BRAINSTORMING ALGORITHM FOR DRONES ROUTING PROBLEM

Jalawi Sulaiman Alshudukhi
Computer Science and Engineering, University of Hail, Hail, Kingdome of Saudi Arabia
j.alshudukhi@uoh.edu.sa

ABSTRACT: *Energy is a critical issue in vehicle routing. UAV's or Drones have been the fundamental way in activities where a human has their limited skills to do. Drones save too much time in accomplishing such tasks. The growing usage of drones by commercial firms has contributed to developing a new Vehicle Routing Problem with Drones (VRPD). Self-driving cars and aircraft can be used to transfer packages from one place to another to customers. Vehicles and drones could have dependent or independent deliveries. A drone takes off from a vehicle for package delivery and then returns to the same vehicle after the delivery as long as the drone's energy restrictions are met. This paper tries to model the UAV's routing process to understand the problem clearly. Besides, the paper proposes a modified version of the Brainstorming algorithm to find the best routing for drones. Experiments are carried out in numerous environments and with various scenarios. The findings indicate the suggested algorithm to solve the drone routing problem is much effective with 70% enhancement than the random routing.*

1. INTRODUCTION

Drones became one of the important problems in industry and academia alike; More and more people are beginning to use Unmanned Aerial Vehicles (UAVs) or Drones. Initially used for military uses, drones and associated developments have recently branched out into a whole different area, including delivery, logistics, surveillance, and so on [9-12]. Their use in otherwise inaccessible or dangerous places has opened new opportunities. For any application, the biggest problem is picking the drone routes. Simultaneously, controlling the complexity of these routes has massive problems, including insufficient energy and low load capacity. Effective use of a drone can be mathematically described as a pathfinding issue with some constraints.

Additionally, drones have sensors in place and can get a precise picture of emergency scenes and gather data that is unattainable by ground-based devices. Most of the drones can detect firesand localize firefighters, helping firefighters saving their time. Atmospheric monitoring, a remote sensing station, agricultural farming, remote sensing using drones give a more precise assessment due to drones cameras and sensors (thermal, hyperspectral, etc.) Drones are also cost-effective for businesses like package delivery to multiple customers.

Drones routing problem could be formulated as an optimization problem where the total travel time is the objective function. Similar problems in different fields are considered in [1-6]. However, drones' routing differs in many issues where three variables need to be considered: the vehicles, the drones, and the customers. Also, in some routing variations, drone travel time and drone capacity might be considered.

This paper is organized as follows: Section 2 explains the problem statement; section 3 presents the Brainstorming approach for the drone routing problem; experiments results are described in section 4, and the paper concludes in section 5.

2. Problem Statement

Assume that there are V vehicles, and each vehicle holds a drone. Those vehicles and drones are supposed to transfer packages to N = {0,1,2, ……., n} customers. Drones must start from the initial position, i, delivering the packages to customers and returning to the same position. The main objective is to find routes that minimize the total transportation distance/time serving all customers. Therefore, the main rules are as follows:

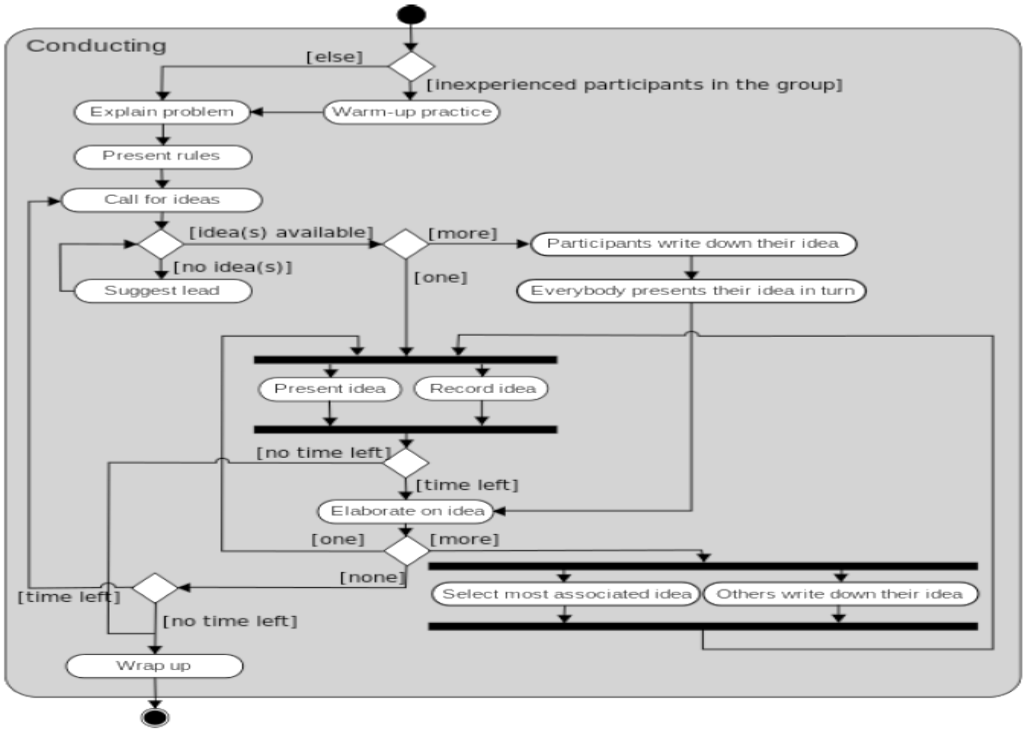
- Drones should start the delivery and finishes it either at the depot or at a customer.
- Vehicles are assumed not moving, and they have a fixed position.
  - Drones can serve only customers within their range.
  - In each flight, the drone can serve only one customer.
  - The drone must return to its own vehicle.
  - The drone loading time is ignored in this paper.
  - Drones environment is assumed safe, and security breaches are not considered in this paper.
  - Drones have a limited capacity of one package.
  - A customer could be within the range of more than one drone.

This problem is one of the *NP-HARD* problems and can not be solved optimally. A greedy algorithm could be suitable for the solution. In the next section, the brainstorming algorithm is proposed as a solution and compared to one of the recent algorithms that use Generic Algorithm (*GA*) with sweep local research [1].

3. Brainstorming Solution for Drones Routing Problem

This section introduces the Brain Storming algorithm for the drone routing problem. BSO is a modern algorithm that utilizes human cognition to solve complicated issues. It incorporates the human brainstorming process. People come together trying to find a solution for a specific problem. They generate their ideas, share them, and then continue to review, pick, and execute the best ones. The flowchart of the initial brainstorming events is illustrated in Figure 1. The details on the figure indicate that the brainstorming method requires iterations to arrive at an optimal solution to the problem. Individuals who are close enough collaborating together to produce new solutions.

Rabie in [7] and Rabie and Ahmed in [8] modified this method of thinking for the purposes of problem-solving in Wireless Sensor Networks (WSNs). To reach successful strategies, humans should follow forms of thought like those of animals. Two iterations of the brainstorming method are split into eight steps, each of which is outlined in Algorithm 1. Step 6 acts as a divergence for people from slipping through the same thoughts



Algorithm 1 : Brainstorming Process

- Step 1: Get people from a different background as much as possible.
- Step 2: People should generate many ideas according to the following rules:
  - Rule 1: Suspend judgment
  - Rule 2 Anything goes
  - Rule 3 Cross-fertilise (piggyback)
  - Rule 4 Go for quantity
- Step 3: Some persons will be selected to be the owners of the problem to pick the good ideas from the gathered people.
- Step 4: The selected ideas will be used as a base for generating more ideas according to the same rules stated in Step 2.
- Step 5: Repeat Step 3 to pick the good generated ideas.
- Step 6: Randomly pick an object and use the functions and appearance of the object as clues, generate more ideas according to the rules.
- Step 7: Let the owners pick up several better ideas.
- Step 8: By this step, we hope that good ideas are reached to be considered as a solution to the problem at hand.

Figure 1. Human Brainstorming technique [7].

To adopt the algorithm to the drone routing problem with the previously mentioned constraints. The ideas are represented in the form of a scalar array, where each value represents a customer. Each scaler array is generated for only one drone. Therefore, each person is responsible for generating a complete solution for all of the drones and customers. Ideas are collected in a pool and evaluated based on the overall drones' traveling distances and time. Ideas are clustered using K-means using the objective function parameters. Further, the Position-Based Crossover Operator (POS) technique is used, where two solutions within each cluster are merged based on POS based on certain probability. The newly generated solutions are then reevaluated, and the process continues for a certain number of iterations defined by the user.

4. EXPERIMENTAL RESULTS

To evaluate the proposed algorithm, some case studies are implemented using Java on 4 core 2.1GHZ desktop. The proposed approach is compared to the random routing approach. The following are the designed case studies:

Case Study 1: in this case study, the algorithm conversion with the number of iterations is studied. The number of iterations goes from 100 to 1000. As shown in Figure 2, although there is fluctuation in the performance, the algorithm converges with the number of iterations in a linear form on average.

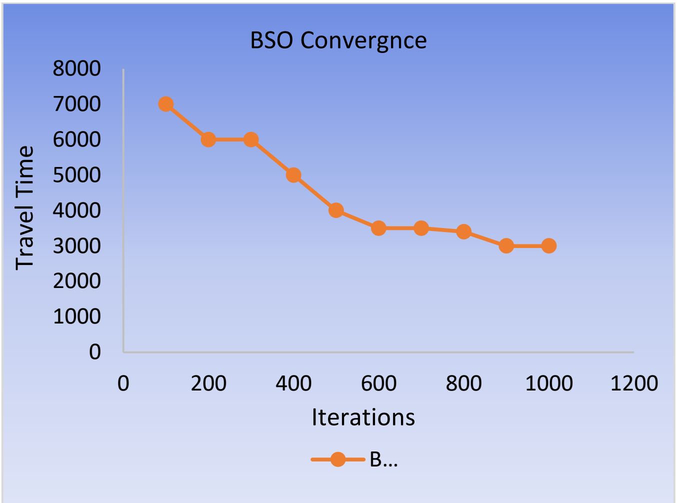


Figure 2. BSO convergence

Case Study 2: In this case study, a fixed number of customers are deployed, and a variable number of drones are utilized. Drones are assumed homogenous in terms of their speed and range. As shown in Figure 3, the number of drones varies from 10 to 50 while the number of vehicles is 5. The number of drones per vehicle is distributed based on a normal distribution. Also, the number of customers in this case study is assumed 100. The figure shows that BSO is producing a much better time to visit all of the customers, more than 50% enhancement in time. However, it worth mentioning that BSO total travel time saves more time as the number of drones increases.

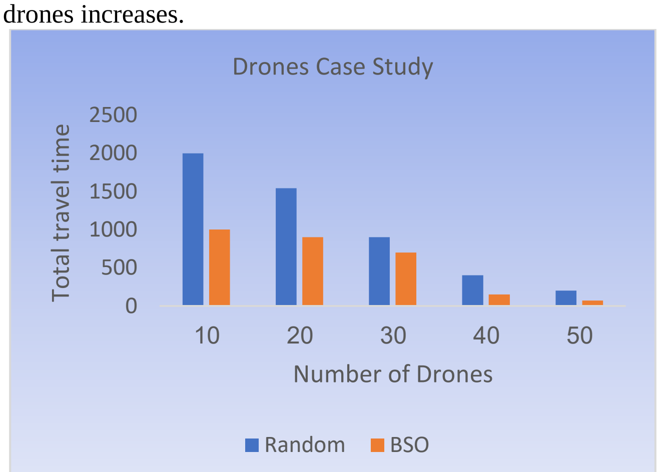


Figure 3. Fixed number of customers case study

Case Study 3: in this case study, a fixed number of drones and a variable number of customers are considered. Also, drones, in this case, are assumed homogenous in terms of their speed and range. Once more, the number of drones per vehicle is distributed based on a normal distribution. Besides, the number of vehicles is set to 5. The number of customers ranges from 20 to 100. As can be seen in Figure 4, the total travel time for BSO shows almost 60% enhancement which confirms our previous set of experiments.

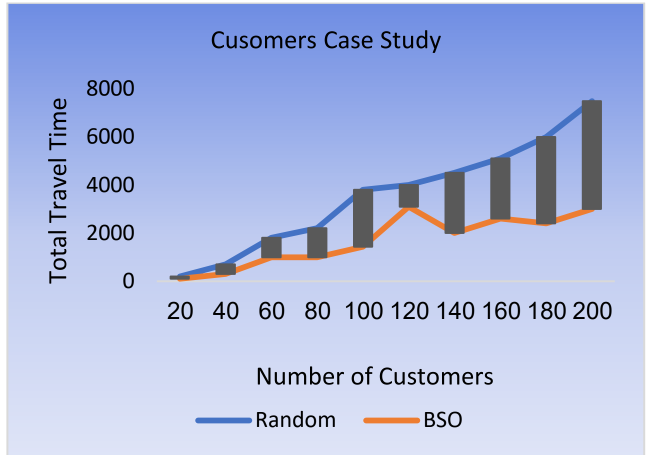


Figure 4. Total time vs. number of customers

Case Study 4: In this case study, the number of customers and the number of drones are assumed fixed while the number of vehicles varies from 5 to10; vehicle positions are considered fixed. The number of customers is assumed 100, and the number of drones is assumed 50. Here, the drones are assumed heterogeneous in terms of their range and speed. As shown in Figure 5, BSO's total travel time shows an overall 50% time reduction. However, it seems that, in some cases, BSO is not performing well, especially when the number of vehicles is small.

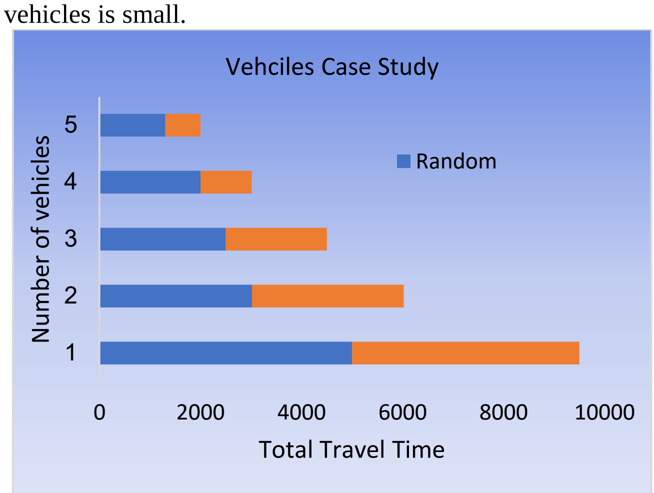


Figure 5. Total time vs. number of vehicles

5. CONCLUSION

This paper studied drone routing using the Brainstorming algorithm. The algorithm tries to find the best route for a single and multiple drones given a set of customers. Drones are assumed loaded on a vehicle or more. The paper tries to find the best drones' travel time making sure that all of the customers are visited. Different case studies are examined with different variations. BSO is compared to random routing, where drones are chosen randomly to visit random customers as well. Based on the conducted experiments, BSO shows up to 70% total travel time enhancement.

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