Marine Ecosystem Monitoring: A New Deep Learning Application For Reef Mapping Based On A Citizen Science Framework

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Background
The world's oceans are being affected by human activities and strong climate change pressures. Biodiversity and habitats in coastal ecosystems have declined by 30-60% over the last decades. Population growth is occurring near the coast with 8 out of 10 people living within 100 km of the coast in 2012.

At the same time, water-based leisure activities are developing and diversifying in all coastal areas. These practices are accompanied by users' expectations in terms of information and promote public awareness of the environmental issues related to the preservation of these ecosystems. The capacity to observe biodiversity, physical and biological marine environments is central for supporting public policies and considering the sustainable development of marine resources while ensuring the ecological and socio-economic viability of associated services. Observation must take up important scientific and technological challenges and must be carried out on a geographical scale that goes beyond the observation means of research institutes. Citizen mobilization in the face of climate change issues is increasing and can, in the general context of citizen science and Open Science, overcome the geographical and institutional limits of marine observation. Thus, it could provide a response to the growing need for access to these data, whether by the general public or by the scientific community. These approaches are complementary to monitoring programs through underwater visual censuses (UVC) which require highly trained scientific divers to note visual observations under water.

Here, we present a citizen science approach for underwater image acquisition combined with artificial intelligence techniques to automatically identify habitats and species for achieving large-scale monitoring in the long term. This method would considerably increase the number of places monitored, allowing a broad and reproducible analysis of ecosystem evolution.

Method
In order to measure the effects of anthropic pressure on these environments, we have studied a new type of underwater monitoring consisting of embedding a GoPro© camera and a differential GPS in sport equipment (such as masks, paddleboards or kiteboards) allowing the acquisition of georeferenced images with centimeter accuracy. Data collection by sport equipment led to the acquisition of 750000 images and as many GPS positions taken in four different places : Mauritius, Mayotte, La Réunion and Europa Island. Among these 750000 images, 13528 were

annotated for the multi-label classification and 1200 for the segmentation classification. All the annotations were made by experts in marine biology and constitute a result in itself as they create environmental data and will be the subject of a data paper.

Then we applied twodeep learning techniques with the aim of classifying marine images : multi-label (classifying the different objects of a picture) and instance segmentation (delineating and classifying objects within a picture). The Pytorch framework was chosen to build the deep learning models.

The first step in creating these models was to annotate a dataset of photos using classes from the second scenario of the Global Coral Reef Monitoring Network (GCRMN) classification. To these classes, we added classes as “Human objects” or “Useless” whose presence in the dataset were induced by the data collection protocol that we implemented.

Both the multi-label and the segmentation neural networks were built using the fine tuning technique. The first one lies on a Resnet50 architecture, while the second on a Mask R-CNN architecture. Models are applied to predict GCRMN classes to the whole images dataset. These predictions are then mapped and co-occurrences of species and habitat are explored.

Results

Current results of this study can be broken down into two themes : firstly, the development of a reproducible and interactive workflow to take control of models predictions and continuously improve their performance and secondly ecological and geographical valorizations of the predictions.

In order to verify the predictions obtained by the multi-label neural network, we decided to classify a huge test dataset of 738000 unlabeled images belonging to 21 classes. Thanks to the geolocation of images, we were able to get feedback on the goodness of the results by constructing species distribution maps. These are simply constructed by comparing the position of the neural network predictions with the satellite image and we obtained valuable results on classes that are clearly visible from satellite images (such as sand and a species of marine plant).

To verify the predictions, we also implemented fiftyone : an open-source tool for building high-quality datasets and computer vision models. This tool enables to correct and validate annotations. Furthermore, interactive maps and plots can be linked to image visualization to discriminate against false or incomplete annotations.

Co-occurrences matrices and, by extension, potential interactions between organisms and habitats were analyzed at the lagoon scale thanks to the predictions made on the 738000 images. As an example, on 97.21% of the images where sea cucumber is identified, the presence of the sand habitat is also predicted by the Neural Network. Furthermore, implementation of the Fiftyone tool is also a stepping stone to achieve continuous improvement of data quality in order to improve models accuracy.

Finally, we created a 3D representation of the seabed using photogrammetry techniques from images collected. This made it possible to produce orthorectified mosaics of the studied areas, allowing a better understanding of the marine ecosystem.

Conclusion

Monitoring species abundance and distribution is one of the main goals of ecological research. We propose a completely new procedure that reduces both data collection and image annotation costs at a big scale and in a reproducible way.