Sex and age determination in European lobsters using AI-Enhanced bioacoustics

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Abstract

This study explores the feasibility of classifying lobster bioacoustic signals using machine learning (ML) and deep learning (DL) models. Addressing a crucial gap in non-invasive monitoring, we recorded lobster sounds within controlled settings, extracting Mel Frequency Cepstral Coefficients (MFCCs) for feature representation. Evaluated a suite of classifiers include Support Vector Machines, K-Nearest Neighbors, and convolutional neural networks, assessing their performance in distinguishing lobster sex and age groups. Results demonstrated that traditional ML models, particularly SVM and KNN, achieved high accuracy, above 96%, with significantly lower computational time compared to Deep Learning (DL) models, which also performed well but required more processing resources. These findings highlight the potential of AI-based bioacoustic classification systems for practical applications in species monitoring, conservation, and aquaculture management. Early results suggest that bioacoustic features reliably encode sex and age-related information in lobster sounds, opening avenues for further development of real-time, passive acoustic monitoring systems. Future work will focus on optimizing models for edge deployment and exploring individual identification capabilities.

Keywords: Lobster bioacoustics, Artificial Intelligence (AI), Machine Learning (ML), DL, age and sex classification, aquaculture management, Passive Acoustic Monitoring (PAM).

1. Introduction

Accurate monitoring of marine species is vital for conservation, fisheries management, and aquaculture. Traditional visual or capture-based methods are often intrusive, labor-intensive, and limited in scope. Recent evidence indicates that lobsters produce distinct sounds associated with their behavior, sex, and age, suggesting bioacoustic signals as a non-invasive monitoring avenue. However, the classification and utilization of these sounds remain underexplored. This research aims to evaluate AI-driven approaches, both ML and DL, for reliable classification of lobster sounds, focusing on their applicability in passive underwater monitoring systems, such as those employed in ecosystem health assessment and resource management.

2. Materials and Methodology

Lobster sounds were recorded in controlled tanks using underwater hydrophones, with careful annotation of sex and age groups. Audio data were preprocessed and segmented into frames for feature extraction, primarily using MFCCs, capturing key spectral characteristics. Figure 1 shows the steps taken for the research.

A range of classifiers, including Support Vector Machines, K-Nearest Neighbors, and neural network architectures (1D-CNN and 1D-DCNN), were trained and validated via cross-validation. Model hyperparameters and architecture layers were optimised to balance accuracy and computational efficiency. Performance metrics such as accuracy, precision, recall, F1-score, and computational time were systematically evaluated. Additionally, ROC curves and feature analysis techniques provided insights into classifier decision boundaries and feature importance. Table 1 shows the dataset sizes for the four classes (male, female, young and adult).

3. Experiments and Results

The classifiers achieved high performance, with SVM surpassing 98% accuracy in sex and age classification tasks, and KNN also demonstrating robust results with faster processing times. DL models, including shallow 1D-CNN architectures, yielded comparable accuracy (up to 98.5%) but required significantly more computational

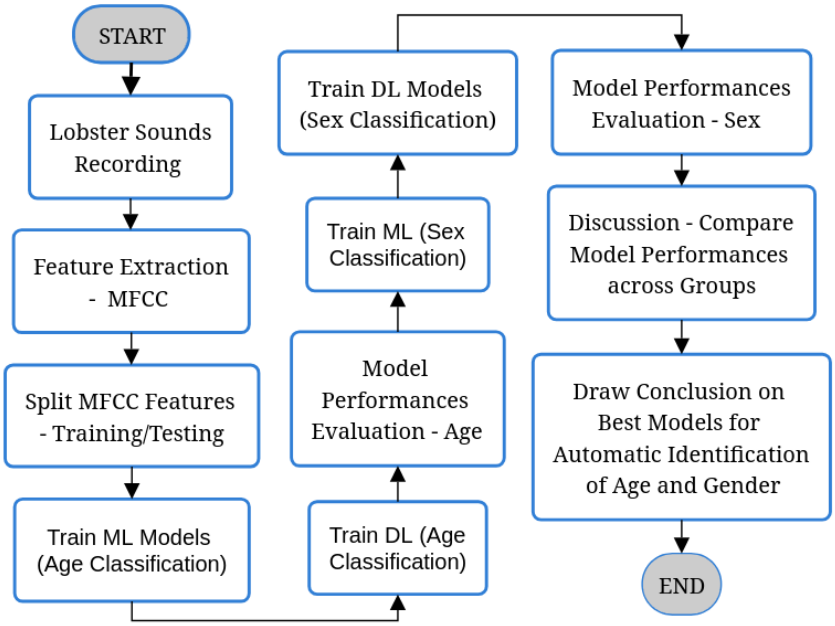

Figure 1: Research Methodology Flowchart

Table 1: Distribution of lobsters dataset sizes in seconds by sex and age categories - dataset before cleansing

Sex Categories	**Age Categories**		**TOTAL**
	Juvenile Lobsters	**Adult Lobsters**	
Male Lobsters	1200	3300	**4500**
Female Lobsters	1200	1700	**2900**
TOTAL	**2400**	**5000**	7400

resources and processing time. The results confirm that bioacoustic features contain distinguishable information correlated with lobster age and sex, and that ML models can effectively exploit this for classification. Tables and figures illustrate model performance metrics, ROC curves, and features' discriminative power, underscoring the late-breaking novelty of applying these AI techniques to lobster bioacoustics.

4. Discussion

Our findings demonstrate that machine learning models, particularly SVM and KNN, provide reliable, efficient tools for classifying lobster sounds by sex and age. While deep learning models offer marginal accuracy improvements, their increased computational demands pose challenges for real-time deployment in field systems. The high separability of classes based on MFCC features suggests robustness of bioacoustic signals for automated monitoring. Limitations include dataset size and variability, which may affect model generalizability. Future work will focus on expanding datasets, optimizing models for low-power hardware, and advancing individual identification for real-time underwater monitoring, contributing to sustainable fisheries and conservation efforts.

5. Conclusions

This research establishes the viability of AI-based bioacoustic classification for lobsters, with ML models offering practical advantages for real-world applications. These results lay the groundwork for developing non-invasive, passive monitoring tools crucial for efficient species management, conservation, and aquaculture practices.

6. Acknowledgements

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