OPTIMIZATION OF MULTI-TRIP VEHICLE ROUTING PROBLEM WITH TIME WINDOWS USING GENETIC ALGORITHM

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ABSTRACT

This research studied the application of multi-trip vehicle routing problem with time windows (VRPTW) on the problems of the tourist routes in Banyuwangi. The problems of ordinary VRPTW has only one route to the finish line that will be targeted with specific time limits while the multi-trip VRPTW has several tourist routes and one central point as the reference point for determining the route of the tour as well as the deadline for each tour. Genetic algorithm used to solve this problem because it can overcome the problem of combinatorial effectively and efficiently, moreover it can reach solutions globally so that it can produce the optimum solution. Chromosome on the Genetic Algorithm represents the permutation of the overall tour. After decoding there are three chromosome segments created, where each segment represents a visit of tourist attractions in one day. This research provides the optimal result i.e. a solution route with the shortest commute time and a fast computing time so it is very helpful in determining the route of the tourist trips with the closest mileage based on their places to stay (centre point).

Keywords: *Multi-trip, VRPTW, Genetic Algorithm, Turist Routes*

1. INTRODUCTION

Tourism is one way to do activity durung. Moreover, tourism is still being a first pick to increase State's income. United Nations World Tourism Organization (UNWTO) shows that there is an increase in foreign tourists by 10% each year. Banyuwangi, as one of the cities in Indonesia, has huge tourism potential. In addition to data from Government Tourist Office of Banyuwangi in 2015, there is a significant increase from 1,495,629 to 1,972,393 tourists or 31% in a year. This increase is due to the infrastructure improvements, governance and the promotion which the Government of Banyuwangi works for untill now. 2016 is estimated to have more tourists than before and it will affect the tourist itself due to the fact that every tourist can not decide their own trip with minimum cost as low as possible and they do not know how to estimate their trip so it can match with the opening time of every tourist attraction. Based on those problems we need a solution to overcome them so they can have a route and schedule as their needs.

Vehicle Routing Problem (VRP) is a term commonly used to solve salesman problem (Bai et al, 2000). VRP solves the route from the point of start and coming back again to that start point. Furthermore, the Vehicle Routing Problem with Time Windows (VRPTW) is the development of VRP with addition of visited point's time restrictions (Wang et al, 2015). Various method have been proposed to get a solution with cost as low as possible (Ursani *et al*, 2011; Mahmudy, 2014; Priandani and Mahmudy, 2015). From every problem solving method, evolution algorithm, as one of meta heuristic algorithms, is considered as a method which can solve the problem efficiently (Kumar and Panneerselvam, 2015; Pierre and Zakaria, 2016; Wang et al, 2015).

Genetic algorithm can solve the multi route problems, in this case, it is the goods distribution, with a very good result (Chunyu and Xiaobo, 2010; Ghoseiri and Ghannadpour, 2010; Kumar and Pannerselvam, 2015). Karakatic and Podgorelec's research (2015) solves the problem of multi VRP by using a different use of production so they can obtain an optimal result compared to previous research. Genetic algorithm can also solve the problem of travel route with a flexible data and achive an optimal result (Heng et al, 2016). Based on research of genetic algorithm, the use of genetic algorithm can solve the problem of multi-travel route optimization optimally and achive the desired result.

On this research we will implement the genetic algorithm to solve the problem of travel route in Banyuwangi. This research will focus on how to represent the solution into genetic algorithm‘s chromosome, how to create a constraint and fitness and which parameter is the best for this problem.

2. PROBLEM DESCRIPTION

The data used in this study is the primary data obtained from Google Maps, which are 19 attractions and 12 hotels. Tourists are visiting for 3 days, on the first day there are 3 places visited, on the second day there are 4 places visited and on the third day there are 3 places that will be visited. Each tourist has his/her own time windows start at 5 am to 7 pm, each attraction has its own time windows as well.

Every tourist stays in the same hotel, so there will be a travel route as shown in Fig. 1.

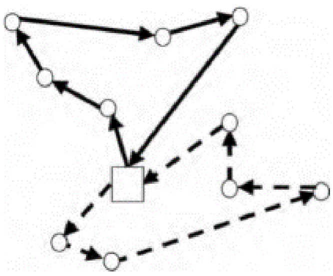

Figure 1. Tourist route forms
(Ghoseiri and Ghannadpour, 2010)

Fig. 1 shows that there are two routes and the centre point represents hotels, used to stay.

3. GENETIC ALGORITHM FOR MULTI-TRIP VRPTW

Genetic algorithm is an optimization method to find a solution of the problem globally (Holland, 1975). There are several operations in genetic algorithm such as the initialization, evaluation, crossover, mutation and selection (Gen and Cheng, 2000). Multi-objective VRPTW is a combinatorial optimization problem and with an appropriate solution we can obtain an optimal solution for genetic algorithm with multi-objective VRPTW.

3.1. Representation of Chromosome

A chromosome is a representation of the problems’s solutions. Each chromosome-shaped array is the character which refers to its genes. In VRPTW, chromosome is an encode of tourist permutation. A mutation representation is considered to give maximum results because it covers the whole attractions so that genetic algorithm can perform a solution searching optimally. Fig. 2 shows a representation of a chromosome.

1	10	11	15	18	13	14	2	15	3	19	16	5
17	4	8	9	6	7							

Figure 2. Chromosome representation

After promosom, the next step is decoding to obtain the right solution in accordance with the constraints. On decoding, the first step is taking the first 10 genes, so the new chromosomes will be acquired as follows:

1	10	11	15	18	13	14	2	15	3

After a new chromosome is obtained, next step is adding some genes to chromosome with index h as a selected hotel in the gen 1, 4, 9 and 13. If the choosen index h is 4, the obtainable chromosomes are shown as follows:

4	1	10	11	4	15	18	13	14	4	2	15	3	4

We obtain a solution which is obtained from the result of chromosome decoding from first route 4-1-10-11-4, second route 4-15-18-13-14-5 and third route 4-2-15-3-4.

3.2. Initialization

Initialization is the first operator to run for optimization. The purpose of this operation is to declare the partial search spaces. The performance of genetic algorithm is very high so it can obtain the best solution and the early convergency might not happen immediately (Pierre and Zakarai, 2016). Chromosomes are generated randomly where each gen with permutation of tourism index value.

3.3. Evaluation

On the optimization process, the evaluation keep running throughout the process to know which individual can survive, by calculating the value of each individual's fitness. The fitness value is shown in equation 1.

$$fitness = \frac{1}{1+time} + penalty, \qquad (1)$$

Equation 1 shows that time is the total time required to travel between the places of origin towards the goals, while penalty is a value of foul. Penalty will be negative if there is a foul in solution. Offenders are used in this study is time windows of tourist and travelers it self.

3.4. Crossover

The crossover is the main individual reproduction process so that this process will greatly affect the results of the optimization. The crossover used is a one-cut-point crossover method (Mahmudy, 2015). For example there are two random individuals selected, as follows:

1	10	11	15	18	13	14	2	12	3	19	16	5
17	4	8	9	6	7							

4	6	17	9	2	5	16	18	15	3	19	14	10
11	8	1	12	13	7							

Then select one random index, for example index 7 as follows:

1	10	11	15	18	13	14	2	12	3	19	16	5
17	4	8	9	6	7							

4	6	17	9	2	5	16	18	15	3	19	14	10
11	8	1	12	13	7							

Form some new individuals where gen on index 1-7 obtained from the first individual on index 1-7 and gen on index 7-19 obtained from the second individual by searching from the first gen, if there is nothing in the new individual genes then it placed in that new individual genes. The results of how to obtain new individuals with crossover can be seen as follows:

1	10	11	15	18	13	14	2	12	3	19	16	5
17	4	8	9	6	7							

4	6	17	9	2	5	16	18	15	3	19	14	10
11	8	1	12	13	7							

1	10	11	15	18	13	14	4	6	17	9	2	5
16	3	19	8	12	7							

3.5. Mutation

Mutation is an extra section in reproduction to get a new variation of individuals. In this research we will use a reciprocal exchange mutation (Mahmudy, 2013b). By selecting one random individual, as follows:

1	10	11	3	18	13	14	2	12	15	19	16	5
17	4	8	9	6	7							

Then select two random indexes and exchange the value in order to obtain a new individual as follows:

1	10	11	15	18	13	14	2	12	3	19	16	5
17	4	8	9	6	7							

1	10	11	3	18	13	14	2	12	15	19	16	5
17	4	8	9	6	7							

3.6. Selection

On the selection part we will use elitisim selection as the selection method. It guarantees every single chromosome to have a high fitness value. The selection is occured by taking numbers of best chromosome equals to the size of population (popSize). Thus it obtains a new individual from selection with elitism selection.

4. EXPERIMENTAL RESULT

4.1. Best Parameter

In stochastic algorithm, its parameters are very influential towards the results of the solution that given. In genetic algorithms, these parameters are population, number of iterations, the crossover rate (cr) and the mutation rate (mr). Testing is conducted by setting the first parameter as shown in the Table 1.

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Table 1. Arranging of initial parameter

Number of population	= 5
Number of iteration	= 5
Value of crossover rate	= 0.6
Value of mutation rate	= 0.4
Number of hotel	= 7

Fig. 3 shows the results of iteration testing in genetic algorithms indicating the amount of iterations 800 which has a biggest average fitness rating. The larger the value of average fitness does not necessarily make it bigger because the genetic algorithm is a random algorithm (stohastic).

Fig. 4 shows the results of population testing which tests the populations by 50% from 100 to 500. The result tests show a population of 400 having a biggest average fitness rating. The amount of population is influencing the value of fitness which can be seen a difference of fitness value in populations.

Fig. 5 shows the results of testing the combination value of cr and mr. Combination of cr and mr has a big influence because it is a deciding parameter of the number of individual reproduction. The test result shows a significant difference of fitness value where a combination of cr = 0.8 and mr. 0.2 has the biggest average fitness value.

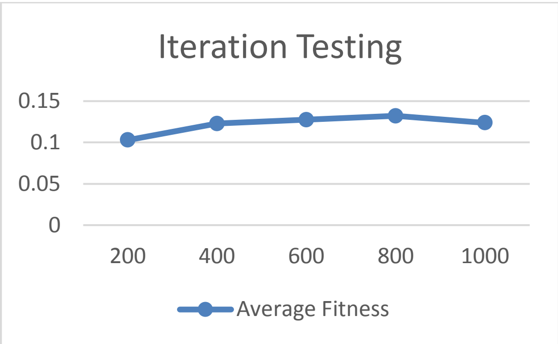

Figure 2. Result of iteration testing

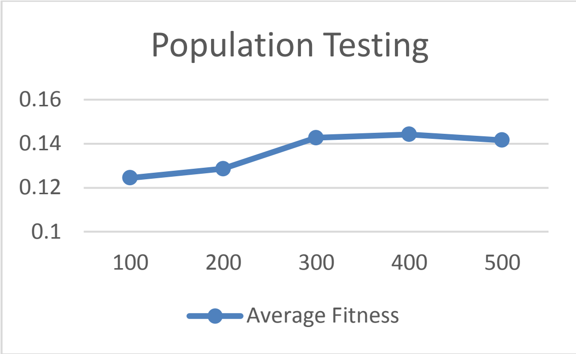

Figure 4. Result of population testing

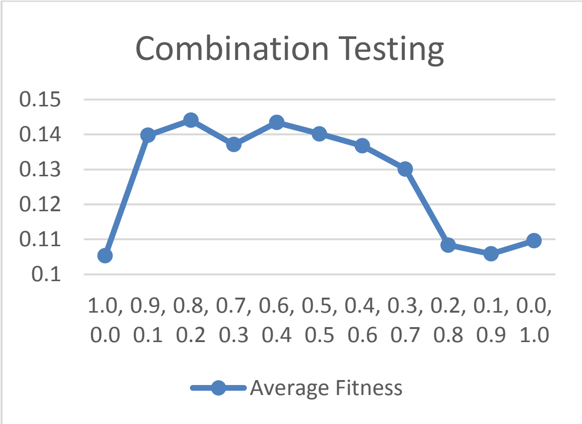

Figure 5. Result of combination *mr* and *cr*

4.2. Results Comparison

In this section we will do a comparison of selection method to get the best fitness value. The selection method will be compared between elitism selection and replacement selection. Table 2 shows that the results of the replacement selection have a better average fitness value and faster computing time than the elitism selection. on a replacment order obtained genetic selection algorithm with maximum result is number of iteration = 1000, number of population = 500, and combination *cr* and *mr* each 0.8 and 0.2.

Fig. 6 shows the comparison results of the elitism selection with replacement selection based on the early convergence which occurs immediately on elitism selection due to its low fitness value even though that chromosomes with low fitness value can potentially achieve the optimum solution.

Research of solving part type selection and loading problem in flexible manufacturing system using real coded genetic algorithms shows the use of replacement selection has a relatively high average fitness resulting comparison to roulette wheel selection, elitism selection and binary tournament selection (Mahmudy et al, 2013). The replacement selection generates good fitness value due to the fact that it keeps the chromosomes with high fitness value and gives a chance to chromosomes with low fitness value.

Table 2. Result of Comparison

Metode	Time (ms)	Fitness
elitism selection	884.7	0.14224751
Replacement selection	737.2	0.1447178

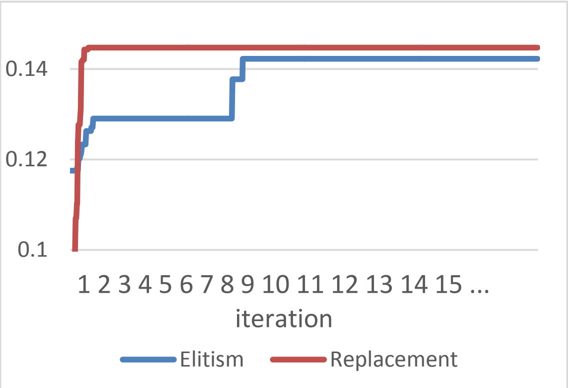

Figure 6. Result of elitism selection and replacement selection

5. CONCLUSION

Based on route optimization in Banyuwangi we can conclude that genetic algorithm can solve the problem of multi-trip VRPTW with optimum results and fast computing time. The best average fitness value obtained by parameters such as number of iterations = 1000, population = 500, the combination of cr and the mr is 0.8 and 0.2, and the use of the replacement selection.

Further research can apply the hybrid genetic algorithm or combining one optimization method with another method to get a better accuracy such as simulated annealing (Novitasari, et al 2016).

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