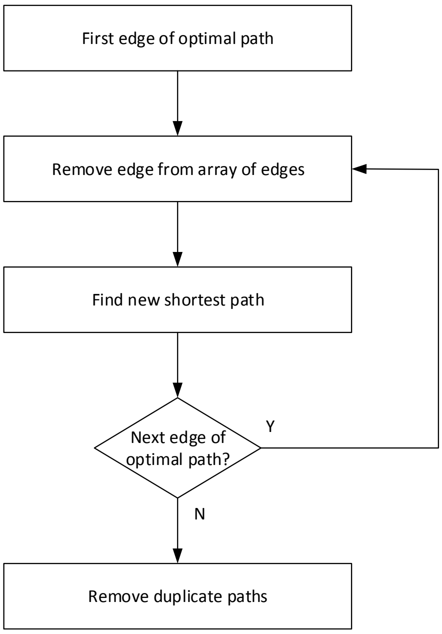

Figure 2. Diagram of searching new paths

3 NUMERICAL EXAMPLE

The figure 1 shows an example of the unreal maritime restricted area. It consists of eight obstacles (in the form of islands), 21 turning points and 29 edges. Each edge is described by value of the distance between two vertices.

All connections are shown in the Table 1. Number of edge corresponds to the edge shown in Figure 1. Each connection is between initial node and final node. The distance between nodes describes a dimensionless measurement of the distance between the nodes.

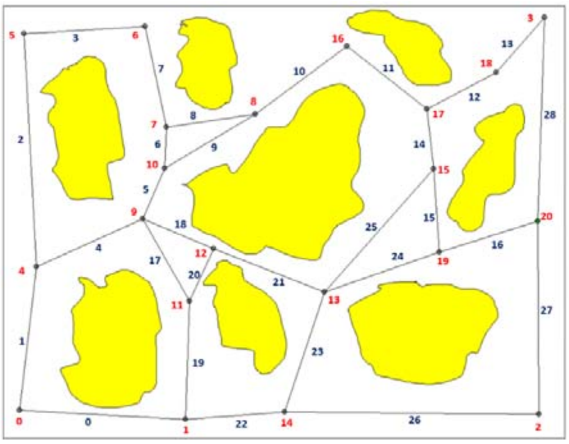

Figure 1. Scheme of traffic among islands

Table 1. Table of all edges

Number of edges	Initial vertex	Final vertex	Distance between the vertices
0	0	1	295
1	0	4	257
2	4	5	415
3	5	6	215
4	4	9	207
5	9	10	98
6	10	7	73
7	7	6	183
8	7	8	160
9	10	8	187
10	8	16	203
11	16	17	181
12	17	18	139
13	18	3	130
14	17	15	107
15	15	19	148
16	19	20	183
17	9	11	168
18	9	12	137
19	1	11	210
20	11	12	102
21	12	13	212
22	1	14	176
23	14	13	225
24	13	19	216
25	13	15	293
26	14	2	452
27	2	20	343
28	20	3	362

Result of the algorithm is a path with a length equal 1365. The algorithm indicated that the shortest distance between the vertex labelled 0 and 3 leading by edges: 0, 22, 23, 25, 14, 12, 13. The shortest path is presented in Table 2 and in Figure 3.

Table 2. Description of shortest path

Number of edges	Initial vertex	Final vertex	Distance between the vertices
0	0	1	295
22	1	14	176
23	14	13	225
25	13	15	293
14	17	15	107
12	17	18	139
13	18	3	130
			Total 1365

Figure 3. Shortest path

An easy way to find another quick way from the source to the target is to modify the optimal path, found a particular method. The article proposes to remove one edge. The cycle was repeated for each edge of the optimal path. In this way calculated two other paths 1,4,5,9,10,11,12,13 and 0,22,23,24,16,28:. Detailed data are shown in the Figures and tables.

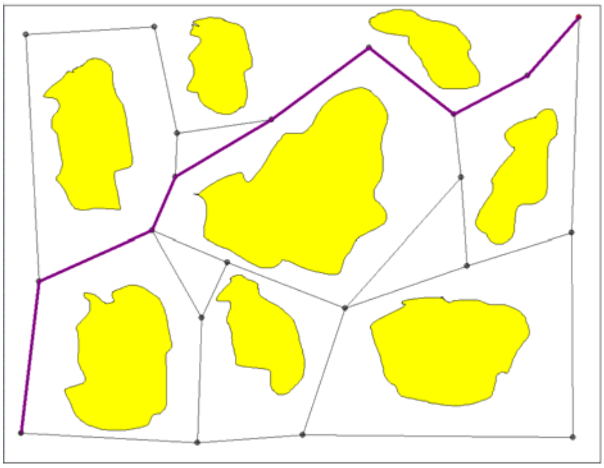

Figure 4. Second path

Table 3. Description of second path

Number of edges	Initial vertex	Final vertex	Distance between the vertices
1	0	4	257
4	4	9	207
5	9	10	98
9	10	8	187
10	8	16	203
11	16	17	181
12	17	18	139
13	18	3	130
			Total 1402

Figure 5. Third path

Table 4. Description of third path

Number of edges	Initial vertex	Final vertex	Distance between the vertices
0	0	1	295
22	1	14	176
23	14	13	225
24	13	19	216
16	19	20	183
28	20	3	362
			Total 1457

For the purposes of demonstration and calculations developed computer application [6] which graphically created schema presented in the article. For middle-class computer all the calculations were done in less than 150ms. Such a short calculation time can be a prerequisite for further research into the search for alternative paths.

The results require further calculations. According to the author to be in the discussion to consider not only the dimensionless values describing the edges, but also values such as time, cost, security etc. It is necessary to use the mechanism of multiple-choice decision or data fusion [4,5].

In a similar way for the selected paths other parameters were calculated. They relate to the average time needed for the transition path, the number of indirect vertices and the calculate of safety factor. The data are summarized in table 5.

Table 5. Summary of results

Path	Distance	Number of indirect vertices	Average time
Path 1	1365	6	220
Path 2	1402	7	260
Path 3	1457	5	200

Selecting one of several paths is a multi-criteria problem. Conventional multi-criteria decision making (MCDM) techniques were largely non-spatial. Use medium or cumulative effects that are considered appropriate for the entire area into account. In this case, subjective approach is proposed to solve the problem. Based on expert opinion, it is possible to submit the results and select the appropriate transition path. It seems that an appropriate tool for this may be Dempster-Shafer theory. Dempster-Shafer theory (DST) is a promising method to deal with certain problems in data fusion and combination of evidence. Based on statistical techniques for data classification, it is used when the evidence is not sufficient to assign a probability of individual events and declares that are mutually exclusive. Also, both input and output may not be accurate and defined by sets. DST concept is relatively simple, and the technique is easily extensible. In the case of maritime transport, as an international business with a high risk, new evidence will appear and become available once the war, diplomatic events or other hazards. DST-based model, which allows incremental addition of knowledge, can satisfy the needs of those conditions. Compared with Bayesian probability theory time zone avoids the necessity of assigning prior probability, and provides intuitive tools to manage uncertain knowledge.

4 AN EXPERT SYSTEM FOR MULTI-CRITERIA DECISION MAKING USING DEMPSTER SHAFER THEORY

Dempster-Shafer Theory is a generalization of the Bayesian theory of subjective probability. Basic functions of degrees of belief of faith (or trust, or trust) to a single question about the probabilities related question. Degrees of belief itself may or may not have the mathematical properties of probability; how they differ depending on how much these two questions are related. In other words, it is a way of representing epistemic plausibilities but it can give the answers that are contrary to those achieved using probability theory.

There are two main functions in DST: the belief function and plausibility function.

The belief function and the plausible function are two non-additive evidential measures of the DST, and they can be calculated from the BPA. For any set $A, B \subseteq \Theta$, the belief function is defined as:

$$\mathrm{Bel}(A) = \sum_{B \subseteq A} m(B)$$

Bel(A) represents the minimum belief, which summarizes all reason to believe in A with the available knowledge. With the definition of BPA, the function satisfies $\mathrm{Bel}(\Phi) = 0$ and $\mathrm{Bel}(\Omega) = 1$.

The plausible function is defined as:

$$\mathrm{Pl}(A) = \sum_{B \cap A \neq \Phi} m(B)$$

Pl represents the maximum belief, which summarizes all reason not to reject in A with the available knowledge. The function also satisfies $\mathrm{Pl}(\Phi) = 0$ and $\mathrm{Pl}(\Omega) = 1$.

According to the definition above, one of the relationships between the belief function and the plausible function is $\mathrm{Bel}(A) \leq \mathrm{Pl}(A)$, and it is possible to describe uncertainty of evidential measures by the lower and upper bounds of an interval $[\mathrm{Bel}(A), \mathrm{Pl}(A)]$.

The principle of connection DST allows people to connect two independent sources of evidence in one or two basic probability assignments are defined on the same frame. Here, the term "independent" in the DST is not strictly defined. The word simply means that a range of evidence shall be determined by a variety of means.

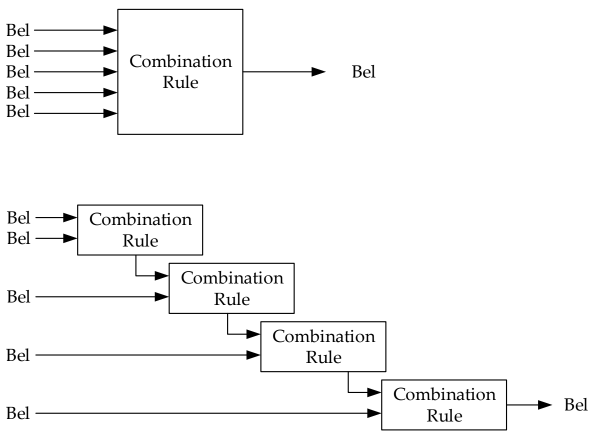

Figure 6. Transformation of multiple combined evidence

Figure 2 shows that the combination of multiple evidence can be converted into a double recursion several combinations of evidence relates to the properties of the combination rules, so it is convenient for people to add a new source of evidence to the old system in an arbitrary order.

In the shown example it is possible to evaluate routes in the following way. One of the experts said, that said that the best of the routes is Path 1, because it is shortest. He assesses it to 40%. Also takes into consideration the path of a second, but I still remember that it is the shortest P1. Thus, selecting a P1 or P2 is estimated at 20%. All cases are shown in Table 6.

Table 6. Summary of experts reviews

Case	Expert 1	Expert 2	Expert 3
P1	0,40	0,20	0,15
P1 or P2	0,20	0,10	0,20
P1 or P3		0,20	0,05
P2	0,10	0,15	0,15
P3	0,05	0,15	0,25
P1 or P2 or P3	0,25	0,20	0,20

The data stored in the table may be analysed using the DST which will be the subject of further consideration.

5 CONCLUSIONS

The Dijkstra algorithm is well known. It was first published half a century ago. To this day, finding connections between vertices is used. But not always the shortest path is the best. It is to consider various criteria. This paper is an introduction to further research.

In this study, we developed a model of the ship routing network that solves problems optimal path using a modified version of Dijkstra's shortest path algorithm and the basic function of the reaction vessel. We have established fidelity models by testing. As you can see, the model avoids the adverse weather conditions and solves the path of least time to your destination. It calculates the useful time, distance, fuel consumption and metrics to quantify routing decisions. The model also shows that manual routing techniques involving multiple calculations and graph plotting can be automated and solutions generated in milliseconds. We have identified how the results can be used by employees of the ship routing, to help in the analysis of alternatives and the routing decision support ship. The performance of the model against historical cases validates skills model and gives insight into the improvements that can be made in the future.

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