Engineering Science and Technology, an International Journal (JESTECH)

journal homepage: jestech.karabuk.edu.tr

Interactive training software for optimum travel route analysis applications in railway networks

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ARTICLE INFO

Article history:
Received 27 November 2013
Accepted 15 April 2013

Keywords:
Railway network,
Network analyses,
Route optimization,
Dijkstra algorithm,
Geographic information systems

ABSTRACT

Optimum travel route analysis applications are so important in railway networks. Especially, itinerary for the passengers and route and duration planning for the trainload. On the other hand, process of route optimization is one of the basic applications of Network Analyses in Geographic Information Systems too. In mathematical background of network analysis applications are graph theory and graph algorithms. Primary graph algorithm employed in process of route optimization is Dijkstra's Algorithm. Dijkstra's Algorithm is placed on the top of linear methods which yield exact solutions. Geographic Information Systems analyses such as the shortest route, the shortest duration and route with the least waiting period etc are solved through Dijkstra's Algorithm. In this study, an interactive training software program, developed for educational use in Railway applications within GIS and Graph Theory is introduced. This software provides the opportunity to use Dijkstra's Algorithm on graphs which they have designed by the user and teaches details of algorithm, its working principles and structure of data to them, step by step, through interactive messages and graphics.

1. Introduction

Transportation or journeys from one location to another are the subjects of network analyses. Network analyses are spatial analyses that help to yield results in order to make decisions through connection types of geographical features which connect with each other and have network structure. Some examples of such networks that come to mind are streets of a town, energy distribution lines, service network of an airport or railway lines of a city. Investigations and analyses to make optimal decisions on these systems are called Geographic Information Systems (GIS) Network Analyses [1]. In this study we will focus on network analyses of railways network systems.

In the 21st century, traffic problems in the metropolitan areas have increased the importance of public transportation. Therefore, as one of the most important elements of public transportation, usage of the railway systems have also increased. Additionally, since the railway transportation is a fast, economic and safe way, comparing to the others, these systems are most preferred transportation method by the people and companies [2]. On the other hand, this increment causes the traffic density in the railway networks and line allocation for the trains becomes more complicated day by day. This complexity is considered as a problem by the scientists which is needed to be optimized. Different solutions have to be introduced for the passengers and railway companies to do route optimization on the lines.

Firstly, considering routing problems in the railway systems for railway companies, it is not economic to organize train service between two stations directly every time. Because the number of passengers that get on the train at the way stations on the line differs and this differences cause to use unnecessary wagons. Even the railway companies can not define the optimum wagon numbers for the the service line, since the passengers numbers may change from time to time, and they add extra wagons to train. Adding extra wagons increase the cost of train services. Therefore the railway companies prefer the connecting services rather than through trains [3]. In the connecting services, the passengers exploit more than one line to reach the arrival station. When using the connecting transportation for the train services, to find shortest path and to define the transferring stations in the railway system is considered as an optimization problem.

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Figure 1. Netherland Railway Lines

At the industrial area, line allocation of railway is also an important problem for big scale factories which have a railway system to transfer material and product in domestic line. There are a lot of constraints about scheduling and workflow at railway transportation in the factories. It is necessary to arrange an optimum freight transportation in the factories. It is needed to have an automation systems to manage the railway traffic, since workload may increase in the factories from time to time or some of railway lines can be damaged sometimes.

Generally passengers have troubles to define the optimum route in a complex railway system networks. It is caused to waste of time and money for the passengers. The passengers need an information system that find the optimum route for themselves by entering departure and arrival station and the time period. There are a lot of studies about finding optimum route done by scientists. To find the optimum route for the passengers, there are some different criteria to be optimized. These criteria may be [4]:

- The minimal time of journey
- The minimal distance of journey
- The minimal cost of journey
- The minimal number of train changes

Many optimization algorithms are used to find the optimum route in railway systems. In this study, railway networks will be considered as a graph and Dijkstra's Algorithm will be used to find optimum route. The main aim of this study is to develop a training visual software to illustrate network analysis which is done by Dijkstra's Algorithm on railway systems [5]. This software will be detailed in section 4.

2. Related Works

Simkowitz touched on hardware and software requirements, topology, overlay processing, and special issues involved in designing a GIS for transportation systems in his study [6].

Müller developed a passenger information system for Germany railway system in his study [7]. In the study there are two parts. In the first part, the information system searches whether there is a direct train service or not. In the second part, if there is not any direct line in the route, the information system searches which station is the most convenient one for transferring. Tulp and Siklossy also studied on the German railway systems and they modified Dijkstra's Algorithm to find the shortest path and shortest time route from a departure to an arrival for passengers [8].

Zwaneveld, Kroon and Hoesel used weighted node packing model to prepare a timetable for railway stations [9]. But they only focused on finding the optimum for preparing timetable. But they remark that it is necessary to add capacity, safety measurements and customer services factors to the model for preparing optimum timetable.

Goczyla and Cieltkowski developed a passenger information system that could response to the passengers' optimum route request in a reasonable time period for Poland railway systems [4]. In the study, it is aimed to arrive to the destination in the possible shortest time rather than the shortest distance. In addition, while they were finding optimum route, they took into account the time of changing train in the connecting station.

Brindha, Anand, Gosakan and Joe Prathap developed an automation named as MAXSMINT (Maximizing Speed and Minimizing Time) for passengers [10]. MAXSMINT asks the departure and destination to the passengers and accordingly these information it finds the optimum route.

In a study by Deng, Inoue and Kawakami, materials and products transportation application on the railways was done in a steel factory [11]. They used Ant Colony Optimization to arrange the optimum transporting traffics by considering the constraints about the factories.

3. Dijkstra's Algorithm

Determining the optimal route between two nodes of a graph is actually the process of determining the route with the least cost between these two nodes. The notion of cost may not always mean length. If costing has been made based on time (factors such as rough surfaces and traffic density may require considering time instead of length), the shortest path found will be denominated in terms of time. It should be remembered that what is meant by the shortest path is the path with the least cost.Path solution with the least cost developed by Edsger W. Dijkstra in the year of 1959 and which can also be applied on directed graphs is known as Dijkstra'a Algorithm [12].

Algorithm works on graphs the cost of lines of which is numbered zero or greater than zero. According to this algorithm, in order to find shortest paths (with least cost) leading from any point of the graph to all other points, it is necessary to do iteration as equal to one less than the number of total nodes starting from that point. During this process, distance of each node to the starting node (root node) is calculated and recorded. Then, the smallest one of these nodes, the distances of which have been calculated, is marked. In the next stage, the same process is done for all nodes starting from the marked one and is continued until all other nodes are reached. By forming this tree that covers all nodes, the cost of transportation between the root node and all other nodes is enabled to be the smallest.

To detail the subject using an example, let us consider that the graph in Figure 2 is a path tree consisting of six nodes and distances between each are stated. When A is chosen as the root node, the process to find optimal routes to other nodes is, step by step, as follows:

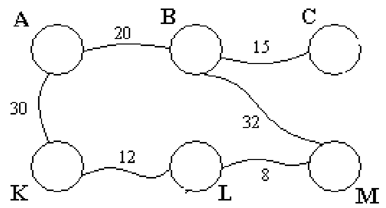

Figure 2. A six-node weighted graph

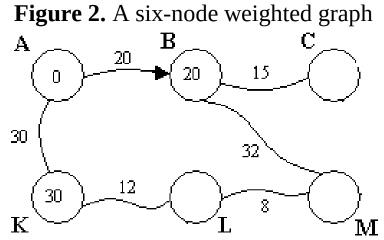

Figure 3. The smallest value belongs to B

1. There are two alternates when started from A node; K and B nodes. Distances between these and A are calculated and these values are written in them. Then, the one with smaller value, that is B node, is selected and marked with arrow (Figure 3).

2. Nodes starting from B, the node which was marked in the previous stage, are checked and their distances are written inside them. According to this, C=35 and M=52. Then, all nodes in which the distance information has been written, except for root node (A) and marked nodes (B), are checked and the smallest one is marked. Therefore, as C=35, M=52 and K=30, K is selected and marked with arrow, based on the route which has got the value written in it (Figure 4).

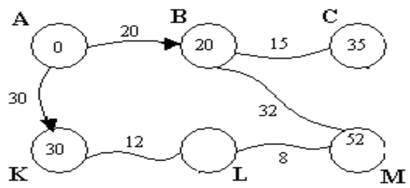

Figure 4. Node with the smallest value is K

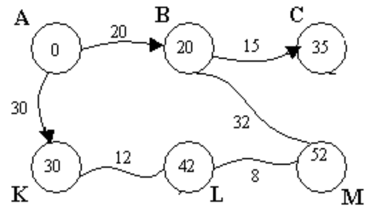

Figure 5. The smallest value belongs to C node

3. As the last marked node is K, following nodes are checked and their distances are written. In this sense, L, which is the node following K, is valued 42. After that, when non-marked nodes the distances of which have been written inside them are checked, it is seen that C is 35, M is 52 and L is 42. As C=35 is the smallest and it has gotten this value from B, it is added to BC line with arrow (Figure 5).

4. Later, the smaller one of the last two nodes is selected (L) and marked (Figure 6).

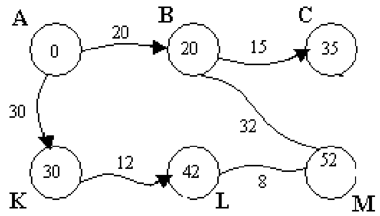

Figure 6. L, smaller one of the last two nodes

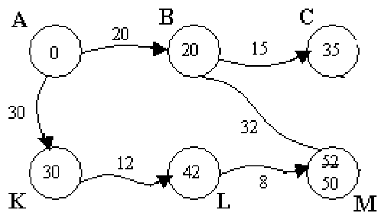

Figure 7. Minimal value of M node

5. Nodes following the last marked node (L) are checked and valued. According to this, we get M 42+8=50. As this value is smaller than 52 which was based on B, 52 is crossed out and replaced by 50 and line coming from L is marked (Figure 7).

After all these processes, the shortest paths leading to all other nodes for the graph above in which A node was chosen the root node are determined as in Figure 8.

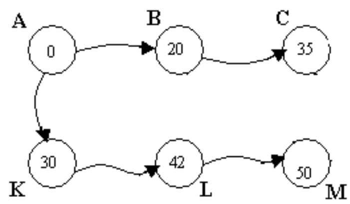

Figure 8. Shortest paths to other nodes from A node

4. Dijkstra's Algorithm Interactive Training Software for Routing Analysis

In this study, railway networks are handled as a graph, railway system is represented by arc-node elements of graph teory. The stations are represented by node and the lines between stations are represented by arcs. Dijkstra's Algorithm is used to find shortest path in the graph. Besides the shortest path criteria does not represent only minimal distance, it can also represents minimal time, minimal cost or minimal train changes as it is mentioned in section 2. Accordingly, in the analysis the arcs of graph are weighted according to shortest path criteria (time, distance, cost, train changes ex.). In this sense, an interactive training software program has been developed for educational use of routing optimization in railways in this study. This software provides students with the opportunity to use Dijkstra'a Algorithm step by step on virtual railway networks which they have designed by themselves, through interactive messages and graphics (Figure 9).

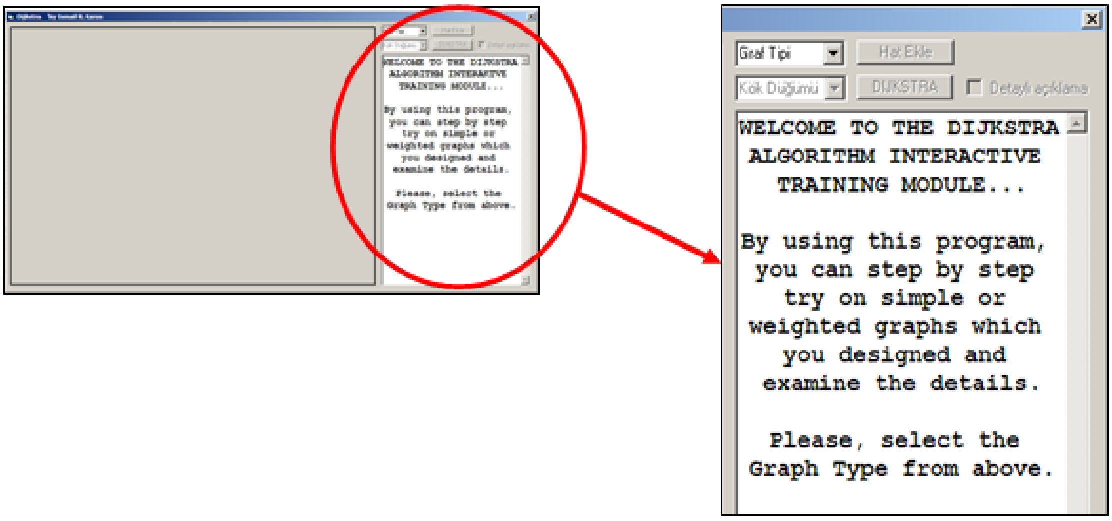

Figure 9. Users can work the Interactive Training Software on graphs designed by them.

Then, Dijktra's Algorithm works on this graph, based on selected root node and users are directed in a similar way to the example explained in Section 2. All stages of the algorithm are simulated visually, clearly and in detail in graphical interface. Also, written messages pop up on user's screen in every stage, explaining current processes in detail (Figure 10).

After all stages are completed, the Shortest Path Tree is introduced to user visually (Figure 11). "Station-Liine-Cost Table" and "Shortest Paths Table" of the tree in question are reported in detail (Figures 12 and 13).

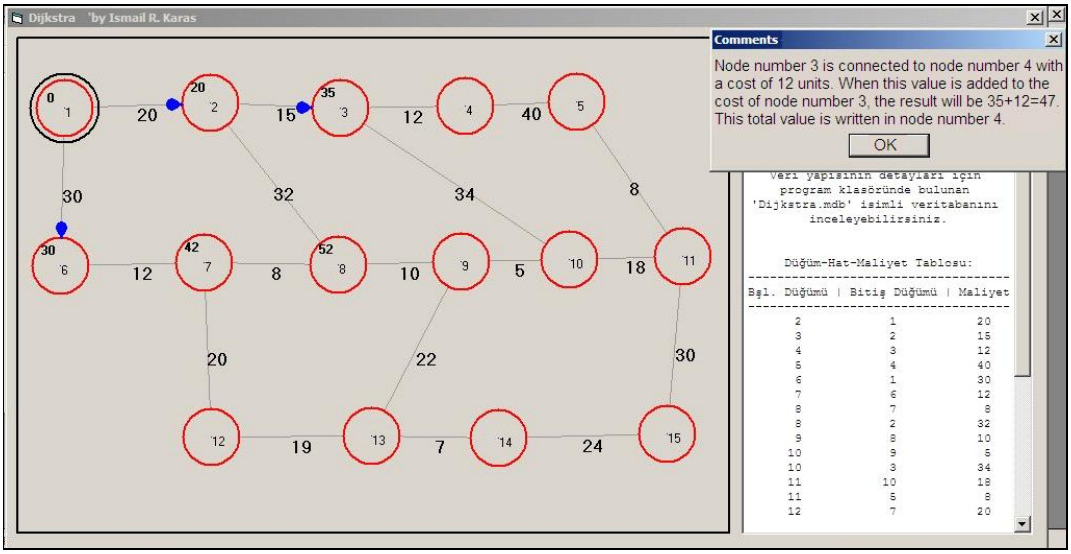

Figure 10. Interactive Training Software enables users to learn visually, step by step, through interactive messages and graphics.

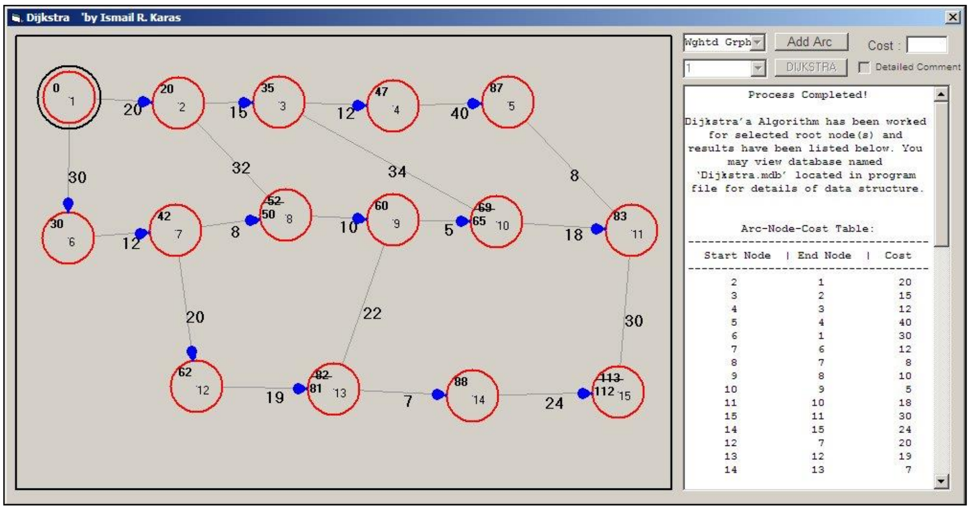

Figure 11. Introducing the shortest path tree as graphic and tabular after completing the algorithm

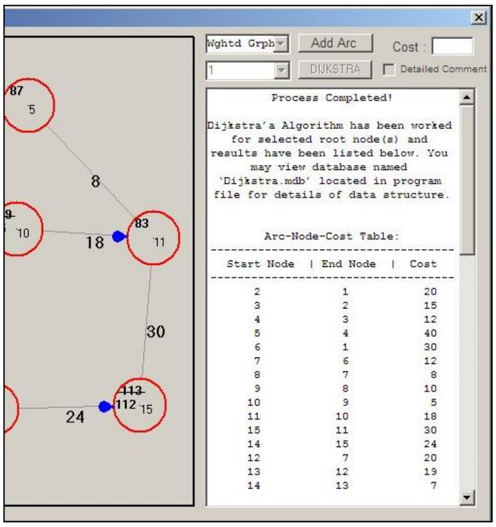

Figure 12. Arc-Node-Cost Table

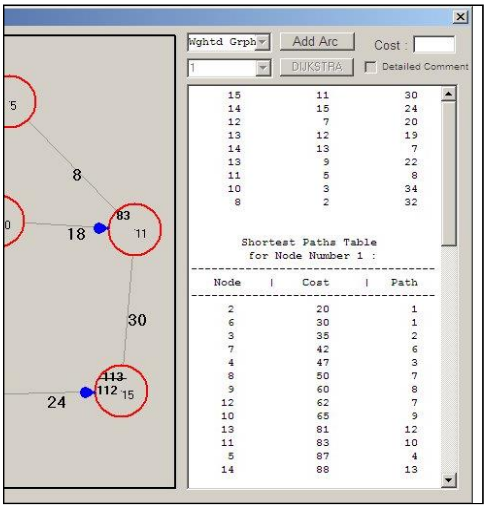

Figure 13. Shortest Paths Table

5. Conclusions

In this study, an interactive training software program, developed for educational use in Railway applications within GIS and Graph Theory is introduced. The railway networks are considered as a graph and Dijkstra's Algorithm is used to find optimum route. Process of route optimization is one of the basic applications of Network Analyses in Geographic Information Systems too. In mathematical background of network analysis applications are graph theory and graph algorithms. Primary graph algorithm employed in process of route optimization is Dijkstra's Algorithm. Dijkstra's Algorithm is placed on the top of linear methods which yield exact solutions. This software provides the opportunity to use Dijkstra's Algorithm on graphs which they have designed by the user and teaches details of algorithm, its working principles and structure of data to them, step by step, through interactive messages and graphics.

Visual learning by making and using simulations and models can enable and enhance learning. It is a proven method resulting in an easier and more effective method of transmitting skills. Students can understand theoretical concepts much easier if they can see, use them, or interact with. Learning by doing uses methods that help students to open their mind.

This study has shown that such interactive and visual training sets contribute to theoretical training to a great extent and thus users can have the opportunity to learn subjects tangibly and clearly.

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