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Characterization of seaweed communities using deep learning applied to UAV-based hyperspectral images

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Abstract

Macroalgal communities provide shelter and food for many organisms and are of interest to the food industry, pharmaceutical, and agriculture. They are also an indicator of environmental change. The use of unmanned aerial vehicles (UAVs) allows the remote collection of images with high spatial and spectral resolution and adjustable time scales. The development of methodologies allowing the processing and the analysis of UAV-based high-resolution imagery would be of economic and environmental importance. That would allow to streamline the identification of species with economic potential, the evaluation of the seasonal and spatial variation of the available biomass, and the monitoring of the coastal ecological status and its evolution. Hyperspectral sensors can nowadays be coupled in UAVs allowing for high spatial and spectral resolution imagery. The data processing powered by deep learning and its increasing diversity of models and architectures is the ideal way to handle and analyze the huge volume of data acquired. In this paper, we present a methodology to make the automatic classification of existing species in macroalgal communities, using deep learning models applied to hyperspectral images collected by UAVs.

Keywords: Seaweed; Macroalgae; Hyperspectral; UAV; Deep learning; Machine Learning

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1. Introduction

Seaweeds or macroalgae have significant environmental and ecological importance and economic interest. Several studies have been carried out to explore their use in many different areas, such as cosmetics [1], livestock diet [2], horticulture [3], medicinal and pharmaceutic [4], or energy [5].

Ecologically, seaweed communities are fundamentals in coastal habitats, being "important primary producers, competitors, and ecosystem engineers" [6], sustaining most temperate coastal ecosystems and providing food and shelter for many associated species, both animals and plants [7]. They are also used as biological indicators to monitor ecosystem health [8].

The mapping and measuring of the seaweed's communities have been done through different approaches. Lately, the use of UAVs has enabled the remote collection of images with high spatial resolution and with adjustable time scales, accessible, and at a controlled cost [9]. The potential of a UAV coupled with a hyperspectral sensor for mapping macroalgal habitats had been demonstrated [10]. It will enable the construction of reflectance profiles of the various species of seaweeds with greater discrimination, facilitating the process of classification. Finally, we believe that machine learning and, particularly, deep learning (DL), with all the recent advances in its models and algorithms, may assist in the automatic image classification process and in getting ecological descriptors and indices.

As such, we aim to develop a system to automatically classify existing species in seaweed communities in intertidal zones and estimate their biomass, using deep learning models applied to hyperspectral images collected by UAVs.

2. Methodology

Figure 1 illustrates the approach taken to address the problem of identifying different types of algae applying DL to hyperspectral UAV-based imagery. After the initial phase of data collection, data will be subjected to various correction and processing techniques. The resulting data will then feed the learning models that will produce the desired results, that is, the classification of seaweeds and the estimation of their biomass.

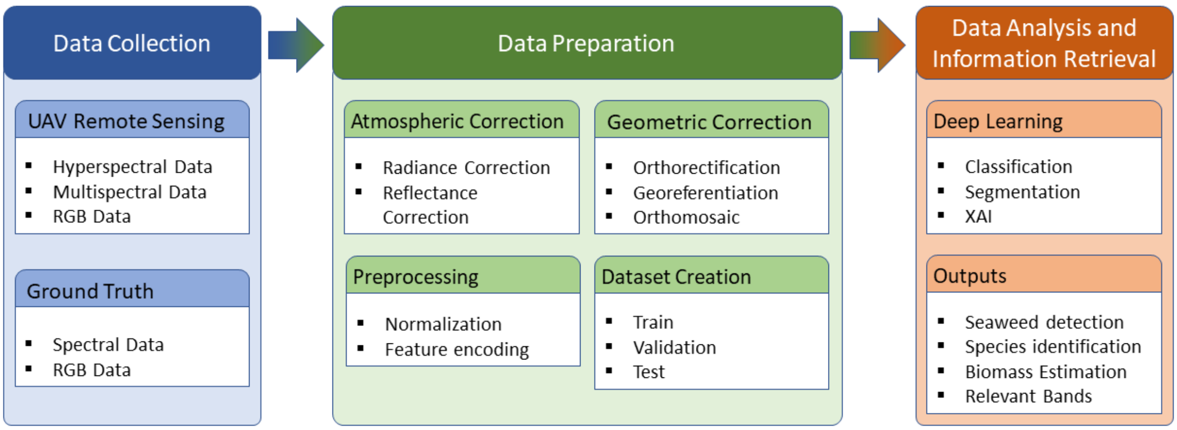

Fig. 1. Methodology phases.

Data collection is done using a UAV equipped with RGB, multispectral, and hyperspectral sensors. The surveys are done over rocky intertidal areas, at different seasons, to allow measure the evolution of seaweed communities, both in terms of their physiological state and the occupied area.

The raw data obtained goes through a process of preparation and transformation, so that they can be reliably used by the ML algorithms. This includes the correction of radiometric and geometric errors resulting from remote sensing, orthomosaic creation, preprocessing, and dataset creation. Ground-truth georeferenced points are implemented in each survey. Each of them is photographed, spectral data is collected, the existing seaweed is identified, and their biomass quantified. This data will then be used in the supervised learning system and for validation of the results.

For data analysis, we intend to explore some deep learning algorithms and models, to assess the ones providing the best results in obtaining the desired outcomes:

1. Identification of the relevant spectral bands for the classification of seaweeds (dimensionality reduction);
2. Seaweed detection and determination of the occupied area;
3. Seaweed species classification;
4. Seaweed biomass regression.

Explainable artificial intelligence (XAI) methods will be combined with DL models used in the seaweed classification, to provide insight into the most sensitive wavelengths in that process. To support the decisions to be taken about the DL algorithms to be used, a comprehensive survey is being carried out on this topic and the technologies involved.

3. Conclusion

Seaweed is the largest group of algae, playing an important role in the marine ecosystem, with great environmental importance, and of economic interest. The possibility of monitoring them promptly, periodically, and in large areas, would be useful, as they are a recognized indicator of ecological status.

We believe that the presented approach will be able to make a meaningful contribution to this topic, developing a solution that allows the detection of the area occupied by seaweed communities, the identification of the species they are constituted by, and the determination of their biomass. To this end, we intend to take advantage of recent technological developments, using deep learning algorithms applied to high-resolution UAV-based hyperspectral imagery.

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