Algorithm for estimating distance between waves crests using coastal images RGB from Google Earth.

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Abstract

Studies about sea waves go from their structure until the effects caused by their interaction with the coast border. Energy estimation of the waves, stream direction and intern waves estimation researches with the aid of aerial and radar images are quite extensive. One of the main object of oceanology studies is the coral reef barrier due that they are ecological and physical structures that diminish a big fraction of the swell strength and also sustain high levels of marine coastal biodiversity. Actual climate change and global warming are leading to the degradation of reefs structures; so, surveillance tools for monitoring changes, degradation or loss of those important structures are more needed that ever. This study introduces an easy methodology for the analysis of the waves energy dissipation before and after they hits the reefs, extracting automatically information about wave distance, central line and width of their crests from Google Earth images and Stitch Maps program. Information from the images is extracted using just digital image processing and plane geometry tools. Despite the low spectral resolution of this kind of images, this study demonstrated that they are very useful for quick analysis of wave behavior and also to analyses its loos of energy when they collide with the reefs, also permitting to analyze, in a subjective way, changes in the coral reef.

Keywords: Digital Image Processing, reefs

1. INTRODUCTION

Reefs are physical structures that dissipates a big part of the force of the waves, either by breaking or by friction (Pascal et al, 2016), in addition to being ecologically important in the maintenance of it associated biodiversity (Kiessling et al, 2010; Stella et al. 2011). From 90-97% waves generated by the wind are absorbed by the reefs and lose 84% of the

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height of the wave (Ferrario et al, 2014) decreasing in a significant percentage the damages in the coasts by effect of natural disasters. The development of methodologies for evaluation, monitoring and analysis of data from these ecosystems it is primordial requirement for caring of that environment.

The more common kind of images in this field are radar images, which are capable of represent intern waves due that they are particularly sensitive to any changes in superficial roughness in small scales (i.e., capillary and ultra-gravity waves) present on the surface of the ocean and that they are altered by the velocity field associated with the internal waves (Rodenas et al. 1997; Henfridsson et al, 2007). Comparison of the radar-determined spectra and surface currents with measured data indicates that the radar system technique and the analysis technique both obtain consistent results (Young et al, 1985; Senet et al, 2001).

Since the 1970s, aerial photographic images, multispectral radiometers and synthetic aperture radar images obtained by spacecraft have focused their efforts on studies of high-frequency, nonlinear internal sea waves. Many works with optical images pursuit the objective to detect stream direction and others use aerial images in the infrared band to measure sea depth (Dugan et al, 1996). Techniques such as Fourier analysis have also been used to extract quantitative wave information in both photographic and electro-optical images (Barber, 1949; Chapman & Irani, 1981; Lubard et al. 1980, Gotwols et al, 1980).

The aims of this study was to estimate the distance between wave crests using Google Earth images in the optical band with the objective of analyze the variation of the distance between waves before and after the reefs. The satellite images used for the study are transformed using digital image processing tools and taken to a black and white raster thematic map. Seeking to automate the data collection for calculations on energy dissipation in these areas and to be able to analyze the images in the shortest time possible, was developed a program in Python 2.7, PyQT4 and OpenCv, named as ACOPI-olas, still in initial version.

2. METHODOLOGY

Our work methodology was as proposed in the flowchart shown in figure 1.

Some images acquired with Google Earth and Stitch Maps programs have lighting differences within the image. In the coastal lower zones, where the waves are dissipated by reefs, their forms lose visibility needing some transformations to highlight these waves. The goal of transforming the RGB image into a black & white image is to build a thematic map, where target class are the wave crests represented in white and the rest of the image is all black. In this study, analyzed coastal images were improved using the Cross Track Illumination Correction filter to be able to diminish the great diversity of the target

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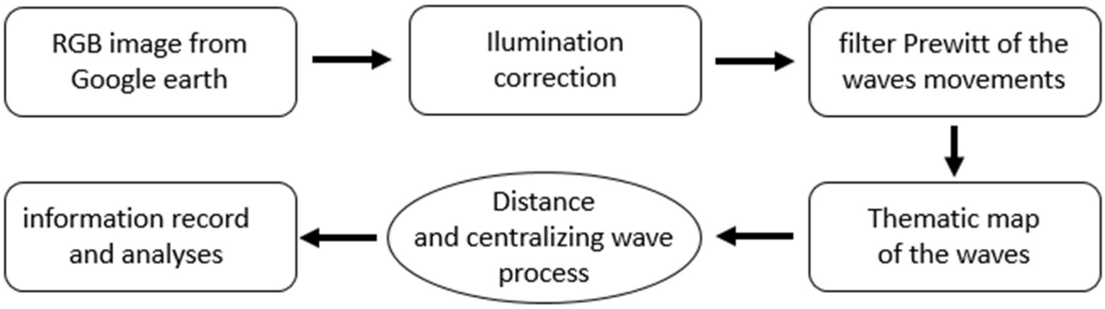

Figure 1. Methodological diagram.

First, we used one RGB Google Earth image of the Jardines de la Reina archipielago coast, Camagüey, Cuba (Fig.1), with spatial resolution of one meter.

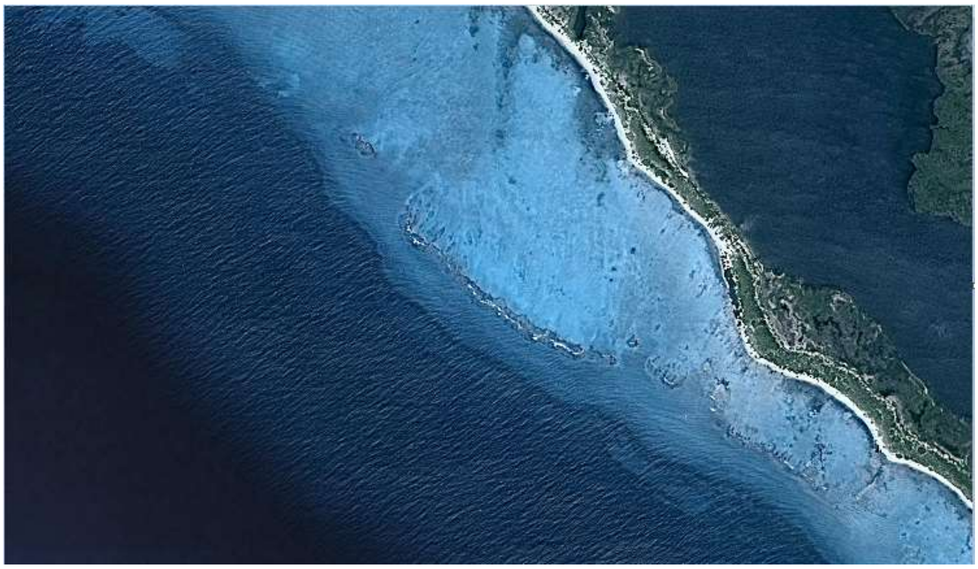

Figure 2: Google Earth image of a fraction of Jardines de la Reina archipielago.

The crests of waves follow certain patterns of shape, tone and direction by the stimulated by wind action. Taking into account that between the waves and the seabed exists a wide contrast, a high pass filter is able to highlight well the borders of each ridge using Cross Track Illumination Correction filter. This type of filter isolates the high frequency components since it accentuates them while letting the low-frequency spatial components pass.

2.1. Images transformation

High pass filters are mostly studied as edge enhancement or edge detection techniques, which transform an image by highlighting the detail of the edges or borders of objects. These contours can be used in subsequent image analysis operations for the recognition of objects or traits. Edge enhancements are implemented through spatial filters.

Prewitt gradient operator determines a directional edge enhancement that generate eight gradient images from an original image (Gonzalez & Woods, 2002), each of which highlights the edges oriented in one of the following eight directions: north, south, east, west, southeast, northwest, southwest and northeast. The corresponding convolution masks (Chuvieco, 1996) for a 3x3 window are shown in Fig.3.

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1	1	1	-1	-1	-1	-1	1	1	1	1	-1
1	-2	1	1	-2	1	-1	-2	1	1	-2	-1
-1	-1	-1	1	1	1	-1	1	1	1	1	-1
	norte			sur			este			oeste	
-1	-1	1	1	1	1	1	-1	-1	1	1	1
-1	-2	1	1	-2	-1	1	-2	-1	-1	-2	1
1	1	1	1	-1	-1	1	1	1	-1	-1	1
	sureste			noroeste			suroeste			noreste	

Figure 3: Convolution masks for a 3x3 window in 8 directions (Chuvieco, 1996)

The crests of waves follow certain patterns of shape, tone and direction created by the influence of the wind. Taking into account that between the waves and the seabed there is a wide contrast, a high pass filter is able to highlight well the borders of each ridge. This type of filter isolates the high frequency components since it accentuates them while letting the low-frequency spatial components pass.

The image transformed by the filter has a clear tonality, and target are in a lighter tone than the rest, meaning that from a threshold determined by the specialist, all those values will correspond to the waves peaks. Due to the fact that the image is quite clear, it is necessary to make a histogram adjustment to increase the contrast and find a more appropriate threshold. By adjusting the histogram with a tool called "Stretching interactive" we adjust the outlier values of the histogram without affecting the information of interest of the image.

After finding the right threshold we divided the histogram into 2 classes, one of which be the targets, wave crests plus clear spectral response all bands present in other regions of the image. The other kind of non-interest will be the black background, and thus create the desired raster thematic map (Fig. 4).

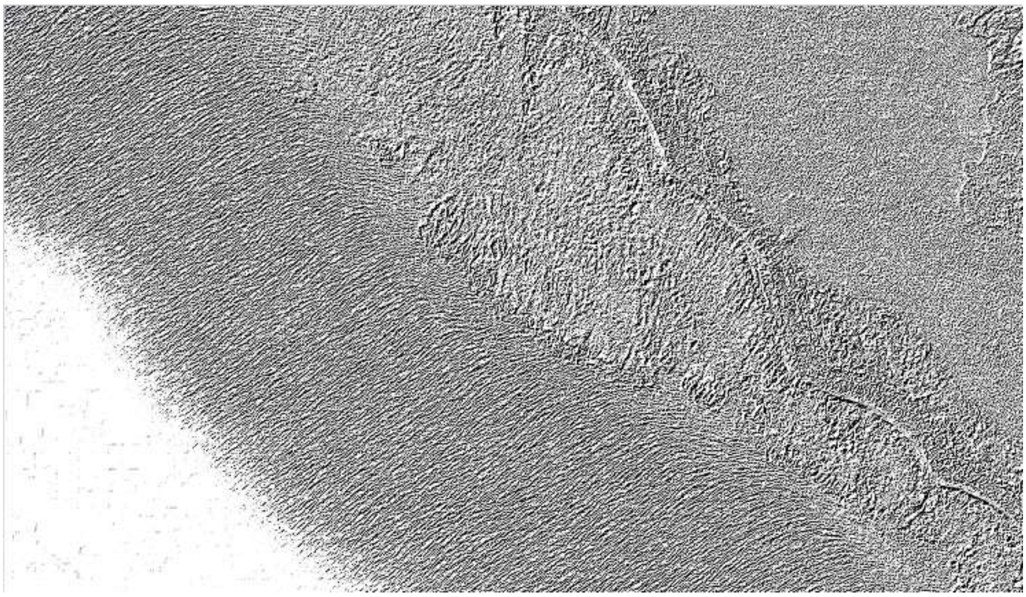

Figure 4: Raster thematic map of wave crests and light spectral objects.

These raster thematic map contain objects classified as target class that should be transferred to the non-interest class.

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Within these areas is everything that is on the coastline for land and a part of the sea that has no information captured by the sensor. To solve this problem, it is proposed to create a mask from a vector (shape) that could be constructed manually or through an unsupervised classification since these limits do not require more details. The raster map result will only have information about wave crests in a white tone and the rest of the black, and this will be the input image to the software ACOPI-waves, developed in the framework of this research to analyze the distances between waves.

2.2. Wave crests centralization method

In order to automate the processes for image analysis and to acquire a larger volume of data in less time, a program with the name of ACOPI-olas was created, developed with Python 2.7, PyQT4 and OpenCv (patent solicited, all rights reserved to the Institute of Cybernetics, Mathematics and Physics (ICIMAF) of Ciudad de La Habana, Cuba).

ACOPI-olas has two algorithms with different purposes:

- To calculates and show the central line of all waves in the image
- Distance calculation between waves on parallel profiles in the direction determined by the specialist.

These two methods were tested to calculate the centerline of the wave crest. The first method has two ways to calculate the center of the wave crests, analyzing both in the horizontal and the vertical the pixels other than zeros and adjust the center of intervals formed by continuous white pixels. In the second method, the adjustment of the center was performed with the center points of the circumferences circumscribed in the white objects. The center of a circle inscribed on the crests of the waves coincides with the center of the crest in that region, we need just moving the first center located and to adjust the diameter of the next circle (Fig. 5). These methods permit the construction of a significant data set allowing to extract the distances between crests that have the highest values, the shortest distances between crests and the average width of each of the crest.

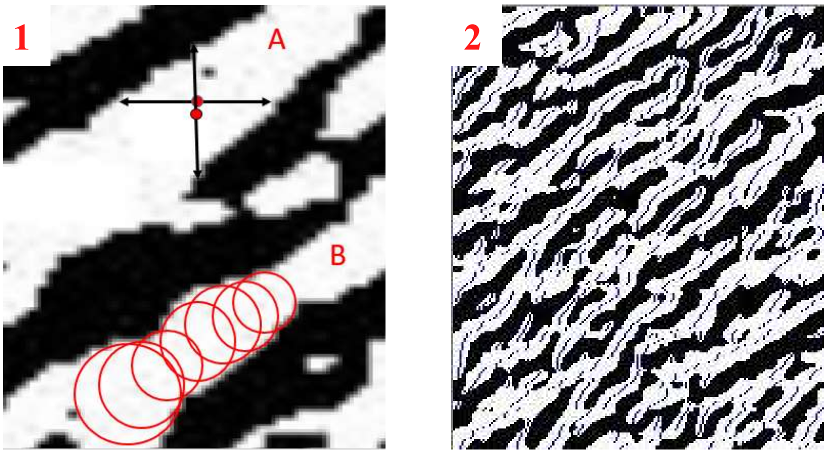

Figure 5: Methods tested to calculate the centerline of the wave crest 1: A Center of vertical and horizontal intervals, B center points of the circumferences circumscribed in the white objects (waves). 2: Image clipping with the centralized line obtained with method A.

The second calculation facilitates to the specialist choosing two points of the image to collect information on parallel linear profiles automatically building from these points. On each parallel profile the distance between each wave will be read (Fig. 6). Each of these profiles will keep a list of distances between the waves that are traversed by the profile and a statistical analysis returned to the specialist with the data collected. The parallel lines in red (Fig. 6B) represent the profiles by which the distances between waves were calculated, such profiles take x-distant information in the direction of the profile of the whole image. It is possible that a profile does not contain any saved distance values, in these cases it means that the profile was built in a region belonging to the terrestrial area and that after the transformation of the image is left with gray values equal to zero. The data collected by the profile is saved automatically in an Excel table and each column represents a profile, giving the possibility to the specialist to analyze the sudden changes between the values.

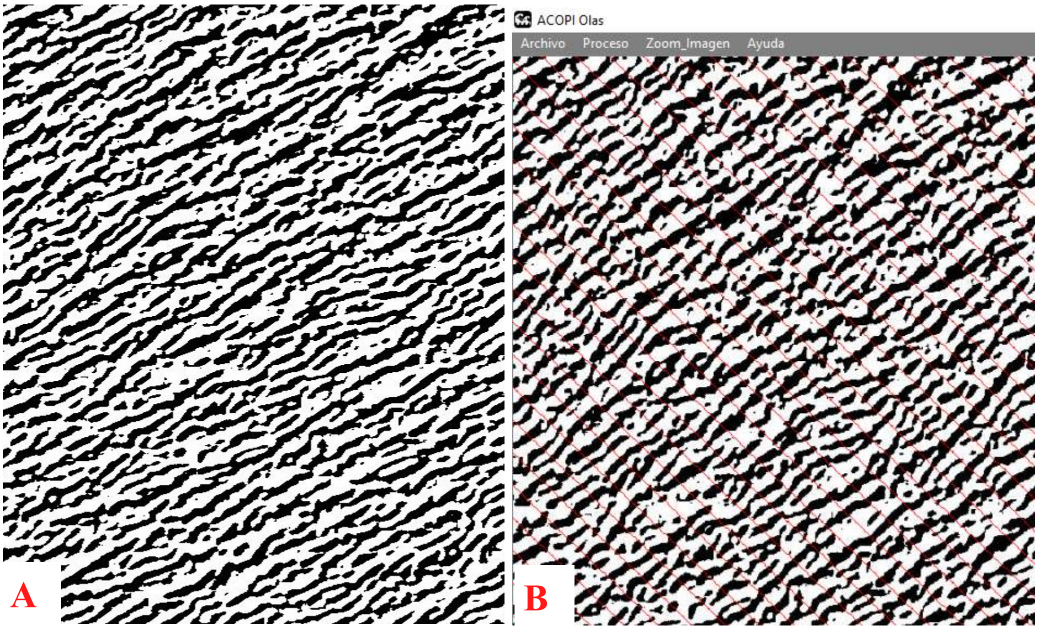

Figure 6: A, image clipping from the tested image, white objects representing the waves, black objects the background; B, image clipping from the software environment with profiles drawn in red.

3. RESULTS AND DISCUSION

Prewitt filter in northeast direction describe well the wave crests with less contrast founded in the original image. In the zone nearest of the coast line, waves do not have organized or visible patterns as those one that are found before the reef (Fig. 2), nevertheless, the filter is capable to highlight the objects in these area.

With the method that calculates central points in the circumscribed circumferences in the target objects (Fig.5A) were obtained better results than with the other method that analyze both in the horizontal and the vertical the pixels. The distances calculated in the image were more homogeneous before interacting with the reef; also, the lists of distances in the profiles before interacting with the reef have a greater number of distances recorded than the profiles closest to the coast. It means that the crests described by the directional filter in the regions near the coasts are wider and less organized, as a result of having had contact with the reefs and lost much of the energy.

ACOPI-olas manages to measure the distances between waves to analyze the loss of the energy of these when they interact with the coral reefs and allows to save all the information obtained from the images analyzed. For the moment, this program is in its initial version, since it needs other statistical tools to facilitate the analysis of the results, as well as the implementation of statistical graphs, besides that it is still not possible to make the transformation of the images in it.

4. CONCLUSIONS.

Our results show that it is possible to automate the measuring process of the distance between waves in RGB images of Google Earth. The algorithms implemented in the ACOPI-waves are able to estimate the central line of the waves and the distances between waves of waves by parallel profiles; the software also has the advantage that the information generated is saved in an Excel file automatically. The user interface of the program is simple and easy to use for researchers who need to do analysis from these coastal images.

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