Video monitoring framework in support of sargassum management

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VIDEO MONITORING FRAMEWORK IN SUPPORT OF SARGASSUM MANAGEMENT

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1. Introduction

The waters off Caribbean islands have seen large amounts of *Sargassum* seaweed during the last years (Wang and Hu, 2016). This record-breaking events of algae blooms and mass stranding started in earnest in 2011, then 2015 saw the next large-scale event and in January 2018, unusually large aggregations of *Sargassum* have been spotted on satellite imagery (Optical Oceanography Laboratory, n.d.). Normally, when floating offshore *Sargassum* provide important habitat and refuge to a large diversity of animals. However, while weeds approach nearshore and beach, due to currents and winds actions, in such massive quantities, they start to be deathtrap for many animals and contribute to the degradation of important coastal habitats, threatening coastal activities and ecosystems. The decomposing mass, which can be several meters high, creates oily slicks in its wake and releases a foul odor, damaging tourism activities since the sight and smell left beaches highly unappealing. Both satellite and modelled surface current data point to the North Equatorial Recirculation Region as the origin of recent mass blooms – north of the mouth of the Amazon, between Brazil and west Africa, in an area not previously associated with *Sargassum* growth (Gower et al., 2013).

A number of factors including nutrients, rising sea temperatures and Sahara dust storms have been put forward as potential causes (Louime et al., 2017). Mathematical models developed to analyze satellite imagery and detect floating algae, the Floating Algae Index (FAI) (Hu, 2009), reveal that it is only in recent years that the area has seen the mass proliferation of *Sargassum* – satellite imagery from before 2011 shows the area to be 'largely free of seaweed'. A number of strategies have been planned to deal with the large accumulations of algae resulting from the mass blooms. Removal and burial of the algae as soon as it gets stranded at beaches has been widely recommended (CRFM, 2016), although it appears to harm the environment (turtle habitat) and more specifically the sediments loss at beach.

Nowadays, the information retrieved from remote sensing satellite system are very useful in order to estimate qualitatively and quantitatively the presence and motions of such macroalgae offshore. Unfortunately, operational warning devices able to anticipate algae washing ashore still have disadvantages related to the inadequate sampling and temporal frequency (MODIS observations e.g., Wang and Hu, 2017) and the interposing obstacles such as cloud shadows, sun glint constitute important issues; actually, there is little room for improvement as these are natural phenomena. Aside the need of anticipation, there is a need for the local government to deal with this severe issue and increase the abilities of quantifying *Sargassum* onshore on a seasonal basis. There is a special need for management planning in order to an increased resilience and benefit from *Sargassum* influxes (Cox, S., 2019). Location and amounts of *Sargassum* ashore can be then accurately evaluated to

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properly plan their comprehensive management and anticipate beach maintenance funding requirements.

The purpose of this study is to implement a video-based framework approach in order to classify the coastal morphologies and specifically detect floating and beached algae in a very efficient and replicable manner with a moderate cost. This is conducted by means of a semi-supervised superpixel-based Deep Convolutional Neural Network (DCNN) classification of ground-sensed images. The implementation of a warning system for algae' quantification with a relative thresholding approach will be described and a discussion on extension for not-instrumented coastal sites will be presented.

2. Instruments and methods

A system composed of low-cost, smartphone-based cameras, ©SOLARCAM (https://www.solarcam.fr) has been installed in the Martinique's island aiming both coastal morphodynamics and beach/water quality monitoring. The latter focused on the investigation of the beached/floating algae in order to help providing instruments and data to local authorities for coastal management policy. At the time of writing, several sites among beach and harbors (n. 14) have been

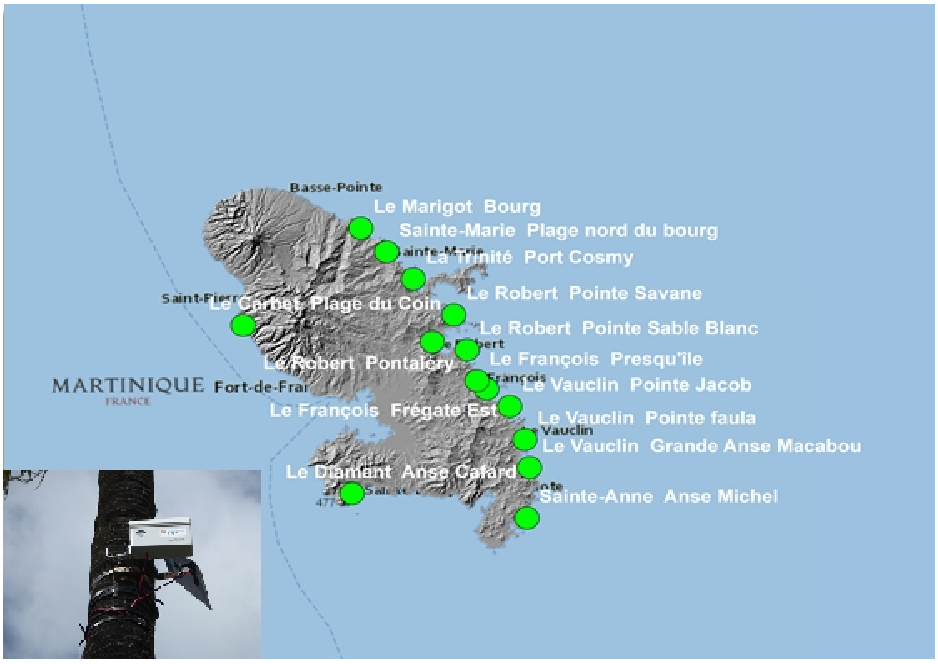

Figure 1. Distribution of installation sites in the Martinique island. **Bottom-Left**: Example of installation on a palm tree at Le Diamant, Anse Cafard.

equipped, starting from October 2018, at both, the Atlantic and Caribbean Sea sides. These are harbors or sandy/muddy beaches, essentially. Among them, nine (9) sites have been chosen for validating the warning methodology (5 beaches). Figure 1 shows the equipped coastal sites distributed over the Martinique Island.

The *Sargassum* warning framework implemented is divided into three main steps (Figure 1). First, before implementing the automatic routines, a convenient training of a DCNN is accomplished by means of a transfer learning procedure. An efficient convolutional neural network, lightweight in its architecture, called MobilenetV2, is applied (Sandler et al., 2018). The training is done on patches (96 pix) of the entire image; the formers are built around each segment centroids of a superpixels over-segmentation (modified sticky edge-adhesive superpixels, i.e. Dollar and Zitnick, 2015; Valentini et al., 2017). The manual labeling has been carrying out (Buscombe and Ritchie, 2018). Several models have been created/retrained on image patches, but trying to merge coastal sites having similar characteristics.

The proper automatize routine is accomplished in the subsequent two phases, which are, as schematized in Figure 2, the semantic classification and the alert system. Initially, a superpixels decomposition is applied, and in order to decrease the number of processing units for most of the sites, a region of interest (ROI) area is masked. Then, the retrained DCNN model (neural network) for classes' prediction is applied on the image patches centered on the superpixels centroids, allowing their classification. In order to permit the refinement of a course semantic classification, the application of a probabilistic approach, based on fully-connected Conditional Random Field, CRF (Krähenbühl and Koltun, 2012) is performed and lastly, the above-mentioned superpixels are snapped to the semantic class map, by majority voting of the regions. This last procedure ensure the edge enhancement at the pixel-scale.

The automatic processing framework makes use of a three-step procedure: (i) collection of the snap image every 3 hours and performing the automatic image segmentation. (ii) Analysis of the predicted classes for the extraction of the potential *Sargassum* blobs, filtering based on relative distances to other classes (e.g. sand, foam or terrain/vegetation, and sky, respectively). Computation of boundaries and areas of each spots. (iii) Determination of potential warning based on relative thresholds (being validated at each site). Georeferenced information are being used, where available, for reporting data in meters rather than pixel, by means of standard method for georectification (Holman and Stanley, 2007).

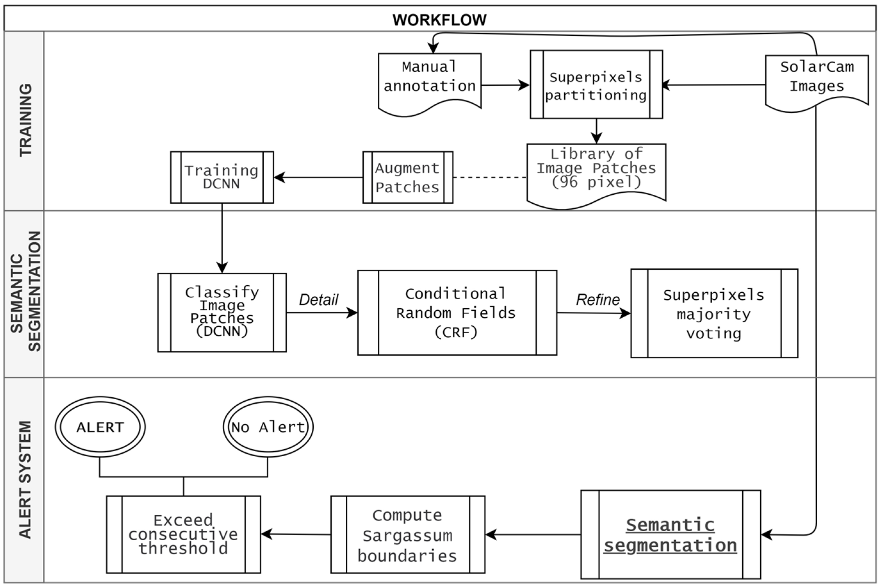

Figure 2. Workflow of the automatic *Sargassum* warning system, based on a DCNN semantic segmentation approach.

3. Results and Discussions

In order to test the capabilities of the model, the metrics based on confusion matrix and the F1 score are used to assess the pixelwise classification. The F1 score is an equal weighting of the precision and recall. The **Figure 3** shows the results pertained to two deep classification models and the semantic segmentation routine when applied to test databases built on 10 and 13 images referred to beach (Fig. 3.a) and harbor conditions (Fig. 3.b), respectively. With respect to both sites, a good overall agreement could be highlighted. Focusing on the beach morphology, (case a) the highest accuracy is associated to the vegetation class (0.98), sky and water are well predicted as well, the less accurate results come from the anthropomorphic features (merged class including coastal structures, persons, sails, etc.). The *Sargassum* class shows value of 0.84. Generally, the achieved per class average pixelwise classification accuracy is between 83% and 91%.

Inaccuracies by using this methodological approach, in terms of misclassified pixels, for *Sargassum* class, derived mostly from the proximity of vegetation areas, which, for some meteorological conditions, lead to failures in CRF detailing.

The optimization in the space of the CRF hyperparameters and based on the number and compactness of superpixels have been performed in order to guarantee the predictions' maximization.

Actually, the warning system for quantification of *Sargassum* is at a calibration phase. For each sites under analysis, the definition of a temporal threshold is being realized, strictly related to spatial constraints. Particularly, as an example with respect to the beach morphology, an absolute minimum threshold is defined as a value, defined as 30% of the beach area. Furthermore, in order to ensure trusted information and avoid the dissemination of useless warning, i.e. typically conditions of false positive, the image under analysis should exhibit a computed *Sargassum* area greater than the 20% of the prior result.

The images and their statistics as time-series data, processed starting from 2018, are being analyzed to retrieve useful parametrization of the meteo-oceanographic forces useful for describing the probability of occurrence of algae degradation over time, disintegration due to wave impact, removal due to tide oscillations.

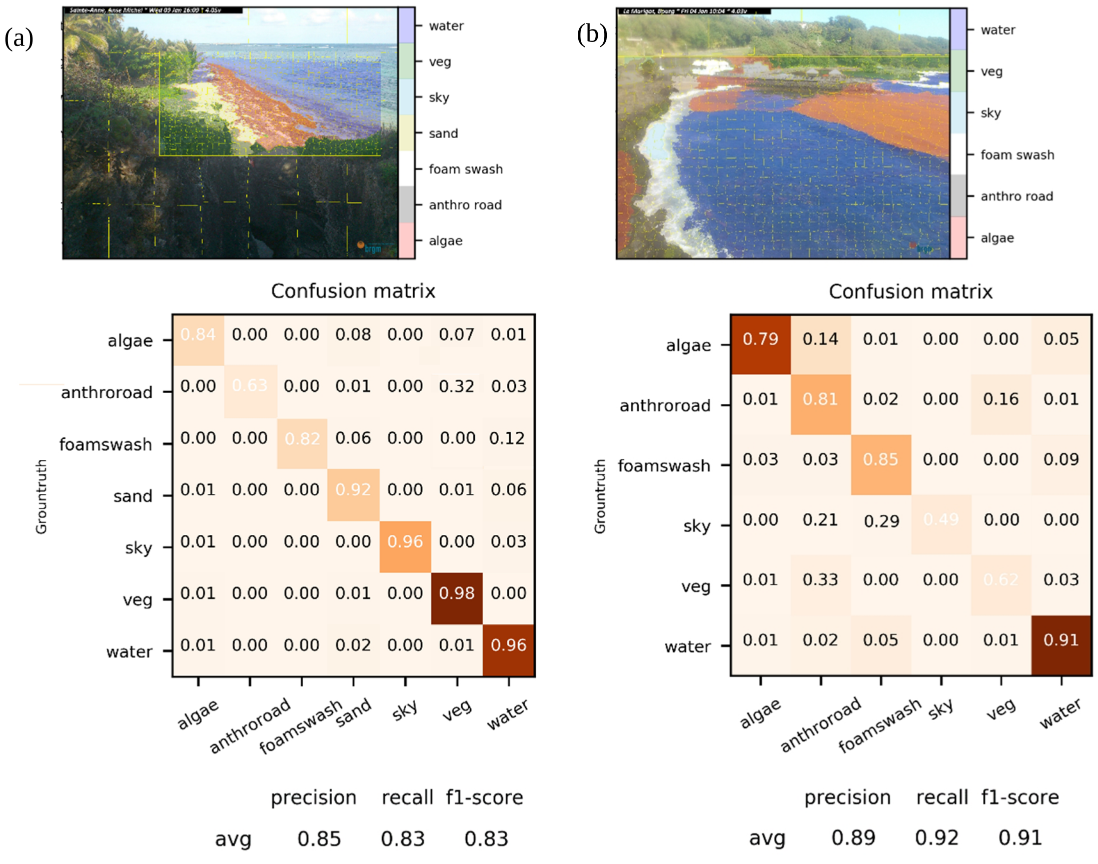

Figure 3 Results related to two different morphological class cover, beach (a) and harbors (b) condition. **Top:** example of a semantic segmentation prediction output. **Bottom:** Confusion matrix and comprehensive metrics for classification assessment.

4. Conclusions

The study demonstrated the opportunity of applying advanced, but still computationally affordable solution of deep-learning neural network aiming classification of image patches. A new methodology has been introduced and a workflow for the implementation of a warning system has been described. This warning framework is being validated for becoming, next, fully operative in assistance to the local municipalities and French agencies for managing beached *Sargassum*.

Furthermore, by employing local meteo-oceanographic parameters, simple empirical relations for trying to evaluate the persistence and departure of the algae, stranded ashore, are being investigated.

Such study will promote further development from a numerical point of view, i.e. would be helpful for investigating the exploitation of such temporal series of stranded algae for the validation of ocean circulation models and/or assimilation strategy for local hydrodynamic models.

Concluding, integrated management approaches are necessary for the adaptation of such *Sargassum* mass events and by a structured coupling of forecast models and observations onsite would allow to respond more effectively and implement timely and adequate mitigation strategies and management plans.

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