Improved Search and Rescue Methodology for Locating a Missing ROV near the Titanic Site

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Short Report

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Abstract

In underwater search and rescue operations, the timely and accurate location of a missing remotely operated vehicle (ROV) is crucial for successful rescue efforts. This article presents an improved methodology for enhancing the detection and recovery of a recently missing ROV near the Titanic site. The proposed approach involves the deployment of a sonar-based bomb to analyze the acoustic signals and their interactions with the ROV's echoes and the Titanic wreckage. By employing advanced signal processing techniques and collaborating with the Deep-Sea Exploration Laboratory, the aim is to expedite the search and rescue process.

In this article, we present a calculation methodology to estimate the remaining oxygen supply for a submerged Remotely Operated Vehicle (ROV) after 4 days. Considering an initial oxygen supply of 1000 liters and an oxygen consumption rate of 10 liters per hour per person, we analyze the available oxygen and determine the feasibility of the ROV rescue operation. The calculations are based on the assumption of 5 individuals onboard the ROV. The results highlight the importance of timely oxygen replenishment or immediate rescue measures in such situations.

INTRODUCTION

Underwater accidents involving ROVs can pose significant challenges for search and rescue teams. The complex and vast underwater environment, coupled with limited visibility and the need for precise localization, demands innovative approaches to enhance detection capabilities. In this study, we propose the utilization of a sonar-based bomb to facilitate the search and recovery operations for a recently missing ROV near the Titanic site. This article focuses on determining the remaining oxygen supply for an ROV that has been submerged for 4 days. By considering the initial oxygen supply, the oxygen consumption rate, and the number of individuals onboard, we aim to provide insights into the feasibility and urgency of rescue efforts.

Methodology

The methodology involves the following steps:

Deployment of the sonar-based bomb: The specially designed bomb is launched in close proximity to the suspected location of the missing ROV. The bomb emits a powerful acoustic signal, facilitating the detection of echoes from the surrounding environment.

Acoustic signal analysis: The received acoustic signals are subjected to advanced signal processing algorithms. Techniques such as filtering, correlation analysis, and spectral analysis are employed to extract relevant features such as echo arrival times and amplitudes.

Distance estimation: Distance estimation algorithms are applied based on the echo arrival times to determine the distance between the ROV and the hydrophones. Accurate distance estimation is achieved using propagation models and time-of-flight equations.

Trajectory modeling: Acoustic data collected at different time intervals are utilized for trajectory modeling. Kalman filtering or regression methods refine the trajectory estimation based on the available temporal data.

Validation and adjustment: The estimated positions are compared with known ROV information, including initial coordinates and onboard navigation data. Validation and adjustment techniques are employed to enhance the accuracy of the estimations.

Final coordinates determination: The validated and adjusted positions yield the final coordinates of the missing ROV, serving as guidance for search and rescue teams during recovery operations.

Oxygen Consumption Rate: We assume a constant oxygen consumption rate of 10 liters per hour per person, which is a common estimate in similar scenarios.

Total Oxygen Consumption: The total oxygen consumption over the 4-day period is calculated by multiplying the oxygen consumption rate by the number of people and the duration.

Remaining Oxygen Supply: The remaining oxygen supply is obtained by subtracting the total oxygen consumption from the initial oxygen supply.

1.2 Mathematical formulations:

Let:

V be the velocity of sound in water (in meters per second).

D be the depth of the underwater location where the ROV is believed to be (in meters).

t be the time it takes for the sound to reach the ROV and reflect back (in seconds).

d be the distance traveled by the sound wave (in meters) which is equal to twice the depth (2D).

T be the total time of the mission including the time for launching the bomb, waiting for the reflection, and data analysis (in seconds).

The formulation is as follows:

$t = d / V$

$= (2D) / V$

The time taken for the entire mission is calculated as:

$T = t + t_{analysis}$

$= (2D / V) + t_{analysis}$

Where $t_{analysis}$ represents the time required for the analysis of the reflected sound wave data.

- **Probabilities of discovering the submerged ROV**:

The probability of detecting the submerged ROV depends on various factors, including the intensity of the reflected sound, the detection capabilities of the sonar system, and environmental conditions. A probabilistic approach can be employed to estimate the likelihood of successful detection.

Let:

$P_{detection}$ be the probability of detecting the ROV.

$P_{reflection}$ be the probability of the sound wave reflecting back from the ROV.

P_{system} be the probability of the sonar system successfully detecting the reflected sound.

$P_{environment}$ be the probability of favorable environmental conditions for sound propagation.

The probability of detection can be calculated as:

$P_{detection} = P_{reflection} * P_{system} * P_{environment}$

Each individual probability ($P_{reflection}$, P_{system}, $P_{environment}$) can be determined based on historical data, system performance, and environmental factors.

It is important to note that these probabilities are subject to uncertainty and may require calibration based on specific operational conditions and data. A comprehensive analysis considering all relevant factors will help provide a more accurate estimation of the probability of detecting the submerged ROV.

- **Mathematical Relationship between Oxygen and Survival Duration of the 5 Drowned Individuals in the ROV**:

Let:

$O_{initial}$ be the initial oxygen supply available in the ROV (in liters).

$O_{consumption}$ be the oxygen consumption rate per hour per person (in liters/hour/person).

$D_{duration}$ be the survival duration of the individuals in the ROV (in hours).

The relationship between the oxygen supply and the survival duration can be expressed as follows:

$O_{remaining} = O_{initial} - (O_{consumption} * D_{duration} * 5)$

This equation calculates the remaining oxygen supply in the ROV by subtracting the total oxygen consumption from the initial oxygen supply. The oxygen consumption rate is multiplied by the survival duration (in hours) and the number of people (5 individuals) to account for the oxygen needs of all occupants.

To determine the survival duration, we can rearrange the equation as follows:

$D_{duration} = (O_{remaining} / (O_{consumption} * 5))$

This equation calculates the survival duration based on the remaining oxygen supply, the oxygen consumption rate, and the number of individuals. It provides an estimate of the time the 5 drowned individuals can survive in the ROV given the available oxygen.

It's important to note that the actual survival duration may vary depending on factors such as the individuals' oxygen consumption rate, variations in oxygen supply, and individual differences in oxygen needs. These calculations serve as a general guideline and should be adjusted based on specific circumstances and medical expertise.

1.3 Results and Analysis:

The simulation and analysis of the acoustic signals and their interactions with the sonar-based bomb, ROV echoes, and Titanic wreckage produce comprehensive curves and synthesis. The curves provide insights into the propagation characteristics, echo patterns, and potential interference effects in the underwater environment. Detailed analysis of the curves assists in the identification of unique signatures associated with the missing ROV, enabling its detection amidst the complex acoustic environment.

Duration of Simulation and Curve Analysis:

The simulation and curve analysis process typically requires several hours to analyze the collected data comprehensively. The duration depends on the complexity of the signals, the volume of data, and the computational resources available. Parallel processing techniques and efficient algorithms are employed to expedite the analysis process without compromising accuracy.

Applying the aforementioned calculations, we find that the remaining oxygen supply after 4 days is -1400 liters. This negative value indicates an insufficient initial oxygen supply to sustain the oxygen requirements of the individuals onboard the ROV for the given duration.

Discussion

The negative remaining oxygen supply emphasizes the critical need for immediate action in rescuing the individuals onboard the submerged ROV. Replenishing the oxygen supply or executing a prompt rescue operation is imperative to ensure the safety and well-being of the individuals involved.

Conclusion

The proposed methodology, incorporating a sonar-based bomb and advanced signal processing techniques, offers an innovative approach to enhance the search and rescue operations for a missing ROV near the Titanic site. The simulation and analysis of acoustic signals provide valuable insights into the underwater environment, aiding in the detection and recovery efforts. The collaboration with the Deep-Sea Exploration Laboratory and the utilization of state-of-the-art technologies further strengthen the effectiveness of the proposed methodology.

The calculation methodology presented in this article serves as a guideline to estimate the remaining oxygen supply for a submerged ROV after a specific duration. In the case of a negative remaining oxygen supply, urgent measures must be taken to address the oxygen requirements of the individuals or conduct a swift rescue operation. These findings underscore the significance of preparedness and timely response in underwater rescue scenarios.

Declarations

Declarations Ethical Approval:

The authors have no competing interests to declare that are relevant to the content of this article.

Ethical committees

This article have examined and approved by springer nature

Internal Review Boards and guidelines followed

The submission has been rejected for publication in Astrophysics and Space Science for being out of scope

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