Problem Chosen	2024	Team Control Number
B	MCM/ICM Summary Sheet	2425413

Ocean's Starfields: The Brightest Beacons in Underwater Search

Summary

With the development of dive tourism, there is an increasing concern about the safety of manned submersibles. This paper aims to develop models for predicting the location of the lost submersible and to implement the fastest search pattern.

For Task 1: A dynamic model is created to predict the submersible's location over time. We develop **the motion equation** with three degrees of freedom to predict the trajectory of the submersible. In addition, we classify the loss of communication. When there is a **partial loss of communication**, the velocity of the submersible is adjusted using **Kalman filtering**. We conduct numerical simulations by applying the **Runge-Kuta** method to solve the motion equation. In the **suspension simulation**, the submersible is suspended at 239.96 m below the surface. In the **sinking simulation**, we calculate the **position distribution** of the submersible after sinking by using random ocean currents.

For Task 2: Given the uncertainty of the prediction model, we believe that the **host ship should carry Sonar and UUV**, while the **rescue vessel should carry Bathysonde and DCP**. We develop an evaluation model to determine the specific equipment models to be carried by the main ship and the rescue vessel. We use the main parameters of the equipment as evaluation indicators. The weights of indicators are determined using the **Entropy Weight Method**. The scores of each type of equipment are calculated separately using the **TOPSIS** method. We suggest that both the primary vessel and the SAR vessel bring the equipment with the highest score.

For Task 3: We develop a search model based on probability. We utilize the **4D Parzen Window** method to estimate **the probability distribution at different moments**. The estimated trajectory of the submersible is determined by the position with the **highest probability density at each moment**. Taking the **vertical dive** of the rescue submersible as the optimal search pattern. The **integration of the probability density** function over the search range is the probability of finding the submersible. Simulated with the equipment selected in Task 2, when the speed of the rescue submersible is -2.056 m/s, the probability of finding the lost submersible after **16 minutes of searching is 76.8%**.

For Task 4: We combine the optimization model with the model from Task 3 to search for **multiple lost submersibles**. We transform the problem of this task into a **multiple traveling salesman problem**, with the optimal objective of **minimizing the time** to complete the rescue. The **genetic algorithm** is then used to solve the optimal rescue strategy in the cases of **six lost submersibles** and **two rescue submersibles**.

Keywords: Equation of Motion, Kalman Filtering, TOPSIS method based on EWM, 4D Parzen Window method, Multiple Traveling Salesman Problem