Determination of the tourist route in Malang Raya by using ant colony optimization

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Abstract. Malang Raya is one of the most popular tourist destinations in Indonesia and has many interesting tourist attractions. Tourists need much time to visit all the tourist attractions. It is not possible to visit all the tourist attractions since vacation time is limited. Therefore, the method for determining the tourist route with the minimum time and satisfy the constraint is needed. The problem is Vehicle Routing Problem (VRP) and can be solved by meta-heuristic. There are several meta-heuristics that can be used to solve VRP, for example Genetic Algorithm (GA), Particle Swarm Optimization (PSO), and Ant Colony Optimization (ACO). ACO has the advantage of a good positive feedback mechanism when compared to GA and PSO. For this reasons, this paper presents the determination of tourist route in Malang Raya by using ACO. However, ACO tends to solution stagnation. In this paper, the solution stagnation of ACO will be solved by applying the dual pheromone tables. The results show that ACO with dual pheromone tables can solve the problem of determining tourist routes in Malang Raya well in terms of quality of solution because ACO with dual pheromone tables can obtain better results in the time cost of the route than standard ACO.

1. Introduction

Malang Raya is one of the most popular tourist destinations in Indonesia. It is located in East Java Province. Malang Raya area has three areas which are Malang City, Malang Regency, and Batu City. Malang Raya has many interesting tourist attractions including nature tourism, game tourism, education tourism, culinary tourism, and history tourism. As one of the popular tourist destinations, many domestic and foreign tourists visit Malang Raya, especially on holidays. According to data from the Department of Culture and Tourism of Malang Raya, tourists visit to Malang Raya in 2017 reached 15.2 million tourists, with details of 4 million tourists in Malang City, 7 million tourists in Malang Regency, and 4.2 million tourists in Batu City. Tourists can choose several interesting tourist attractions in Malang Raya. The tourist problem is that the increasing number of tourist attractions that want to be visited, it will increase the visited time for all of the tourist attractions, while the vacation time owned by tourists is limited. In addition, each tourist may not be able to determine a travel route that has a minimum time and does not exceed the vacation time that the tourist has. Therefore, a good planning is needed in order that all selected tourist attractions can be visited in a minimum time without breaking the existing constraints, but tourists can still enjoy the holiday well.

One of the plans that can be done is determining the optimal route by using a particular application based on an optimization method. The results of determining the route will be taken into consideration in making decisions to choose the path to be traversed. The problem of determining the optimal route from a source to a number of destinations without violating certain constraints is Vehicle Routing.
Problem (VRP) [5]. Therefore, the problem of determining tourist routes in Malang can be described as a VRP with limited vacation time constraints. VRP is a combinatorial optimization problem that can be solved by meta-heuristic method. Some examples of meta-heuristic methods include Genetic Algorithm (GA), Particle Swarm Optimization (PSO), and Ant Colony Optimization (ACO). The performance of them to solve VRP was shown by [9] based on several previous studies. The first previous study is that GA is used to solve Bi-Objective Vehicle Routing Problems with Forced Backhauls [2]. The research in [1] proposed the PSO to solve Vehicle Routing Problems with Simultaneous Pickup and Delivery. The research in [3] used ACO to solve Time Dependent Vehicle Routing Problem with Time Windows. The results obtained show that GA has the ability to calculate quickly but it is difficult to obtain optimal global solutions. PSO has fast search capabilities but presents premature convergence easily. While, ACO has good positive feedback mechanism, but prone to stagnation of solution.

This paper presents the determination of the tourist route in Malang Raya by using ACO because it can be used to solve VRP and has the advantage of a good positive feedback mechanism when compared to GA and PSO [9]. The stagnation of the ACO solution will be solved by applying the dual pheromone tables [8]. Dual pheromone tables consist of two kinds of pheromones, which are positive pheromones and negative pheromones. They has advantages for increasing the probability of searching all potential directions so as to improve the quality of the final result. The calculation results of ACO with dual pheromone tables will be compared with ACO without modification (standard ACO) [5] for performance evaluation.

2. Methodology
This section will describe the problem description, the research data, the standard ACO method, ACO with dual pheromone tables, and flowchart of the method and evaluation of method.

2.1. Problem Description
Tourist can choose one hotel as a source from the hotel datasets and several tourist attractions to be visited from the tourist attraction datasets. Tourists depart from a hotel to visit several selected tourist attractions and return to the hotel when all tourist attractions have been visited. If the time spent visiting several tourist attractions exceeds the available time in one day while there are tourist attractions that have not been visited, then tourist must return to the hotel and continues the trip the next day. Figure 1 shows an illustration of the route from the problem description with details of 1 hotel with 6 tourist attractions and visited for 2 days.

![Figure 1. Tourist route form.](image)

2.2. Research data
Malang Raya has many interesting tourist attractions. We select the 15 most popular tourist attractions in Malang based on [6] as a dataset of tourist attractions and we select the Hotel Santika Premiere Malang as the depot because it is located in the center of Malang Raya. The data of travel time are taken...
from Google Maps and the data of duration of tourists in tourist attractions are set up first. The data of tourist attractions and the duration of tourists in tourist attractions \( (s) \) are presented in the Table 1.

### Table 1. The data of tourist attractions.

| Tourist attraction          | \( s \) (minute) |
|-----------------------------|------------------|
| Taman Selecta               | 90               |
| Kusuma Waterpark            | 120              |
| Kampung Jodipan             | 45               |
| Taman Kelinci               | 60               |
| Jatim Park 1                | 180              |
| Jatim Park 2                | 120              |
| Jatim Park 3                | 150              |
| Museum Angkut               | 90               |
| Kebun Teh Wonosari          | 60               |
| Coban Rondo                 | 60               |
| Taman Labirin               | 120              |
| Pantai Goa Cina             | 60               |
| Pantai Balekambang          | 60               |
| Toko Oen                    | 45               |
| Predator Fun Park           | 120              |

2.3. **Overview of ant colony optimization (ACO)**

Ant colony optimization (ACO) is a meta-heuristic inspired by the foraging behavior of real ants. Initially, real ants forage for food randomly, depositing a chemical substance called pheromones on their paths. The path between the colony and the nearest food source tends to receive more pheromones, which attracts more ants to follow the same path. Once the food source is exhausted, the ants abandon the path and the pheromones evaporate, forcing the ants to start searching for another food source randomly [4].

2.4. **The standard ACO Method**

There are three main steps of standard ACO which are described as follows [5]:

2.4.1. **Initialization.**

This step contains inputting the hotel and tourist attractions data, \( t_{ij} \) as travel time, \( \tau_0 (\tau_0 = (n \times \text{mean of } t_{ij})^{-1} \) as initial pheromone value, \( m \) as number of ants, \( n \) as number of iterations, \( n \), \( \alpha \) as parameter influencing the contribution of pheromone intensity in path selection, \( \rho \) as evaporation parameter, and \( \beta \) as parameters that affect the contribution of visibility value in path selection. The value of \( T \) (minute) as the available time in one day and the value of \( s \) (minute) as the duration of the tourists being in the tourist attraction are also input in this step.

2.4.2. **Solution construction.**

In the solution construction process, the ant \( k \) at point \( i \) will move to the destination point \( j \) using the probability rule as follows:
\[ P_{ij}^k = \frac{[\tau_{ij}^\alpha \eta_{ij}^\beta]}{\sum_{j \in N_i^k} [\tau_{ij}^\alpha \eta_{ij}^\beta]}, \text{ if } j \in N_i^k \]  

(1)

where \( \tau_{ij} \) is the pheromone intensity on the edge \((i,j)\), \( \eta_{ij} = (t_{ij})^{-1} \) is the visibility value on the edge \((i,j)\), and \( N_i^k \) is the feasible neighborhood of ant \( k \) when being at city \( i \). This paper uses the roulette wheel selection [10] to determine the point \( j \) to be visited, which is a random number \( r \in [0,1] \) is taken to get the point \( j \) which will be selected based on the probability distribution of (1). The selection of point \( j \) with this strategy is called exploration.

2.4.3. Update pheromone.

After the ant has finished constructing the solution, the pheromone intensity value is updated using the following equation:

\[ \tau_{ij} = (1 - \rho)\tau_{ij} + \sum_{k=1}^{m} \Delta \tau_{ij}^k, \]  

(2)

where \( \rho \) (\( 0 \leq \rho \leq 1 \)) is the evaporation rate of pheromone and \( \Delta \tau_{ij}^k \) is the number of pheromones added by ant \( k \) which is defined as follows:

\[ \Delta \tau_{ij}^k = \begin{cases} Q/L_k, & \text{if ant } k \text{ uses edge } (i,j) \\ 0, & \text{other} \end{cases} \]  

(3)

where \( Q \) is a constant, and \( L_k \) is the length of the solution obtained by ant \( k \).

2.5. ACO with dual pheromone tables

ACO with dual pheromone tables is an extension of the ACO introduced by [8] to prevent ACO from experiencing local optimal and solution stagnation. Dual pheromone tables rule consists of two kinds of pheromones, namely positive pheromones and negative pheromones, which function to increase the probability of searching all potential directions so as to improve the quality of the final result. In general, the steps in ACO with dual pheromone tables are the same as ACO but there are some modifications made to ACO as follows:

2.5.1. Solution construction. In order to integrate two pheromone tables into ACO, the way the probability is calculated has to be modified, which in turn changes the solution construction operators, as given below.

\[ s = \begin{cases} \arg\max_{j \in N_i^k} \left\{ [\tau_{ij}^\alpha \eta_{ij}^\beta] \right\}, & \text{if } q \leq q_0 \\ v, & \text{if } q_0 < q \leq q_1 \\ w, & \text{if } q > q_1 \end{cases} \]  

(4)

where \( q \) is a random value to determine which strategy will be used to choose the point \( j \). \( q_0 \) and \( q_1 \) are used to predefine the intervals of the three used strategies. \( v \) represents the exploration strategy that will be used if \( q_0 < q \leq q_1 \). \( w \) represents the strategy that will be used if \( q > q_1 \) by using the probability rule as follows:
\[
q^k_{iz} = \begin{cases} \left[\tau^k_{iz}\right]^\alpha \left[\eta^k_{iz}\right]^\beta, & \text{if } z \in N_i^k \setminus B^k_i \\
0, & \text{otherwise}
\end{cases}
\]

(5)

\[
B^k_i = B^k_i \cup \{iz\} \quad \forall z \in N^k_i \quad \text{dan } \tau^b_{iz} < r_b
\]

(6)

\(B^k_i\) represents the path that will not be selected, \(r_b \in (0,1)\) represents a random value, \(\tau^b \in (0,1)\) represents the negative pheromone intensity on the path, and \(q^k_{iz}\) represents the probability value for determining the next point.

2.5.2. Update pheromone.
ACO with two pheromone tables has two pheromone tables, namely positive pheromone table and negative pheromone table so that pheromone updates are applied to the two tables. The pheromone update in the positive pheromone table uses the same mechanism as the standard ACO while the negative pheromone table uses a different mechanism, namely using the following equation:

\[
\tau^b_{ij} = \gamma \tau^b_{ij}, \quad \forall (i,j) \in T^{iw},
\]

(7)

where \(\gamma\) is a constant in the range \([0,1]\) which indicates the evaporation rate in the negative pheromone and \(T^{iw}\) denotes the worst iteration solution.

2.6. The flowchart of ACO and evaluation of method.
The flowchart of ACO presents an overview of how the ACO works. The flowchart is presented in Figure 2. The evaluation of method uses the best solutions of the time cost of the route for all runs in minutes and execution time in seconds.

**Figure 2.** The flowchart of ACO.
3. Experimental result

We conducted experiments from the data to obtain the solution using standard ACO [5]. We also conducted experiments using ACO with dual pheromone tables [8] for performance evaluation in order to find out whether ACO with two table pheromones could improve standard ACO. We implemented ACO with dual pheromone tables and standard ACO in MATLAB R2014 and the computer system with the specification Intel(R) Core(TM) i5-3337U CPU 1.80GHz, RAM 4 GB, hard disk 500 GB and Microsoft Windows 8 Pro as the operation system.

The values of the parameters used in the experiments of ACO with dual pheromone tables and standard ACO are presented in the Table 2.

| Parameter | ACO with dual pheromone tables | Standard ACO |
|-----------|--------------------------------|--------------|
| $\alpha$  | 0.1                            | 1            |
| $\beta$   | 11                             | 2            |
| $\rho$    | 0.1                            | 0.5          |
| $T$       | 540                            | 540          |

The parameter values in ACO with dual pheromone tables are determined based on [8] and the parameter values in standard ACO are determined based on [5] because at these parameter values, the two methods are able to get the best value. In this experiment both ACO with dual pheromone tables and standard ACO were run 10 times for 100 iterations and 100 ants.

We compared the methods with respect to the best solutions of the time cost of the route for all runs in minutes and execution time in seconds. The experimental results are shown in Table 3. The first column shows the result of ACO with dual pheromone tables. The second column shows the result of standard ACO.

| ACO with dual pheromone tables | Standard ACO |
|--------------------------------|--------------|
| Best solutions (minute)        | Best solutions (minute) | Execution time (second) | Execution time (second) |
| 2047                            | 83.2797      | 2055 | 91.8173 |
| 2047                            | 83.4955      | 2052 | 78.1577 |
| 2043                            | 82.7904      | 2050 | 83.8287 |
| 2043                            | 78.8484      | 2050 | 76.8805 |
| 2045                            | 80.2691      | 2050 | 78.3186 |
| 2045                            | 85.5628      | 2050 | 81.3179 |
| 2050                            | 81.9197      | 2050 | 77.9513 |
| 2051                            | 78.6125      | 2052 | 78.9970 |
| 2047                            | 79.4621      | 2050 | 78.6526 |
| 2045                            | 83.5527      | 2050 | 78.4321 |
Table 3 indicates that ACO with dual pheromone tables for solving the problem of determining tourist routes in Malang Raya has better results in the cost of the route than standard ACO in each experiment even though it requires a little more computation time.

Figure 3 shows the solution results of ACO with dual pheromone tables and standard ACO in each iteration. Figure 3 indicates that ACO with dual pheromone tables has a better chance than standard ACO to choose a different search direction so that ACO with dual pheromone tables converges faster to its minimum value. This is because the negative pheromone in ACO with dual pheromone tables used to eliminate the most impossible paths so as to increase the probability of choosing worse paths in the table can prevent the ants from falling into local optima.

![Figure 3](image_url)

**Figure 3.** The solution results of ACO with dual pheromone tables and standard ACO.

4. Conclusion

The experimental results show that ACO is able to solve the problem of determining tourist routes in Malang Raya well so that the results obtained can become consideration for tourists when on vacation to Malang Raya. In addition, the performance evaluation shows that ACO with dual pheromone tables is able to obtain better results in the time cost of the route than standard ACO in each experiment which means that the dual pheromone tables can be applied to ACO and can improve the performance of ACO in quality of solution even though it requires a little more computation time. The negative pheromone in ACO with dual pheromone can prevent the ants from falling into local optima. Our future work is to reduce the computation time of the ACO with dual pheromone tables while at the same time enhancing its quality.

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