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Vessels Route Planning Problem with Uncertain Data

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ABSTRACT: The purpose of this paper is to find a solution for route planning in a maritime transport networks, where the factor of safety and travel time are ambiguous. This approach is based on the Dempster-Shafer theory and well known Dijkstra's algorithm. In this approach important are the influencing factors of the mentioned coefficients using uncertain possibilities presented by probability intervals. Based on these intervals the quality intervals of each route can be determined. Applied decision rules can be described by the end user.

1 INTRODUCTION

Many works deal with route selection, navigation in the transport sector, very few models take uncertainty into account information (or lack of information). There are some works in transport research, which take account of the uncertainty by Dempster-Shafer theory. The major application of this theory is the decision making, statistics and geographic information systems. Intelligent Driving recognition with Expert System used Dempster-Shafer theory for recognizing performed by the driver manoeuvres the data from the sensors is installed in a vehicle. Uncertainty information models have been used only for the local problem, but our focus is global: The aim of the research is based information to solve routing problems on uncertainty. Dempster-Shafer theory is a theory of uncertainty that can quantify a specific statement the extent to which support some source of evidence. In fact, there is an alternative to traditional probability theory, so that the explicit representation of ignorance and combination of evidence. This theory was originally developed by Dempster [3] and then extended by Shafer in his book in 1976, A Mathematical Theory of Evidence [14].

The scientific and technological progress is bringing some new solutions. There are more and more electronic devices on the vessel's bridge. That cause1 navigator has the access to various systems of the exchange of data. Some of them can receive data, other combines send-receive operation. The navigator's assessment of collision risk depends on his knowledge about own ship's motion and other ships' motion. The available means for assessing the other ships' motion are for example: visual sighting, radar, ARPA, AIS and the voice communication with other ships. Each of enumerated systems possesses particular reliable features. Voice communication, radar and visual sighting give real time information. Each of them is a separate system on the bridge of the vessel. The most difficult for the navigator can be predicting the situation in advance if the safety margins are small, as in congested waters. The same applies for Automatic Identification Systems (AIS) if only the text display is provided. It is appeared, that the AIS will be able to replace many of enumerated means of communication [6].

Routing problems in networks are the problem in the context of sequencing and in recent times, they have to receive increasing attention. Such problems usually occur in the areas of transportation and communications. A network problem involves identifying a route from the source to destination because there are a number of alternative paths in various stages of the journey. The cost, time, safety or cost of travel are different for each routes. Theoretically, the method comprises determining the cost of all possible routes and the find with minimal cost. In practice, however, the number of such alternatives are too large to be tried one after another. The traveling salesman problem is a routing problem associated with rather severe restrictions. Another routing problem arises when it can to go from one place to another or several other places, and choose the shortest route with the least distance or time or cost of many alternatives to achieve the desired station. Such acyclic route network problem easily can be solved by job sequencing. A network is defined as a series of points or nodes that are interconnected by links. One way to go from one node to another is called a path. The problem of sequencing may have put some restrictions on it, such as time for each job on each machine, the availability of resources (people, equipment, materials and space), etc. in sequencing problem, the efficiency with respect to a minimum be measured costs, maximize profits, and the elapsed time is minimized. The graph and the costs of edges is given in the figure 1. In this theoretical concept the road network is represented by a graph. A graph is given with an ordered pair G: = (V, E) comprising a set V of vertices or nodes together with a set E of edges (paths), which connect two nodes. The task is to reach the N1 node from N3 node in the graph at smallest cost [10].

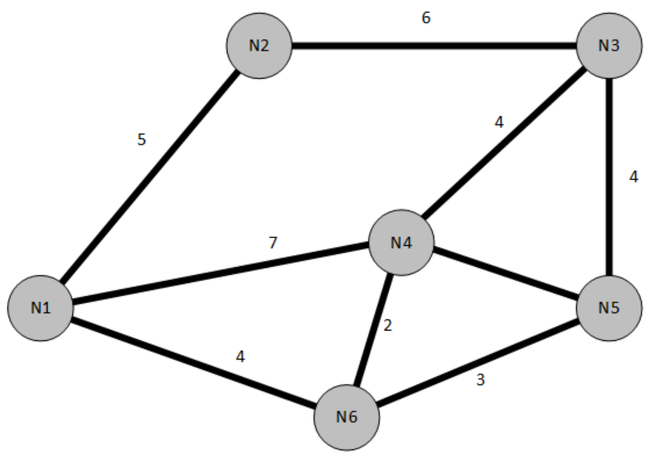

Figure 1. Graph with defined values of costs of paths.

Conventional Dijkstra's [3] should provide the shortest route in the graph with non-negative edge path costs, but described example include uncertainty. Therefore Dempster-Shafer theory is required, which concern with uncertainty by belief functions. In Dempster-Shafer theory the set $\Omega = A_1, A_2, \ldots, A_n$ of all the eventual conditions of the structure. It can be presented by $P(\Omega)$ the powerset 2^{Ω}.

$$P(\Omega) = 2^{\Omega} = \{\{\ \}, \{A_1\}, \{A_2\}, \ldots, \{A_1, A_2\}, \ldots, \Omega\} \quad (1)$$

Dempster-Shafer theory designate functions (m) called Basic Belief Assignment on the $P(\Omega)$.

$$m : 2^{\Omega} \rightarrow [0,1] \quad (2)$$

It permits not commonly work out the portions of evidence presented by power set $P(\Omega)$. A basic belief assignment (m) appeases:

$$m(\phi) = 0 \quad (3)$$

$$\sum_{A \in P(\Omega)} m(A) = 1 \quad (4)$$

Belief function $Bel(A)$ for a set A is defined as the sum of all Basic Belief Assignment of subsets of A defined and said that a part of faith B are assigned, must be assigned to other hypothesis, that it means:

$$Bel(A) = \sum_{B|B \subseteq A} m(B) \quad (5)$$

The Dempster-Shafer theory also defines the plausibility $Pl(A)$ as the sum of all the Basic Belief Assignment of sets B that intersects the set of A:

$$Pl(A) = \sum_{B|B \cap A \neq 0} m(B) \quad (6)$$

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 [13].

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 *Path finding algorithm*

A path finding algorithm for transit network is proposed to handle the special characteristics of transit networks such as city emergency handling and drive guiding system, in where the optimal paths have to be found. As the traffic condition among a city changes from time to time and there are usually a huge amounts of requests occur at any moment, it needs to quickly find the best path. Therefore, the efficiency of the algorithm is very important . The algorithm takes into account the overall level of services and service schedule on a route to determine the shortest path and transfer points. There are several methods for pathfinding: In Dijkstra's algorithm the input of the algorithm consists of a weighted directed graph G and a source vertexs in Graph. Let's denote the set of all vertices in the graph G as V. Each edge of the graph is an ordered pair of vertices (u, v) 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→[0, ∞]; therefore w (u, v) is the non-negative cost of moving from vertex u to vertex v. The cost of an edge can be thought of as 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]

2.2 *Model input*

Contribution to the example record vessel properties, motion report data and digital climate prognosis data: the example will join consumption curves, velocity diminution curves, vessel class, ship wind and weather sea borders, motion statement velocity, maximal permitted speed, motion statement trace data to contain waypoints, their latitude and longitude. On top of it to data related to the motion of the ship it is indispensable to the specification of the surroundings. In particular significant is the specification of the practicable routes between the first point and the last one.

2.3 *Dijkstra's algorithm*

For a published source apex (node) in the graph, the algorism discovers the way with smallest cost (i.e. the shortest path) among that vertex and every other ones. It could also be used for discovering the smallest cost way from one vertex to a goal vertex by stoppage the algorism is intended by the smallest way to the goal vertex. For instance, if the apexes of the graph describe the cities and there are given costs of flowing ways distances among pairs of points combined immediately to the road, Dijkstra's algorism can be used to discover the briefest route among one city and all other cities. Consequently, the briefest path algorism is highly used in routing protocols in a web network, in particular the IS-IS and Open Shortest Path First.

3 ROUTE PLANNING WITH UNCERTAIN INFORMATION MODEL IN TRANSPORT NETWORKS

Mainly in the road transportation area the most important data for routing is the traffic on the roads. It can be easily calculate into two states: congestion or not congestion. Thus in this model the investigated two hypotheses in Dempster-Shafer theory are the $Congestion\ (CO)$ and $No\ Congestion\ (NC)$, so $\Omega = \{CO, NC\}$ and $P(\Omega) = \{\{\ \}, \{CO\}, \{NC\}, \{CO, NC\}\}$ characterized by the Basic Belief Assignment values of the focal elements $m(CO), m(NC), m(\Omega)$, where $m(\Omega)$ expresses the uncertainty.

On the case of congestion on a particular road costs twice considered by the predetermined cost. The evolving traffic congestion can be caused by several factors. These factors can be calculated as follows: weather, traffic density and closed track. So the basic belief assignment functions are the following: m_1: bad weather, m_2: high vehicle density, m_3: closed lane.

The mathematical theory of evidence deals with function combining information contained in two sets of assignments, subjective expert ratings. This process may be interpreted as a knowledge update. Combining sets results in forming of new subsets of possible hypotheses with new values characterising probability of specific options occurrence. The aforementioned process may continue as long as provided with new propositions. This function is known as Dempster's rule of combination. If more than one factor appears on an edge, then it is possible to cumulate them based on the following formula, where A is the investigated set, B, C are elements of $P(\Omega)$.

This equation is proposed by Dempster:

$$m(C) = \frac{\sum_{A \cap B = C} m_1(A) m_2(B)}{1 - \sum_{A \cap B = \phi} m_1(A) m_2(B)} \tag{7}$$

Combination rules specify how two mass functions, say m_1 and m_2, are fused into one combined belief measure $m_{12} = m_1 \times m_2$ (we here let the binary operator $\times$ denote any rule for mass function combination). Many combination rules have been suggested (several are presented in [3]), and below we briefly discuss the ones we use in this study.

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.

Short characteristic of Dijsktra algorithm [11] presented is in figure 2.

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01. The input of the algorithm consists of a weighted directed graph G and a source
        vertex s in G
02. Denote V as the set of all vertices in the graph G.
03. Each edge of the graph is an ordered pair of vertices (u,v)
04. This representing a connection from vertex u to vertex v
05. The set of all edges is denoted E
06. Weights of edges are given by a weight function w: E → [0, ∞)
07. Therefore w(u,v) is the cost of moving directly from vertex u to vertex v
08. The cost of an edge can be thought of as (a generalization of) the distance between
        those two vertices
09. The cost of a path between two vertices is the sum of costs of the edges in that path
10. 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)
11. It can also be used for finding costs of shortest paths from a single vertex s to all
        other vertices in the graph.
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Figure 2. Dijkstra algorithm.

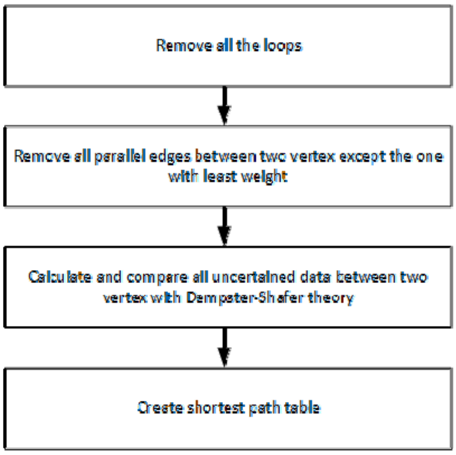

Figure 3. Diagram of searching new paths.

4 ROUTE PLANNING ALGORITHM WITH UNCERTAIN INFORMATION

In the previous chapter, the decision of the relative interval was simply because the lowest one was worse than the highest value of the other. If there is an overlap between the intervals, then the decision is not easy. When both endpoints of the interval than the end points of the other less: In this case, the routing method may choose fewer values. However, when an interval is the inner part of another interval, the decision is not clear. A possible choice is the comparison of the center points of the intervals. The election rules depend on the human decision: The end user can develop worst-case design, or at best, design or other design choices [7].

So far it looked at the transportation planning problem as a static problem. Of course this is in fact not the case. Uncertainty can through events such as errors in the communication between automated guided vehicles and the system maintained stay reservations, break-down of a mobile unit (engine failure) or failures are caused (for example due to traffic accidents) in the transport network. Uncertainty can also be caused by a change in the transport requests. For example, does the arrival of a new transport request a current plan unworkable.

Uncertainty and especially incidents can be dealt with proactive or active. Proactive methods try to create robust plans, while reactive methods of incidents actually recover they occur. A typical proactive approach is to insert limp in plans, so that, for example, delays have no consequences and new demands can be easily inserted. If nothing unexpected happens these plans take much longer than necessary. [15]

For a given source vertex in the graph, the algorithm finds the path with lowest cost 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.

The proposed scheme is shown in figure 3. Provides an overview of the optimal path, the removal of all further edges [12].

Because of the uncertainty of the road network after disasters, it is possible that the chosen path is blocked, although its reliability is very high and the journey time is short. In such cases, one can do nothing but set the path is blocked. So another option for the adjustability of the path is proposed. This ensures that if the chosen path is blocked, we do not have to circle. This problem is not solved in presented procedure.

When the assessment of the situation undergoes solely a subjective expert rating, the results are only to be obtained in form of linguistic variables. Theories presented show [16] possibility of transforming such values into figures with use of the fuzzy sets theory, a concept created by L.A. Zadeh in the sixties of the 20th century and developed ever since (mainly by its author), which increasingly intercedes in various economic issues. According to Zadeh, the aforementioned theory has not been sufficiently employed for the purpose of detection analysis of marine units. A more extensive use of possibilities offered by the fuzzy sets theory appears as a necessity for rational construction of new maritime traffic monitoring systems [7,8].

A fuzzy nature can be attributed to events which may be interpreted in fuzzy manner, for instance, inaccurate evaluations of precisely specified distances to any point. Subjective evaluations in categories: near, far, very far may be expressed with fuzzy sets defined by expert opinions. Such understanding of fuzzy events is natural and common. Introduction of events described by fuzzy sets moderates the manner in which the results of processing are used, expands the versatility of such approach, as well as changes the mode of perceiving the overall combining procedure. Deduction of specific events involved in the process of combining pales into insignificance, as obtaining information on related hypotheses is of greater interest. Combining evidence of fuzzy values brings new quality into knowledge acquisition due to the usage of combination results as a data base capable of answering various questions. Other possibilities of the mathematical theory of evidence in problems of transport in navigation can be found in [6].

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.

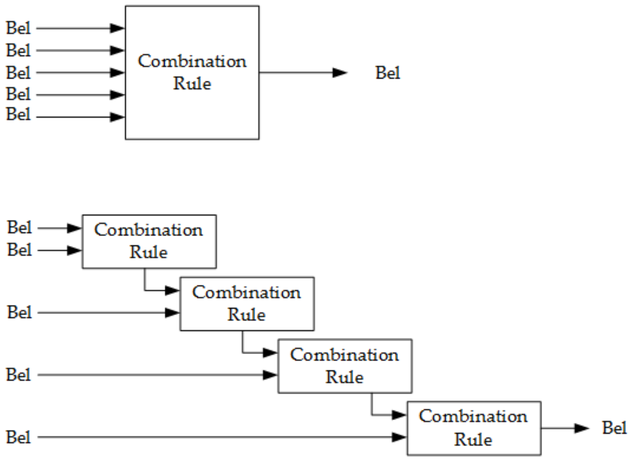

Figure 5. Transformation of multiple combined evidence.

Figure 5 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.

5 NUMERICAL EXAMPLE

The figure 6 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 Figure 6. Number of edge corresponds to the edge shown in Figure 6. Each connection is between initial node and final node. The distance between nodes describes a dimensionless measurement of the distance between the nodes.

For the purposes of demonstration and calculations developed computer application [9] 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.

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 7.

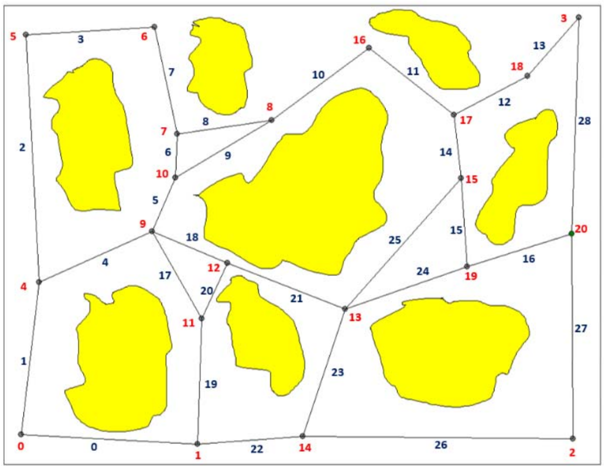

Figure 6. Scheme of traffic among islands.

Figure 7. The shortest path.

Table 2. Description of shortest path

Number of edges	Initial vertex	Final vertex	Distance between 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			

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.

6 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.

Shortest path problems widely exist in real world applications. The paper presents a model to be considered and an algorithm for routing in road network of uncertainty of status information of roads, cost factors and their uncertainty. In presented model uncertainty have the probability values using defined probability of at least and maximum values using Dempster-Shafer theory. Decision rules can be defined for nodes by the end user. The calculations are based on basic belief assignment values. Results of presented paper can be used for travel decisions, in which the decision is a binary, crisp values, intervals and fuzzy numbers.

This paper explained the problem of shortest path problem with crisp and fuzzy arc length resulting in extending the Dijkstra algorithm. The method which is proposed under fuzzy arc lengths to find the shortest path is based on the graded mean integration representation of fuzzy numbers. A numerical example was used to illustrate the efficiency of the proposed method. As far as real applications are concerned in the field of transportation systems, logistics management, and many other network optimization problem that can be formulated as shortest path problem this method can be applied. Through an example this paper also tried to simplify the application of routing planning in our general life which basically gave the shortest path between some important cities of the world. At the same time,the uncertainty in the shortest path is not limited to the geometric distance this is also shown by this paper. For example, even if the geometric distance is fixed due to the weather and other unexpected factors, the travel time from one city to another city may be represented as a fuzzy variable.

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