An Optimal Oil Skimmer Assignment Based on a Genetic Algorithm with Minimal Mobilized Locations

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ABSTRACT

Oil spill cleanups in the ocean often involve oil skimmers to be mobilized from all the reserved locations, which is not efficient. In this study, optimization was performed to minimize the mobilization points of the arrangement in the existing study. For this purpose, a simulation was run to validate the solution produced by the genetic algorithm based on scenarios similar to the actual situation. The scenarios are based on 19 of the largest oil spills that have occurred in South Korea and are compared with the existing work time minimization strategy. By utilizing the mobilization point minimization strategy, the number of areas required for a given work time was reduced by approximately 12.38% on average and approximately 7.08% on average in terms of work time.

CCS CONCEPTS

• **Computing methodologies** → **Genetic algorithms**; *Optimization*;

KEYWORDS

genetic algorithm, optimization

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1 INTRODUCTION

South Korea is geographically a peninsula, surrounded by water on three sides, and thus, it has control resources that are deployed in a total of 16 areas for oil spill management. Optimized allocation of control resources, used to efficiently prepare for oil spills in the sea, is an important task in the real world. There have been studies in which the allocation of control resources was conducted manually [1], and the minimization of total allocation size and oil recovery time was carried out using a genetic algorithm (GA) [2]. In addition, a study to devise a surrogate model [3] that replaces the simulation-based method for validating the GA with deep neural networks has been conducted. In the event of an oil spill in the maritime jurisdiction of South Korea, in principle, control resources from all areas will have to depart toward the affected area. Upon arrival, based on the assumption that the constraints are met, the control resources recover the area. In this process, there may be unnecessary control resources that have yet to reach the area, even though the work has reached its conclusion. To overcome the shortcomings of the existing allocation method [2], it can be inferred that mobilizing only from the necessary areas is efficient. In addition, if the target amount can be recovered with the given work time, it will be more efficient to minimize the mobilization area without violating the constraints. In this study, using the optimized control resource allocation amount derived from existing studies, further optimization to minimize the mobilization points was conducted through experiments. In this experiment, unlike the existing studies, 19 oil spill scenarios in South Korea were used.[1] In addition, based on the scenarios that resemble the real situation, a simulation was set up to validate the solution derived using the GA. The experimental results compare the mobilization point minimization strategy proposed in this study with the work time minimization strategy of the existing study.

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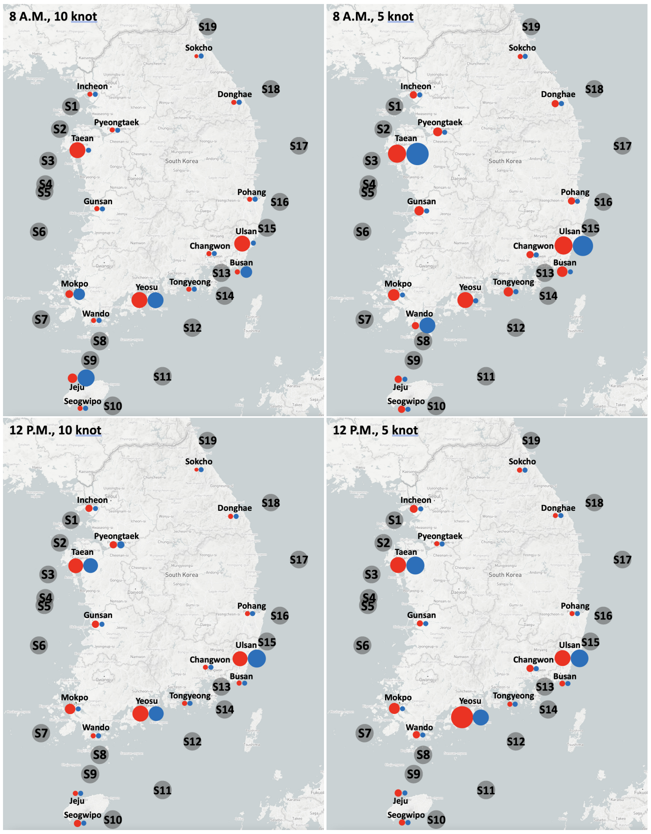
2 MOBILIZATION POINT MINIMIZATION

The mobilization point minimization strategy for the new control resource allocation plan uses 19 oil spill scenarios that have not been used in existing studies. The selection criteria for the scenario areas were selected as the largest spills that could occur at various locations without bias to one area of the South Korean Sea. In Figure 1, the 19 black areas represent the location of the accidents based on the scenario, and the 16 red areas represent the location of control resources distributed throughout South Korea. The objective function for validating the solution generated by the GA consists of simulations. The simulations evaluate the recovery up to a target amount (one-third of the spilled oil) within a given work time (24 h), while minimizing the number of areas to be mobilized. The selection operation applied to the GA was the roulette wheel method, with a mutation probability of 0.001 and uniform crossover. In addition, elitism, which maintains the best solution per generation, was applied with a generation of 60,000 and a population of 100. The GA was implemented in C++ language on an Intel Core i7-7700 CPU (3.6 GHZ) with 16 GB memory and took about 11.19 s to derive an allocation plan. The evaluation function of the GA, as can be seen in Equation 1, minimizes the total number of mobilization points required for recovery in the i-th scenario sce_i of n scenarios based on the p-th allocation of the g-th generation $c(g,p)$.

$$\sum_{i=1}^{n} \text{simulation}(sce_i, c_(g, p)) \quad (1)$$

[1] http://www.geosr.com/eng/



: allocation plan of work time minimization strategy

: allocation plan of mobilization point minimization strategy

Figure 1: Accident scenarios and control resource locations with allocation plan in South Korea

The simulation function uses the efficiency coefficient α and the mobilization rate β to recover the target amount $Q_i/3$ corresponding to a third of the spillover amount Q_i in the i-th scenario sce_i, as shown in Equation 2. It then solves for the recovery amount q_{jk} with work time k for the j-th control resource, subsequently returning the minimum number of points l that satisfy the conditional equation.

$$\begin{aligned} &\min(l) \\ \text{subject to} \quad & Q_i/3 - \alpha\beta\max\left(\sum_{j=1}^{l}\sum_{k=1}^{t} q_{jk}\right) \le 0, \qquad (2) \\ \text{where} \quad & 0 < l \le 16,\ t = 24,\ \alpha = 1/5, \text{and } \beta = 1/3 \end{aligned}$$

By further optimizing the total allocation amount by combining the mobilization point minimization strategy with the GA, it was expected that the number of required areas would gradually decrease. Simultaneously, the combination of areas where key control resources are located would be identified.

3 RESULT AND DISCUSSION

In Figure 1, each of the 16 red and blue areas is the allocation plan that takes into account the work start time and the control resource movement speed. The results derived from the work time minimization strategy of the existing study and the mobilization point minimization strategy proposed in this study are listed in Table 1. Both strategies recover the target amount of all 19 scenarios within the given work time without violating the constraints. However, Table 1 shows that through the mobilization point minimization strategy proposed in this study, the number of areas to be mobilized during the work time decreased on average in all cases; the overall decrease was approximately 12.38%. Surprisingly, it was confirmed that the overall work time was also reduced by approximately 7.08% compared to the existing work time minimization strategy. This shows that applying the optimization to the existing optimization strategy effectively reduces the problematic space to derive a good solution. When we observe the allocation plan to which our mobilization point minimization strategy is applied, control resources are mainly distributed around each on the three sides, which confirms the combination of regions that can be the key to the response of maritime accidents in South Korea. This strategy presents a new guide for the deployment of control resources that are not available in the existing maritime accident response system of South Korea. The recovery process for a specific scenario during a given time can be verified through the web-link.[2] Future studies can attempt to optimize the recovery process by including work efficiency, and develop a deep learning-based method as an alternative to the simulation-based method.

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[2] https://bit.ly/3iV4LJl

Table 1: Comparison of the number and time of mobilization points by scenario

Scenario number		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	Average
Oil spill (ton)		29,600	29,600	29,600	29,600	21,600	21,600	28,000	17,400	28,000	19,000	29,600	28,000	29,600	29,600	28,700	28,700	28,000	27,500	5,100	
8 A.M.	Prev.	3/22	3/21	3/20	3/20	2/14	2/15	3/19	2/13	2/16	2/18	2/20	2/19	2/19	2/19	2/19	**2**/20	1/12	2/18	2/15	2.2/17.8
10 knot	Ours	3/20	3/18	**2**/15	**2**/14	2/11	2/13	**1**/10	2/10	2/12	2/14	2/17	2/15	2/17	2/17	2/19	3/19	1/14	2/13	**1**/11	**2.0**/14.7
8 A.M.	Prev.	2/21	1/17	1/17	1/17	1/19	1/15	2/18	1/12	2/18	1/13	2/17	1/13	1/17	1/17	2/21	2/22	1/17	2/17	1/14	1.4/16.9
5 knot	Ours	1/22	1/18	1/16	1/14	1/18	1/13	2/15	1/10	2/16	1/12	**1**/18	1/14	1/18	1/17	2/21	2/22	1/17	2/17	1/11	**1.3**/16.3
12 P.M.	Prev.	3/12	3/19	3/19	3/19	2/15	2/18	3/20	1/11	2/17	2/15	2/18	2/16	2/18	2/18	2/20	3/21	1/12	2/17	2/12	2.2/16.7
10 knot	Ours	3/19	**2**/17	**2**/16	**2**/15	2/14	2/16	3/14	1/8	2/13	2/12	2/15	2/13	2/17	2/19	2/20	**2**/20	1/18	2/14	**1**/9	**1.9**/15.2
12 P.M.	Prev.	2/22	2/22	2/20	2/21	2/23	2/19	**1**/17	1/13	**1**/19	1/12	1/12	1/11	2/17	1/16	2/24	2/24	1/16	**1**/15	1/15	1.5/17.8
5 knot	Ours	**1**/19	**1**/19	**1**/19	**1**/19	**1**/22	**1**/18	2/16	1/16	2/22	1/15	1/15	1/14	**1**/17	1/19	2/23	**1**/24	1/12	2/18	1/17	**1.2**/18.1

* One can see the location of each scenario from Figure 1. In each "X/Y" value, it means that "X" is the number of mobilization points, and "Y" is work time (h).