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The Application of Artificial Bee Colony Algorithm to Optimizing Vehicle Routes Problem

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Abstract

The problem of vehicle routing with capacity is a combinatorial optimization problem that is included in the NP-Hard category. In this article, we suggest an artificial bee colony algorithm, which is a technique inspired by the clever behavior of bees in searching for food sources. To achieve the best outcomes, the artificial bee colony algorithm will be developed in conjunction with other algorithms. To determine how well the artificial bee colony method handles the issue of optimizing vehicle routes with capacity, eight distinct benchmark problems will be completed and then contrasted with other algorithms. The output of this research is a matrix showing the sequence of vehicle routes formed.

Keywords: vehicle, optimization, food, problems.

INTRODUCTION

As the industrial world has developed in the past decade, competition between companies has become commonplace. Every company is competing to improve its performance in order to survive in this very tight global competition (Winston, 2004). Improving the quality of service to meet consumer demand is one of the ways companies survive in the industrial world. One way to achieve this is by optimizing the distribution process, which is supported by current technological advances. Of course, every company wants an effective distribution channel with minimum travel costs (Christian, 2011). The Capacited Vehicle Routing Problem (CVRP), a particular kind of problem, is a representation of the issues discussed earlier. In the category of NP-Hard Problems, which are problems that become more complex and time-consuming as the size of the issue data rises, CVRP is a complex combinatorial optimization problem. In the CVRP problem, each route made up of multiple vehicles must adhere to a number of requirements: (a) each route must begin and end at the depot; (b) only one vehicle may visit each customer at a time; (c) the sum of all requests must not exceed the capacity of the vehicle Q; and (d) the total cost of all routes must be as low as possible. Each side of the network represents the connection between the two points and also indicates the direction in which they are traveling (Toth & Vigo, 2002). The number of routes in the network is equivalent to the number of vehicles used. So, one vehicle is used only for one route. With the aim of minimizing transportation costs, distance calculation is an important process (Bhagade & Puranik, 2002).

Along with the development of optimization methods, several new approaches have been found to solving optimization problems. The Artificial Bee Colony (ABC) method is one of them. A novel method called ABC was created in 2005 by Turkish researcher Darvis Karaboga. It has been used to solve a variety of optimization issues, including the traveling salesman problem and the vehicle routing problem (Szeto et al., 2011). Integer programming, mixed integer programming, tabu search, genetic algorithms, simulated annealing, ant colony, branch and cut, artificial bee colony, and other techniques have all been created to handle CVRP problems (Caric et al., 2008).

This research is a follow-up study from previous researcher and is a physical proof of how CVRP is applied in real conditions (Rera, 2010). However, previous studies have not explained how the model and form of solving the algorithms are built. In this study, the neighborhood operator random swap and random insertions will be used to modify the Artificial Bee Colony (ABC) approach in order to solve the CVRP problem. The branch and cut procedure will be used to compare the simulation results with the data supplied as input for the programming simulation (Nismah, 2006). The expected result is that this research can show the performance of ABC computation for the CVRP problem and the computer program as the implementation of the algorithm.

METHOD

This research was conducted to apply and develop the ABC model for solving CVRP problems. Basically, the methodology carried out by the researcher can be divided into four parts, namely: (1) literature study, which the researcher prepares by studying the CVRP problem and the ABC algorithm; (2) development stage: at this stage, the researcher tries to develop the ABC algorithm so that it can be applied to CVRP problems; (3) Testing phase: at this stage, the researcher tries to apply the model that has been made to the CVRP problem through programming simulation; (4) Discussion and conclusion stage: for this stage, the researcher has obtained the desired results through programming simulations and then analyzed them to draw conclusions from this study. A literature study conducted by researchers is aimed at obtaining and understanding theories related to the methods used and the problems in this study. Besides that, this literature study is also used to find references to previous studies, especially those related to the ABC algorithm and CVRP problems. At this stage, the development of the ABC algorithm model is carried out in order to be able to solve CVRP. The development of the algorithm model is divided into two phases: the first phase is route construction, and the second phase is distance improvement. In the first phase, the researchers used the Clark and Wright algorithm. Meanwhile, in the second phase, the ABC algorithm is used to improve the total distance from the solution generated in the first phase.

In this testing phase, testing of models that have been developed previously through programming simulations is carried out, which will then be tested on validation problems and compared with other methods such as Harmony Search. Algorithm testing will be carried out using programming simulations. As for the hardware specifications used, it is a computer with an AMD A6-3400M APU quad-core 1.4 GHz processor and 4 GB of RAM. For the testing phase of the test data, researchers used test data from the Branch and Cut website. Because the website provides data for free and at the same time generates optimal value from the results of their research, this optimal value can be used by researchers as a reference for comparing the optimal value generated through this research. In this study, researchers used eight test cases with different numbers of customers. At this discussion and conclusion stage, an analysis of the results obtained in the testing process is carried out to determine whether the results are satisfactory or not, and the researcher will try to compare the results of the ABC algorithm with those of other algorithms. Then the results of this study will be concluded.

RESULT AND DISCUSSION

In the data used in the trial process carried out on the ABC algorithm for solving CVRP problems, there are seven different types of problems, namely: Data A-n32-k5 with 32 customers and 5 vehicles. Data A-n45-k7 with 45 customers and 7 vehicles. Data A-n46-k7 with 46 customers and 7 vehicles. Data A-n60-k9 with 60 customers and 9 vehicles. Data B-n78-k10 with 78 customers and 10 vehicles. P-n101-k4 data with 101 customers and 4 vehicles. M-n121-k7 data with 121 subscribers and 7 vehicles. F-n135-k7 data with 135 customers and 7 vehicles. The data above will be entered into the formation of a route that is carried out using the ABC algorithm. The formation of the initial route using the Clark and Wright algorithm is as follows: Based on the saving value matrix, the initial route is selected by inserting the customer pair that has the largest saving value, namely (5, 9), and the initial route formed is [1 5 9 1]. Then select the customer who has the largest saving value, namely (9, 10), then insert customer 10 into the route after customer 9, so the temporary route is [1 5 9 10 1]. After that, check whether the customer demand on the route formed exceeds the vehicle capacity. If not, then continue inserting the route with the largest saving value. From the saving value matrix table above, if customer 4 is inserted into the route before customer 5, then the route formed is [1 4 5 9 10 1]. Then check again to see whether the customer demand on the route formed exceeds the vehicle capacity. If so, a new route must be formed. The total demand for the route formed above is 49 with a vehicle capacity of 50, so it is no longer possible for the route above to be inserted by new customers. Choose a new customer with the largest saving value as the initial customer for the formation of a new route, namely, the possible customer pair is (3,7), and the new route formed is [1 3 7 1]. Check whether the customer demand on the route formed exceeds the vehicle capacity. If not, then continue inserting the customer on the route. Customers that may be inserted are customer 8, and the route formed is [1 3 7 8 1]. Re-check the vehicle capacity to determine whether the demand exceeds the vehicle capacity. Because the total requests on the route formed are 49, there are no more possible customers to be inserted. Create a new route by selecting the customer pair with the largest saving value. Because the remaining customers are (2, 6), the last route formed is [1 2 6 1]. The following is a route formed with a maximum of three vehicles: [1 4 5 9 10 1], [1 3 7 8 1], [1 2 6 1].

After the initial route formation was carried out using the Clark and Wright method, the route improvement stage was continued using the ABC algorithm in order to get the minimum distance. In this case, several parameters and rules are used, as follows: The initial route that is formed is combined into one matrix row and stored as the best temporary route. Best Food = [1 4 5 9 10 1 3 7 8 1 2 6 1]. The number of vehicles cannot exceed the specified initial value of the trial, which is 0. Step 1 Employed Bee as follows: Randomize two different matrix indices; in this case, the 4th and 7th indices are selected. Then swap or exchange the two indices, and the route [1 4 5 9 10 1 3 7 8 1 2 6 1] changes to [1 4 5 3 10 1 9 7 8 1 2 6 1]. Check the total demand from each route to see whether it exceeds the vehicle capacity. If not, then compare the distance with the previous route, and if yes, then return two different random matrix indices and add the trial value by 1. In this case, the total demand from each route above is [62, 34, 26]. Due to the maximum capacity of 50 vehicles, the route above is not possible to form, and the route returns to its original form. Because the above experiment failed, the trial value was 1. Enter the next iteration. Then randomize the two matrix indices again, and this time the 7th and 8th indexes are selected. Swap the indexes, and the route formed is [1 4 5 9 10 1 7 3 8 1 2 6 1] by exchanging customer 3's position with customer 7. Check the demand for each route to see if it exceeds capacity. The total demand for the above routes is [47, 49, 26], and the routes that are formed do not exceed capacity. After checking the request, check whether the route distance that is formed is less than the previous route. If yes, then the route can be used, saved as Best Food, and the trial value changed to 0. Since the total route distance above is better, namely 569.4584, than the previous one (574.8824), then Best Food = [1 4 5 9 10 1 7 3 8 1 2 6 1]. Perform the steps above until they meet the length of the route. The trial value will continue to be added to 1 if the route improvement attempt does not produce the best route, and the trial value will be changed to 0 if the best route is found. Then calculate the probability value for each route based on the distance.

Then Step 2: Onlooker Bee, as follows: Choose a route based on probability; in this case, the route chosen is the first route, namely [1 4 5 9 10 1]. Select the matrix index on the first route randomly, and index 3 is selected on the first route. Randomly select any matrix index; this time the 10th index is selected. Insert index 3 after the 10th route index, and then the route formed is [1 4 9 10 1 7 3 8 1 5 2 6 1 chosen is the first route, namely [1 4 5 9 10 1]. Select the matrix index on the first route randomly, and index 3 is selected on the first route. Randomly select any matrix index; this time the 10th index is selected. Insert index 3 after the 10th route index, and then the route formed is [1 4 9 10 1 7 3 8 1 5 2 6 1], with customer 5 in substitute after the 10th index. Check whether the total demand for each route exceeds capacity; if not, then proceed to the next stage, which is to compare the total distance with the previous route; if yes, then return to the initial stage of step 2, and the trial value is added by 1. Total requests from the route above are [28, 49, 45]. Because it does not exceed the capacity of the vehicle, the route is compared in distance to the previous route. Because the total distance of the previous route was better, namely 569.45584, and the repair route was 708.4247, the repair route was not used, and the trial value was increased by 1. Best Food remained unchanged. Then return to the initial Onlooker Bee stage and repeat the steps above until it meets the length of the route. Just like in step 1, the trial value will continue to be added by 1 if the route repair attempt fails, and the trial value is changed to 0 if the best route is found. Then save Best Food into Global Food. After that, check whether the trial value exceeds the limit; if not, return to step 1 employed bee, and if so, go to step 3 scout bee. The last step is the Scout Bee, as follows: When the trial value exceeds the specified limit, a new random route is made, and the new route is called Best Food. This is done so that the bee algorithm is not stuck at a local minimum value. Change the trial value to 0 and return to step 1 until it meets the specified iteration. From the experiment above using programming simulation with a maximum of 100 iterations and a limit of 10, the optimal route is obtained with a minimum distance of 486.8920, and the route formed is [1 6 10 9 5 1 3 4 7 1 2 8 1].

based on experimental results from 8 different data problems solved by the ABC algorithm, especially for data A-n32-k5, A-n45-k7, An46-k7, A-n60-k9, and B-n78-k10, a better solution was produced. This shows that for problems with medium-sized customers, the ABC algorithm is able to solve problems better because there is a limit system, namely that the best route will be discarded if the attempted improvement on the route has reached the specified limit. This is done so that ABC does not get stuck on the local optimal solution. Of the 8 problems, only 3 are problems where the ABC algorithm is not better than the Branch and Cut algorithm, namely for problems over 100 customers. This is due to the method of repairing the route by the ABC algorithm using the random function, where the search will be more difficult as more customers are added. In solving these problems, it is not only solved by using the ABC algorithm but also the Clark and Wright algorithm as the initial route builder. The route improvements carried out by the ABC algorithm above appear to be able to produce better solutions than the Branch and Cut algorithm for certain problems. However, to get the optimal solution for the ABC algorithm, it requires several trials to find the best solution. This is because the solution search for the ABC algorithm uses a random function. In addition, determining the limit also affects the formation of optimal solutions.

In its implementation, when route improvements are made at the Employed Bee and

Onlooker Bee stages, changes will always occur to the route. With the changes that occur, the consequences of the overall solution also change. With strict limitations, especially the minimum number of vehicles and total distance, a change in solution is not always acceptable. In this condition, the solution will return to its original state. In addition, when the trial value has exceeded the limit, the best solution will be abandoned and a new random route as a whole is carried out. However, the best solution before being abandoned will be stored first in memory, so the best solution is still stored, and a new random route will be repaired again to get the best solution that is better than before.

CONCLUSION

The ABC optimization method is a metaheuristic algorithm that can be an alternative and can be applied to solve CVRP problems properly. In experiments carried out to solve problem data for customers less than 100, the ABC algorithm was able to produce a better solution than the Branch and Cut algorithm problem data for customers less than 100, the ABC algorithm was able to produce a better solution than the Branch and Cut algorithm. Meanwhile, for problem data that has more than 100 customers, the ABC algorithm is able to solve it, but it is no better than the comparison algorithm. The ABC algorithm is an alternative to solving CVRP. The algorithm applied is still a simulation. For the problem of vehicle routing, the development is very broad.

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