CNN-based species recognition and counting system for multispecies seagrass

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Abstract

Effective exercise techniques aim at maintaining coastal biodiversity, carbon accumulation zones, and overall marine health, focusing on increasingly important seagrass ecosystems. Conventional species identification and counting methods require extensive fieldwork, are labor-intensive, and are highly error-prone. This paper proposes an automated method based on deep learning techniques for species identification and counting from underwater photos in seagrass multihabitats. In this paper, Convolutional Neural Networks (CNN), will automatically identify and categorize several seagrass species through underwater imaging. The approach includes a vast annotated dataset of seagrass photos containing images of various species from various habitats. The model constructed addresses issues related to water and light conditions and numerous species environments by using advanced image processing, multi-stage feature extraction, and custom-designed CNNs. The results reveal that these species are being identified and counted more accurately than the conventional methods, irrespective of the reporting and operational timelines claimed by those methods. Reliability and scalability are also surpassed in these latter-day techniques. Results also support more efficient monitoring in broader areas with reduced resources, proving advantageous for environmental assessments, thanks to the CNN framework. In addition, the innovation is ideal for marine biologists and conservators as it provides opportunities to integrate automated systems for

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continuous surveillance and real-time ecosystem monitoring of seagrass for ecosystem monitoring.

Keywords: Convolutional neural networks, Coastal biodiversity, Seagrass, ecosystems

Introduction

Seagrass habitats serve as important ecosystems that aid marine biodiversity and help sequester carbon, protect the coastline, and improve water quality. However, due to human activities like coastal development and pollution, these ecosystems are increasingly being put at risk (Ibrahim, Youssef and Fathalla, 2023). Rapid action and measures are necessary to conserve and monitor these sensitive environments their environments. Counting and identifying seagrass species is mostly done through manual field surveys, which are labor- and time-intensive and prone to error. In addition, conventional methods require a large amount of fieldwork, are not easy to scale up, and make long-term monitoring difficult, defeating proper conservation planning (Iyengar and Bhattacharya, 2024).

This paper proposes a novel algorithm based on deep learning for sargassum species recognition and population counting in multispecies seagrass beds (Ravshanova *et al.,* 2024; Alam *et al.,* 2024). The aim is to develop a model that will automatically classify, recognize, and enumerate different seagrass species from underwater images using the power of CNNs (Armstrong and Tanaka, 2025). Translation of intricately curated datasets is fundamental to the proposed model; thus, the system is trained on an extensively annotated image dataset depicting morphologies of different species, water conditions, and lighting variabilities (Mobarakeh *et al.,* 2024; Afif *et al.,* 2023). The solution features the most advanced methods of image preprocessing, feature extraction, and custom-designed backbone CNN harnessed to fit the peculiarities of underwater systems (Saimassay *et al.,* 2024). The model architecture is robust to challenges posed by turbidity, lighting, and complex species overlap while ensuring accuracy and reliability under harsh conditions. It has been proven that the best results are attained with a CNN-based approach over traditional species counting and identification techniques, considering time efficiency, accuracy, reliability, and replication of results (Chen *et al.,* 2024; Yemunarane *et al.,* 2024).

The proposed framework offers a revolutionary asset for marine ecologists and conservationists by enabling automated, precise, and large-scale monitoring of seagrass ecosystems (Karar *et al.,* 2023; Laouamer *et al.,* 2020). It reduces the need for manual survey work, lowers monitoring costs, and allows for continuous and real-time evaluation of the ecosystem (Nair and Rathi, 2023). Ultimately, this innovation improves our ability to routinely monitor and control seagrass habitats with large-scale environmental studies, supporting international initiatives aimed at ocean conservation and climate change mitigation (Ranjan and Bhagat, 2024; Lenin Marksia and Yesubai Rubavathi, 2024).

Contributions

- This study presents a CNN-based deep learning model to detect, categorize, and quantify several seagrass species from submerged images. The approach successfully handles problems like species similarity, complicated backdrops, and changing water and lighting conditions using a big, annotated dataset from various aquatic habitats.
- To improve the accuracy of feature extraction and classification, the suggested system uses state-of-the-art image preprocessing methods and CNN architectures that were specifically developed for the purpose.
- This strategy outperforms manual and semi-automated approaches by making models more resistant to environmental noise, such as changes in lighting, water turbidity, and picture distortion.

This paper is structured as follows: In section 2, the literature survey is studied. In section 3, the methodology is explained. In section 4, the paper is concluded.

Literature Survey

Though they need substantial architectural optimization and design, deep learning techniques, particularly CNNs, have transformed picture categorization. To improve the efficiency and accuracy of monitoring maritime ecosystems at risk from human activities and climate change, this research presents the OFDA as a means to automate CNN generation for multispecies seagrass classification (Noman *et al.,* 2024a).

OFDA-CNN

Image categorization has recently seen a surge in deep learning approaches based on CNN. Despite CNNs' impressive performance on visual recognition tests, building deep learning models with CNNs requires careful architectural engineering and hyperparameter optimization. To automate the building of CNNs and tune their hyperparameters for usage in multispecies seagrass classification tasks, this paper introduces a new metaheuristic approach called the OFDA in this research. Unfortunately, seagrasses are in danger from both human interference and the effects of climate change, despite the vital role they play in preserving marine ecosystem stability and biodiversity (Afif, *et al.,* 2023; Navath, 2023).

Artificial Neural Network

Divers or underwater surveying robots with specialized camera payloads may capture many photos. Because of the high expense and time commitment associated with manually reviewing these photographs to extract ecological data, there is a compelling need to automate this process using machine learning techniques (Jelena and Srđan, 2023). This research presents our deep convolutional neural network–based seagrass multispecies detector and classifier. In addition, this paper provides a straightforward approach to semi-automatically labeling picture patches, which reduces the need for human labeling (Saimassay *et al.,* 2024; Farfoura *et al.,* 2023; Nayak and Raghatate, 2024).

Support Vector Machine (SVM)

The dataset used for this investigation and the source code and pre-trained models that may be used to repeat our experiments are all described and made freely available. Seagrasses are necessary to keep coastal ecosystems healthy because they offer homes for aquatic animals. Underwater picture limitations, such as limited visibility, fluctuating illumination, and distortion, make conventional classification techniques difficult to use when manually identifying seagrass species (Noman *et al.*, 2024b). To overcome the constraints of underwater photography, this work mainly focuses on the difficulty of developing a strong automated system (Lenin Marksia and Yesubai Rubavathi, 2024; Kordnoori *et al.*, 2025).

Using CNNs optimized by the Opposition-based Flow Direction Approach, this research introduces OFDA-CNN, an automated deep-learning method for multispecies seagrass classification. To overcome the obstacles in underwater imagery, this paper also investigates using a deep neural network and an SVM method to improve ecological data extraction and species identification.

Most deep learning systems that rely on visual perception processes are Convolutional Neural Networks. CNNs are a kind of deep learning model that can directly extract data. Even while CNNs come in a wide variety of designs, their fundamental components are rather standard. Layers that make up the CNNs model include convolutional, pooling, and fully connected ones. A convolutional layer performs automatic feature representation learning of the input data. A feature map links Each neuron to its neighbors in the preceding layer. To generate feature maps, CNNs apply kernels or filters to the pictures.

Proposal of the Deep CNN Framework

Automated species identification and quantification in complicated situations is possible with the help of the CNN-Based Species Recognition and Counting System. Utilizing deep learning, it efficiently and scalable analyses underwater photos, delivering high-quality monitoring vital for environmental conservation initiatives, even in the face of hurdles like changing illumination and water conditions.

Methodology

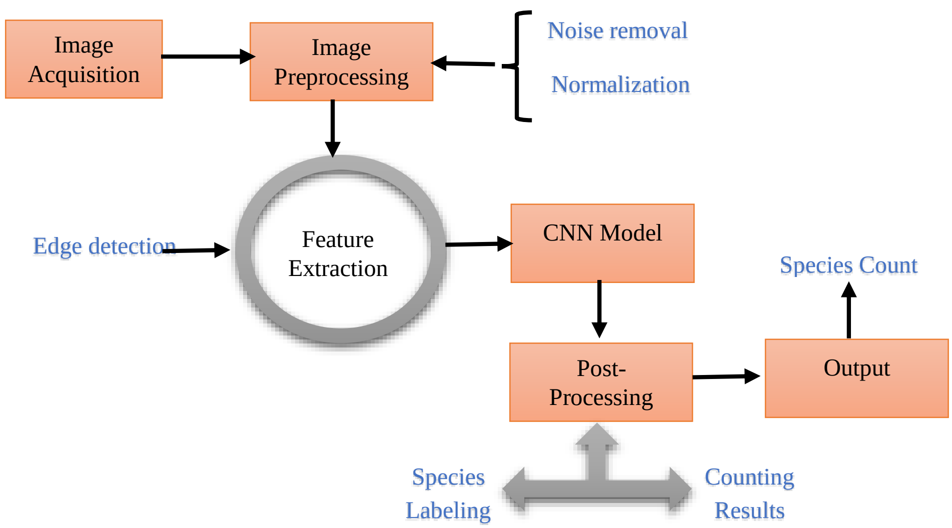

Figure 1: CNN-based species recognition and counting system.

From the image in Figure 1, the action multispecies counting and species identification seagrass system is automated and combines image processing and machine learning for efficient underwater seagrass ecosystem surveillance analysis. This is done by detecting and classifying different seagrass species in the images captured. Like all AI systems, the proposed system starts with image data, where further actions such as noise removal and interpolation precede counting. To facilitate categorization and counting, a convolutional neural network model was developed to perform edge, texture, and color recognition. In this model, species identification and counting are performed successively, followed by postprocessing of results. Reports generated offer a convenient way to enhance monitoring and observation of seagrass ecosystems, facilitating more effective conservation efforts.

Dataset Description

Identifying species using CNN facilitates the differentiation of numerous seagrass species in a complex underwater environment. Due to light and water conditions and marine plant interferences, these systems are automated to distinguish features and species, sometimes referred to as obstacles, able to overcome varying light, water clarity, and intersecting plant forms. Through extensive supervised learning on seagrass images, the model associates distinctive visual patterns with distinct species, capturing the essence of each member's patterns in the images. Advanced image preprocessing and custom-designed networks allow for further performance enhancements.

Species Recognition

Unlike traditional methods of automatic species identification, these algorithms are more efficient, precise, and adaptable, leading to streamlined ecological system monitoring changes while improving the conservation of sensitive marine environments. Seagrass species recognition with CNN enables accurate identification of these species. The method can tackle underwater challenges of turbidity and illumination using complex multi-vision algorithms, becoming better at monitoring ecosystems.

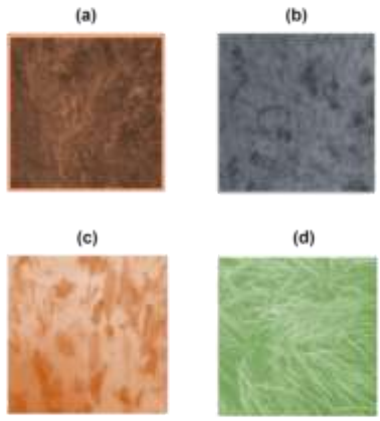

Figure 2 (a): Sample images from the species recognition (Yemunarane *et al.*, 2024).

The high-sea visual similarities and the blooming spatial changes in illumination and environment make species identification within seagrass communities multispecies seagrasses difficult. This paper addresses these challenges by applying a convolutional neural network (CNN) model on a richly annotated image dataset of seagrass spanning various ecosystems. Advanced image processing techniques minimize blurring and smoothing due to water turbidity and changing illumination while maximizing feature sharpness. Discrimination between visually similar species is made possible by accurately capturing complex features using the tailored CNN model designed for the task. The integrated automated recognition approaches offer unprecedented speed, reliability, and scalability that far surpass outdated manual methods. In Figure 2(a), effective species identification aids ecological assessment, habitat restoration and management, and conservation operations governing timely and precise responsive action to environmental changes, enabling precision decision-making, making them indispensable for modern eco-socio systems.

Seagrass Dataset

Accurate underwater seagrass species identification is now possible with deep learning using CNNs. These models consider changes in water clarity, light, and species overlap by extracting complex visual data from diverse seagrass ecosystems. Marine conservation and ecosystem management may benefit from this method's enhanced large-scale monitoring capabilities.

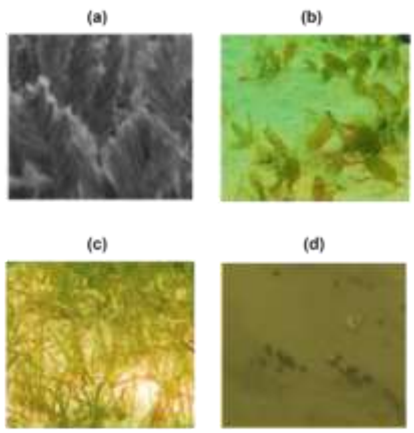

Figure 2 (b): Sample image patches from the seagrass (Alam *et al.*, 2024).

Seagrass is a marine plant that occurs in shallow coastal waters worldwide. While seaweed is an alga, seagrass is a real flowering plant, having roots, stems, and leaves. It contributes significantly to maintaining marine diversity through habitat and food for various species, such as fish, crustaceans, and sea turtles. Seagrass beds stabilize the sea floor, protect shorelines from erosion, and enhance water quality by filtering impurities. Significantly, seagrass is a substantial carbon sink that can absorb large volumes of carbon dioxide, rendering it vital in combating global warming and for the well-being of ocean ecosystems in Figure 2(b).

Conclusion

This paper describes a CNN-driven system for automated detection and quantification of seagrass in multiple species, providing a quantum leap over labor-intensive manual methods. The system presents high accuracy, scalability, and efficiency even with difficult underwater imaging conditions through deep learning algorithms, advanced image processing, and a strong annotated dataset. The system enables mass-scale, real-time seagrass ecosystem monitoring, thus supporting environmental surveys and conservation. The system lessens dependence on time-consuming field surveys, conserving precious resources and allowing uninterrupted habitat assessment. Eventually, this technology offers marine ecologists and conservationists an effective tool to boost coastal biodiversity conservation, carbon sequestration practices, and marine health management, supporting the worldwide effort to protect our crucial marine ecosystems.

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