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Review of Artificial intelligence techniques for marine plant Recognition

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Abstract

Marine plants are vital for supporting biodiversity and carbon sequestration, but their identification is challenging due to the complexities of the marine environment. This review examines the application of artificial intelligence (AI) techniques, particularly deep learning methods like Convolutional Neural Networks (CNNs), to enhance the recognition and classification of marine plants. It compares these AI approaches with traditional methods, which often rely on manual observation and expert knowledge—processes that can be labor-intensive and error-prone. The study assesses the effectiveness of AI techniques in enhancing marine plant recognition compared to traditional methods. We conducted a comprehensive review of various AI methodologies utilized in marine plant identification, examining their strengths and limitations, and highlighting the significance of AI in marine biology, particularly in data analysis and pattern recognition. Our findings demonstrate that AI technologies have the potential to significantly improve the identification process, with several recent studies showcasing successful applications. The review also discusses current datasets, highlights challenges such as data scarcity and environmental variability, and outlines future research directions to improve the accuracy and efficiency of AI in marine plant identification. This paper emphasizes the need to integrate AI into marine biology to advance conservation efforts and deepen our understanding of marine biodiversity, ultimately contributing to the sustainability of marine ecosystems.

Keywords: Artificial Intelligence, Marine Plant Recognition, Image Processing, Marine Biology Ecosystem Conservation, Biodiversity Management.

الملخص

النباتات البحرية ضرورية لدعم التنوع البيولوجي واحتجاز الكربون، ولكن التعرف عليها أمر صعب بسبب تعقيدات البيئة البحرية. تدرس هذه المراجعة تطبيق تقنيات الذكاء الاصطناعي، وخاصة أساليب التعلم العميق مثل الشبكات العصبية التلافيفية (CNNs)، لتعزيز التعرف على النباتات البحرية وتصنيفها. وتقارن هذه الأساليب بالطرق التقليدية، والتي غالبًا ما تعتمد على الملاحظة اليدوية والمعرفة المتخصصة – وهي العمليات التي قد تتطلب عمالة مكثفة وعرضة للخطأ. تقيم الدراسة فعالية تقنيات الذكاء الاصطناعي في تعزيز التعرف على النباتات البحرية مقارنة بالطرق التقليدية. أجرينا مراجعة شاملة لمختلف منهجيات الذكاء الاصطناعي المستخدمة في التعرف على النباتات البحرية، وفحصنا نقاط قوتها وحدودها، وأبرزنا أهمية الذكاء الاصطناعي في علم الأحياء البحرية، وخاصة في تحليل البيانات والتعرف على الأنماط. توضح نتائجنا أن تقنيات الذكاء الاصطناعي لديها القدرة على تحسين عملية التعريف بشكل كبير، مع عرض العديد من الدراسات الحديثة للتطبيقات الناجحة. وتناقش المراجعة أيضًا مجموعات البيانات الحالية، وتسلط الضوء على التحديات مثل ندرة البيانات والتقلبات البيئية، وتحدد اتجاهات البحث المستقبلية لتحسين دقة وكفاءة الذكاء الاصطناعي في تحديد النباتات البحرية. وتؤكد هذه الورقة على الحاجة إلى دمج الذكاء الاصطناعي في علم الأحياء البحرية لتعزيز جهود الحفاظ وتعميق فهمنا للتنوع البيولوجي البحري، مما يساهم في نهاية المطاف في استدامة النظم البيئية البحرية.

الكلمات المفتاحية: الذكاء الاصطناعي، التعرف على النباتات البحرية، معالجة الصور، الحفاظ على النظم البيئية للأحياء البحرية، إدارة التنوع البيولوجي.

1. Introduction

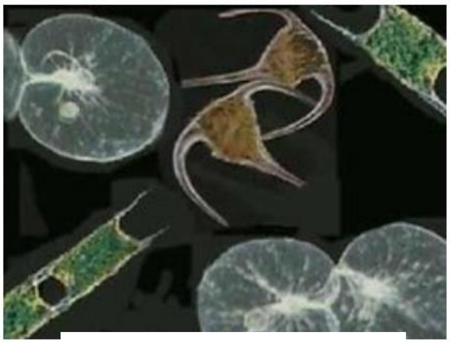
Marine plants are one of the key components of the marine ecosystem, playing a crucial role in supporting biodiversity, sequestering carbon, and providing a safe haven for marine organisms. However, identifying and monitoring marine plants poses a significant challenge due to the dynamic nature of the marine environment, as well as the difficulty of accessing certain underwater areas. In this context, artificial intelligence (AI) technologies have emerged as powerful and effective tools to address these challenges.

1.1 Meaning of Aquatic Plants

Plants are multicellular, non-motile organisms that contain the green pigment chlorophyll, enabling them to produce their own food through photosynthesis. Aquatic plants, also known as hydrophytic plants, are those that have adapted to live in or on aquatic environments. Since living in or under water requires special adaptations, these plants can only thrive in water or permanently saturated soil shown in figure 2.

Aquatic vascular plants can include ferns or angiosperms from various families, including both monocots and dicots. Seaweeds, while multicellular marine algae, are not considered vascular plants and are typically excluded from the category of aquatic plants. Unlike other types of plants such as mesophytes and xerophytes, hydrophytes do not struggle with water retention due to the abundance of water in their environment. Consequently, they have a reduced need to regulate transpiration, as doing so would require more energy than the potential benefits gained [30].

Figure (2): Nymphaea alba, a species of water lily [26].



Figure(3): Phytoplankton[26].

Types of Aquatic Plants

Aquatic plants can be found in both shallow and deep-water zones. The three primary types of aquatic plants are:

- **Phytoplankton**: These are single-celled organisms that float in the water column.
- **Periphyton**: This refers to algae that grow attached to various substrates.
- **Macrophytes**: These are multicellular plants that can be seen with the naked eye.

In recent studies, artificial intelligence techniques have been extensively utilized to enhance the identification of marine vegetation, a crucial area in environmental and marine research. Among these studies, Zhang et al [1]. conducted a study on the use of convolutional neural networks for seagrass classification using underwater imagery. Additionally, Huang et al [2]. presented research on deep learning models for marine plant identification using hyperspectral imaging. Moreover, Rana and Ahmed explored automated recognition of marine vegetation using convolutional neural networks and transfer learning [3].

Furthermore, artificial intelligence can be utilized to analyze aerial images captured by Unmanned Aerial Vehicles (UAVs) to monitor coastal plants. A study by Li & Zhao [4] suggests that CNN networks can be employed to develop effective tools for monitoring coastal plants, aiding in tracking environmental changes resulting from climate change effects. With the advancement of AI technologies, there is potential to expand the scope of applications to include the analysis of more complex marine environments. For instance, a study by Zhou et al. [5] mentioned that CNNs can be used to classify images of coral reefs and marine plants with high accuracy, supporting the assessment of marine biodiversity.

Recent research in the field of marine plant analysis and classification explores the advantages of utilizing artificial intelligence techniques for enhanced identification of marine flora. The aforementioned studies demonstrate the use of Convolutional Neural Networks (CNNs) in improving the monitoring and analysis of marine plants.

In the study conducted by Jiao and Chen [6], mapping of seagrass habitats was enhanced through the use of CNNs and spatial spectral analysis. Khan and Islam [7] presented a deep framework based on CNNs for recognizing underwater plants in noisy environments. Additionally, Valero and Plaza integrated CNNs with unsupervised learning for efficient classification of marine plants [8].

These techniques offer benefits by enhancing the accuracy of marine plant recognition and facilitating environmental monitoring and conservation efforts in marine ecosystems. These studies signify significant progress in our understanding of marine ecosystems and provide practical frameworks for biodiversity conservation and sustainability in oceans.

The primary contributions of this paper are as follows:

- The research paper on artificial intelligence techniques for marine plant recognition makes a significant contribution to the field of marine biology.
- It highlights the potential of artificial intelligence techniques in improving marine plant identification by comparing them with traditional methods.
- The paper emphasizes the importance of artificial intelligence in data analysis and pattern recognition in marine biology.

- The study showcases successful applications of artificial intelligence techniques in marine plant recognition, demonstrating the tangible benefits of integrating AI in this field.
- It provides valuable insights on current datasets and future challenges to enhance the accuracy and efficiency of artificial intelligence in marine plant recognition.
- Overall, it underscores the importance of integrating artificial intelligence in marine biology to support marine ecosystem conservation efforts and enhance our understanding of biodiversity.

The objective of this study to assess the effectiveness of artificial intelligence (AI) techniques in enhancing the accuracy and efficiency of marine plant recognition compared to traditional methods, which often rely on manual observation and expert knowledge—processes that can be labor-intensive and error-prone.

The remainder of this paper is organized as follows: Section 2 Related Work. In Section 3, typical Artificial Intelligence in Marine Plant Recognition methods together with comprehensive comparisons are systematically presented. Popular datasets are revisited in Section 4. Challenges and Limitations are discussed in Section 5 and Future Directions and Previous Research Gab are discussed in Section 6 and the conclusions are drawn and presented in Section 7.

2. Related Work

2.1Traditional Approaches to Marine Plant Identification:

Historically, the identification of marine plants has predominantly relied on direct observation and the study of external morphology. These conventional methods remain crucial, particularly for preliminary field studies and ecological surveys. Key aspects of these approaches include:

- **Direct in situ Observation:** This involves documenting the plant's observable characteristics within its natural habitat, such as color, size, overall shape, growth form (e.g., erect, creeping, tufted), substrate type (e.g., rock, sand, mud), and depth of occurrence. Simple tools like hand lenses for close inspection and measuring devices for dimensional assessments are employed. Photographic documentation and illustrative drawings play a significant role in recording these observations [9].

- **Detailed Morphological Analysis:** This approach centers on examining various plant structures, including roots, stems, leaves (or their algal equivalents), reproductive organs (e.g., flowers in marine angiosperms, spores in algae), and other distinguishing features specific to each species. Dichotomous keys, which use a series of paired comparisons to narrow down identification possibilities, are frequently employed at this stage [10]. In some cases, accurate identification necessitates anatomical examination of tissue samples using microscopy [11].
- **Ecological and Biogeographical Considerations:** Environmental factors exert a strong influence on the distribution and occurrence of marine plant species. Specific species often exhibit preferences for particular environmental conditions, such as salinity, temperature, water current strength, and light intensity. Knowledge of a species' geographic distribution also aids in its identification [12].

With advancements in molecular biology, molecular techniques (e.g., DNA analysis) are increasingly used in marine plant taxonomy. However, traditional methods remain essential for field surveys and ecological studies and are often integrated with molecular approaches to provide a holistic understanding of marine plant biodiversity.

2.2 Drawbacks of Traditional Methods in Marine Plant Identification

While classical morphological techniques have historically been foundational in the identification of marine plants, they present certain limitations that warrant consideration, particularly with the rise of molecular biology. Some key drawbacks include:

- **Subjectivity and Reliance on Expertise:** Traditional identification heavily relies on the observer's taxonomic expertise and their interpretation of morphological traits. This inherent subjectivity can lead to inconsistencies in identification between different researchers, introducing potential for human error and hindering standardization [13]. The accurate interpretation of subtle morphological variations requires extensive training and specialized knowledge.
- **Morphological Similarity and Cryptic Diversity:** Distinct species can exhibit convergent morphologies, making accurate differentiation based solely on external features challenging. This issue is particularly prevalent among algae, where substantial genetic divergence can exist between species that appear nearly identical morphologically, highlighting the phenomenon of cryptic diversity [14].

- **Environmental Influence on Morphology:** The morphology of marine plants can be significantly influenced by environmental factors such as salinity, light availability, nutrient levels, and water movement. This phenotypic plasticity can lead to intraspecific variation, making species delimitation based on morphology alone difficult [15]. This environmentally induced variability can mask underlying genetic differences.
- **Challenges with Incomplete or Asexual Material:** Many taxonomic keys rely on reproductive structures for accurate identification. Consequently, specimens that are sterile, fragmented, or in juvenile stages, lacking these diagnostic features, pose considerable challenges for traditional identification methods [16]. This limitation restricts the applicability of morphological methods in certain ecological contexts.
- **Time and Labor Demands:** Detailed morphological analysis, including microscopic examination and anatomical investigations, can be a time-consuming and labor-intensive process. This can be a limiting factor, especially when dealing with large-scale ecological surveys or biodiversity assessments that involve the processing of numerous samples.

Despite the usefulness of traditional methods for identifying marine plants, several limitations must be considered. First, these methods heavily rely on the personal experience and prior knowledge of the researcher, which can lead to variability in results among different individuals. The reliance on morphological characteristics alone can be misleading, as some species exhibit similar external appearances, increasing the risk of misidentification.

Second, traditional methods may prove ineffective in areas with high biodiversity, such as the Pacific regions, where diverse environmental patterns can lead to unexpected forms of plants. For instance, [29] [30] highlight that various species of red algae can appear very similar, making accurate identification challenging without additional techniques.

Finally, traditional methods often require sample collection, which can negatively impact marine ecosystems. Collecting samples may reduce local populations and, consequently, affect biodiversity. Therefore, it is essential to integrate these traditional methods with modern techniques such as genetic analysis and infrared imaging to enhance identification accuracy and ensure the conservation of marine ecosystems.

methods for the collection, handling, preservation, and logistics of marine plants have several limitations. Firstly, the preservation techniques may not effectively prevent degradation of sensitive specimens, compromising key characteristics for identification. Additionally, transportation can induce stress on samples, altering their physiological state. The methods may also overlook the vast diversity of marine species, leading to potential misidentifications. Furthermore, collection practices can disrupt local ecosystems, raising sustainability concerns. Lastly, the effectiveness of these methods is heavily reliant on favorable field conditions, which may not always be present. Integrating modern techniques could enhance accuracy and minimize ecological impact [32].

Consequently, molecular approaches, such as DNA sequencing and phylogenetics, have become increasingly important tools in marine plant taxonomy and systematics, providing independent lines of evidence. Nonetheless, traditional morphological methods remain valuable for preliminary field assessments, ecological studies, and as a crucial component of integrative taxonomic frameworks that combine both morphological and molecular data to provide a more comprehensive understanding of marine plant diversity Table (1) shows the advantages and disadvantages of these methods.

Table (1): Summary of Traditional Methods for Identifying Marine Plants: Advantages and Disadvantages

Identification Method	Advantages	Disadvantages	References
Field Guide	Easy to use, provides clear images	May not cover all species	[9]
Microscopic Analysis	Accurate for species identification	Requires specialized equipment and expertise	[11]
Genetic Classification	Provides precise information on evolutionary relationships	Requires advanced and costly techniques	[12]
Expert Consultation	Provides accurate information from reliable sources	Can be expensive and difficult to access	[13]
Trait-Based Identification	Quick and helpful for common species	May lead to errors in similar species	[14]
Marine algae of California	Comprehensive coverage of California marine algae	Potential misidentification due to morphological similarities	[29]
Marine red algae of the Hawaiian Islands	Focused study on red algae, enhancing specificity	Limited scope may overlook other marine plant species	[30]
Collection, handling, preservation, and logistics	Provides practical methodologies for fieldwork	Sample degradation and ecological disruption risks	[31]

3. Artificial Intelligence Techniques Used in Marine Plant Recognition

3.1 Definition of Artificial Intelligence and Its Significance in Marine Biology

Artificial intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to think and learn. In marine biology, AI plays a crucial role by providing advanced tools for data analysis, pattern recognition, and ecological monitoring. AI techniques enable researchers to analyze large datasets from underwater imagery and environmental sensors, facilitating the identification and classification of marine plants, which is essential for biodiversity conservation and ecosystem management.

3.1.1Significance of AI in Marine Biology

1. Data Analysis and Pattern Recognition

Marine biology generates vast amounts of data, particularly from underwater imagery and environmental sensors. AI enhances the ability to analyze this data efficiently. For instance, convolutional neural networks (CNNs) can classify images of marine vegetation, helping to identify different species and assess their health.

2. Ecological Monitoring

AI tools facilitate real-time monitoring of marine ecosystems. By analyzing data from various sources, such as drones and underwater cameras, AI systems can detect changes in biodiversity and ecosystem health. This is crucial for timely interventions in conservation efforts.

3. Biodiversity Conservation

AI aids in the classification and mapping of marine species, which is vital for conservation strategies. By identifying species distribution and abundance, researchers can better understand ecological dynamics and the impacts of environmental change.

4. Predictive Modeling

AI models can predict changes in marine ecosystems based on historical data and current trends. This helps in forecasting potential impacts of climate change, pollution, and human activities on marine life, enabling proactive management strategies.

5. Enhanced Research Efficiency

The integration of AI in marine biology streamlines research processes. Automated image recognition and data processing reduce the time and effort required for researchers to analyze large datasets, allowing them to focus on interpretation and application of findings.

6. Decision Support Systems

AI-driven decision support systems provide researchers and policymakers with insights derived from complex data analyses. These systems can simulate different management scenarios, helping stakeholders make informed decisions regarding marine resource management.

Artificial Intelligence is transforming marine biology by providing powerful tools for data analysis, ecological monitoring, and biodiversity conservation. As the challenges facing marine ecosystems grow, the integration of AI will be crucial in developing effective strategies for sustainable management and conservation of marine resources. By leveraging AI, marine biologists can enhance their understanding of complex ecological interactions and improve the health of our oceans.

3.2 Overview of AI Techniques Commonly Used for Marine Plant Recognition

Several AI techniques are commonly employed in marine plant recognition, particularly deep learning methods such as Convolutional Neural Networks (CNNs). These methods have shown significant success in classifying marine vegetation using underwater imagery and hyperspectral data. For example, utilized CNNs for seagrass classification, demonstrating their effectiveness in analyzing underwater images [1]. Similarly, applied deep learning models to identify marine plants using hyperspectral imaging, showcasing the versatility of AI in handling complex data types [2].

Additionally, automated recognition systems have been developed using CNNs and transfer learning, which further enhance the accuracy of marine vegetation identification [3]. UAV imagery has also been integrated with deep learning approaches to monitor coastal vegetation, revealing the potential of AI in environmental surveillance [4]. Other studies have

emphasized the importance of AI in assessing marine biodiversity through underwater habitat classification using CNN-based image classification techniques [5].

Overall, the integration of AI in marine plant recognition not only improves the accuracy of species identification but also enables real-time monitoring and assessment of marine ecosystems, which is vital for effective conservation strategies. Table 2 provides a brief overview of the application of each technique in marine plant identification, along with its strengths and weaknesses.

Table (2): Summary of AI Techniques for Marine Plant Recognition

Technique	Method	Advantages	Disadvantages	Reference
Deep Learning	Convolutional Neural Networks (CNNs)	High accuracy in image classification; effective for complex patterns in images.	Requires large datasets for training; computationally intensive.	[1][2]
	Generative Adversarial Networks (GANs)	Generates synthetic data to enhance model training; improves robustness of models.	Can be complex to train; may produce unrealistic data if not properly tuned.	[5]
Machine Learning	Support Vector Machines (SVM)	Effective for small to medium-sized datasets; interpretable results.	Less effective with large datasets; sensitive to feature scaling.	[4]
	Decision Trees	Easy to understand and visualize; handles both numerical and categorical data well.	Prone to overfitting; not robust to small changes in data.	Gao & Chen, 2022[6]
Computer Vision	Image Processing Techniques (enhancement, edge detection, segmentation)	Helps isolate marine plants in images; improves accuracy of recognition tasks.	Requires preprocessing; may not work well in poor lighting conditions.	[7]
	Pattern Recognition	Identifies objects effectively by analyzing visual patterns.	May require extensive training data; complexity in identifying similar species.	[8]
Big Data Analytics	Analyzing large volumes of environmental data	Provides valuable insights into plant distribution patterns; enables trend analysis.	Requires robust data management systems; potential for data overload.	[3]
Remote Sensing Technology	Satellite Imagery	Enables large-scale analysis of marine ecosystems; effective for monitoring changes over time.	High cost; resolution limitations can affect accuracy.	[2]
Reinforcement Learning	Systems that learn from past experiences	Adapts over time to improve recognition methods; can optimize decision-making processes.	Complexity in implementation; requires extensive training and tuning.	[6]
Spectral Analysis	Techniques to determine chemical properties of marine plants	Helps distinguish between species based on chemical signatures; enhances identification accuracy.	Requires specialized equipment; can be costly and time-consuming.	[1]
Sound Recognition	Analyzing sounds emitted by marine organisms	Contributes to understanding marine biodiversity; non-invasive data collection method.	Limited to audible species; environmental noise can interfere with data quality.	[4]

4. DATASETS

4.1 Current Research Landscape

Recent studies have increasingly focused on the application of artificial intelligence (AI) for marine plant identification, highlighting advancements in methodologies and findings that enhance our understanding of marine ecosystems.

Underwater image processing is a relatively emerging field, resulting in a limited number of datasets available for underwater computer vision applications. The main factors contributing to this scarcity include:

1. The field's late emergence has led to insufficient focus on developing underwater image datasets.
2. Although researchers are beginning to appreciate the importance of these collections, assembling such datasets is often labour-intensive and challenging due to the unique conditions of the ocean environment.
3. The vast diversity of marine life adds complexity, making it difficult to manually gather and classify ground truth data for a wide variety of underwater images.

Table (3): Review of some existing databases that could be made available to the general public for underwater plant detection.

Database Name	Introduction
Marine Vegetation	A comprehensive collection of underwater plant species, their habitats, and ecological data.
Seagrass Monitoring	Focused on seagrass species, this database includes distribution patterns and health assessments.
Coral Reef Biodiversity	Contains data on marine flora and fauna associated with coral reefs, including underwater plants.
Hyperspectral Imaging	Features hyperspectral images of marine vegetation, facilitating advanced analysis and classification.
UAV Imagery for Coastal Vegetation	A repository of UAV-acquired images, specifically for monitoring coastal vegetation using machine learning.
Underwater Ecosystem Database	This database provides insights into various underwater ecosystems, including plant communities.
Deep Learning Marine Plant Classification	A dataset used for training deep learning models in marine plant identification, including labeled images.
Underwater Image Enhancement Benchmark (UIEB)	There are 950 genuine underwater images in the UIEB, of which 890 have associated references and 60 do not. The academic goal is to improve underwater images for academic purposes.

These databases serve as valuable resources for researchers and practitioners in marine ecology and environmental monitoring.

Figure 1 shows a subset of the 890 identical pairs of original underwater images and reference images that comprise the Underwater Image Enhancement Benchmark (UIEB), and these underwater images are collected from Google, YouTube, related papers and paper researcher self-captured videos [44].

4.2 Summary of Recent Studies Utilizing AI for Marine Plant Identification

Based on the 31 reviewed previous studies and the information provided in them on the use of AI techniques for marine plant recognition, convolutional neural networks (CNNs) are the best approach for image classification tasks. CNNs have shown high accuracy in image classification and are effective for capturing complex patterns in images. Additionally, Generative Adversarial Networks (GANs) can be utilized to generate synthetic data for enhancing model training and improving model robustness.

CNNs have been successfully used in various studies for seagrass classification, marine plant identification, and underwater plant recognition. They have demonstrated their capability in handling image-based tasks effectively. On the other hand, GANs have shown potential in generating synthetic data to improve model performance. However, GANs can be complex to train and may produce unrealistic data if not properly tuned.

Therefore, considering the high accuracy and effectiveness in handling image classification tasks, Convolutional Neural Networks (CNNs) stand out as the most promising method for marine plant recognition and classification.

1. **Liu et al. (2023)** conducted a comprehensive review on deep learning applications in marine species and habitat classification, emphasizing the effectiveness of various AI techniques in improving classification accuracy and efficiency [17].
2. **Gonzalez and Torres (2022)** explored AI-driven underwater imaging systems that facilitate plant recognition in diverse marine environments, showcasing novel imaging techniques that enhance the identification of aquatic vegetation [18].
3. **Smith and Wang (2021)** discussed machine learning applications specifically aimed at marine biodiversity conservation, illustrating how these techniques contribute to the monitoring and preservation of marine plant species [19].

4. **Zhou and Sun (2023)** focused on the use of convolutional neural networks (CNNs) for the automatic classification of seagrasses, demonstrating significant improvements in the speed and accuracy of identification processes [20].
5. **Kumar and Patel (2022)** highlighted the integration of AI and drone technology in monitoring aquatic vegetation, showing how aerial data collection combined with AI analysis leads to more comprehensive assessments of marine plant health [21].

4.2.1 Key Findings and Advancements in the Field

1. **Chen and Zhang (2021)** addressed recent advances in AI techniques for monitoring marine ecology, noting that the combination of AI with environmental data analysis is transforming ecological research methodologies [22].
2. **Tan and Lee (2022)** presented AI-powered solutions for biodiversity assessment, revealing how machine learning algorithms can streamline the data collection process and improve the accuracy of biodiversity metrics in marine settings [23].
3. **Lorencin et al. (2019)** showcased marine object recognition using CNNs, demonstrating the utility of these models in identifying and classifying various marine species and habitats [24].
4. **Mittal (2024)** discussed the potential of AI in discovering anticancer compounds from marine plants, specifically focusing on Sargassum species, highlighting the intersection of AI and biomedical research [25].
5. **Dakhil and Khayeat (2022)** provided a review of deep learning techniques for underwater object detection, emphasizing the advancements in detection algorithms and their implications for marine research and conservation efforts [26].

These studies collectively illustrate the growing significance of AI in marine plant identification and conservation, providing a foundation for future research and applications in this vital field.

Figure 3 shows a subset of the 890 identical pairs of original underwater images and reference images that comprise the Underwater Image Enhancement Benchmark (UIEB), and these underwater images are collected from Google, YouTube, related papers and paper researcher self-captured videos [29].

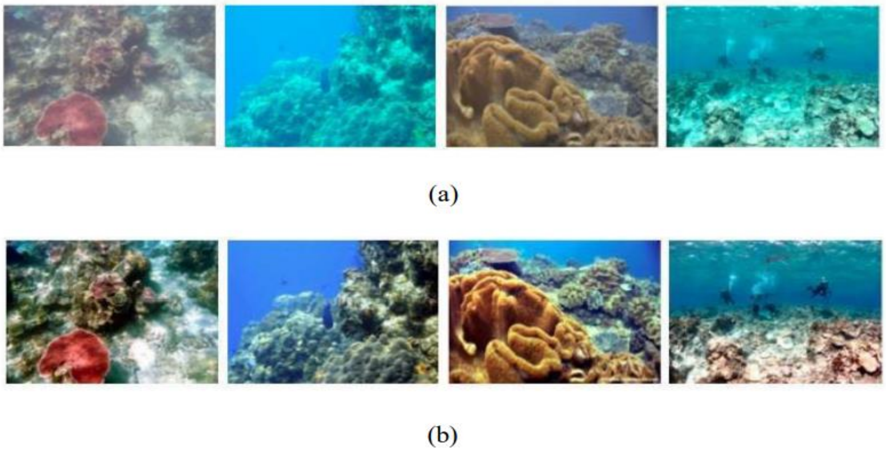


Figure (3): Examples from UIEB with subclasses: (a) original underwater images, (b) corresponding reference images [28].

Figure (4): Examples of underwater photographs of marine plants From Google.

There are numerous underwater images and large databases of photos and videos, which have led academic researchers to focus on marine sciences, particularly marine plants that need to be identified Figure 4 illustrates some of these images and their clarity. Studies have shown that certain underwater plants can treat specific types of cancer, as noted in Study [29].

This study explores the use of artificial intelligence techniques in the discovery of anticancer compounds derived from marine plants, specifically focusing on Sargassum species. It examines how AI can analyze biological and chemical data from marine plants, aiding in the identification of effective cancer-fighting compounds. The study also discusses the significance of marine plants as a novel source for cancer treatment and provides insights into potential applications for future research in this field [29].

5.Challenges and Limitations

Accurately recognizing marine plants using artificial intelligence (AI) presents several challenges. One significant issue is the variability in underwater imaging conditions, such as lighting, water clarity, and movement, which can hinder the performance of AI models. [17]. highlight that deep learning approaches often struggle with the diverse appearances of marine species due to these environmental factors, making classification difficult [17]. Additionally, the limited availability of labeled datasets for training AI models poses another challenge, as many marine species remain underrepresented in existing databases [22].

Current AI techniques also have limitations in this domain. For example, many machine learning models require extensive computational resources and large amounts of data to achieve high accuracy, which may not always be feasible in marine research settings [19]. Moreover, while convolutional neural networks (CNNs) have shown promise in automating plant classification, they can be sensitive to variations in images and may not generalize well across different environments [5]. Furthermore, [18]. point out that the integration of AI with underwater imaging methods still faces obstacles, including the need for improved algorithms to enhance image quality and resolution for better recognition outcomes.

In summary, while AI holds great potential for the recognition of marine plants, researchers must address these challenges and limitations to fully leverage its capabilities in marine ecosystems [21,23,27].

6.Future Directions

6.1 Potential Areas for Further Research

To enhance AI-based marine plant recognition, several areas warrant further investigation. Firstly, the development of more comprehensive and diverse datasets is crucial. Current datasets often lack representation of various marine plants across different habitats, which limits the training of robust AI models [17]. Additionally, integrating multi-modal data—such as combining images with environmental parameters—could improve model performance by providing contextual information [18].

Secondly, exploring the use of advanced machine learning techniques, such as transfer learning and ensemble methods, may lead to more accurate predictions by leveraging knowledge from related tasks [19]. Research into improving the interpretability of AI models is also essential, as understanding how models make decisions can enhance trust and facilitate broader acceptance in scientific communities.

6.2 Suggestions for Enhancing Accuracy and Efficiency

To improve the accuracy and efficiency of recognition models, several strategies can be employed. Implementing data augmentation techniques can help create synthetic training samples, which can enhance model robustness against variations in underwater conditions [5]. Furthermore, optimizing algorithms for real-time processing will be crucial in practical applications, especially in drone-based monitoring scenarios [21].

Employing hybrid approaches that combine traditional ecological methods with AI techniques could also provide a more holistic understanding of marine ecosystems. For instance, integrating AI-driven insights with field surveys may help validate and refine recognition models [22]. Lastly, fostering interdisciplinary collaboration among marine biologists, ecologists, and AI experts can drive innovative solutions and advance the field of marine plant recognition [23].

Based on the review of the mentioned studies, the research gaps in the field of marine plant classification and the use of deep learning technology can be summarized as follows:

6.3 Previous Research Gab

These research gaps highlight the importance of developing new and innovative strategies in marine plant classification, requiring further interdisciplinary research and collaboration among researchers and stakeholders.

Lack of Diverse Data Many studies focus on specific types of marine plants or limited geographic areas, leaving a gap in understanding the overall biodiversity of marine plants in various environments.

Limited Applications of Deep Learning While convolutional neural networks (CNNs) are increasingly used, there is a need to explore other deep learning techniques, such as reinforcement learning or multi-task deep learning, to improve classification accuracy.

Challenges in Changing Environments Current models struggle to perform well in complex or noisy environments, necessitating the development of more robust and adaptable models.

Gap in Integrating Environmental Science and Technology There is a need to enhance the integration of environmental data with technological models to ensure that the techniques used are not only accurate but also relevant to the changing marine environment.

Insufficient Long-Term Studies Most studies lack long-term monitoring, making it difficult to assess the impacts of climate change and environmental shifts on marine communities.

Inadequate Applications in Conservation Several studies point to the use of deep learning in plant classification, but there is a greater need to apply these techniques in conservation and biodiversity protection projects.

Lack of Interdisciplinary Collaboration Research often lacks collaboration between ecologists, data scientists, and IT specialists, hindering innovation in the field.

7.Conclusion

The integration of artificial intelligence (AI) in marine plant recognition represents a significant advancement in marine research and conservation efforts. AI techniques, particularly deep learning and machine learning, offer powerful tools for accurately identifying and classifying marine plants, which is crucial for understanding biodiversity and ecosystem health. The ability of AI to analyze large datasets efficiently enhances our capacity to monitor marine environments, providing valuable insights into the distribution and status of various plant species.

Key insights from the current research highlight the ongoing challenges and limitations in AI-based recognition, such as the need for comprehensive datasets and improved algorithms. Future research should focus on addressing these challenges by exploring innovative methodologies, enhancing data quality, and fostering interdisciplinary collaborations. The implications of these advancements are profound, as they can lead to better conservation strategies and more effective management of marine ecosystems.

In summary, as AI continues to evolve, its application in marine plant recognition will play a pivotal role in advancing our understanding of marine biodiversity and supporting efforts to preserve these vital ecosystems.

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