School Bus Routing in the City of Denpasar using Differential Evolution Algorithm

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Abstract: The Denpasar City Transportation Office has launched school buses for school students since 2017. Through this school bus, The Denpasar City Transportation Office has helped parents to pickup students. The problem that often occurs in the transportation system is finding the optimal route. The purpose of this study is to create a method to get an effective route, namely, in the form of the shortest route. Route selection uses the Differential Evolution algorithm. At the initialization stage, the Differential Evolution algorithm generates a population (random route). The random route generated has a distance of between 46.976602126788194 km to 9999 km. A score of 9999 is not the true distance, but the score assigned to a bad individual candidate. Considered as a bad individual candidate because the random route generated was the pickup location as the final destination. Furthermore, each individual goes through a process of mutation, recombination, selection with a certain number of iterations. The system will produce a better population, with shorter routes with each iteration. With the selection process, shorter route variations that result from iterations replace routes with longer distances. The Differential Evolution algorithm is very effective to use to get the minimum value. Based on the final results obtained from the application, the optimal route candidates are obtained. The farthest route is 26.624917440178955 km, and the route with the shortest distance is 25.75039590845092 km.

1 INTRODUCTION

The Denpasar City Transportation Office has launched school buses and provided bus stops as places to pick up students since 2017. This program is very useful in providing a sense of security for students and parents of students. Through this school bus, the Transportation Office has helped parents to pick up and drop off.

One of the problems that often occur in the public transportation system is determining an effective route, finding the path between the departure location, pickup location, and final destination location. In this research, an application is made that can provide the shortest alternative route for school buses in Denpasar City. Route selection uses the Differential Evolution Algorithm. This algorithm is one of the evolutionary algorithms, which is famous for its convergence speed (Leung, et al., 2007). The application can generate an effective route for each school bus so that the driver takes students to school with faster travel time.

2 THEORY

2.1 Evolutionary Computation

Evolutionary Computation is one of the fields of artificial intelligence. Evolutionary Computation is an abstraction that requires specific engineering to produce an optimization algorithm to solve the problem (Leung, et al., 2007). Evolutionary Computation adopts various theories and fields of science. For example, physics, statistics, probability, but Evolutionary Computation is part of computer science (Eiben, et al., 2003). Optimization algorithms are becoming important techniques in many disciplines (Lin, 2013). Many practical engineering or decision-making problems involve optimization to find the best design solution. In the case of multi-objective optimization gives rise to a Pareto-optimal solution because of the interactions between various conflicting objectives (Deb, 2001).

There are several algorithms that are included in the Evolutionary Computation family. Algorithms that are included in the Evolutionary Algorithm are

Genetic Algorithm, Genetic Programming, Evolutionary Strategies, Differential Evolution, Evolutionary Programming, and Grammatical Evolution (Suyanto, 2008). Besides, there are many more systems that combine various features or characteristics of the algorithms mentioned above, making it difficult to classify.

2.2 Differential Evolution Algorithm

Differential Evolution is a population-based algorithm. First developed by Storn and Price (Storn, et al., 1997). With the advantages of simplicity and fewer parameters, the Differential Evolution algorithm has been widely used in various fields, such as engineering, electricity, data mining, biogeography, structural optimization, and so on (Gong, et al., 2014). Differential Evolution is an optimization method to find the minimum value of a nonlinear and non-differentiable continuous space function (Storn, et al., 1997). Differential Evolution is considered the latest study to solve the problem of finite optimization, multi-purpose global optimization, and other complex real-world applications.

In the Differential Evolution Algorithm, individuals have a real value, which is the true value of the solution being sought. This real value can then be considered a vector. Differential Evolution generates new vectors (individuals) by involving three vectors (individuals) as parents. The generation of new vectors is done by adding one vector (1st parent) with the difference between the other two vectors (2nd and 3rd parent). This process is called Differential Mutation.

In the mutation process for each vector $\underline{x}_{i,G}$ = 0,1,2,…, NP-1, a new vector is generated based on the formula:

$$\underline{v} = \underline{x}_{r1,G} + F(\underline{x}_{r2,G} - \underline{x}_{r3,G}) \tag{1}$$

Where $r1, r2, r3 \in [0,NP-1]$ are integers randomly selected in the interval [0, NP-1]. Whereas F is called a scale vector in the form of a real number which is a constant that controls the gain of the differential variation $(\underline{x}_{r2,G} - \underline{x}_{r3,G})$. To increase the diversity of the parameter vectors, the vector $\underline{v}$ is recombined (crossover) with an arbitrary vector in the population $(\underline{x}_{i,G})$. The crossover process produces the following vector $\underline{u}$.

$$\underline{u} = (\underline{u1}, \underline{u2},...,u_D)^T \tag{2}$$

where

$$\underline{u}_j \begin{cases} \underline{v}_j \text{ for } j = \langle n \rangle_D, \langle n+1 \rangle_D, ..., \langle n+L-1 \rangle_D ; \\ (\underline{x}_{i,G}) \text{ for other } j \end{cases}$$

The symbol $\langle \rangle_D$ represents the Modulo function, which is a function that issues the remainder of the division. From the above equation, it can be seen that certain vector elements in a certain order are the same as the vector $\underline{v}$. The remaining elements of the vector $\underline{u}$ are derived from $\underline{x}_{i,G}$. The prefix index n in the above equation is randomly selected in the interval [0, D-1]. The integer L is randomly selected in the interval [0, D-1] with the probability $Pr(L=\underline{v}) = (CR)^v$ where $CR \in [0,1]$ is the crossover probability and represents a control variable for the Differential Evolution scheme. Generating random numbers for n and L is done every time the generation of a new vector $\underline{v}$. When $(n+L-1)$ is greater than maximum j then j returns equal to 0.

3 RESEARCH METHODOLOGY

Basically, the Differential Evolution algorithm will find the shortest route based on the given criteria value. The route search process can be described, as shown in Figure 1. Some of the processes that this algorithm goes through to obtain the optimal route are initialization, mutation, recombination, and selection.
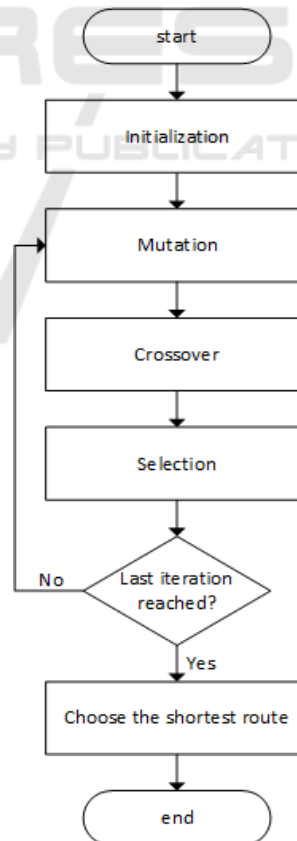

Figure 1: Flowchart of routing with differential evolution.

3.1 Initializing Chromosomes

At the initialization of the population, each point (location), namely the departure location, school location, and pickup location, will become the genes forming individual chromosomes. The number of individuals who are raised randomly in a certain number. The individual refers to the solution candidate as parents. The solution candidate (individual) is coded into the chromosome. Each chromosome consists of genes that are located in random positions and are assigned a certain value.

3.2 Mutation

The mutation process makes use of existing chromosomes to get better individuals. In Differential Evolution, individuals are considered as vectors. In the mutation process, the generation of a new vector will involve three vectors (individuals) as parents. This vector generation uses Formula 1.

3.3 Crossover

The crossover process increases the diversity of existing vectors (individuals). Vector v is recombined (crossover) with an arbitrary vector in the population ($x_{i,G}$). The crossover process generates new (individual) vectors.

3.4 Selection

The crossover result vector replaces the parent vector if it has a greater fitness value. This means that the vector u will replace the vector $x_{i,G}$ in the next generation. But if u has a fitness value smaller than $x_{i,G}$, then vector u does not replace $x_{i,G}$. In other words, $x_{i,G}$ will still appear in the next generation. A greater fitness value will be obtained from the vector with the shortest route distance.

3.5 The Shortest Route

In the last stage, when the specified number of iterations has been reached, there will be a number of individuals who have shorter routes than the individuals who were raised during initialization. The individual candidates selected are the individuals who have the shortest route.

4 RESULTS AND DISCUSSION

4.1 First Population

At the initialization, a number of random populations were generated. This random population is generated from the data entered into the application. This data includes the location of departure, location of destination schools, and pickup locations. Table I shows some of the population formed. In the initial population, the route distance obtained will vary greatly. The route distance obtained is between 46.976602126788194 km to 9999. The value of 9999 does not reflect the actual route distance. The largest value, 9999 km, indicates a bad route candidate. This route produces the pickup location as the final destination in the overall route. In contrast, the expected final destination location on the route is a school.

Table 1: First population.

No	Route	Distance
1	UPT Pelayanan Transportasi Darat - Jl. Meduri - SMP PGRI 9 Denpasar - Toko Chaca - Jl. Astasura - SMP Negeri 8 Denpasar - Jl. Gadung - SDN 28 Dangin Puri - Banjar Tulangampiang - Apotek Cempaka - Jl. Antasura - SD Dwijendra Denpasar - Jl. Nangka - SMP PGRI 2 Denpasar - WR. Supratman - SD Saraswati 6 Denpasar - Jl. Patimura - Indomaret A.Yani - SD Saraswati 2 - Jl. Suradipa - Indomaret Antasura - Jl. Lembusora	9999
2	UPT Pelayanan Transportasi Darat - SMP PGRI 9 Denpasar - Indomaret Antasura - Jl. Meduri - SD Dwijendra Denpasar - Banjar Tulangampiang - SD Saraswati 6 Denpasar - Jl. Antasura - Indomaret A.Yani - Jl. Patimura - WR. Supratman - SMP Negeri 8 Denpasar - Jl. Astasura - Toko Chaca - Jl. Gadung - SD Saraswati 2 - Jl. Nangka - SDN 28 Dangin Puri - Jl. Suradipa - Apotek Cempaka - Jl. Lembusora - SMP PGRI 2 Denpasar	64.556750386786166
3	UPT Pelayanan Transportasi Darat - SD Saraswati 2 - SMP PGRI 9 Denpasar - Jl. Meduri - SMP PGRI 2 Denpasar - Jl. Nangka - SMP Negeri 8 Denpasar - WR. Supratman - Jl. Astasura - Jl. Gadung - SDN 28 Dangin Puri - Jl. Antasura - SD Saraswati 6 Denpasar - Jl. Patimura - Apotek Cempaka - Jl. Lembusora - Jl. Suradipa - Banjar Tulangampiang - Toko Chaca - Indomaret Antasura - Indomaret A.Yani - SD Dwijendra Denpasar	47.872730159451166
4	UPT Pelayanan Transportasi Darat - SMP PGRI 9 Denpasar - Jl. Patimura - Jl. Gadung - SD Saraswati 6 Denpasar - Jl. Antasura - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Jl. Lembusora - Jl. Astasura - Jl. Nangka - Jl. Suradipa -	9999

No	Route	Distance	No	Route	Distance
	Indomaret A.Yani - Banjar Tulangampiang - Indomaret Antasura - SD Saraswati 2 - WR. Supratman - SDN 28 Dangin Puri - Toko Chaca - SD Dwijendra Denpasar - Apotek Cempaka			PGRI 2 Denpasar - Banjar Tulangampiang - SMP Negeri 8 Denpasar - Jl. Antasura - WR. Supratman - Jl. Patimura - Indomaret Antasura - Indomaret A.Yani - SMP PGRI 9 Denpasar	
5	UPT Pelayanan Transportasi Darat - SMP PGRI 9 Denpasar - Jl. Gadung - Jl. Antasura - Jl. Suradipa - WR. Supratman - Banjar Tulangampiang - Apotek Cempaka - Toko Chaca - Jl. Nangka - Indomaret A.Yani - Jl. Lembusora - SMP PGRI 2 Denpasar - SD Saraswati 6 Denpasar - Jl. Meduri - Jl. Astasura - SD Dwijendra Denpasar - SDN 28 Dangin Puri - SMP Negeri 8 Denpasar - SD Saraswati 2 - Jl. Patimura - Indomaret Antasura	9999	11	UPT Pelayanan Transportasi Darat - Jl. Meduri - Jl. Astasura - Banjar Tulangampiang - Apotek Cempaka - SDN 28 Dangin Puri - Indomaret A.Yani - Jl. Nangka - Jl. Gadung - Jl. Suradipa - SMP PGRI 2 Denpasar - Jl. Patimura - Jl. Antasura - Jl. Lembusora - SD Dwijendra Denpasar - SD Saraswati 2 - SD Saraswati 6 Denpasar - WR. Supratman - Indomaret Antasura - Toko Chaca - SMP PGRI 9 Denpasar - SMP Negeri 8 Denpasar	60.067789228702125
6	UPT Pelayanan Transportasi Darat - SMP PGRI 9 Denpasar - Indomaret Antasura - Jl. Lembusora - Jl. Gadung - SMP PGRI 2 Denpasar - Jl. Meduri - Indomaret A.Yani - SD Saraswati 6 Denpasar - Jl. Patimura - Jl. Astasura - SDN 28 Dangin Puri - Banjar Tulangampiang - Jl. Nangka - WR. Supratman - SD Dwijendra Denpasar - Jl. Suradipa - SD Saraswati 2 - Apotek Cempaka - Toko Chaca - Jl. Antasura - SMP Negeri 8 Denpasar	64.773847912443407	12	UPT Pelayanan Transportasi Darat - Jl. Patimura - Apotek Cempaka - Indomaret A.Yani - SMP Negeri 8 Denpasar - SD Saraswati 2 - Jl. Astasura - WR. Supratman - SMP PGRI 2 Denpasar - Indomaret Antasura - Jl. Nangka - Jl. Antasura - Jl. Lembusora - Jl. Meduri - Jl. Suradipa - Banjar Tulangampiang - Jl. Gadung - SMP PGRI 9 Denpasar - Toko Chaca - SD Saraswati 6 Denpasar - SDN 28 Dangin Puri - SD Dwijendra Denpasar	63.0249853063988 9
7	UPT Pelayanan Transportasi Darat - Banjar Tulangampiang - SMP Negeri 8 Denpasar - Jl. Lembusora - SDN 28 Dangin Puri - Jl. Meduri - SMP PGRI 2 Denpasar - WR. Supratman - Apotek Cempaka - Jl. Nangka - Jl. Patimura - SD Dwijendra Denpasar - SMP PGRI 9 Denpasar - SD Saraswati 2 - Jl. Astasura - SD Saraswati 6 Denpasar - Jl. Suradipa - Indomaret A.Yani - Toko Chaca - Jl. Gadung - Indomaret Antasura - Jl. Antasura	9999	13	UPT Pelayanan Transportasi Darat - SD Dwijendra Denpasar - Jl. Nangka - SMP Negeri 8 Denpasar - SMP PGRI 2 Denpasar - Jl. Patimura - Toko Chaca - SD Saraswati 2 - Indomaret A.Yani - Jl. Gadung - SDN 28 Dangin Puri - Jl. Lembusora - Apotek Cempaka - WR. Supratman - SD Saraswati 6 Denpasar - Indomaret Antasura - Jl. Antasura - SMP PGRI 9 Denpasar - Banjar Tulangampiang - Jl. Suradipa - Jl. Astasura - Jl. Meduri	9999
8	UPT Pelayanan Transportasi Darat - SDN 28 Dangin Puri - Banjar Tulangampiang - Jl. Patimura - Jl. Astasura - Jl. Nangka - Jl. Meduri - Jl. Suradipa - Jl. Antasura - SD Saraswati 2 - Toko Chaca - SD Saraswati 6 Denpasar - SMP PGRI 2 Denpasar - Jl. Gadung - Apotek Cempaka - SMP Negeri 8 Denpasar - SMP PGRI 9 Denpasar - Indomaret Antasura - Indomaret A.Yani - SD Dwijendra Denpasar - WR. Supratman - Jl. Lembusora	9999	14	UPT Pelayanan Transportasi Darat - SD Dwijendra Denpasar - Jl. Meduri - SD Saraswati 6 Denpasar - Jl. Nangka - Jl. Astasura - Banjar Tulangampiang - Indomaret A.Yani - SD Saraswati 2 - Indomaret Antasura - Toko Chaca - SDN 28 Dangin Puri - SMP Negeri 8 Denpasar - WR. Supratman - Jl. Antasura - SMP PGRI 2 Denpasar - Jl. Gadung - Jl. Lembusora - Apotek Cempaka - Jl. Patimura - SMP PGRI 9 Denpasar - Jl. Suradipa	9999
9	UPT Pelayanan Transportasi Darat - Banjar Tulangampiang - Apotek Cempaka - Jl. Astasura - SDN 28 Dangin Puri - SMP Negeri 8 Denpasar - Toko Chaca - Jl. Suradipa - Indomaret A.Yani - Jl. Gadung - Jl. Patimura - SD Dwijendra Denpasar - SMP PGRI 2 Denpasar - Jl. Lembusora - Indomaret Antasura - Jl. Antasura - SMP PGRI 9 Denpasar - SD Saraswati 2 - Jl. Meduri - WR. Supratman - Jl. Nangka - SD Saraswati 6 Denpasar	52.9543026973108 2	15	UPT Pelayanan Transportasi Darat - Toko Chaca - SD Saraswati 6 Denpasar - SMP PGRI 2 Denpasar - SD Dwijendra Denpasar - Jl. Patimura - SMP PGRI 9 Denpasar - SMP Negeri 8 Denpasar - Jl. Suradipa - WR. Supratman - Jl. Gadung - Jl. Meduri - Indomaret Antasura - Indomaret A.Yani - Apotek Cempaka - Jl. Astasura - Jl. Nangka - Jl. Lembusora - SD Saraswati 2 - Jl. Antasura - Banjar Tulangampiang - SDN 28 Dangin Puri	64.7841289352247 4
10	UPT Pelayanan Transportasi Darat - Jl. Suradipa - Toko Chaca - Jl. Nangka - SD Dwijendra Denpasar - Jl. Lembusora - Apotek Cempaka - SDN 28 Dangin Puri - SD Saraswati 6 Denpasar - Jl. Astasura - SD Saraswati 2 - Jl. Gadung - Jl. Meduri - SMP	59.7769870774727 7	16	UPT Pelayanan Transportasi Darat - SD Saraswati 2 - Jl. Suradipa - SD Dwijendra Denpasar - Jl. Antasura - SDN 28 Dangin Puri - Toko Chaca - Indomaret A.Yani - Jl. Nangka - Jl. Gadung - Jl. Lembusora - Jl. Astasura - SMP PGRI 2 Denpasar - SMP	9999

No	Route	Distance
	PGRI 9 Denpasar - Indomaret Antasura - Jl. Patimura - Jl. Meduri - Apotek Cempaka - WR. Supratman - SMP Negeri 8 Denpasar - SD Saraswati 6 Denpasar - Banjar Tulangampiang	
17	UPT Pelayanan Transportasi Darat - Jl. Patimura - Banjar Tulangampiang - SMP PGRI 2 Denpasar - Jl. Lembusora - Jl. Suradipa - WR. Supratman - Toko Chaca - SMP Negeri 8 Denpasar - SD Saraswati 2 - Apotek Cempaka - SD Dwijendra Denpasar - Jl. Antasura - Jl. Astasura - SMP PGRI 9 Denpasar - Jl. Gadung - SD Saraswati 6 Denpasar - Indomaret A.Yani - Jl. Nangka - Jl. Meduri - Indomaret Antasura - SDN 28 Dangin Puri	66.07797 15707438 1
18	UPT Pelayanan Transportasi Darat - SMP Negeri 8 Denpasar - Banjar Tulangampiang - Jl. Lembusora - Jl. Antasura - SDN 28 Dangin Puri - SD Saraswati 6 Denpasar - SD Dwijendra Denpasar - Apotek Cempaka - Jl. Patimura - SMP PGRI 2 Denpasar - Jl. Astasura - SMP PGRI 9 Denpasar - Indomaret Antasura - Indomaret A.Yani - Jl. Meduri - WR. Supratman - SD Saraswati 2 - Toko Chaca - Jl. Nangka - Jl. Gadung - Jl. Suradipa	9999
19	UPT Pelayanan Transportasi Darat - Jl. Nangka - Indomaret Antasura - Toko Chaca - Jl. Lembusora - Apotek Cempaka - SD Saraswati 6 Denpasar - WR. Supratman - Jl. Patimura - SD Saraswati 2 - SD Dwijendra Denpasar - SMP PGRI 2 Denpasar - Jl. Suradipa - Indomaret A.Yani - Jl. Antasura - SDN 28 Dangin Puri - Jl. Gadung - Jl. Meduri - Banjar Tulangampiang - Jl. Astasura - SMP PGRI 9 Denpasar - SMP Negeri 8 Denpasar	48.36256 59710800 9
20	UPT Pelayanan Transportasi Darat - Banjar Tulangampiang - Indomaret Antasura - Jl. Antasura - Toko Chaca - SD Dwijendra Denpasar - Jl. Meduri - Jl. Patimura - SMP PGRI 2 Denpasar - SD Saraswati 6 Denpasar - Jl. Lembusora - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Astasura - Jl. Suradipa - Jl. Gadung - Apotek Cempaka - SDN 28 Dangin Puri - Indomaret A.Yani - WR. Supratman - SMP Negeri 8 Denpasar - SD Saraswati 2	46.97660 21267881 94

4.2 Final Population

Applications that have been built using the Differential Evolution algorithm. The output of the application is a route candidate that is getting shorter and shorter. Table II shows the final population results. The last population has the same number as the population that was raised at the time of initial initialization. In the last population, a more optimal route candidate has been obtained with varying route distances. The resulting difference in route distance is much smaller than that of the first population route.

Table 2 shows the minimum route distance value obtained is 25.75039590845092 km, and the maximum is 26.624917440178955.

Table 2: Final population.

No	Route	Distance
1	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP Negeri 8 Denpasar - SMP PGRI 2 Denpasar - Jl. Meduri - WR. Supratman - Apotek Cempaka - Jl. Patimura - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Gadung - SD Saraswati 2 - SDN 28 Dangin Puri - SD Dwijendra Denpasar	26.28123 79401957 48
2	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP Negeri 8 Denpasar - SMP PGRI 2 Denpasar - Jl. Meduri - Jl. Gadung - Apotek Cempaka - WR. Supratman - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SD Saraswati 2 - SDN 28 Dangin Puri - SD Dwijendra Denpasar	26.24865 28273547 8
3	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Apotek Cempaka - Jl. Gadung - WR. Supratman - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SD Saraswati 2 - SDN 28 Dangin Puri - SD Dwijendra Denpasar	26.28879 54928038 43
4	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Apotek Cempaka - Jl. Gadung - WR. Supratman - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SD Saraswati 2 - SDN 28 Dangin Puri - SD Dwijendra Denpasar	26.28879 54928038 43
5	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Apotek Cempaka - Jl. Gadung - WR. Supratman - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SD Saraswati 2 - SDN 28 Dangin Puri - SD Dwijendra Denpasar	26.28879 54928038 43
6	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl.	26.39077 67633963 4

No	Route	Distance	No	Route	Distance
	Meduri - WR. Supratman - Apotek Cempaka - Jl. Gadung - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SD Dwijendra Denpasar - SDN 28 Dangin Puri - SD Saraswati 2			Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Jl. Gadung - Apotek Cempaka - WR. Supratman - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SD Saraswati 2 - SDN 28 Dangin Puri - SD Dwijendra Denpasar	
7	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Jl. Gadung - Apotek Cempaka - WR. Supratman - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SD Saraswati 2 - SDN 28 Dangin Puri - SD Dwijendra Denpasar	26.24865 28273547 8	13	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Jl. Gadung - WR. Supratman - Apotek Cempaka - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SDN 28 Dangin Puri - SD Saraswati 2 - SD Dwijendra Denpasar	26.19511 97169122 84
8	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Apotek Cempaka - Jl. Gadung - WR. Supratman - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SDN 28 Dangin Puri - SD Dwijendra Denpasar - SD Saraswati 2	26.04539 31569802 2	14	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Toko Chaca - Banjar Tulangampiang - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Jl. Gadung - Jl. Patimura - WR. Supratman - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Apotek Cempaka - SD Saraswati 2 - SDN 28 Dangin Puri - SD Dwijendra Denpasar	27.33332 78207907 14
9	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Apotek Cempaka - Jl. Gadung - WR. Supratman - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SDN 28 Dangin Puri - SD Dwijendra Denpasar - SD Saraswati 2	26.04539 31569802 2	15	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP Negeri 8 Denpasar - SMP PGRI 2 Denpasar - WR. Supratman - Jl. Gadung - Apotek Cempaka - Jl. Meduri - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SDN 28 Dangin Puri - SD Dwijendra Denpasar - SD Saraswati 2	26.43319 43464800 82
10	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Jl. Gadung - Apotek Cempaka - WR. Supratman - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SD Saraswati 2 - SDN 28 Dangin Puri - SD Dwijendra Denpasar	26.24865 28273547 8	16	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Jl. Gadung - WR. Supratman - Apotek Cempaka - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SD Dwijendra Denpasar - SDN 28 Dangin Puri - SD Saraswati 2	26.62491 74401789 55
11	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Apotek Cempaka - Jl. Gadung - WR. Supratman - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SD Saraswati 2 - SDN 28 Dangin Puri - SD Dwijendra Denpasar	26.28879 54928038 43	17	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SD Saraswati 6 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Jl. Gadung - Apotek Cempaka - WR. Supratman - SMP PGRI 2 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SDN 28 Dangin Puri - SD Dwijendra Denpasar - SD Saraswati 2	26.44615 42127098 2
12	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2	26.24865 28273547 8	18	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI	26.24865 28273547 8

No	Route	Distance
	2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Jl. Gadung - Apotek Cempaka - WR. Supratman - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SD Saraswati 2 - SDN 28 Dangin Puri - SD Dwijendra Denpasar	
19	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - Jl. Gadung - Apotek Cempaka - WR. Supratman - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SD Saraswati 2 - SDN 28 Dangin Puri - SD Dwijendra Denpasar	26.248652827354 78
20	UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - WR. Supratman - Jl. Gadung - Apotek Cempaka - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SDN 28 Dangin Puri - SD Dwijendra Denpasar - SD Saraswati 2	25.750395908450 2

Based on the data from the Differential Evolution algorithm in Table II, the shortest route obtained is the minimum distance route of 25.75039590845092 km. The route obtained is as follows:

UPT Pelayanan Transportasi Darat - Indomaret A.Yani - Banjar Tulangampiang - Toko Chaca - Jl. Lembusora - SMP PGRI 2 Denpasar - SMP Negeri 8 Denpasar - Jl. Meduri - WR. Supratman - Jl. Gadung - Apotek Cempaka - SD Saraswati 6 Denpasar - Jl. Antasura - Jl. Astasura - Indomaret Antasura - Jl. Suradipa - SMP PGRI 9 Denpasar - Jl. Nangka - Jl. Patimura - SDN 28 Dangin Puri - SD Dwijendra Denpasar - SD Saraswati 2.

5 CONCLUSIONS

Based on the data of the initial population and the final population from the Differential Evolution algorithm, it was found that the individual candidates (routes) in the final population were much better with a shorter route than the initial population. We can conclude, the Differential Evolution algorithm is effectively used to find the minimum value in the case of route search.

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