Optimization of automotive goods preparation pattern for export using algorithm genetics

S Hasibuan	extsuperscript{1*}, K S Indarto	extsuperscript{2}, B P Ichtiarto	extsuperscript{1}, C Jaqin	extsuperscript{1} and J Hidayati	extsuperscript{3}

	extsuperscript{1}Industrial Engineering Department, Universitas Mercu Buana, Jakarta, Indonesia
	extsuperscript{2}International Logistic Network, Supply Chain Management, PT. Nissan Motor Indonesia
	extsuperscript{3}Industrial Engineering Department, Universitas Sumatera Utara, Medan, Indonesia

*Email: sawarni02@mercubuana.ac.id

Abstract. In the case of delivery of goods for export purposes with large box dimension variations, the arrangement of goods in the fleet becomes very important as it affects the efficiencies of the cost. This situation is felt by all industrial sectors, one of which is the automotive industry. One problem is due to loading container issues, which in this case is due to the use of fleets for unfilled shipping. This is due to the fact that the delivery pattern of goods within the shipping ship is still not optimal. One solution is to optimize the space and layout of the items in the fleet. Genetic algorithm is a method of solving solutions that can be used to solve container loading problems with non-linear and heterogeneous data items, inspired by the theory of evolution. Genetic algorithm can provide optimization solutions for item preparation patterns that practice natural selection methods to get selected individuals that contain the best genes. Then the data will be repeated for several generations and yield the best array pattern output or achieve the target, in this case the minimum free space.

1. Introduction

In accordance with industrial development makes all business to be efficient in all sides of business. One of which is from the aspect of cost. Logistics is one part which can not be separated from industrial world. It can not be denied that logistics cost is one of the biggest cost. However logistics in a company is one of many factors to produce money which greatly contributes to financial position of a company [1][2]. This problem is only experienced by domestic businessmen but also foreign businessmen. According to data from Association Importers National(GINSI), logistics cost in Indonesia is one of the most expensive in ASEAN.

This condition is also experienced by automotive industry in Indonesia. One of industrial industry which has export business line also experiencing the same problem so in this case it needs innovation in the process in efficiency the cost. One way is by optimalization the use of container in every shipping process.

If in the process of delivery, the goods entered in the container are not solid, and not patterned so there are still many gaps or empty spaces. We still need additional container to carry other goods in the store rooms. This condition is one problem included in Container Loading Problem. So to optimize the use of container, thing that we can do is by making goods arrangement in the container as maximum as possible. In this case by minimalizing empty spaces in the container or the fleet that will be used.
2. Literature review

2.1. Genetic Algorithm

Genetic algorithm is a randomized search methodology having its roots in the natural selection process. Initially the neighborhood search operators (crossover and mutation) are applied to the preliminary set of solutions to acquire generation of new solutions. Solutions are chosen randomly from the existing set of solutions where the selection probability and the solution’s objective function value are proportional to each other and eventually the aforesaid operators are applied on the chosen solutions. Genetic algorithms have aided in the successful implementation of solutions for a wide variety of combinatorial problems.

The robustness of the Genetic algorithms as search techniques have been theoretically and empirically proved [3]. The artificial individual is the basic element of a GA. An artificial individual consists of a chromosome and a fitness value, similar to a natural individual. The individual's likelihood for survival and mating is determined by the fitness function [4]. In accordance with the Darwin’s principle, individuals superior to their competitors, are more likely to promote their genes to the next generations. In accordance with this concept, in Genetic Algorithms, we encode a set of parameters mapped into a potential solution, named chromosome, to the optimization problem [5]. The population of candidate solutions is obtained through the process of selection, recombination and mutation performed in an iterative manner [6]. Chromosomes refer to the random population of encoded candidate solutions with which the Genetic algorithms initiate with [3]. Then the set (called a population) of possible solutions (called chromosomes) are generated [7].

A function assigns a degree of fitness to each chromosome in every generation in order to use the best individual during the evolutionary process [8]. In accordance to the objective, the fitness function evaluates the individuals [6]. Each chromosome is evaluated using a fitness function and a fitness value is assigned. Then, three different operators—selection, crossover and mutation—are applied to update the population. A generation refers to an iteration of these three operators [9]. The promising areas of the search space are focused in the selection step. The selection process typically keeps solutions with high fitness values in the population and rejects individuals of low quality [6]. Hence, this provides a means for the chromosomes with better fitness to form the Mating Pool (MP) [7]. After the process of Selection, the crossover is performed. In the crossover operation, two new children are formed by exchanging the genetic information between two parent chromosomes (say C1 and C2 which are selected from the selection process) [12].

A crossover point is chosen at random by the crossover operator. At this point, two parent chromosomes break and then exchange the chromosome parts after that point. Consequently, the partial features of two chromosomes are combined to generate two off springs. The chromosome cloning takes place when a pair of chromosomes does not cross over, thus creating off springs that are exact copies of each parent [8]. The ultimate step in each generation is the mutation of individuals through the alteration of parts of their genes [6]. Mutation alters a portion of a chromosome and thus institutes variability into the population of the subsequent generation [7,13]. Mutation, a rarity in nature, denotes the alteration in the gene and assists us in avoiding loss of genetic diversity [6]. Its chief intent is to ensure that the search algorithm is not bound on a local optimum [8, 14].

3. Research Methods

Before the process of genetic algorithm formed, first we should make the function, purpose and definition. In this case the purposive function and definition is formed based on the purpose of research and the condition of the field in the company. The company has the purpose to increase the efficiency of container usage by minimalizing the empty spaces in the container. These empty spaces can be counted by subtracting total volume of container’s capacity with the pallet and subtracting the total volume of pallet’s capacity with the content of goods in the pallet. So the purposive function to be used is:

\[ X_{\text{min}} = \Sigma \text{internal volume of container} - \Sigma \text{volume of goods} \]  \hspace{1cm} (1)
The process of doing genetic algorithm begins with the process of determining parameter to be used in making the gen. Below are the terms used in the genetic algorithm.

| Term       | Definition                                                                 |
|------------|-----------------------------------------------------------------------------|
| Gen        | Part which represents a good and the position in the chromosome             |
| Alele      | Value of a gen consists of the Goods’ code, length, width, height and weight. |
| Locus      | Position of a gen in a chromosome                                           |
| Genotype   | Writing the series of goods code in the chromosome.                         |
| Chromosome | Consists of gens as the amount of user input data                           |
| Phenotype  | Reading the series of goods code in the chromosome to be arranged in three dimensional space |
| Evaluation | Process of evaluating arrangement of goods produced from the gen to get the fitness of each individual |
| Individual | Consist of a chromosome having certain fitness                              |
| Population | Consist of some individuals                                                 |
| Selection  | Process done to select individual in the determined population based on the value of probability. |

Flow process of Genetic algorithm is shown in Figure 1

After deciding the next parameter, further step is continued by doing optimalization of arrangement by using genetic algorithm, those are:

- **Step 1.A** Initializing chromosome is the step in defining the form of chromosome to be processed in genetic algorithm. This process is done by using random generator to generate initial data as chromosome.

- **Step 1.B** Forming population is the step to decide the form and size of population of the chromosome decided before.

- **Step 1.C** Encoding chromosome, is the step to arrange and translate the chromosome to become collection of information of a model. The result of this process will then become representation of a solution.

- **Step 2.A** Evaluating individual is the step to define the function of fitness so that the determined function can become the reference of measurement in optimization.

- **Step 2.B** Linear fitness ranking, is the step of sorting chromosome in a population based on the ranking of fitness value which is added the value variation.

- **Step 2.C** Selecting the parents is the process of selecting chromosome to become parents after doing the sorting. The method used is roulette wheel.

- **Step 3** Crossover, is the mating step between selected parents.

- **Step 4** Mutation, is the step of changing gen value of the chromosome. Each chromosome will have probability value to experience the process of mutation.

- **Step 5** Forming population (generation), the formed population will then be counted on its best fitness.
The steps performed on this research were modified, adapting to the needs of the industry and subsequently compiled programs for simulation with the following stages.

1. Determining the target/the result
   The purpose of this research is the minimize of empty space in the fleet so that according to the model used in container loading problem, the target is smaller or equal to the volume of the fleet.

2. Determining the scope of the result
   This scope of research is then modelled with mathematical model according to the need to ease in making the program later. One important scope in this research is not only about the lay out but also considering weight of the goods when making the lay out to anticipate damage of the goods in actual simulation.

3. Determining the size of population to make.
   The population to be made is suited with how many the amount of goods to be sent to a destination. An amount of goods will then be optimized by using genetic algorithm.

4. Determining how big is the mutation rate to use.

---

**Figure 1.** Genetic algorithm structure of research [12]
The mutation rate is determined by *trial and error*, because this process should suited with the need of data mutation. The bigger mutation rate the longer the program in finding the best individual. While the smaller mutation rate the more difficult in finding the best individual.

5. Determining the purposive function.

The purposive function is suited with the target to achieve. In this research the purposive function to be used is volume of the fleet subtracted by volume of goods to be carried.

6. Process of making individual by generating (random number).

7. Process of making population by combining gen and target.

8. Calculating the *fitness* of individual and population.

9. Doing process of selection by finding the best individual in the population

10. Process of *crossover* and choosing parent (2 best individuals)

11. Process of Mutation is the mutation process of the individual chosen among other individuals with the mutation rate determined before.

12. Process of regeneration is forming new population after finding excellent individuals.

13. Process of *looping* or iteration is the process to be done if the excellent or the best product has not been found. The process will begin from selection process.

14. Process termination is the process to be done to stop the process of *looping* or iteration when the best individual product has been found.

4. Result and Discussion

In this research will be used 40 types of modules to be exported to Malaysia. The target of this research is making arrangement of parts in the pallet with the percentage bigger than 85% than maximum volume of the steel pallet RV5 2.22 m³. The data will then be simulated in the program to make the population of arrangement part in the pallet with the fitness approaching the determined target. Result of the program is gained 30 samples. After the population was formed, the sample obtained 2 samples with the best fitness with a percentage of the volume of 84.59% for sample No. 24 and 83.14% for sample No. 29.

![Figure 2. Selection results](image-url)
From result of the selection then the process of crossover and mutation is done by the program. Then the program will do the iteration until is gained simulation of module with the best fitness. In the simulation program is done 1125 times iterations. After the process is then produced the best arrangement pattern shown below.

| P.NO  | P.NAME           | L    | W    | H    | V     | Gm   |
|-------|------------------|------|------|------|-------|------|
| 'X157' | 'BLADE ASSY-MS WIPER' | 700  | 350  | 225  | 0.055125 | 0.0042 |
| 'X156' | 'BLADE ASSY-MS WIPER' | 700  | 350  | 225  | 0.055125 | 2.0228 |
| 'X199' | 'FIN-PR HMAC, LH' | 700  | 520  | 175  | 0.6937  | 5.299 |
| 'X176' | 'GARN ASSY-PR FLR, LH' | 800  | 520  | 200  | 0.1248  | 4    |
| 'X177' | 'GARN ASSY-PR FLR, LH' | 800  | 820  | 800  | 0.1248  | 8.78  |
| 'X178' | 'Console ASSY-CTR' | 1050 | 520  | 450  | 0.2457  | 10.7  |
| 'X7'   | 'GARN ASSY-CTR PLB LMK, RH' | 700  | 700  | 700  | 0.343   | 11.62 |
| 'X16'  | 'FR COOLING UNIT COMP' | 1010 | 1120 | 755  | 0.09406 | 20.6  |
| 'X125' | 'FIN-PR HMAC, RH' | 720  | 520  | 175  | 0.6937  | 5.299 |
| 'X169' | 'SPCR-PR FLOOR RH, LH' | 700  | 520  | 650  | 0.1638  | 5.56  |

**Figure 3.** Result of the best parts combination pallet 1

The following is the result of program simulation for 40 parts. This 40 parts can be entered into 4 pallets RV5 with the percentage of optimization more than 85% so that the rest of the volume wasted in the pallet is the least. With the result of optimization, the company can easily do the arrangement in the field.

**Table 2. Simulation result of genetic algorithm program**

| Simulation 40 Parts | Pallet 1 | Pallet 2 | Pallet 3 | Pallet 4 |
|---------------------|---------|---------|---------|---------|
| Optimization program | 95.43%  | 99.23%  | 90.60%  | 85.84%  |
| Total part          | 10      | 10      | 10      | 20      |
| Target volume (M³)  | 2.220   | 2.220   | 2.220   | 2.220   |
| Volume result (M³)  | 2.119   | 2.110   | 2.010   | 1.900   |
| Rest of wasted volume (M³) | 0.101 | 0.110 | 0.210 | 0.320 |

From the result of program simulation, it can be known that the smaller the amount of the parts the longer the process to find the most optimal arrangement. Percentage of optimizations becomes smaller in accordance with the less variation of box. Container used for simulation of 40 parts is 20ft. In 1 container 20ft can be filled with 10 pallets RV5. So in the case of Knock Down in which the buying uses lot size, for the case of 40 data parts the company can used the system of bundling order by using multiplication of 4 RV5 each lot. For the best optimization so the company can use 5 lots order as minimal order to gain 1 full container.

From the research, it has been proved that genetic algorithm can be made approaching the wished result by determining fitness and arranging logical limitation based on condition in the field. So result of optimization gained can approach the actual condition and can be implemented by doing simulation of arranging goods in actual situation in industry.
5. Conclusion

Genetic algorithm can be used as one of the methods to solve the problem of optimization in container loading problem for parts with good results. In determining the mutation rate, there are many times of simulation to find the stability of data change and to find the wished result. For certain conditions related to the goods and the terms and condition in the field, it is better to be put in the scope of research to sharpen optimization results.

References

[1] Caban W 2001 Ekonomia. Podręcznik dla studiów licencjackich, PWE, Warszawa.
[2] Behzadi S, A.A. Alesheikh and E. Poorazizi, 2008. Developing a genetic algorithm to solve shortest path problem on a raster data model. Proc. J. Applied Sci., 8: 3289-3293.
[3] Khadwilard A and Pongcharoen P 2007 Application of genetic algorithm for trajectory planning of two degrees of freedom robot arm with two dimensions. Thammasat. Int. J. Sci. Technol., 12: 88-94.
[4] Sharbafi M A, M.S. Herfeh, C. Lucas and A.M. Nejad, 2006. An innovative fuzzy decision making based genetic algorithm. Proc. World Acad. Sci. Eng. Technol., 13: 180-183.
[5] Butter T, Rothlauf F, J. Grah, T. Hildenbrand and J. Arndt 2006 Developing genetic algorithms and mixed integer linear programs for finding optimal strategies for a student's "sports" activity. Proceeding of the Working Papers in Information Systems, Mar. 2006, University of Mannheim, pp: 1-16.
[6] Qureshi S A, S.M. Mirza and M. Arif, 2006. Fitness function evaluation for image reconstruction using binary genetic algorithm for parallel ray transmission tomography. Proceeding of the International Conference on Emerging Technologies, Nov. 13-14, Peshawar, pp: 196-201.
[7] Tareeq S M, Parveen R, L.J. Rozario and Md. Al-Amin Bhuiyan, 2007. Robust face detection using genetic algorithm. Inform. Technol. J., 6: 142-147.
[8] Soryani M and N. Rafat, 2006. Application of genetic algorithms to feature subset selection in a farsi OCR. Proc. World Acad. Sci. Eng. Technol., 13: 113-116.
[9] Caldeira J L, R.C. Azevedo, C.A. Silva and J.M.C. Sousa, 2007. Supply chain management using ACO and beam-ACO algorithms. Proceeding of the IEEE International Fuzzy Systems Conference, July 23-26, London, pp: 1-6.
[10] Gunadi K, Julistiono I K, Hariyanto B 2004 Optimasi Pola Penyusunan Barang Dalam Ruang Tiga Dimensi Menggunakan Metode Genetic Algorithms. Jurnal Informatika, 4(1), 13-17.
[11] Irvan, Trisakti B, Sidabutar R, Situmeang CW, Siregar FMR 2020 IOP Conf. Ser: Mater. Sci. Eng. 801(1) 012043
[12] Trisakti B, Sidabutar R, Lumbangaol AK, Hutagalung A, Lumbangaol P, Irvan 2020 *IOP Conf. Ser: Mater. Sci. Eng.* **801**(1) 012038

[13] Misran E, Sarah M, Irvan, Dina SF, Harahap SAA, and Nazar A 2020 *IOP Conf. Ser: Journal of Physics* **1542**(1) 012068

[14] Nizar M, Munir E, Munawar E and Irvan 2018 *IOP Conf. Ser: Journal of Physics* **1116**(5) 052045