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Application of Genetic Algorithm on Knapsack Problem for Optimization of Goods Selection

Indah Mauludina Hasanah[1], Lukman Widoyo Mulyo[2],
Muhammad Fardeen Khan[3], Nemia Agustin[4], Rizki Apriva Hidayana[5*]

[1,2,3,4]*Student of Mathematics Study Program, National University of the Republic of Indonesia, Bandung, Indonesia.*
[5]*Department of Mathematics, Faculty of Mathematics and Natural Sciences, National University of the Republic of Indonesia, Bandung, Indonesia*

**Corresponding e-mail*: *rizkiaprivahidayana@mipa.ukri.ac.id*

Abstract

Knapsack Problem is one of the combinatorial optimization problems that often arise in everyday life, especially in making decisions about selecting goods with limited capacity. This study combines two previous studies that apply genetic algorithms to real cases: the selection of basic necessities and packaged fruits in limited containers. Genetic algorithms are used because they are flexible and able to find more than one optimal solution. The process includes the formation of an initial population, fitness evaluation, selection (roulette wheel), crossover, and mutation. From the two case studies analyzed, it was found that genetic algorithms consistently produce increased fitness between generations and are able to maximize the value of goods without exceeding capacity or budget limits. This study strengthens the potential of genetic algorithms as an effective method in solving Knapsack Problems based on real needs.

Keywords: Genetic Algorithm; Knapsack Problem; Optimization of Goods; Selection of Basic Necessities; Packaged Fruits

1. Introduction

Knapsack Problem is a classic problem in the world of optimization that requires the selection of a number of goods with maximum profit but still within a certain capacity limit. This problem is widely applied in logistics, distribution, and daily shopping. Two examples of real implementations are the selection of basic necessities and packaged fruit. Genetic algorithms (GA), as evolutionary algorithms, are able to solve this problem efficiently because they work with population and probabilistic approaches. This study combines approaches from two case studies to demonstrate the consistency and flexibility of GA in solving the Knapsack Problem. Previous studies have compared the effectiveness of genetic and greedy algorithms, where genetics excels in scenarios of varying total prices of goods.

Knapsack Problem has been widely studied in various fields, such as logistics planning, budget management, and limited resource selection. This problem is classified as NP-Hard, which means that no deterministic algorithm can solve it efficiently for all cases. Therefore, metaheuristic-based approaches such as genetic algorithms are promising alternative solutions (Basuki, 2003). Genetic algorithms work based on the principle of natural selection, using artificial reproduction mechanisms such as crossover and mutation to efficiently explore the solution space. Several studies have shown that this algorithm is able to achieve near-optimal solutions in relatively fast computing time (Setemen, 2010; Fachry et al., 2019).

In addition, genetic algorithms have the advantage of being flexible in their application to various variations of the Knapsack Problem, including 0-1 knapsack, multiple knapsack, and multidimensional knapsack. This makes them a versatile tool for solving complex decision-making problems in various industrial sectors. For example, in the case of purchasing groceries, AG can calculate budget limits and the combination of goods that best suit household needs. Meanwhile, in the distribution of packaged fruit, AG is able to optimize profits by considering aspects of shelf life and market needs simultaneously. Another advantage of AG is its ability to provide several alternative solutions that enable more adaptive decision-making in dynamic real-world situations.

2. Literature review

The title of this research is "Application of Genetic Algorithm on Knapsack Problem for Optimization of Goods Selection" refers to the combination of two relevant previous studies. The main focus of this research is the application of genetic algorithm to solve real-case Knapsack problems, which require goods selection with capacity or budget constraints.

A study by Setemen (2010) entitled Implementation of Genetic Algorithm on Knapsack Problem for Optimization of Fruit Selection in Box Packaging discusses how GA can be used to determine the optimal combination of fruit in packaging based on profit, weight, volume, shelf life, and market demand. This study uses a binary chromosome coding approach and evaluation based on fitness functions that consider these parameters.

Meanwhile, research by Fachry et al. (2019) entitled Application of Genetic Algorithm for Optimization of Grocery Purchases as a Solution to the Knapsack Problem applies AG to the selection of groceries with budget constraints. In this study, AG is applied to select a combination of goods with prices that do not exceed the available funds but still maximize the value of needs.

These two studies strengthen the argument that AG is effective in solving the Knapsack Problem because it is able to provide optimal solutions through an evolutionary process consisting of selection, crossover, and mutation. The results of both studies show an increase in fitness values with increasing generations and population size, as well as the ability of AG to explore the solution space efficiently.

3. Materials and Methods

3.1 Material

This research material combines two studies with the following data:

a) Basic Food Study (Fachry et al., 2019): The goods data consist of rice, sugar, cooking oil, chicken, eggs, condensed milk, corn, noodles, and salt with variations in weight and price. The main limitation is the budget of IDR 350,000.

b) Packaged Fruit Study (Setemen, 2010): Data in the form of 20 types of packaged fruit with the following parameters: weight (kg), volume (ml), profit (Rp), shelf life (days), and level of market demand.

3.2 Method

3.2.1 Knapsack Problem

Knapsack problem is a form of combinatorial optimization problem, where someone must choose a combination of items from a number of goods so that the total maximum value can be achieved without exceeding a certain capacity or limit. In its general form, the mathematical model of the Knapsack Problem 0-1 can be formulated as follows:

$$\text{Maximize } Z = \sum_{i=1}^{n} p_i x_i \text{ and with constraints } \sum_{i=1}^{n} w_i x_i \leq W \; x_i \in \{0,1\}$$

Information:

Z = the maximum total value (profit) you want to achieve,
p_i = value (profit) of the ith item,
w_i = weight of item i,
W = maximum capacity,
x_i = binary variable (1 if item i is selected, 0 otherwise).

This problem can be extended to a multidimensional knapsack problem by adding additional constraints, such as volume, shelf life, or demand level. For example:

$$\sum_{i=1}^{n} v_i x_i \leq V \text{ and } \sum_{i=1}^{n} a_i x_i \leq A$$

Information:

v_i = volume of goods I,
V = maximum volume limit,
a_i = additional parameters such as shelf life or market demand,
A = additional constraint limits.

3.2.2 Genetic Algorithm

Genetic algorithm (GA) is used to solve the Knapsack problem through an evolutionary approach. The following are the stages of the method used:

a) Chromosome Representation

(1) Using binary numbers (1 if item i is selected, 0 otherwise).

(2) Chromosome length = number of available items.

b) Objective Function and Fitness Evaluation

(1) In the study of basic necessities: $Fitness = h_{max} - \sum_{k=1}^{n} h_k$ where:

a. h_k = price of the kth item,

b. h_{max} = maximum money limit (Rp 350,000)

(2) In the study of packaged fruit: $Fitness = (\sum_{i=1}^{n}(p_i \times b_i + 1))$ with the condition: $\sum w_i \leq W_{max}$, $\sum v_i \leq V_{max}$ where:

a. p_i = profit

b. b_i = market needs

c. w_i, v_i = weight and volume of item i

d. W_{max}, V_{max} = knapsack capacity

c) Selection

Selection using the Roulette Wheel method, which is selecting chromosomes probabilistically based on their fitness values. The fitness probability (p_i) is calculated as follows:

$$p_i = \frac{f_i}{\sum f_i}$$

$$cumulative\ fitness = \sum_{j=1}^{i} p_j$$

d) Crossover

The crossover method used is One-Point Crossover, which is crossing two chromosomes at one dividing point to produce two new chromosomes.

e) Mutation

Mutations are done to prevent premature convergence. Mutations are done on 20% of the total population genes. Formula:

$$t_{gen} = j_{gen} \times p$$

$$m_{gen} = p_m \times t_{gen}$$

Information:

t_{gen} = total genes in a population

j_{gen} = number of genes in one chromosome

p = population size

p_m = mutation opportunity

m_{gen} = number of mutated genes

In its implementation, the genes to be mutated are randomly selected based on random numbers, then their values are changed according to the domain of each gene.

4. Results and Discussion

a. Research study by Setemen (2010) entitled Implementation of Genetic Algorithm on Knapsack Problem for Optimization of Fruit Selection in Box Packaging.

This study applies genetic algorithm to solve Knapsack Problem in selecting fruits to be packed in boxes. The main objective is to obtain the highest profit fruit combination without exceeding weight and volume limits, and considering shelf life and market demand. The system is developed with Visual Basic 6.0 and allows users to set parameters such as population size, crossover probability, and mutation.

Testing was conducted with two types of scenarios. In the first scenario, the genetic algorithm was tested on data with various variations, such as weight, volume, market demand level, and profit. The results showed that the algorithm was able to select a combination of items that generated maximum profit without violating the specified weight and volume capacity limits. In the second scenario, the effect of the initial population size on the fitness value generated by the algorithm was tested, namely the greater the initial population size, the higher the fitness value obtained.

Overall, these results indicate that the genetic algorithm can solve the optimization problem of selecting boxed fruit well, providing optimal results, and is able to adjust the selection of items based on various important factors such as weight, volume, market demand, and profit. In addition, algorithm parameters such as population size are also proven to affect the quality of the resulting solution.

b. Research Study by Fachry et al. (2019) entitled Application of Genetic Algorithm for Optimization of Grocery Purchases as a Solution to the Knapsack Problem.

This study applies a genetic algorithm to find the most optimal combination of basic food purchases with a certain budget limit. The main goal is to help consumers choose basic necessities efficiently, without exceeding the available funds, but still get priority items. The items considered include rice, sugar, cooking oil, chicken, eggs, milk, corn, noodles, and salt. Each with varying brands, sizes, and prices.

The process begins with the formation of an initial population in the form of a random combination of goods, which is then evaluated using a fitness function based on the total price. The results in the first generation showed the highest fitness value of 237,000, and increased in the second generation to 350,000. This indicates that the system has succeeded in finding a combination of goods that is close to the budget limit optimally. The best solutions found include Rojo Lele rice, Gulaku Premium sugar, Bimoli cooking oil, chicken wings, kampung chicken eggs, Frisian Flag milk, Qooali sweet corn, Indomie instant noodles, and Dolpin salt. In addition, the average fitness value of the population also increased from 123,625 to 214,425, proving an increase in the quality of the solution along with the evolution process.

Overall, this study shows that genetic algorithms are able to solve shopping problems with many variables and constraints, and produce a combination of goods that balances needs and cost efficiency.

5. Conclusion

Both studies show that genetic algorithms are effective in solving real-life optimization problems. In the context of selecting packaged fruit, the algorithm is able to generate optimal combinations based on profit, market demand, volume, and shelf life; while still meeting the weight and volume limits of the packaging. The flexibility of the algorithm allows users to set priorities according to their needs. Meanwhile, in the case of purchasing groceries, the genetic algorithm successfully found an efficient combination of goods that covered basic needs without exceeding the budget. The increasing fitness value in each generation indicates that the system is able to learn and improve the solution gradually. Both studies show that genetic algorithms have great potential to be applied in everyday decision making, especially when there are many choices and constraints that must be considered simultaneously.

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