Ant System Algorithm in Renewing Pheromone for Completing Quadratic Assignment Problem

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Abstract. Quadratic Assignment Problem (QAP) is often encountered with facility layout issues. Facility layout is a matter of assigning n facilities to n locations to minimize the total cost of the assignment. The QAP application examined in this research is the layout of the production facilities at PT. Slamet Langgeng. The search for QAP solutions uses the Ant System algorithm by examining three pheromone update algorithms, namely the Ant Cycle, Ant Density, and Ant Quantity algorithms. The simulation of the three algorithms in the completion of QAP uses the help of Matlab 7.0.4 software. Based on the results of the QAP completion simulation, the best QAP solution offered by the Ant Cycle, Ant Density, and Ant Quantity algorithms produce different minimum distances. The best QAP solution with the smallest minimum distance is offered by the Ant Cycle algorithm of 4,967.2 m for 1,000 iterations. The QAP solution has the same minimum distance with an optimal distance of 4,967.2 m so that the layout of the production facilities at PT. Slamet Langgeng in 2019 is optimal in terms of the distance of labor between production processes. The Ant Density algorithm produces the best QAP solution of 5,271.4 m for 2,000 iterations. The Ant Quantity algorithm produces the best QAP solution of 5,471.6 m for 500 iterations.

1. Introduction

Since World War II until now, operational research has experienced rapid development. Operations research contributes a lot to decision-makers, especially in terms of resource management. One technique in operations research that is useful in solving resource allocation problems is Linear Programming (LP). The special case of a well-known LP is the Assignment Problem. One extension of the Assignment Problem is the Quadratic Assignment Problem (QAP), which is a combinatorial optimization problem that was first introduced by Koopmans and Beckmann in 1957. QAP applications that are often encountered include layout planning, hospital setting and so on. The method that is widely used to solve combinatorial optimization problems is the metaheuristic method.

Stutzle (1997: 1) states that very successful metaheuristics are inspired by ant behavior. Ant behavior research was first carried out by Dorigo, et al in 1991 called the Ant System. According to Dorigo, et al (1996: 30) in the Ant System algorithm there are three pheromone update algorithms namely Ant Cycle, Ant Density, and Ant Quantity. Research on the performance of the Ant Cycle, Ant Density, and Ant Quantity algorithms was conducted by Dorigo et al in 1996 to solve the Traveling Salesman Problem. Therefore, the authors in this study, are interested in studying the three Ant System algorithms in...
pheromone updates, namely Ant Cycle, Ant Density, and Ant Quantity to complete QAP. Because the completion of QAP using the algorithm takes a long time if done manually, the authors use the help of Matlab software 7.0.4. The QAP application under study is planning the layout of production facilities. Therefore, the authors are interested in examining the layout of production facilities at PT. Slamet Langgeng is the only legendary candy industry company in Purbalingga.

2. Research method

2.1 Data and data sources
The data used in this study is the layout of the production facility layout at PT. Slamet Langgeng in 2019 and the average number of labor trips between production processes in one day.

2.2 Research methods
The method used in this research is the literature study and case study of the production facility layout at PT. Slamet Langgeng. The steps to be taken are as follows:

1. Processing data obtained during research at PT. Slamet Langgeng so that it meets the QAP criteria.
2. Complete QAP using the Ant Cycle, Ant Density and Ant Quantity algorithms with the help of a program created using Matlab 7.0.4 software.
3. Determine the best QAP solution.
4. Determine the difference in simulation results obtained by the Ant Cycle, Ant Density and Ant Quantity algorithms in QAP completion.

The Ant System steps in the program are described in the flowchart in Figure 1 below:

![Flowchart Ant System algorithm](image_url)

Figure 1. Flowchart Ant System algorithm
3. Results and discussion

3.1 Data analysis

Based on observations at the factory site, PT. Slamet Langgeng has 10 production facilities to run the production process. The names of the production facilities and their initials can be seen in Table 1. Initial facilities are used in the program to facilitate calculations.

**Table 1. Name of production facilities of PT. Slamet Langgeng**

| Initials of Facilities | Name of Production Facility          |
|------------------------|-------------------------------------|
| 1                      | The Sugar Room                      |
| 2                      | The Sugar Milling Room              |
| 3                      | The Pulp Room                       |
| 4                      | The Mixing Room and Oven            |
| 5                      | The Powder Storage Room             |
| 6                      | The Oil Room                        |
| 7                      | The Print Room                      |
| 8                      | The Roll Machine Room               |
| 9                      | The Manual Roll Packing Room        |
| 10                     | The Product Storage Room            |

(Source: an interview with the Head of Production of PT. Slamet Langgeng)

The average number of labor trips in transporting material between production processes in a day is presented in Table 2 below:

**Table 2. Average number of labor trips between production processes**

| Production Activities                                      | Average Number of Labor Trips (times/day) |
|------------------------------------------------------------|------------------------------------------|
| The sugar room to the sugar milling room                    | 13                                       |
| The sugar milling room to the pulp room                     | 13                                       |
| The pulp room to the mixing room and oven                   | 13                                       |
| The mixing room and oven to the powder storage room         | 26                                       |
| The powder storage room to the oil room                     | 75                                       |
| The oil room to the print room                              | 15                                       |
| The print room to the roll machine room                     | 15                                       |
| The roll machine room to the manual roll packing room       | 60                                       |
| The manual roll packing room to the product storage room    | 7                                        |

(Source: an interview with the Head of Production of PT. Slamet Langgeng)

Based on Table 1 and Table 2, symmetry matrix of switching frequency between facilities is obtained, \( F \), is obtained with the following order 10×10:
Then each initial facility occupies each location described in the layout plan of the production facility at PT. Slamet Langgeng in 2019 presented in Figure 2 below:

\[
F = \\
\begin{pmatrix}
0 & 13 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
13 & 0 & 13 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 13 & 0 & 13 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 13 & 0 & 26 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 26 & 0 & 75 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 75 & 0 & 15 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 15 & 0 & 15 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 15 & 0 & 60 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 60 & 0 & 7 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 7 & 0 & 0 \\
\end{pmatrix}
\]

3.2 Analysis of distance between locations

After knowing the placement of ten facilities to each location in Figure 2, the distance between locations will be sought using the Euclidean distance to obtain the symmetry matrix of the distance between locations, \( D \), is obtained with the following order 10×10:

**Figure 2.** The Layout plan of the production facility at PT. Slamet Langgeng in 2019

3.2 Analysis of distance between locations

After knowing the placement of ten facilities to each location in Figure 2, the distance between locations will be sought using the Euclidean distance to obtain the symmetry matrix of the distance between locations, \( D \), is obtained with the following order 10×10:
3.3 Search for optimal distances of layout production facilities at PT. Slamet Langgeng 2019

Based on the layout plan of PT. Slamet Langgeng in 2019, it can be seen that the assignment of each production facility to each location forms the following $\varphi$ permutation:

$$\varphi = (1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7 \ 8 \ 9 \ 10)$$

Next to find the optimal distance for the layout of production facilities at PT. Slamet Langgeng in 2019 can be done in a program by calculating the QAP objective function. Calculations using the help of Matlab 7.0.4 software obtained program output in Figure 3 below:

![Figure 3. Layout of production facilities at PT. Slamet Langgeng 2019](image)

Based on Figure 3, obtained the optimal distance of the layout of production facilities at PT. Slamet Langgeng of 2019 amounted to $4.967200e + 003$ m or equivalent to 4,967.2 m. Calculation with the help of this program only takes 0.057288 seconds. Then for an overview of the placement of each facility in each location in Cartesian coordinates is presented in Figure 4.
3.4 QAP completion using Ant Cycle, Ant Density and algorithms Ant Quantity

3.4.1 Simulation of QAP completion using Ant Cycle algorithms

Based on the program output, the best QAP solution is obtained using the Ant Cycle algorithm with the smallest minimum distance of 4,967.2 m, which is obtained the fastest during 1,000 iterations whose value is equal to the optimal distance of 4,967.2 m. Then the description of the assignment of the best QAP solution using the Ant Cycle algorithm with a minimum distance of 4,967.2 m is presented in Figure 5.

3.4.2 Simulation of QAP completion using Ant Density algorithm

Based on the program output, the best QAP solution is obtained using the Ant Density algorithm with the smallest minimum distance obtained most quickly for 2,000 iterations with a minimum distance of 5,271.4 m, the value of which is greater than the optimal distance of 4,967.2 m. Then the description of the assignment of the best QAP solution using the Ant Density algorithm with a minimum distance of 5,271.4 m is presented in Figure 6.
3.4.3 Simulation of QAP completion using Ant Quantity algorithms

Based on the program output obtained the best QAP solution using the Ant Quantity algorithm with the smallest minimum distance obtained during 500 iterations with a minimum distance of 5,471.6 m whose value is greater than the optimal distance of 4,967.2 m. Then the assignment description of the best QAP solution using the Ant Quantity algorithm with a minimum distance of 5,471.6 m is presented in Figure 7.

3.5 Determination of the best QAP solution

Based on the simulation results of the three algorithms, the Ant Cycle algorithm offers the best QAP solution with the smallest minimum distance of 4,967.2 m, the value of which is equal to the optimal distance of 4,967.2 m. Thus, it can be concluded that the layout of production facilities at PT. Slamet Langgeng in 2019 has been optimal in terms of the distance of labor between production processes. In this case, if the condition of each location remains the same, for example not experiencing room expansion, narrowing of the room and changing the location of the room door, changes in the layout of production facilities in the future are not necessary.

3.6 Difference results of simulation of Ant Cycle, Ant Density and Ant Quantity algorithms

After the best QAP solution is obtained, three different algorithms will be searched for in producing the QAP solution. The following are the differences in the simulation results of each algorithm in Table 3.

Table 3. Differences in the three algorithms in QAP completion
Algorithm | The Best QAP Solution (m) | Maximum Iteration
--- | --- | ---
Ant Cycle | 4,967.2 | 1.000
Ant Density | 5,271.4 | 2.000
Ant Quantity | 5,471.6 | 500

Based on Table 3, it can be concluded that the performance of the Ant Cycle algorithm is better than the Ant Density and Ant Quantity algorithms because it solves with the smallest minimum distance. This is reinforced by the statement of Dorigo, et al (1996: 33) that the use of the Ant Density and Ant Quantity algorithms gives worse results than those obtained by the Ant Cycle algorithm.

4. Conclusions and suggestions

4.1 Conclusions

Based on the results and discussion regarding the completion of the Quadratic Assignment Problem (QAP) in the case of the layout of production facilities at PT. Slamet Langgeng, obtained several conclusions as follows:

1. The best QAP solution offered by the Ant Cycle, Ant Density and Ant Quantity algorithms with the help of Matlab 7.0.4 software produces different minimum distances.
2. The best QAP solution with the smallest minimum distance is obtained by Ant Cycle algorithm of 4,967.2 m for 1,000 iterations. The QAP solution has the same minimum distance with an optimal distance of 4,967.2 m so that the layout of the production facilities at PT. Slamet Lasting 2019 is already optimal in terms of the distance of labor between production processes.
3. The Ant Density algorithm produces the best QAP solution of 5,271.4 m for 2,000 iterations.
4. The Ant Quantity algorithm produces the best QAP solution of 5,471.6 m for 500 iterations.
5. The difference in the best QAP solutions produced by these three algorithms reinforces the assumption that the performance of the Ant Cycle algorithm is better used in the Ant System than the Ant Density and Ant Quantity algorithms because it produces the solution with the smallest minimum distance.

4.2 Suggestions

Suggestions for further research are as follows:

1. Further research can use the Euclidean distance measured straight from the center of one location directly to the center of another location.
2. The use of other more efficient algorithms, such as genetic algorithms.

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