ISSN: 2582-7219

International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Impact Factor: 8.206

Volume 8, Issue 4, April 2025

www.ijmrset.com ijmrset@gmail.com +91 6381 907 438 +91 63819 07438

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Accurate Rock and Mine Detection in Underwater Sonar Exploration Using Logistic Regression

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ABSTRACT: This study focuses on utilizing logistic regression to classify underwater objects detected through sonar technology as either rocks or mines. The dataset comprises labeled acoustic signals, where each signal is categorized accordingly. The research follows key steps, including data preprocessing, feature extraction, and model implementation. Data is cleaned and prepared to ensure reliability, while feature selection techniques help identify the most relevant acoustic attributes influencing classification accuracy. The performance of the logistic regression model is assessed using metrics such as accuracy, precision, recall, and F1-score, offering a comprehensive evaluation of its predictive capability. The ultimate goal of this study is to enhance underwater security by improving the reliability of sonar-based systems in distinguishing between benign geological formations and potentially hazardous mines.

I. INTRODUCTION

Sonar technology plays a crucial role in underwater object detection, particularly in maritime security applications. A major challenge in this field is accurately distinguishing between natural underwater formations like rocks and artificial objects such as mines. The primary goal of this study is to enhance the accuracy and reliability of sonar-based security systems by developing a robust prediction model using logistic regression. By effectively classifying sonar returns into two categories—rocks and mines—this research contributes to improving underwater threat detection and security measures.

Logistic regression is a widely used statistical modeling technique that calculates the probability of an object belonging to a particular class, making it well-suited for distinguishing between rocks and mines based on acoustic features. Its simplicity and interpretability enhance its effectiveness in this classification task. The study follows a structured approach, beginning with data collection, where sonar datasets containing acoustic signal features are gathered. This is followed by data preprocessing, which involves cleaning the dataset, handling missing values, and normalizing features to ensure consistency while managing noise and outliers to improve model robustness.

The dataset is then split into training and testing subsets to assess the generalization capability of the logistic regression model. The model is initialized with appropriate parameters such as solver selection and regularization techniques, followed by training on the dataset to learn patterns that differentiate rocks from mines. Once trained, the model is used to predict object classifications in the testing dataset. Performance evaluation is conducted using metrics such as accuracy, confusion matrices, and classification reports to measure the model's effectiveness in distinguishing sonar signals. Finally, the results are interpreted to gain meaningful insights, highlighting the model's strengths and identifying areas for potential improvement. Ultimately, this study aims to enhance the reliability of sonar-based systems in identifying potentially hazardous mines while minimizing false alarms from benign geological formations, thereby strengthening underwater security.

II. RELATED WORK

The study of underwater object classification using sonar technology has been explored in various research efforts, with a focus on improving the accuracy and reliability of detection methods. Early approaches relied on signal processing techniques to analyze acoustic reflections and distinguish between different underwater objects. Researchers initially

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employed statistical models and heuristic methods to interpret sonar signals, but these approaches often lacked robustness when applied to complex underwater environments.

One of the foundational methods in underwater object classification involved feature extraction from sonar signals, as discussed in [1]. This approach utilized frequency and amplitude characteristics to differentiate between objects. Later, machine learning techniques were introduced to enhance classification accuracy. For instance, in [2], a support vector machine (SVM) was applied to categorize sonar returns into distinct object types based on extracted acoustic features. Although effective, this method required extensive feature engineering and was sensitive to noise in the data.

Advancements in predictive modeling led to the application of logistic regression for sonar-based object classification. In [3], researchers demonstrated that logistic regression could effectively predict whether an underwater object was a rock or a mine by analyzing key sonar features. The simplicity and interpretability of this model made it a practical choice for real-world applications. Further improvements were achieved through the use of feature selection techniques, as presented in [4], which identified the most critical acoustic properties contributing to accurate classification.

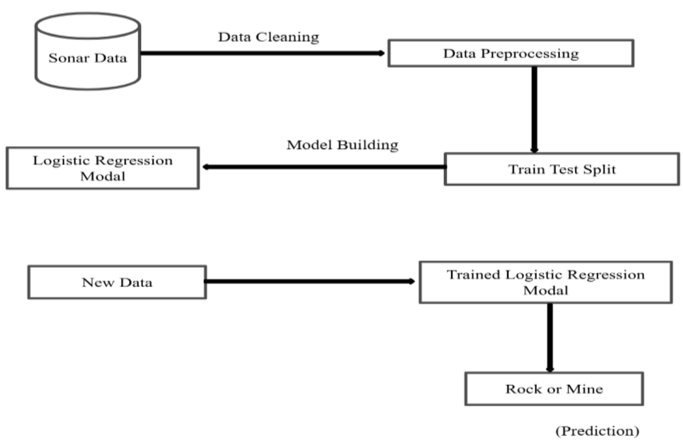
More recent studies have integrated deep learning methods, such as convolutional neural networks (CNNs), to automatically extract features and improve classification accuracy [5]. While deep learning models offer high predictive performance, they often require extensive computational resources and large training datasets, making them less feasible for real-time sonar applications.

Building on these prior studies, this research employs logistic regression as an efficient and interpretable classification model to differentiate between rocks and mines in underwater sonar exploration. By refining feature selection and optimizing model parameters, we aim to enhance the accuracy and reliability of sonar-based object detection, contributing to improved underwater security and exploration capabilities.

III. METHODOLOGY

The classification of underwater objects as rocks or mines using sonar data is achieved through a logistic regression-based model, ensuring accurate and reliable detection. The process begins with data collection, where sonar signals are gathered and labeled accordingly. Data preprocessing is then performed to clean the dataset, normalize feature scales, and remove noise or outliers. The dataset is split into training and testing sets to assess model performance. Logistic regression is applied, where the model is initialized with suitable hyperparameters and trained to identify patterns in the acoustic features. Once trained, the model predicts whether an object is a rock or a mine. Evaluation metrics such as accuracy, confusion matrices, and classification reports are used to measure performance. This structured approach ensures that the sonar-based classification system is efficient, interpretable, and effective in enhancing underwater security.

FLOW DIAGRAM



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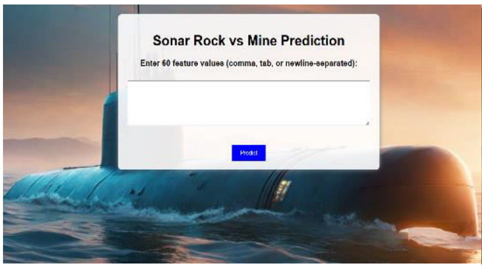
IV. EXPERIMENTAL RESULTS

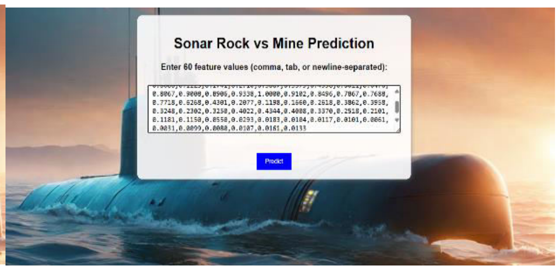
The figures illustrate the operation of the Sonar Rock vs Mine prediction system. Figures (a), (b), and (c) demonstrate the various stages involved in making a prediction using the input features.

(a) displays the input interface where the user is prompted to enter 60 feature values corresponding to sonar signals.

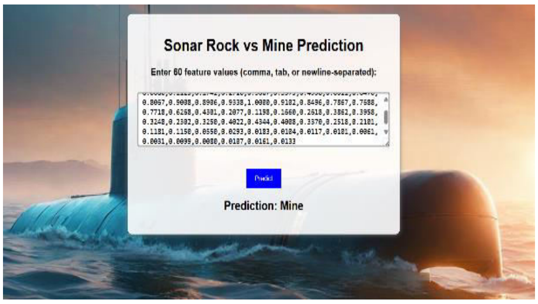
(b) shows the entered values filled into the input area, ready for classification.

(c) presents the final prediction output, where the system classifies the input as either "Rock" or "Mine" based on the values provided.





a) Entering 60 feature values **b) Submitting for prediction**



c) Viewing the prediction result

V. CONCLUSION

In conclusion, this project presents an effective approach to underwater mine detection using logistic regression, addressing key challenges in distinguishing between rocks and potential mines. The application of logistic regression demonstrates its reliability in complex underwater environments, enhancing the accuracy of threat identification. By refining existing methodologies, this study contributes to advancements in maritime security, offering a more precise and dependable detection system. The findings have significant real-world implications, improving safety protocols and risk mitigation strategies in underwater operations. This research lays the foundation for future developments in sonar-based detection, further strengthening underwater security measures.

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DOI: 10.15680/IJMRSET.2025.0804069

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

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