Arc Routing Problem and Solution Approaches for Due Diligence in Disaster Management

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Abstract. Due to the increasing number of disasters in the world, the number of studies in the field of disasters is increasing. The planning, implementation, management and coordination of disaster management activities are very important. Search and rescue, humanitarian assistance, evacuation operations, etc. special infrastructures must be provided to manage situations. One of the most important issues in disaster management is establishing due diligence immediately after the disaster occurs. Quick detection of debris, especially during earthquakes, is extremely important and necessary to reduce the number of casualties. As infrastructures such as the internet, telephone and power lines are damaged in major disasters such as earthquakes, due diligence becomes difficult. Identifying wreckage locations is essential to support search and rescue efforts. In this study, an arc routing problem is considered to determine the condition of buildings in a region affected by an earthquake. The objective is to determine the locations as quickly as possible by checking every road and path in the disaster area at least once. For disaster management, however, it is of great importance to obtain a quick solution to arc routing problems rather than optimal results. Therefore, the solution was sought by the heuristic method of nearest neighbor search, which is widely used in the literature, and the results were recorded.

Keywords: Arc routing · heuristic approach · disaster management · due diligence

1 Introduction

Disasters are events where it is uncertain when they will occur. Therefore, it is very important to always be prepared for these events. Once a disaster occurs, it is important to respond as quickly as possible. An important phase of good disaster management is to plan search and rescue operations quickly and properly. Quick planning plays a major role in reducing the loss of life.

The earthquake is the focus of this study. Communication and transportation infrastructures are severely damaged during major disasters such as earthquakes. This situation affects communication with the disaster area, transportation to the region, and due diligence operations in the region. It is necessary to quickly identify the wreckage on which

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search and rescue operations will be conducted. This situation plays an important role in reducing casualties.

During major disasters, infrastructures such as electricity, internet, etc. are severely damaged. For this reason, teams responding to the disaster are also affected by this situation. Identifying heavily damaged or destroyed buildings during an earthquake and directing search and rescue teams to the debris is difficult. Because of the damage to infrastructure, it is more difficult to determine where the destruction lies in the first moments of the disaster. In this study, a nearest neighbor search heuristic is proposed to perform due diligence studies in a region devastated by earthquakes. The problem is an arc routing problem. It aims to control every street in the affected area by passing them at least once. The best solutions to the related problem can be found through solvers. However, the focus of this study is on rapid damage assessment at a time when there are major deficits in solvers, computers, the internet, electricity, etc.

2 Literature

Since the costs associated with the edges may vary in real-life applications, Keskin and Yılmaz have proposed a formulation for the postman problem that takes this into account [1]. The arc-cycle formulation, an extended version of the formulation in Wang and Wen's [2] pioneering work that directly models time-varying CPP, was proposed by Sun et al. [3]. The cost of travel on a bow varies depending on travel time and time. Vincent and Lin proposed an iterated greedy heuristic for the time-dependent prize-collecting arc routing problem [4]. Tagmouti et al. investigated an arc routing problem with capacity constraints and time-dependent service costs [5]. In another study, Tagmouti et al. proposed a variable neighborhood descent heuristic method to solve the problem under capacity constraints and time-dependent service costs [6]. Street sweeping [7], electric meter reading [8], refuse collection [9] and snow removal [10] are real-life problems modeled as CARP (capacitated arc routing problem). Another of these problems has been winter gritting. Tagmouti et al. discussed the dynamic capacity arc routing problem for winter gritting applications [11]. Black et al. have described a new problem called TD-PARP (Time-Dependent Prize-Collecting Arc Routing Problem). A solution to this problem was sought using the Variable Neighborhood Search and Tabu Search meta-heuristics [12].

Post-disaster damage assessment studies have recently been an important area of study. For example, Nex et al. introduced a new approach for real-time UAV mapping of building damage [13]. Again, a rapid approach to disaster response using UAV and aircraft was presented by Sugita et al. [14]. Another study is the deep learning-based damage map estimation proposed by Tran et al. [15]. Many of these studies are not suitable for use immediately after major disasters. Because, in order to carry out these works, there is a need for qualified personnel to carry out the related works besides electrical power, internet, and computers. The focus of this study is a due diligence proposal to be used in cases where there is no infrastructure such as telephone, internet, computer, electrical power etc. For this purpose, a nearest neighbor search heuristic based on the arc routing problem is proposed.

3 Methodology

The arc routing problems (ARP) is one of the well-studied problems in the literature [1]. The goal of the Chinese Postman problem (CPP) is to find the shortest closed path that visits each edge of an undirected network. CPP is a variant of ARP. It is classified as undirected and directed depending on the state of the edges. Another issue to consider is cost. For the problem in this study, the cost is considered as distance. Therefore, the edges in this study are undirected. Moreover, the problem is symmetric since the distances are independent of the transition direction.

The heuristic proposed in the study aims to visit all arcs at least once without returning to the initial arc. The purpose of the heuristic is not to create a tour that visits the arcs. It is sufficient to visit the arcs at least once in any direction. By passing through each street or avenue at least once, it is ensured that the situation there is determined.

The stages of heuristics are as follows:

1. Initially save the number of passes from the edges as 0 ($n_i = 0$). n_i represents the number of passes of the edge i.
2. Select the starting node. Rank the number of passes and costs of the edges that are connected to the node from smallest to largest.
3. Select the edge with the least cost from the edges with the least number of passes. If the number of passes of the edges is equal, choose the least costly edge. If the number of passes of the edges is equal and the costs are equal, make the selection at random. Increase the number of passes of the selected edge by 1 ($n_i = n_i + 1$).
4. When the new node is reached, update the starting node with the new node and return to Step 2.
5. Continue until the number of passes of all edges is at least 1.

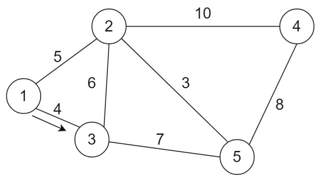
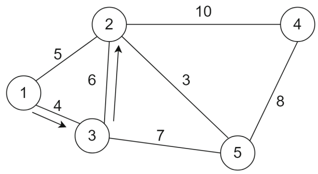
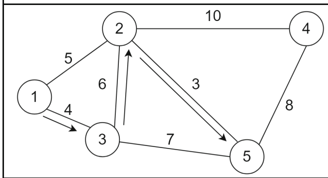
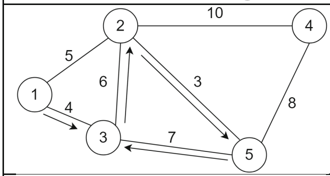
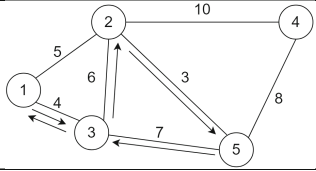
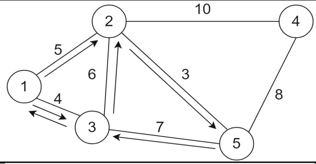
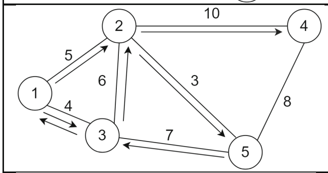
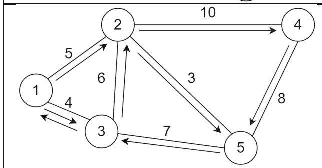
With the proposed heuristic, a search and rescue team with only a network and the costs of the edges can quickly complete debris detection with this information. One of the most important points of the heuristic is that it can be easily calculated by people without the need for any technological infrastructure. It is a very useful heuristic in environments where infrastructures are damaged, such as phones, computers, and the internet.

4 Case Study

The proposed nearest neighbor search heuristic is run in a network consisting of 5 nodes and 7 edges. Details of each step of the heuristic solution are given. Cost refers to the individual cost of all edges that can be traveled from the starting node. The number of passes is the number of times that each edge that can be traveled from the starting node has been used separately. The feasible edge refers to the edges that can be used in the next step according to the proposed heuristic (Table 1).

The route formed according to the result of the proposed heuristic is as follows: 1-3-2-5-3-1-2-4-5. The cost of the relevant route is: $4 + 6 + 3 + 7 + 4 + 5 + 10 + 8 = 53$ units. As can be seen, all edges have been visited at least once. The twice visited edge is only 1–3 arcs.

Table 1. An Example of Proposed Heuristics

The Heuristic Solution	
	Start Node: 1 Costs: 1-2 (5), 1-3 (4) Number of Passes: 1-2 (0), 1-3 (0) Feasible Edges: 1-2 (5), 1-3 (4) Selected Edge: 1-3 (4)
	Start Node: 3 Costs: 3-1 (4), 3-2 (6), 3-5 (7) Number of Passes: 3-1 (1), 3-2 (0), 3-5 (0) Feasible Edges: 3-2 (6), 3-5 (7) Selected Edge: 3-2 (6)
	Start Node: 2 Costs: 2-1 (5), 2-3 (6), 2-5 (3), 2-4 (10) Number of Passes: 2-1 (0), 2-3 (1), 2-5 (0), 2-4 (0) Feasible Edges: 2-1 (5), 2-5 (3), 2-4 (10) Selected Edge: 2-5 (3)
	Start Node: 5 Costs: 5-3 (7), 5-2 (3), 5-4 (8) Number of Passes: 5-3 (0), 5-2 (1), 5-4 (0) Feasible Edges: 5-3 (7), 5-4 (8) Selected Edge: 5-3 (7)
	Start Node: 3 Costs: 3-1 (4), 3-2 (6), 3-5 (7) Number of Passes: 3-1 (1), 3-2 (1), 3-5 (1) Feasible Edges: 3-1 (4), 3-2 (6), 3-5 (7) Selected Edge: 3-1 (4)
	Start Node: 1 Costs: 1-2 (5), 1-3 (4) Number of Passes: 1-2 (0), 1-3 (2) Feasible Edges: 1-2 (5) Selected Edge: 1-2 (5)
	Start Node: 2 Costs: 2-1 (5), 2-3 (6), 2-5 (3), 2-4 (10) Number of Passes: 2-1 (1), 2-3 (1), 2-5 (1), 2-4 (0) Feasible Edges: 2-4 (10) Selected Edge: 2-4 (10)
	Start Node: 4 Costs: 4-2 (10), 4-5 (8) Number of Passes: 4-2 (1), 4-5 (0) Feasible Edges: 4-5 (8) Selected Edge: 4-5 (8)

5 Conclusion

After the disaster has occurred, it is necessary to establish a detailed damage assessment in a timely manner. This is of great importance in accelerating search and rescue activities and assisting survivors. Vehicles such as unmanned aerial vehicles have accomplished great things in this field in recent years. However, there may be such great disasters that it becomes very difficult to reach the disaster site. In addition to this transportation problem, various infrastructures are damaged. Electrical power, computer, telephone, communication tools, etc. types of equipment are vital needs for first response and disaster management. In cases where these infrastructures cannot be provided, it is necessary to know where the debris is, especially in the hours immediately after the disaster occurs. With the nearest neighbor search heuristic proposed for this purpose, debris detection can be performed without the need for any infrastructure, technology or qualified personnel.

The only information needed for the proposed heuristic is a detailed map of the relevant disaster area and the distance to the streets. In light of this information, the damage assessment team, which starts working from any point, will have passed all the ways as soon as possible. Thus, a great contribution will be made to the disaster response and disaster management stages. Because search and rescue efforts are dynamic and complex. The more consciously the work is started, the faster the chance of responding to the disaster occurs. Therefore, detection studies have importance to direct all disaster management and response studies.

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