OPTIMIZATION OF FROZEN FOOD DISTRIBUTION USING GENETIC ALGORITHMS

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ABSTRACT

Nowadays, 30% of Indonesian consume frozen foods because it is more practical and efficient. The increase of demand requires a good distribution system. The distribution problem can be solved using genetic algorithms. Crossover method used in this study is one-cut point crossover, the mutation method used is reciprocal exchange mutation and the selection method used is elitism selection. The data used in this study is 15 of customers, 11 of product types, 5 vehicles and distance data between regions. From the tests, we found that optimal results are achieved using the population size of 1950, 700 generations, a combination of crossover rate (*cr*) = 0.5 and mutation rate (*mr*) = 0.6. The final result is a combination of the customer and vehicle order that distribute all products to all customers with the minimum total distance and cost.

Keywords: *genetic algorithm, optimization, frozen food, distribution*

1. INTRODUCTION

The distribution is an activity of transferring goods or products from the manufacturer to the customers. On the technical execution of the process, the distributor uses some vehicle as a carrier of the products. To minimize distribution cost, a good strategy is required. This strategy includes determining routes of the vehicles. The problem is called the Vehicle Routing Problem (VRP). The VRP is considered as a combinatorial optimization problem has been solved using various methods (Kumar & Panneerselvam 2012; Mahmudy 2014a).

On the technical execution of the distribution of goods, the distributor will use some of the vehicles as a carrier of goods to be distributed to customers. The different areas of customers require distributors to determine the route of travel distribution of goods. The main objective of solving the problem is minimizing the distribution cost. A minimum distribution cost may be achieved by minimizing distribution routes and also minimizing used vehicles in the distribution process. In addition to these, the capacity of the vehicles should also be considered (Pitaloka, Mahmudy & Sutrisno 2014). The better the quality of the distribution process, the greater the benefits will be obtained.

Finding a solution in the distribution process is a part of decision-making process in supply chain management (Moon, Lee & Seong 2012). The various problem of distribution process has been addressed in the literature. For example, Hsu, Hung and Li (2007) address a distribution of perishable foods. The objective of this study is delivering the foods as soon as possible as their value will decrease during distribution. The objective can be achieved by minimizing the distribution routes of vehicles. A similar study is carried out by Osvald and Stirn (2008) that address the distribution of fresh vegetables.

This problem can be solved by many methods, one of them is Genetic Algorithm. The genetic algorithm is a search technique in computer science to provide optimal solutions to the complex issues such as planning and production scheduling, scheduling lectures, multi-traveling salesman problem (M-TSP) and the visit of efficient travel (Dipesh Mittal et al. 2015; Mahmudy, Marian & Luong 2013a; Widodo & Mahmudy 2010).

In this study, frozen food companies still use manual systems in the distribution of goods to the existing route. It will certainly take a lot of time making it less efficient and effective. Therefore, optimization of distribution routes will take advantage of information technology in the shortest path search based on the capacity of the vehicle. So that the delivery of goods to customers to be more effective and efficient to have an impact on the increase in corporate profits in the form of an increase in customers.

2. PROBLEM DESCRIPTION

Frozen food is a form of food through pickling process to be frozen so that it can last longer. This is done to slow down the decomposition by changing the water content remaining to ice that inhibited bacterial growth and food last longer (Brecker & Fricke 1999; Wang & Zou 2014).

Freezing food is not only done by farmers, fishermen or hunters. This freezing process creates a new business that attracted many people, especially housewives. In addition to the raw foods, freezing is also done for the half-cooked food.

In addition to providing convenience, the success of the frozen food business was also supported by a number of consumer's interest. In addition to convenience, consumers prefer frozen food than fresh food because of better nutritional content.

The data used in this study has several attributes, namely customer data, product data and distance data from household industry M-frozen snack. The third attribute is used to solve the problems of the distribution of the frozen food by knowing the distance between the customer and charge capacity based on the number of bookings. So the best solution based on the shortest distance, distribution costs and residual charge on the delivery of frozen foods show minimal results. The attributes used in the optimization process that customer data is shown in Table 1, the type of products are shown in Table 2, the transportation costs of the vehicle when full and empty and capacities described in Table 3, then Table 4 indicating the distance between the customer and the customer resources with one another.

Optimization distribution observed in this study only covers the area of Surabaya, East Java. While frozen food to be distributed is assumed to have the quality and the same survival time.

Distribution costs will be optimized in this research is the cost used by the distributor when the distribution of goods to customers. The distribution cost is calculated starting from the supplier to the customer (cost of going) at the same time the distributor back to the supplier (cost of the home). Costs incurred in the distribution process is based on several aspects, including mileage (j), transport costs when the vehicle is empty (t_0), transport costs while the vehicle is charged (t_1), the contents are transported by the vehicle (w) and the contents of the vehicle maximal (w_{max}). Costs go can be calculated using the formula in equation (1) and equation (2) to calculate the departure and return journey cost respectively.

$$Cost\ of\ departure = j * (t_0 + (t_1 - t_0) * \frac{w}{w_{\max}}) \quad (1)$$

$$Cost\ of\ return = j * t_0 \quad (2)$$

Table 1. List of Customer

Customer ID	Address
A1	Surabaya – Sepanjang
A2	Surabaya – Mergorejo
A3	Surabaya – Wonokromo
A4	Surabaya – Tenggilis
A5	Surabaya – Tegalsari
A6	Sidoarjo – Tropodo
A7	Sidoarjo – Taman
A8	Gresik
A9	Surabaya – Sawahan
A10	Surabaya – Mulyorejo
A11	Surabaya – Sukolilo
A12	Sidoarjo – Sukorejo
A13	Sidoarjo – Candi
A14	Gresik
A15	Sidoarjo – Waru

Table 2. Types of Products

No	Product	Name of Product
1	P1	Donat Keju
2	P2	Donat Kacang
3	P3	Donat Coklat
4	P4	Donat Bulat
5	P5	Risol Mayo
6	P6	Sosis Solo
7	P7	Tahu Bakso
8	P8	Samosa
9	P9	Martabak
10	P10	Pastel
11	P11	Kebab

Table 3. Cost and Vehicle Capacity

Vehicle	Number of Units	Cost /km (empty)	Cost /km (full)	Capacity
K1	1	5.000	7.000	200 pcs
K2	1	5.000	7.000	200 pcs

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Table 4. Distance amongs Customers

Distance (km)	Source	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
Source	0	20	22	23	21	24	20	19	48	27	29	32	9	5	48	21
A1	20	0	8	7	7	10	11	6	32	13	15	17	15	24	32	6
A2	22	8	0	4	3	5	8	11	29	7	10	13	14	21	29	4
A3	23	7	4	0	4	4	10	13	29	7	10	12	16	23	29	6
A4	21	7	3	4	0	7	8	12	31	9	8	11	15	23	31	6
A5	24	10	5	4	7	0	13	16	21	3	7	11	18	26	21	9
A6	20	11	8	10	8	13	0	13	36	16	12	14	13	21	36	4
A7	19	6	11	13	12	16	13	0	34	18	20	25	12	26	34	8
A8	48	32	29	29	31	21	36	34	0	19	26	31	40	48	0	31
A9	27	13	7	7	9	3	16	18	19	0	9	14	20	28	19	16
A10	29	15	10	10	8	7	12	20	26	9	0	7	23	31	26	14
A11	32	17	13	12	11	11	14	25	31	14	7	0	25	33	31	16
A12	34	49	51	52	52	55	52	51	73	61	60	63	0	32	73	48
A13	5	24	21	23	23	26	21	26	48	28	31	33	10	0	49	19
A14	48	32	29	29	31	21	36	34	0	19	26	31	40	49	0	31
A15	21	6	4	6	6	9	4	8	31	16	14	16	9	19	31	0

3. OPTIMIZATION USING GAs

Frozen food distribution problem is solved using Genetic Algorithms. As one of the combinatorial algorithm, Genetic Algorithm is able to solve various problems by providing a solution that is near optimal (Mahmudy 2014b).

There is a fleet of vehicles (K), a producer as a source, a number of customers (n), three kinds of products (A1, A2 dan A3) and a diverse customer demand (m_i). Customers are served in dots geographically dispersed so that it can be calculated the distance of each point as the distance between the customers (d_{ij}). Each distance (i,j) has a certain costs ($c_{i,j}$) assumed to be symmetric, ie $c_{ij} = c_{ji}$ and on condition that $c_{ii} = 0$. Shipping products to customers uses two vehicles with a payload capacity of uniform. Table 5 is a customer demand for each product from the manufacturer.

Table 5. Customer Demand

Customer	Product 1 (P1)	Product 2 (P2)	Product 3 (P3)
A1	30	30	10
A2	30	10	40
A3	10	30	50

Besides the data request, the manufacturer also has the vehicles used to carry out the distribution process. Table 6 is the data of each vehicle.

Table 6. Data Cost Vehicle

Vehicle	Number of Units	Cost /km (empty)	Cost /km (full)	Charge
K1	1	3.000	5.500	150 pcs
K2	1	3.000	5.500	150 pcs

Figure 1 is a graph of the location of the three customers who book (A1, A2, and A3) and the distance between end-users.

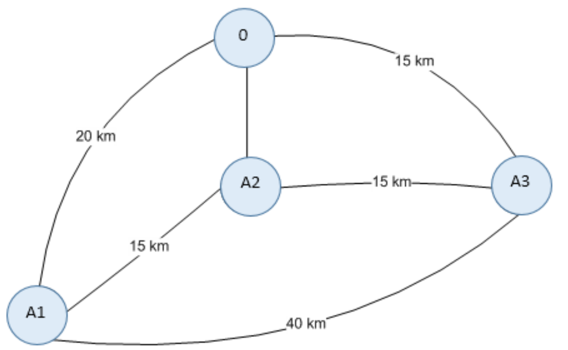

Figure 1. Graf customer location

3.1 Chromosome Representation and Fitness Value

To explain chromosome representation, a simple case is given as an example. The process involves 3 customers (A1, A2, and A3) who book at 3 types of items (P1, P2, and P3). The distribution uses 2 vehicles which can carry 200 items at one time.

Representation of chromosomes uses permutations of the two segments. The first segment is a permutation-based customer with a certain length indicating the number of customers. While the second segment is a permutation-based vehicle with a certain length indicating the number of vehicles used to carry out the distribution process. This problem can be illustrated in Figure 2.

Segment 1			Segment 2	
A1	A2	A3	K1	K2
2	1	3	1	2

Figure 2. Chromosome Representation

In Figure 2, the yellow color indicates the segment 1. The red color indicates the two gene segments 1 and 2. Segment 1 contains three genes, namely 2, 1 and 3 are a number of genes which means the distributor will serve A2 beforehand. Then the service is done to the A1 and the latter on the A3. Segment 2 consists of two genes that are represented in the last 2 digits on the chromosome, ie 1 and 2. This indicates that the service will be conducted by K1 A2 beforehand. If the charge on the K1 has been met then K2 will be filled. This process continues until all customers need are fulfilled.

Once the chromosomes are formed, the next step is the calculation of the value of *fitness*. This calculation aims to determine the ability of each individual to survive. In this study, the *fitness* value to be achieved is the total cost and the rest of the charge on each delivery of frozen foods (Sen et al. 2011). It is intended that the cost of distribution to each customer becomes more optimal.

The calculation of the value of *fitness* in these issues is obtained from the value of the remaining *penalty* charge and the total cost. Penalty is given if the vehicle has a residual charge. The total distance obtained can be a reference for how much cost is used for one-time distribution process. The costs is derived from multiplying the distance to the vehicle cost when empty or loaded. The fitness value is calculated based on the sum of the *penalty* and the total cost. The greater the value of the sum of the penalty and the total cost, then the *fitness* value obtained will be smaller. This is because the *fitness* using function minimization can be formulated to equation 3.

$$f = \frac{1}{total\ cost + total\ residual\ charge}\ x\ C \qquad (3)$$

In the formulation of the fitness value by minimizing the function multiplied by a constant C so that the fitness value calculation easier. It also avoids the fitness value which is too small.

Chromosomes are formed is [2 1 3-1 2]. Based on the chromosome, the fitness value calculation is as follows

Table 7. Calculation of *fitness*

Vehicle	Customer	Capacity	Residual Charge	Cost
1 – K1	A2	80	70	43333
	A1	70	0	115000
2 – K2	A3	90	60	150000
		Total	60	308333

Table 7 shows the penalty and the total cost obtained if the arrangement of chromosomes in certain individuals is [2 1 3-1 2]. K1 is doing the distribution to the customer 1 (A1) with a maximum payload of 150 pcs. But K1 penalized because the charge on delivery is not optimal. Freight shipments in Q1 amounted to only 80 pcs so are the remaining 70 pcs in K1. This is called a penalty.

Cost calculation carried out in accordance with the cost of each vehicle in Table 6 and the total distance according to Figure 1. In K1, made 2 distribution to customers, namely A1 and A2. So that the route of the K1 is a manufacturer - A2 - A1 - producers. Distance unknown manufacturer to A2 is 10 km, the distance A2 to A1 is 15 km and the distance A1 to the manufacturer is 20 km. While the cost of distribution at K1 when a full charge is equal to 5500 / km and when the empty payload of 3,000 / km. The total cost of distribution by K1 to A2 and A1 is shipping on the A1 A2 plus shipping and fees back to the manufacturer. Costs incurred by K1 for the distribution of A2

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is 10 x (3000 + ((5500-3000) x 80/150)) = 10 x 4333.33 = 43333. Then the cost of distribution by K1 on the A1 is 15 x (3000 + ((5500 - 3000) x 70/150)) = 15 x 3666.67 = 55000. On this issue, the cost of which is used to return to the manufacturer accumulated by the customer last visited, namely A1. So the total cost of distribution to P1 K1 is 55000 + (20 x 3000) = 55000 + 60000 = 115000. The process of calculating the distribution of K-2 also has the same stage.

After the total penalties and cost of the problem are obtained, then the fitness value can be calculated using the equation previous fitness. The resulting fitness value is

$$f = \frac{100.000}{308333 + 60} = 0.324261575$$

3.2 Population Initialization

The system will generate initial population randomly which contain a number of individuals. The number is determined by predetermined variable named population size (*popsize*):

3.3 Crossover

One method to produce new individuals is is a cross exchange or crossover. Reproduction by using the crossover will produce a number of children (offspring) in accordance with *cr* (crossover rate) and its *popsize*. *cr* ratio is a proportion of children to be produced using crossover operator. The calculation of the amount obtained by multiplying *cr* and popsize.

The method used is the one-cut point crossover. The initial process begins with the calculation of the child (offspring) that will be generated. Value cr on these problems is 0.6 with popsize of 5, the offspring resulting from crossover is a 0.6 x 5 = 3 offspring. Next, we chose two individuals at random to be the parents in the process of reproduction. Suppose individuals selected are individuals 3 and 5 shown in Table 8.

Table 8. Chosen Individual for *Crossover*

Parent	Segment 1			Segment 2	
P3	3	1	2	1	2
P5	3	2	1	2	1

After the parent is selected, the next step is determinin the cut-off point at random in each segment. Table 9 is the process of cutting each of the parental chromosomes.

Table 9. *Offspring Crossover* Process Results

Individual	**Segment 1**			**Segment 2**	
P3	3	1	2	1	2
P5	3	2	1	2	1
C1	3	1	2	1	2

Process crossover segment 1, are on the cutting-point-2 genes into the parent 1. Thus, two genes in the parent 1 to 2 first gene offspring on segment 1. The next step is checking the parent 2. If the gene in question is already present in offspring, then checking is proceed to the next gen. So we get the genetic make-up of offspring is 3 1, 2, 3 and 1 is derived from one parent while the 2 genes derived from parent 2.

Calculation of segment 2 has the same stages with the stages of the calculation of segment 1. The following is a list of crossover offspring result.

3.4 Mutation

Another way to produce offspring is by mutation. The number of children (offspring) generated in the process of mutation is determined by *mr* (mutation rate) and population size. Mr is a likelihood ratio to produce a child in a mutation. The calculation of the amount of child obtained by multiplying the mr and popsize. On this issue, the method used is the *reciprocal exchange*.

Reproduction of the problems in the previous section can be started with the calculation of the number of children (offspring) that will be generated. *mr* value is set to 0.4 with popsize 5, the offspring resulting from a mutation is a number of 0.4 x 5 = 2 offspring. Then we randomly choose one chromosome to be a parent in the process of reproduction. Example of selected individual in shown in Table 10.

Table 10. Chosen Individual for Mutation

Individual	**Segment 1**			**Segment 2**	
P2	2	1	3	2	1

After the parent is selected, then determine the two genes randomly in each segment. Table 11 is the selection of the parent chromosome genes in the process of mutation.

Table 11. *Offspring* Mutation Process Result

Individual	Segment 1			Segment 2	
P2	2	1	3	2	1
C4	3	1	2	1	2

Mutations in done in one segment, the genes to be exchanged are the first gene and a third gene, ie 2 and 3. Therefore, when the composition of the parent gene segment 1 is 2 1 3 3 1 2 turn out to be the offspring. While the process of mutations in two segments, genes will be exchanged are the first and second gene, ie 1 and 2. Therefore, when the composition of the parent gene segment 2 is 2 1, is changed to 1 second in the offspring.

The second mutation process is carried out in the same manner as in the first mutation but using newly acquired individuals randomly from the population.

3.5 Selection

The selection process is doneto establish a new population by using selection methods elitism. Elitism selection method will select individuals of the initial population (the parent) and children (offspring) to get a new population on the population as much as the previous generation. This new population is the population with the best fitness value which will be the population in the next generation.

The selection process using the method of selection is elitism sort a collection of individuals and offspring based on the value of fitness. Once sorted the selected individuals with the best fitness number popsize.

4. EXPERIMENTAL RESULT

Testing conducted to evaluate whether the genetic algorithm is able to solve the problems of optimization of the distribution of frozen foods. Based on the genetic algorithm parameter best results of the tests are expected to offer solutions that maximize and near optimal. Testing parameters of the genetic algorithm will be performed 10 times. Due to the nature of the stochastic algorithms that yield different solutions each run, the best results of each test will be better if obtained from the average (Mahmudy, Marian & Luong 2013b).

4.1 Testing of Population Size

The first stage in the numerical experiment is determining the best population size. In this stage, number of generation, *cr*,and *mr* are set to 100, 0.6 and 0.4 respectively. The testing result is presented in Figure 3.

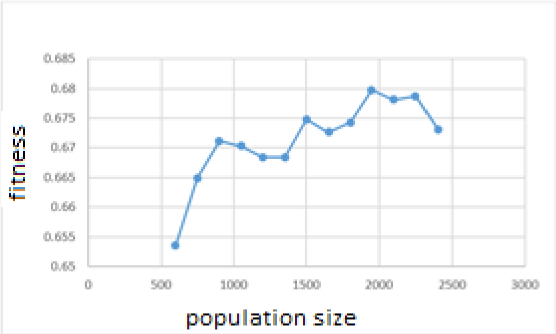

Figure 3. Population size test

From the graph in Figure 3, it appears that the change in the value of the size of the population heavily influence the fitness value. The larger the size of the population, then the fitness value generated even greater. In testing with population size in 1950 resulted in the average highest fitness value, which is 0.67974382. Furthermore, the average fitness value obtained is not much different from the value average maximum. This is because the results of reproduction have the same resemblance to its parent.

4.2 Testing of Generation/Iteration

Testing generation / iteration was conducted to determine the best generation that can solve the problems of distribution of frozen foods. Parameters on the testing of this generation's best to use the population size of the previous test results used population size of 1950. Value of *cr* is 0.6 and *mr* is 0.4. Range number of generations used in the test is 100 to 1200. Figure 4 represents the result of generation testing.

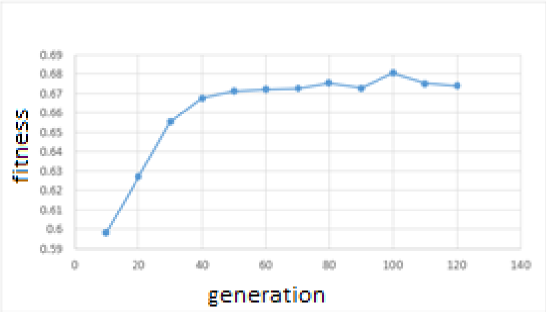

Figure 4. Chart of the test results from Generation / Iteration

From Figure 4, it appears that the change in the value of the generation heavily influence the fitness value is obtained. The greater the value of the generation / iteration, the computing time required increases. In the test with the value of the generation / iteration 100 generates the average highest fitness value, which is 0.68050289. Furthermore, the average fitness values obtained in the next generation is not much different from the value average maximum.

4.3 Testing of *cr* & *mr* Combination

cr and *mr* testing were conducted to determine the best combination of value to get the best fitness value. The best population size and the number of generations from previous test results will be used in testing combination of *cr* and *mr* as the parameters. *cr* is tested in the range of 1 to 0.1 contrasts to *mr* in the range between 0.1 to 1. Figure 5 shows the result of combination testing.

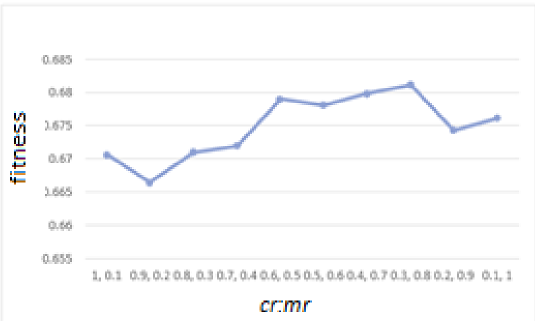

Figure 5. The test results of *cr* & *mr* combination

From the graph in Figure 5, the change in value *cr* and *mr* greatly affect the value of fitness. *cr* and *mr* combination determines the performance of the genetic algorithm in exploring and exploit the search space (Mahmudy, Marian & Luong 2013b). *cr* and *mr* value will be different on each problem. In this study, combination of *cr* and *mr* to get value average highest fitness is *cr* = 0.3 and *mr* = 0.8 with the average highest fitness value is 0.681114481.

4.4 Testing using the Best Parameter

The last experiment is conducted to determine the best parameter best fitness value using the best parameter values from previous testing. The population size is 1950, the number of next-generation is 100 and the combination is *cr* = 0.3 with a value *mr* = 0.8. Figure 6 is the result of the test with the best parameters.

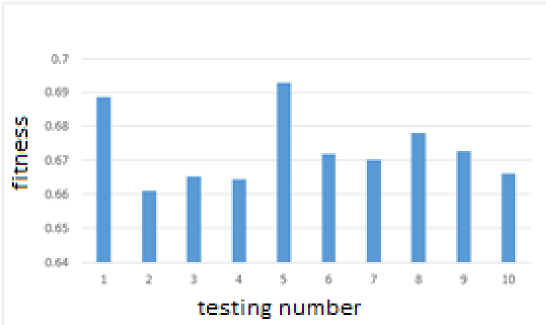

Figure 6. The test results with the best parameters

From the graph in Figure 6, it appears that the change in the value of fitness is not so significant. Fitness values obtained in testing using the best parameters fall in the range between 0.66 - 0.6927.

5. CONCLUSION

Genetic algorithms can be applied to a wide range of issues, including the distribution of frozen foods. The highest fitness value is obtained from the combination of parameters used, namely population size of 1950, generation of100, crossover rate of 0.3 and mutation rate of 0.8.

Further research may consider hybridization of genetic algorithms with other algorithms to get a better solution.

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