Optimization of Crew Boat Routing for Support Routine Operation of Offshore Oil and Gas Production Using Combination of Genetic Algorithm and Ant Colony Optimization

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Abstract

The production operations of oil and gas in offshore areas require a fleet of ships to support their logistics activities. One of the commonly used types of fleets is the Crew Boat. The Crew Boat is used to support routine oil and gas offshore production operations with daily movement activities that are quite dense, thus requiring an evaluation of the Crew Boat movement routes. This research aims to obtain an optimal route for the movement of Crew Boats in supporting routine oil and gas offshore production operations with a case study conducted at an offshore installation in Indonesia. This research used a combination of genetic algorithms and ant colony optimization to obtain an optimal route. The results of this research found that the combination of genetic algorithms and ant colony optimization can provide optimal solutions for the traveling salesman problem with fewer iterations compared to solving it using genetic algorithms alone.

Keywords
Route Optimization, Crew Boat, Ant Colony Optimization, Genetic Algorithm and Traveling Salesman Problem.

1. Introduction
The business activities in the upstream sector of the oil and gas industry may include exploration and exploitation. Exploration is a part of the upstream oil and gas activities aimed at discovering new oil and gas reserves. Meanwhile, exploitation is a production operation aimed at extracting oil and gas from reservoirs, bringing them to the surface, and transporting them to oil and gas processing facilities. Oil and gas production operations can be carried out onshore or offshore.

Offshore oil and gas production operations require a fleet of ships to support logistics activities. According to Coyle (1992), logistics activities aim to ensure product availability in the right quantity, condition, time, place, and cost for customers. Logistics activities in offshore oil and gas production operations include equipment and material supply operations required for production operations, well maintenance activities, and facility maintenance activities. In addition, a fleet of ships is also needed as a means of transporting personnel or materials from one facility to another.

In one of the offshore areas in Indonesia, there is an upstream oil and gas business operator's working area. As an offshore field, the working area requires a fleet of ships to support daily production operations. Currently, daily operational activities in the working area are supported by one crew boat. The crew boat serves as a means of sea transportation to transport personnel between platforms. Currently, personnel transportation is carried out for production operator shift changes as well as security personnel changes between platforms. The crew boat is also used to support routine patrols of navigation aids and subsea pipeline facilities.

Based on the explanation above, the daily movement activities of the crew boat are quite busy. However, to date, there has been no evaluation of the crew boat's movement route to obtain an optimal movement route. An optimal movement route can be obtained through the solution of the Traveling Salesman Problem (TSP). According to Chen & Chien (2011), the Traveling Salesman Problem (TSP) can be solved using the parallelized genetic ant colony system

(PGACS) method, which combines genetic algorithm and ant colony optimization methods. Therefore, this paper aims to optimize the route of crew boat in one of the offshore areas in Indonesia using a combination of genetic algorithm and ant colony optimization methods.

1.1 Objectives
The main objective of this research is to obtain the optimal route of a crew boat in supporting the daily routine of offshore oil and gas production operations, with a case study conducted at an offshore installation located in Indonesia.

2. Literature Review
According to Durigo & Stutzle (2004), the Traveling Salesman Problem (TSP) can be defined as the problem of a salesman starting from his hometown and determining the shortest route to visit all of his customers exactly once, and then return to his hometown. Formally, TSP is defined as a complete weighted graph G = (N, A) with N as the set of nodes (vertex) and A as the set of arcs, where each arc is assigned a weight d_{ij} that represents the distance between node i and node j, with $i, j \in N$. Then, a Hamiltonian path graph with the shortest distance is determined. A Hamiltonian graph is a graph with a closed path and each node is visited exactly once. The optimal TSP solution is a permutation π of the node set indexed {1, 2, 3, 4, ..., n} such that f(π) is minimized, where f(π) is:

$$f(\pi) = \sum_{i=1}^{n} d_{\pi(i)\pi(i+1)} + d_{\pi(n)\pi(1)}$$

In the application of TSP, the calculation of the weight between two nodes is usually done using Euclidean distance.

Currently, there are several methods that have been developed to solve TSP problems, including Integer Linear Programming (Kara and Bektas, 2006), Branch and Cut (Benavent and Martinez 2013), Genetic Algorithm (Kardel et al. 2007), and Ant Colony Optimization (Javadian and Ghafurian 2011).

3. Methods
The problem in this study is solved by combining the methods of genetic algorithm and ant colony optimization. The genetic algorithm is a heuristic search algorithm based on the mechanism of biological evolution. Genetic Algorithm is a heuristic search algorithm that is inspired by the process of natural selection and evolution in biology. It works iteratively on the possible solutions (chromosomes) in a population using three genetic operators, namely selection, crossover, and mutation at each generation until the algorithm stopping criteria are met (Majumdar et al, 2011). The ant colony optimization (ACO) algorithm is an optimization technique inspired by the behavior of ant colonies in finding the path to food sources. ACO works by simulating the behavior of ants that lay pheromone trails on the paths they pass, so that other ants will follow the path if the pheromone is strong enough. In ACO, pheromone trails are considered as information that directs the best solution.

Chen & Chien (2011) conducted a study on a new method called parallelized genetic ant colony system (PGACS) to solve the traveling salesman problem by combining genetic algorithm and ant colony optimization. In this paper, the authors also propose a combination of genetic algorithm and ant colony optimization to solve the traveling salesman problem, with a proposed flow chart as follows in Figure 1:

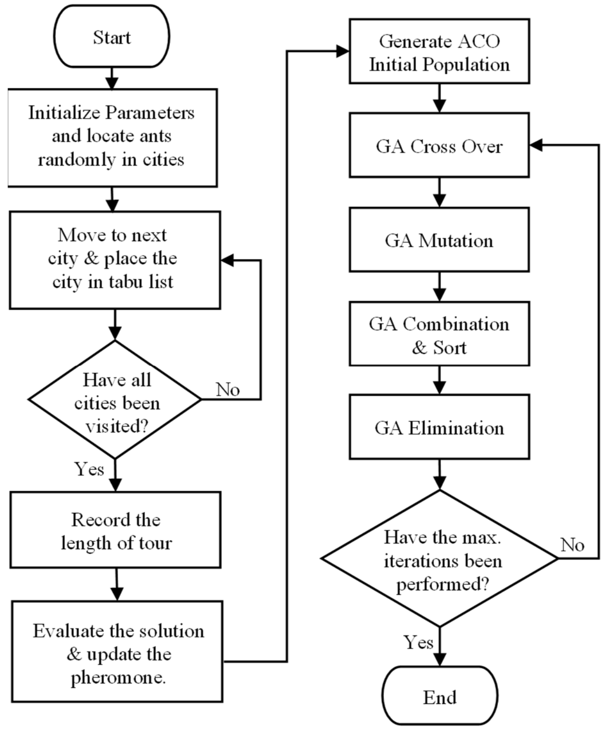

Figure 1 Flow Chart Combination of Genetic Algorithm and Ant Colony Optimization

Based on the above flow chart, the ant colony optimization method is first performed to generate a set of optimal routes. The optimal routes obtained from the ant colony optimization iteration are then used as the initial population for the genetic algorithm. Next, the initial population undergoes genetic algorithm operations, including crossover, mutation, combination, sorting, and elimination. Once the number of genetic algorithm iterations is reached, an optimal route is obtained and proposed as a solution to the problem.

In comparison, this paper also discusses solving the traveling salesman problem using the genetic algorithm method. In this solution, the initial population is generated using the permutation method. Then, the optimal solution of the genetic algorithm method is evaluated with the optimal solution obtained from the combination of genetic algorithm and ant colony optimization methods.

4. Data Collection

The research data used in this study is a case study from one of the Offshore Installations in Indonesia. The crew boat performs ship movement activities with 1 (one) depot. The distances between facilities are obtained by referring to the coordinate data. Subsequently, the coordinate data of these facilities is illustrated in the graph below.

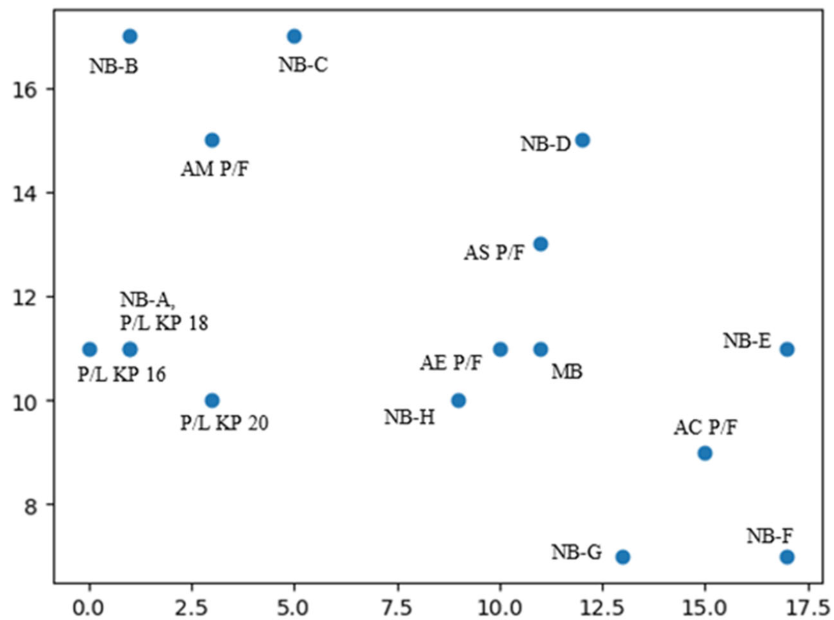

Figure 2 Illustration of facility coordinates

Based on the data above, the distance between points is calculated using the Euclidean distance equation. The distance between points is needed to calculate the total distance value that will be produced by the algorithm iteration.

5. Results and Discussion

5.1 The Result of Iteration using the Combination of Genetic Algorithm and Ant Colony Optimization

The iteration of ant colony optimization was conducted with initial parameters, including the number of iterations = 100, the number of ants = 20, the importance of intensity in the probabilistic transition (α) = 1, the importance of visibility of trail segment (β) = 2, and the trail persistence or evaporation rate (ρ) = 0.5. After completing the iteration of ant colony optimization, 5 (five) best solutions were obtained as follows:

Table 1 Best Solution of Ant Colony Optimization

No.	Route																	Distance
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1	1	3	13	2	9	10	4	11	12	14	15	16	6	5	8	7	1	56
2	1	3	13	2	9	10	4	12	11	8	7	5	14	15	16	6	1	61
3	1	3	13	2	9	4	11	10	12	14	15	16	6	7	5	8	1	56
4	1	3	13	9	2	14	6	16	15	5	7	8	10	4	12	11	1	59
5	1	3	13	9	2	10	4	12	11	5	7	8	14	6	16	15	1	66

Furthermore, the best solution obtained from the iteration of ant colony optimization is used as the initial population for the genetic algorithm. After 100 iterations of the genetic algorithm, the results show the shortest route distance and the iteration-distance graph, as presented below:

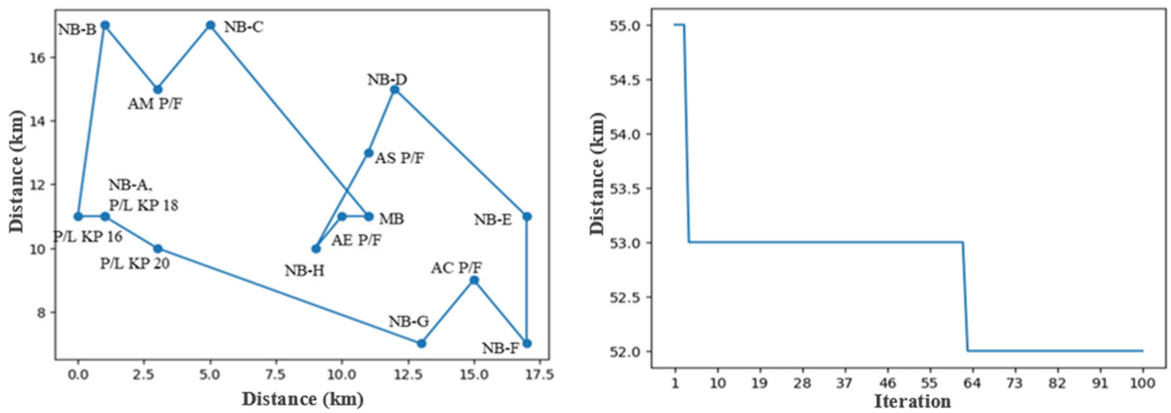

Figure 3 The shortest route distance (left) and the iteration-distance graph (right)

Based on the results above, it was found that the optimal solution was obtained at the 63rd iteration with a distance of 52 km. The optimal route solution is as follows: AS → NB-D → NB-E → AC → NB-F → NB-G → KP20 → KP-18 → KP16 → NB-A → AM → NB-C → NB-B → MB → AE → NB-H → AS.

5.2 Results of Genetic Algorithm Iteration

The problem-solving of this research was conducted using the genetic algorithm method as a comparison to the effectiveness of the combination of genetic algorithm and ant colony optimization. The initial population of the genetic algorithm was obtained using permutation method. Furthermore, the optimal genetic algorithm solution was obtained through 500 iterations, resulting in a plot of the shortest distance route and a graph of iteration versus distance as follows in Figure 4:

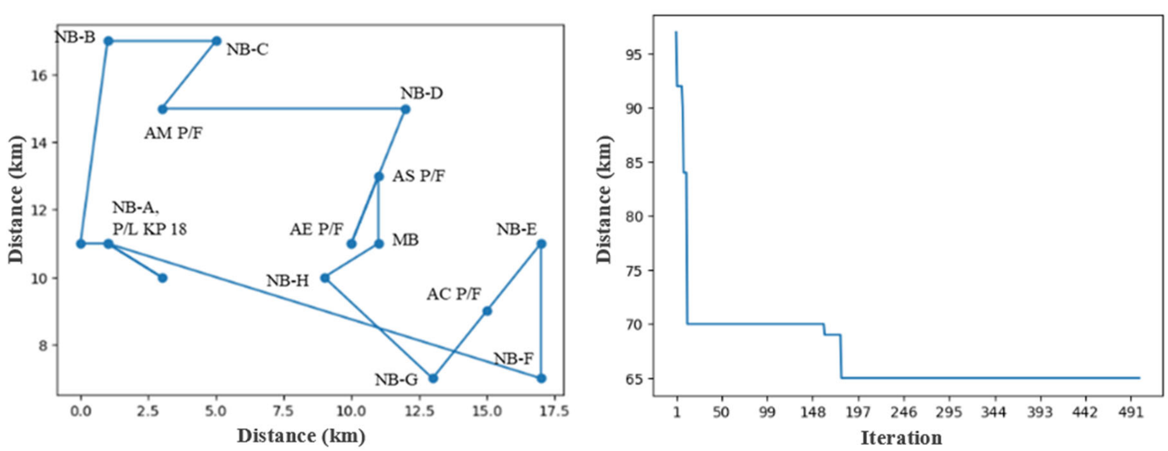

Figure 4. The shortest route distance (left) and the iteration-distance graph (right)

Based on the above results, it was found that the optimal solution was obtained in the 179th iteration with a distance of 65 km. The optimal route solution is AS → MB → NB-H → NB-G → AC → NB-E → NB-F → KP18 → KP20 → NB-A KP-16 → NB-B → NB-C → AM → NB-D → AE → AS.

5.3 Discussion

The problem-solving using genetic algorithm at point 5.2 obtained an optimal solution of 65 km in the 179th iteration. In the 500th iteration, the genetic algorithm still provided an optimal solution of 65 km. Meanwhile, the optimal solution generated by the combination of genetic algorithm and ant colony optimization was 52 km in the 63rd iteration. Therefore, it can be concluded that the combination of genetic algorithm and ant colony optimization can provide a better optimal solution for the traveling salesman problem with a shorter number of iterations.

6. Conclusion
The optimal route for the movement of crew boats to support routine offshore oil and gas production operations can be obtained using a combination of genetic algorithm and ant colony optimization. This research concludes that the combination of genetic algorithm and ant colony optimization can provide a better optimal solution for the traveling salesman problem with a shorter number of iterations than using genetic algorithm alone. The authors need to convey that this research only considers the route for the routine movement of one crew boat unit without considering external factors, such as weather conditions, waves, and sea currents.

References
Benavent, E. Martinez, A., *Multi-Depot Multiple TSP: A Polyhedral Study and Computational Results*, Ann Oper Res, 2017, pp. 7-25, 2013.

Chen, Shyi-Ming and Chien, Chih-Yao, *Parallelized genetic ant colony systems for solving the traveling salesman problem*, Expert Systems with Applications, pp. 3873–3883, 2011

Coyle, J. J., *The Management of Business Logistics*, 5th edition, West Group, 1992

Dorigo, M. Stutzle, T., *Ant Colony Optimization*, A Bradford Book, The MIT Press, 2004

Ghafurian, S. Javadian, *An Ant Colony Algorithm for Solving Fixed Destination Multip-Depot Multiple Traveling Salesman Problem*, Applied Soft Computing, vol. 11, pp.1256-1262, 2011.

Goldberg, D. E., *Genetic Algorithm in Search, Optimization, and Machine Learning*, Addison Wesley, 1989.

Kara, I. Bektas, T, *Integer Linear Programming Formulations of Multiple Salesman Problem and Its Variations*, European Journal of Operational Research, vol. 174, pp. 1449-1458, 2006

Kardel, K. Javadian N. Adbesh, F, *A new Approach to Solving the Fixed Destination Multi-Depot Multiple Traveling Salesman Problem Using Genetic Algorithms*, 7th International Conference on Optimization Techniques and Applications, 2007.

Majumdar, J. and A. K. Bhunia, *Elitist Genetic Algorithm for Assignment Problem with Imprecise Goal*, Durgapur Government College and The University of Burdwan, India pp. 684-692, 2007

Xu, F., Qin, Z., Ning, L., and Zhang, Z., *Research on computing offloading strategy based on Genetic Ant Colony fusion algorithm*, Simulation Modelling Practice and Theory, 2022

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