Journal scientific and applied research, vol. 27, 2024
International Journal

Original Contribution

ISSN 1314-6289 (Print)
ISSN 2815-4622 (Online)

APPLICATION OF HEURISTIC ALGORITHMS IN LOGISTICS

Andrey I. Bogdanov

ENGINEERING LOGISTICS, FACULTY OF TECHNICAL SCIENCES, KONSTANTIN PRESLAVSKY UNIVERSITY OF SHUMEN, SHUMEN 9712, 115, UNIVERSITETSKA STR., E-MAIL: a.bogdanov@shu.bg

ABSTRACT: *The paper deals with algorithms for solving logistics problems. It describes types of heuristic algorithms focusing on their strengths and weaknesses. Incorporating the advantages and disadvantages of heuristic algorithms, it offers feasible solutions.*

KEY WORDS: *Logistics management, Analytical hierarchy process, Storage area.*

1. Introduction

Many logistic problems are combinatorial by nature. Combinatorial optimization problems could be solved by exact or by heuristic algorithms. The exact algorithms always find the optimal solutions. The wide usage of the exact algorithms is limited by the computer time needed to discover the optimal solutions. In some cases, this computer time is enormously large [1].

Heuristic algorithm could be described as a combination of science, invention, and problem solving skills. In essence, a heuristic algorithm represents procedure invented and used by the analysts in order to “travel” through the space of feasible solutions. Good heuristics algorithm should generate quality solutions in an acceptable computer time. Complex logistic problems of big dimensions are usually solved with the help of various heuristic algorithms [2]. Good heuristic algorithms are capable of discovering optimal solutions for some problem instances, but heuristic algorithms do not guarantee optimal solution discovery

2. Related work

An example of approximation is described by Jon Bentley [3] for solving the traveling salesman problem (TSP) so as to select the order to draw using a pen plotter. TSP is known to be NP-Complete (Nondeterministic Polynomial time) so an optimal solution for even a moderate size problem is intractable. Instead, the greedy algorithm can be used to give a good but not optimal solution (it is an approximation to the optimal answer) in a reasonably short amount of time.

The problem can be defined as follows: Find the shortest itinerary, which starts in a specific node, goes through all other nodes exactly once, and finishes in the starting node. In different traffic, transportation, and logistic problems, the traveling salesman can represent airplanes, boats, trucks, buses, crews, etc. Vehicles visiting nodes can deliver or pick up goods, or simultaneously perform pick-up and delivery.

“Greedy” heuristic algorithms build the solution of the studied problem in a step-by-step procedure [4]. In every step of the procedure the value is assigned to one of the variables in order to maximally improve the objective function value. In every step, the greedy algorithm is looking for the best current solution with no look upon future cost or consequences. Greedy algorithms use local information available in every step. The fundamental concept of greedy algorithms is similar to the “Hill-climbing” technique.

In case of “Hill-climbing” technique the current solution is continuously replaced by the new solution until it is not possible to produce further improvements in the objective function value. “Greedy” algorithms and the “Hill-climbing” technique are similar to the hiker who is trying to come to the mountaintop by never going downwards (Fig. 1).

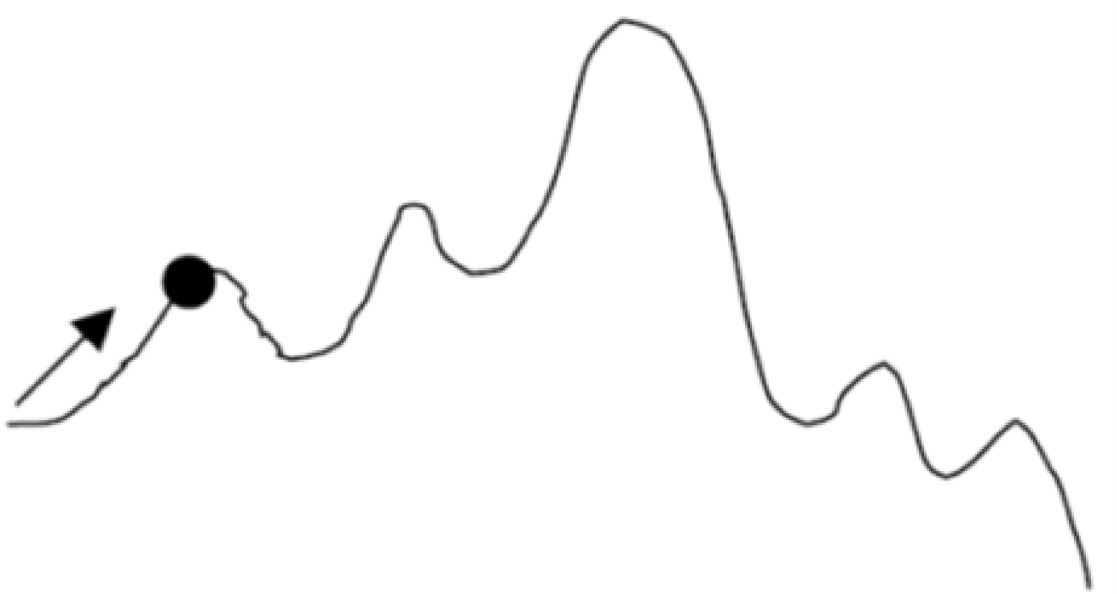

Fig. 1. Hiker who is trying to come to the mountaintop by going up exclusively

As it can be seen from Figure 1, hiker's wish to never move down while climbing, can trap him or her at some of the local peaks (local maximums), and prevent him or her from reaching the mountaintop (global maximum). "Greedy" algorithms and the "Hill-climbing" technique consider only local improvements.

The Nearest Neighbor (NN) heuristic algorithm is a typical representative of "Greedy" algorithms. This algorithm, which is used to generate the traveling salesman tour, is composed of the following algorithmic steps:

Step 1: Arbitrarily (or randomly) choose a starting node in the traveling salesman tour.

Step 2: Find the nearest neighbor of the last node that was included in the tour. Include this nearest neighbor in the tour.

Step 3: Repeat Step 2 until all nodes are not included in the traveling salesman tour. Connect the first and the last node of the tour.

The NN algorithm finds better solutions than the algorithm based on random choice, as it uses the information related to the distances between nodes.

Let us find the traveling salesman tour starting and finishing in node 1, using NN heuristic algorithm (Figure 2)

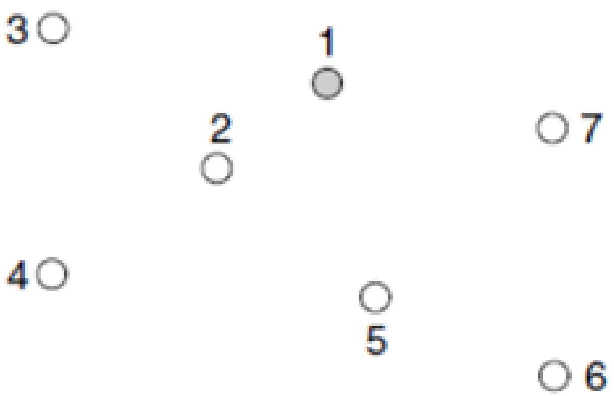

Fig. 2. Network in which a traveling salesman tour should be created using NN heuristic algorithm

The distances between all pairs of nodes are given in the Table 1.

1	**2**	**3**	**4**	**5**	**6**	**7**
0	75	135	165	135	180	90
75	0	90	105	135	210	150
135	90	0	150	210	300	210
165	105	150	0	135	210	210
135	135	210	135	0	90	105
180	210	300	210	90	0	120
90	130	210	210	105	120	0

The route must start in node 1. The node 2 is the NN of node 1. We include this NN in the tour. The current tour reads: (1, 2). Node 3 is the NN of node 2. We include this NN in the tour. The updated tour reads: (1, 2, 3). Continuing in this way, we obtain the final tour that reads: (1, 2, 3, 4, 5, 6, 7, 1). The final tour is shown in Figure 3.

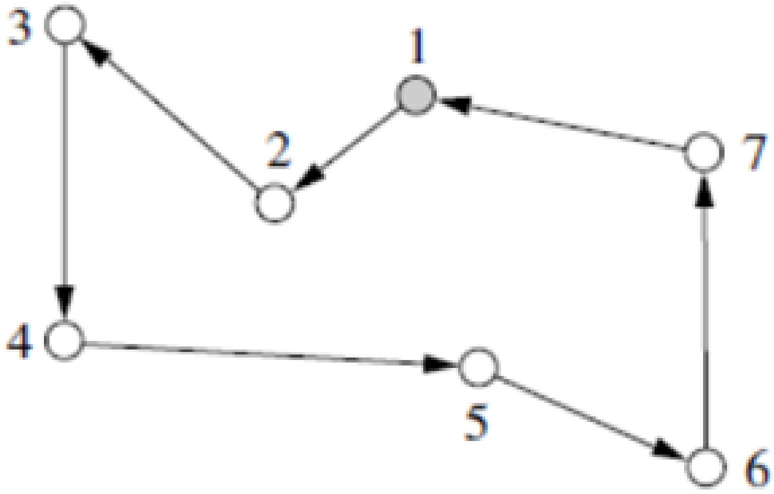

Fig. 3. Traveling salesman tour obtained by the NN heuristic algorithm

When applying "greedy" approach, the analyst is forced, after a certain number of steps, to start to connect the nodes (in case of TSP) quite away from each other. Connecting the nodes distant from each other is forced by previous connections that significantly decrease the number of possible connections left.

Exchange heuristic algorithms are based on the idea of interchange and they are widely used. The idea of interchange is the idea to start with the existing solution and check if this solution could be improved.

Exchange heuristic algorithm first creates or selects an initial feasible solution in some arbitrary way (randomly or using any other heuristic algorithm), and then tries to improve the current solution by specific exchanges within the solution.

The good illustration of this concept is two-optimal tour (2-OPT) heuristic algorithms for the TSP [3-OPT and k-optimal tour (k-OPT) algorithms are based on the same idea]. Within the first step of the 2-OPT algorithm, an initial tour is created in some arbitrary way (randomly or using any other heuristic algorithm). The two links are then broken (Fig. 4).

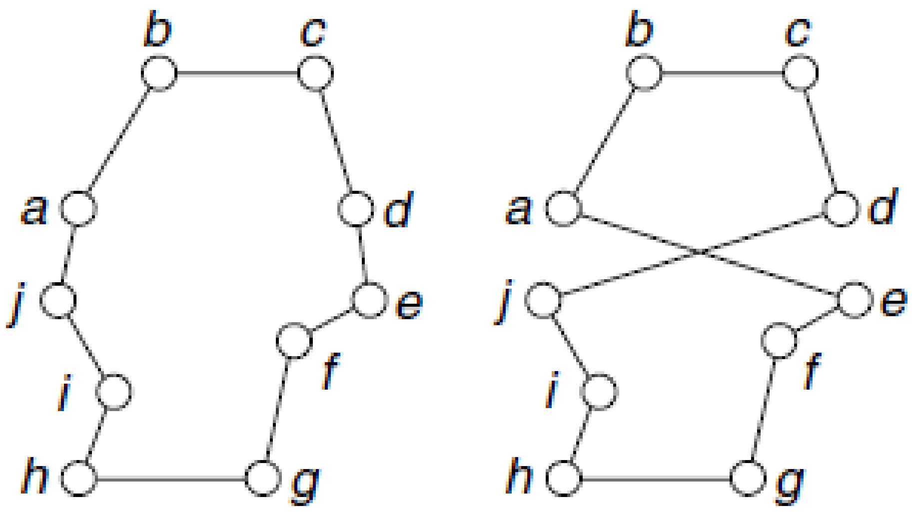

Fig. 4. Interchange of two links during 2-OPT algorithm

The paths that are left are joined so as to form a new tour. The length of the new tour is compared with the length of the old tour. If the new tour length is less than the old tour length, the new tour is retained. In a systematic way, two links are broken at a time, paths are joined, and comparison is made. Eventually, a tour is found whose total length cannot be decreased by the interchange of any two links. Such a tour is known as two-optimal tour (2-OPT).

By using the 2-OPT algorithm, we will try to create the traveling salesman tour for the network shown in Figure 2. The distances between nodes are given in Table 1. The traveling salesman should start his trip from node 1. The initial tour shown in Figure 3 is generated by the NN algorithm. It was not possible to decrease the total length of the initial tour by interchanging of any two links. Our initial tour is 2-OPT

In some cases it is desirable to decompose the problem considered into smaller problems (sub problems). In the following step every sub problem is solved separately. Final solution of the original problem is then obtained by “assembling” the sub problem solutions. We illustrate this solution approach in case of the standard vehicle routing problem (VRP).

The Sweep algorithm is one of the classical heuristic algorithms for the VRP [5]. This algorithm is applied to polar coordinates, and the depot is considered to be the origin of the coordinate system. Then the depot is joined with an arbitrarily chosen point that is called the seed point. All other points are joined to the depot and then aligned by increasing angles that are formed by the segments that connect the points to the depot and the segment that connects the depot to the seed point. The route starts with the seed point, and then the points aligned by increasing angles are included, respecting given constraints. When a point cannot be included in the route as this would violate a certain constraint, this point becomes the seed point of a new route, and so on. The process is completed when all points are included in the routes (Fig. 5).

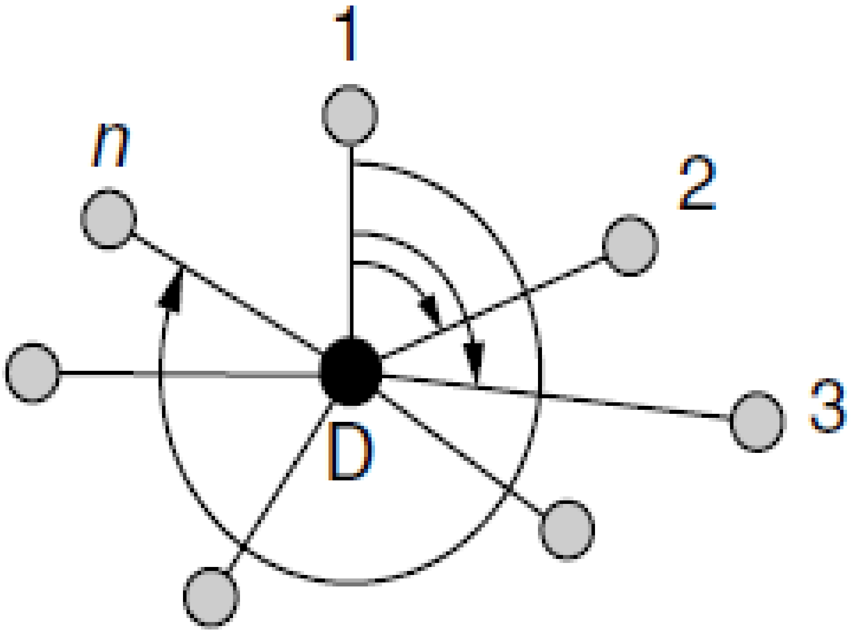

Fig. 5. Sweep algorithm

In case when a large number of nodes need to be served, the Sweep algorithm should be used within the "clustering-routing" approach. In this case, considering clockwise direction, the ratio of cumulative demand and vehicle capacity should be checked (including all other constraints).

The rotating calipers technique for designing geometric algorithms may also be interpreted as a form of plane sweep, in the projective dual of the input plane. A form of projective duality transforms the slope of a line in one plane into the x-coordinate of a point in the dual plane, so the progression through lines in sorted order by their slope as performed by a rotating calipers algorithm is dual to the progression through points sorted by their x-coordinates in a plane sweep algorithm.

3. Conclusion

The objective of a heuristic is to produce a solution in a reasonable time frame that is good enough for solving the problem at hand. This solution may not be the best of all the actual solutions to this problem, or it may simply approximate the exact solution. But it is still valuable because finding it does not require a prohibitively long time.

The final solution depends on a choice of the seed point. By changing locations of the seed point it is possible to generate various sets of vehicle routes. For the final solution the set of routes with minimal total length should be chosen.

References:

[1] Apter I., Michael J., The Computer Simulation of Behaviour. London: Hutchinson & Co. p. 2013.

[2] Gillett B., and Miller L., A Heuristic Algorithm for the Vehicle Dispatch Problem, Oper. Res., 22, 340–352, 2022

[3] Hillier F., and Lieberman G. J., Introduction to Operations Research, McGraw-Hill Science, Columbus, OH, 2012.

[4] Bentley J., Writing Efficient Programs. Prentice Hall. 2014 p. 11.

[5] Taha H., Operations Research: An Introduction (8th Edition), Pearson Prentice Hall, Upper Saddle River, NJ, 2016.