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# WAVELET BASED TEXTURE MODELING FOR PANCHROMATIC VERY HIGH RESOLUTION IMAGE CLASSIFICATION: APPLICATION TO OYSTER RACKS DETECTION

*O. Regniers*<sup>a</sup>, *L. Bombrun*<sup>a</sup>, *V. Lafon*<sup>b</sup>, *A. Dehouck*<sup>b</sup>, *C. Tinel*<sup>c</sup>, *C. Germain*<sup>a</sup>

<sup>a</sup> Laboratoire IMS, University of Bordeaux, Talence, France - <sup>b</sup> Geo-Transfert, Talence, France –

<sup>c</sup> CNES, Toulouse, France

[olivier.regniers@ims-bordeaux.fr](mailto:olivier.regniers@ims-bordeaux.fr)

## ABSTRACT

This study evaluates the potential of wavelet-based texture multivariate modeling for the detection of cultivated oyster fields and their differentiation from abandoned fields in Very High Resolution panchromatic PLEIADES data. The proposed models are tested in a supervised classification context using a training database composed of extracted image patches representative of the land covers of interest. The obtained classification results exhibit high detection rate for cultivated fields. Classification errors appear however in the detection of abandoned fields. These results demonstrate the interest of such model for the characterization of intertidal ecosystems and opens up perspectives for their use in the management of oyster farming activities.

**Index Terms**—Texture analysis, classification, very high resolution, wavelet, oyster culture.

## 1. INTRODUCTION

Very High Resolution (VHR) imaging has been widely used in coastal monitoring for purposes such as coastline change detection or coastal resource management. Previous works using VHR airborne data showed the interest of such high resolution data for oyster reef monitoring [1-2]. Recent VHR spaceborne sensors (e.g. PLEIADES, GeoEye, WorldView, Ikonos) enable to capture the geometric properties of small landscape objects. Inland, this is for instance the case for vegetation rows in vineyards, orchards and young trees in managed stands. On coastal areas, this is also true for oyster racks. The classification of such land cover types displaying regular patterns could therefore be improved by considering inter-pixel dependencies to represent the spatial organization of these patterns.

Approaches using textural analysis have proven to be a valuable solution in this VHR classification context. Various tools such as Grey Level Co-occurrence Matrices (GLCM), variograms or wavelet representations are commonly used to characterize textured land covers [3-5]. These approaches

enable to statistically analyze the local spatial dependency between a pixel and its neighboring pixels. Descriptors can be extracted from these statistics providing small-sized representation of the textural content. These descriptors can be further used as input in a classifier or a segmentation algorithm.

Many works in textured image recognition have shown that the wavelet representation is a well-adapted domain to characterize texture, yielding to a multi-scale and multi-orientation analysis scheme in which each wavelet subband is modeled separately. Some authors investigated the modeling of the empirical histogram of wavelet subbands using univariate models such as the Generalized Gaussian Distribution (GGD) [6]. Nonetheless, these approaches do not fully exploit the textural information as they do not explore local spatial dependencies. To overcome this problem, some works have pointed out the pertinence of considering multivariate modeling such as multivariate GGD [7], Spherically Invariant Random Vector (SIRV) [8-9] and copula-based models [10] in order to take into account this spatial dependency of wavelet coefficients.

Here, we investigate how these multivariate models applied in the wavelet domain can help in the characterization of an inter-tidal ecosystem. In particular, we focus on the differentiation of cultivated and abandoned oyster fields in a supervised classification context.

This paper is structured as follows. The next section presents the image data as well as the test site with a brief description of the oyster farming activities in the area and their related management problems. The third section describes the proposed methodology with details on the feature extraction step. Finally, the results, discussion and conclusions are detailed in the last two sections.

## 2. STUDY SITE AND DATA

The study site is located in the Arcachon Bay, a mesotidal lagoon of 180 km<sup>2</sup> located on the French Atlantic coast. In this ecosystem, shell farming and in particular oyster farming is an important economic activity. Recently, it

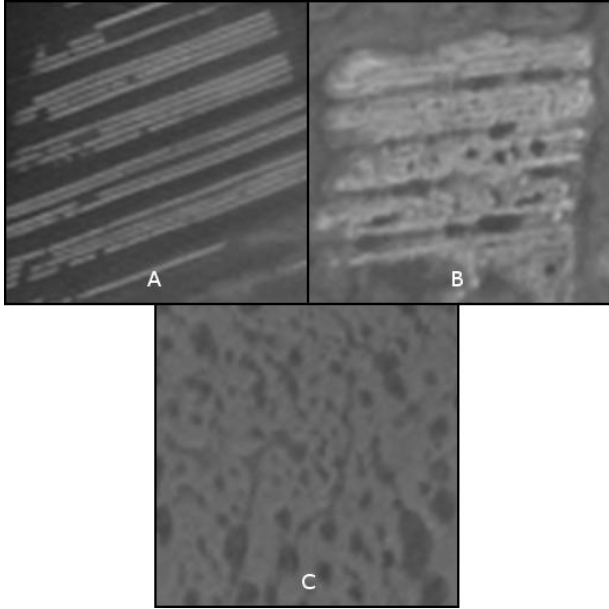


Fig. 1. Texture classes. A – Cultivated oyster racks, B – Abandoned fields, C – Foreshore.

underwent recurrent lethal crisis that implies the necessity to improve management operations of both farms and natural growing areas. Areas occupied by oyster cultures in the Arcachon Bay are indeed in a constant evolution, some parks being abandoned and others re-cultivated. An environmental management tool used for mapping oyster-farming activities of the Arcachon lagoon was previously designed [11]. It is based on a semi-automatized detection method of the nature and status (clean/dirty) of oyster farms. It exploits very high resolution remote sensing imagery and uses texture indicators derived from Grey Level Co-occurrence Matrices to extract oyster field contours. Although interesting in the first steps of the oyster fields mapping since it enables to detect oyster fields either cultivated or not, this strategy does not allow discriminating the first from the second ones. Therefore, an alternative methodology has been developed in order to map cultivated parcels.

To achieve this objective, we used the panchromatic band of a PLEIADES data acquired at low tide on 25 April 2013. It covers a large central part of the Arcachon Bay where oyster farming is predominant. The PLEIADES sensor provides a VHR panchromatic band with a 0.7 m resolution resampled to 0.5 m. Oyster racks typically have a width of 1 m. The level of precision provided in the PLEIADES panchromatic band is thereby sufficient to clearly distinguish them in the image (Fig. 1-A).

### 3. METHODOLOGY

The methodology used in this study is divided in two steps. The first step is dedicated to the training phase during which

a textural feature set is extracted from each image patch of a training database using wavelet-based multivariate modeling. In the second step, the supervised classification process is carried out on an extract of the PLEIADES panchromatic band corresponding to an area of interest. Both steps are detailed below.

#### 3.1 Feature Extraction

In order to perform the classification, a training database was created by extracting image patches (128x128 pixels) representative of three identified classes of interest: cultivated oyster racks, abandoned oyster fields and foreshores (Fig.1). Prior to the feature extraction, an orthogonal wavelet transform (Daubechies filter db4) is applied on each of the image patches. Two scales and three orientations of decomposition are applied leading to the production of six wavelet subbands.

In each of these subbands, the wavelet coefficients located in a 3x3 neighborhood around the current spatial position are clustered in a random vector  $k$ . The dimension of each observed vector  $k$  equals 9 (3x3). The distribution of these observations can be further modeled using multivariate probability density functions (pdf) whose parameters are estimated according to the maximum likelihood principle.

In this paper, we consider a generalization of the multivariate Gaussian distribution, i.e. the Spherically Invariant Random Vector SIRV. In SIRV-based models, the observed vector  $k$  can be decomposed as  $k = \sqrt{\tau}z$  where  $\tau$  is a scalar random variable called the multiplier and  $z$  a real independent Gaussian vector with zero mean and covariance matrix  $[M]$ . The multiplier  $\tau$  is used to modulate the Gaussian distribution of vector  $z$  to better fit the heavy-tail behavior of the wavelet coefficients. Various models were proposed in the literature to represent the multiplier  $\tau$ . Here, we chose a configuration using an inverse gamma distributed multiplier  $\tau$  leading to a SIRV  $k$  vector with a  $G^0$  (student-t) distribution (SIRVg0 in the following) [9]. For each image patch, a feature vector containing the estimated covariance matrix and the parameters of the multiplier distribution is extracted for each wavelet subband.

#### 3.2 Supervised Classification

In order to stay in an object-oriented context, the image to classify is first segmented using a Mean-Shift algorithm [12]. The result is deliberately over-segmented (Fig. 2) to preserve the contours of the small oyster fields (minimum region size = 100 pixels).

The classification is performed according to the maximum likelihood principle. The same wavelet decomposition as the one used during the training phase is applied on the extract of the PLEIADES panchromatic data to classify. For each region of the pre-segmentation, a likelihood criterion is computed between the observed local

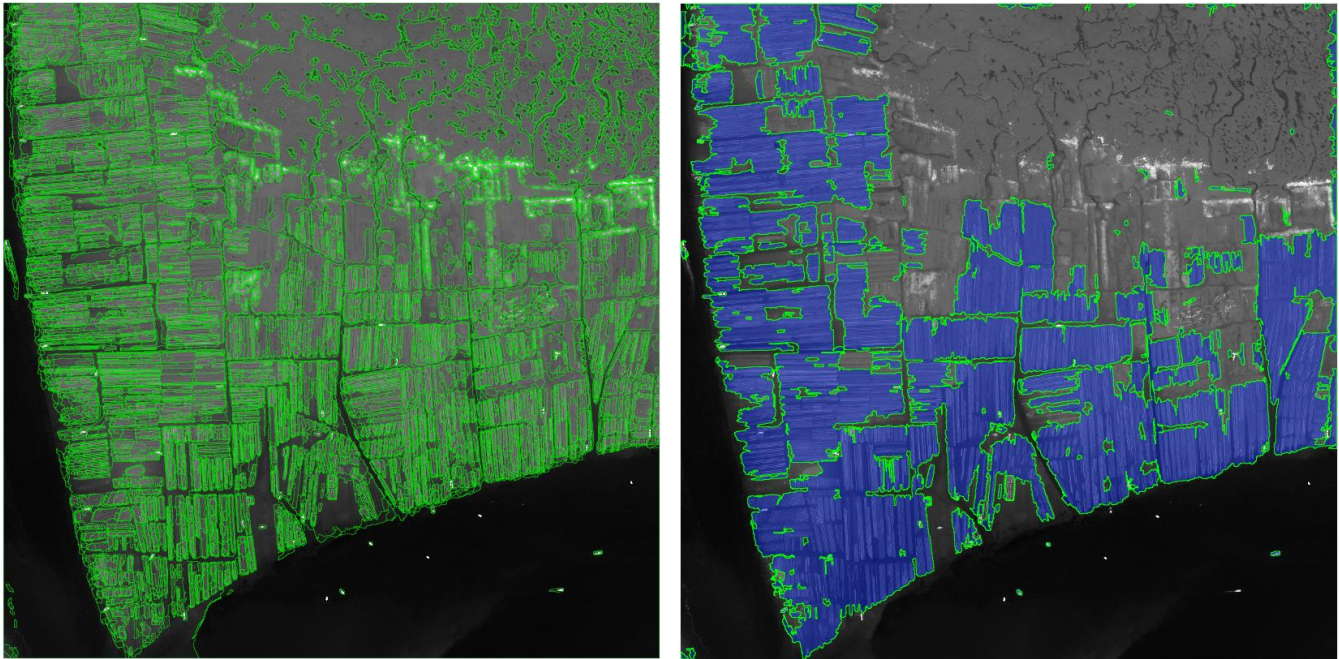


Fig. 2. Left – Pre-segmentation obtained by Mean-Shift (green lines indicate the limits of the regions).  
Right - Classification results obtained with SIRVg0 wavelet-based models.

spatial dependencies of the region and the SIRVg0 models estimated during the training stage. The region is then labeled according to the class of the patch maximizing this likelihood criterion.

#### 4. RESULTS AND DISCUSSION

Classification result obtained on an extract of the PLEIADES panchromatic band with SIRVg0 wavelet-based model is shown in Fig. 2. Overall, cultivated fields are visually well detected and well separated from abandoned fields confirming the interest of such multivariate models for the detection of oyster racks.

This result along with classification results obtained on three other areas of interest in the Arcachon Bay were further validated with *in situ* observation data (Natura 2000 at Sea and Direction Départementale des Territoires et de la Mer de Gironde) as well as with the oyster parcel plan for a total of 1021 validation points. Each point indicates whether it corresponds to cultivated or abandoned fields.

Oyster racks are well detected with a producer's accuracy of 98%. Detection errors occur nevertheless in partially submerged areas where the contrast between oyster racks and their surroundings is reduced. Besides, in a significant number of cases (66 out of 405 points), abandoned parks are misclassified as cultivated parks. These classification errors are mainly due to the presence of recently abandoned racks or of dense unstructured abandoned parks, both sharing common characteristics with cultivated fields. The overall accuracy is nonetheless satisfactory (92%) and the classification result provides an

efficient separation between the cultivated parks and the abandoned fields.

#### 5. CONCLUSION

We investigated the interest of wavelet-based texture modeling using SIRV-based models for the detection of cultivated oyster racks in VHR PLEIADES panchromatic data. The obtained supervised classification results showed that these models enable to efficiently detect cultivated racks and differentiate them from abandoned fields. Nonetheless, some classification errors occur.

Improvements in the characterization of abandoned fields could probably be achieved with the use of other type of classifier such as SVM. Considering filtering operations such as anisotropic diffusion filters prior to the pre-segmentation could also enhance the quality of the contours of the regions to be classified and further improve classification results.

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