Determination of the coastline, the dissipation zone and basic wave parameters through video images by remote observation

Benjamin Fell[1], Roberto Agredano Martín[2]

[1] Pontifical Catholic University of Chile. E-mail: bfell@uc.cl
[2] Pontifical Catholic University of Chile. E-mail: ragredano@uc.cl

Abstract. The time-averaged video images of the coastal area show the wave breaking processes as one or more white bands a in the longshore direction, which correspond to the preferred location of submerged sand bars that cause dissipation due to breakage of the surf. Starting from a known bathymetry profile, the position of these dissipation zones can be predicted through wave transformation models. Due to this fact, the possibility of estimating bathymetries through video observations by processing the observed intensities is proposed. The objectives of this paper are: 1) to present a time-averaged video image processing technique to determine both the position of the coastline and the wave dissipation zones (break zone),

Keywords: dissipation, wave break, coast, breaker

1. Introduction

The importance for this project is based on the difficulty that arises to estimate the bathymetry of coastal areas by conventional means based on sonar or acoustic measurements with amphibious ships since, as well as being very expensive, they do not work well in areas as energetic and dynamic as those that concern us.

Coastal zones up to 10 meters deep are very important when planning and managing these environments, producing relatively rapid changes both due to erosion and accretion. The use of these image processing techniques allows obtaining data faster and with less operational cost, allowing more efficient management.

For this reason, this type of applications based on video observation has begun to be studied, which are then complemented with depth prediction models.

For the research to which the study presented in this document refers, an exhaustive study of averaged images and time-stacks images was necessary (Figure 1), since being real images in the open air they have great variability in terms of climatic conditions. An attempt was made to find the optimal relationship for the initial processing with respect to noise and lighting, in order to later detect the break zones as best as possible and determine parameters such as period, wavelength and speed.

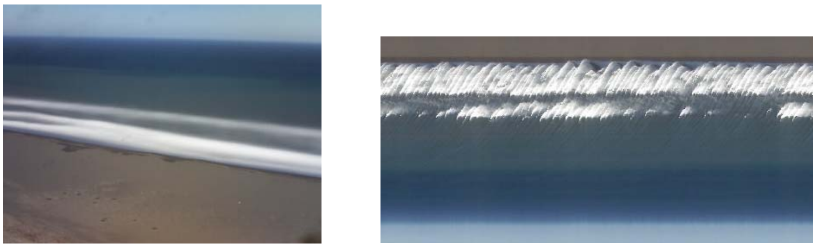

Figure 1: Averaged image (left) and time-stack image (right) taken by a coastal video monitoring system. Source: Department of Environmental Hydraulic Engineering of the Pontificia Universidad Católica de Chile

2. State of the art

In the early 1990s the Oregon State University Coastal Imaging Laboratory introduced the use of video coastal monitoring. They developed the Argus system, which is used worldwide in coastal research and management. From here, video monitoring is considered an efficient tool to analyze the morphology of beaches and their evolution over time.

Due to the evolution of cameras and video technologies, many systems have been developed for coastal monitoring purposes in recent years. [1].

As early as 1989, TC Lippmann and RA Holdman [1] propose a technique for determining the morphology of sand bars based on the detection of the wave dissipation zone using averaged video images.
Cameras used for these purposes typically collect images in real time at specific time intervals. These images are called “snapshots” and are made by specific software[2].
The processed images are mainly classified into:

- Time-averaged images

They are obtained by processing and overlaying snapshot images where random ocean conditions and run-up and swash variability are eliminated. [3]. Variations in the intensity of the color will make it possible to better distinguish the morphological characteristics of the beach. They are also an excellent instrument for determining the topography of submerged sand bars.

- Time-stack images [4]

They are created by extracting a line of pixels along a predefined profile in the video frame and for a selected period of time. They are useful images to extract information on morphological characteristics of the beach, crossshore variations, run-up and swash.

The most recent works carried out in this direction are those carried out by Stefan GJ Aarninkhof and BG Ruessink [5] [6]. In these investigations, a model called SBM (Subtidal Beach Mapper) was proposed to find the break zones near the coast.

Other more recent studies are those that propose [7], where the determination of the Illumination intensity is performed along evenly spaced transverse profiles to find morphological patterns in the break zone. These are mainly directed to coasts with great morphological variability in the transverse direction.

3. Proposed method

To make this study representative, method checks were performed on a series of images covering the widest possible lighting and climatic conditions. All images were provided by the Department of Hydraulic and Environmental Engineering of the Pontificia Universidad Católica de Chile. These are images of the coast in the Maule Region, specifically in the area of the mouth of the Mataquito River. Fixed cameras are installed in this area that take two photos per second, then the averaged image of all of them is obtained every 15 min, so we will have images at different times of the day, and therefore lighting, and with different weather conditions depending on the selected day. We also have another group of images, previously called time-stacks.

The two types of images were treated separately. This is why the proposed methods are presented for each of the images and objectives to be obtained from each of them.

The development of the codes used was in the Matlab software, so all the commands described will refer to the programming language of said software.

Time-averaged images

The proposed method consists of processing the images in shades of gray, applying the Otsu segmentation technique. [8].
Initially, the image in shades of gray is increased the contrast with a basic tool for the transformation of the intensity,

```
g = imadjust (f, [low_in high_in], [low_out high_out], gamma)
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As illustrated in Figure 2, this function transforms the intensity values of the image f to new values in g. The gamma parameter specifies the shape of the curve and, if omitted, takes the value 1.

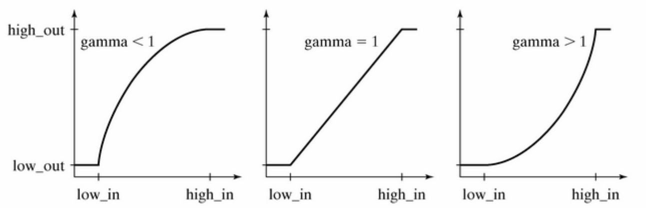

Figure 2: Operation of the imadjust command to transform the intensity values of the image into grayscale.

Then the Otsu technique itself is applied, which is a segmentation technique used when there is a clear difference between the objects to be extracted from the image and the background. In the case of our images, we will have two clearly differentiated areas that are, land and water.

The Otsu method is a non-parametric procedure that selects the optimal threshold by maximizing the variance between classes through an exhaustive search.

where is the total mean intensity and are the binarization levels. Otsu showed that the optimal threshold was the , with 1 <t <L (number of classes).

It has the advantage that it is a method that responds well to most situations in the real world (noisy, poorly lit images, ...) and does not require supervision since the threshold search is automatic.

Time-stack images

To calculate the wave parameters, the time-stack images were analyzed:

i) Wave speed

To calculate the speed of the swell, it was first necessary to find a representative place in the image to extract samples, since the lines that separate one wave from the next in the image vary their slope depending on how far it is from the coast (at The shorter the distance from the coast, the slower the waves are due to the compaction suffered by the wave due to the positive slope of the seabed). For this, a horizontal line was defined that is calculated by means of a method that finds the break zone of the image (which has a lot of intensity on the gray scale) and defines a rectangle just below the break zone to then apply the Canny method and get the edges of the image.

Diagram 1: Methodology to calculate wave speed. (Source: self made).

Having a binary image of the edges between waves, we proceeded to use the Hughes method to obtain the 10 most representative lines (most regular), calculate their slope and average them to obtain approximately the real speed of the waves in that period of time.

ii) Wavelength, period and wave frequency

To calculate these parameters, the following methodology was used:

Diagram 2: Methodology used to calculate wavelength, period and wave frequency. (Source: self made)

To obtain these attributes, it was first necessary to increase the overall contrast of the image using the command *imadjust ()* explained above, where the intensities of the grayscale image are mapped in such a way that only 1% of the pixels will be saturated in the high and low frequencies of the original image.

From the contrasted image, it was more effective to apply a high-pass filter in the frequency domain (obtained by the Fourier transform), and thus obtain the separations between each wave. The filter used is shown below.

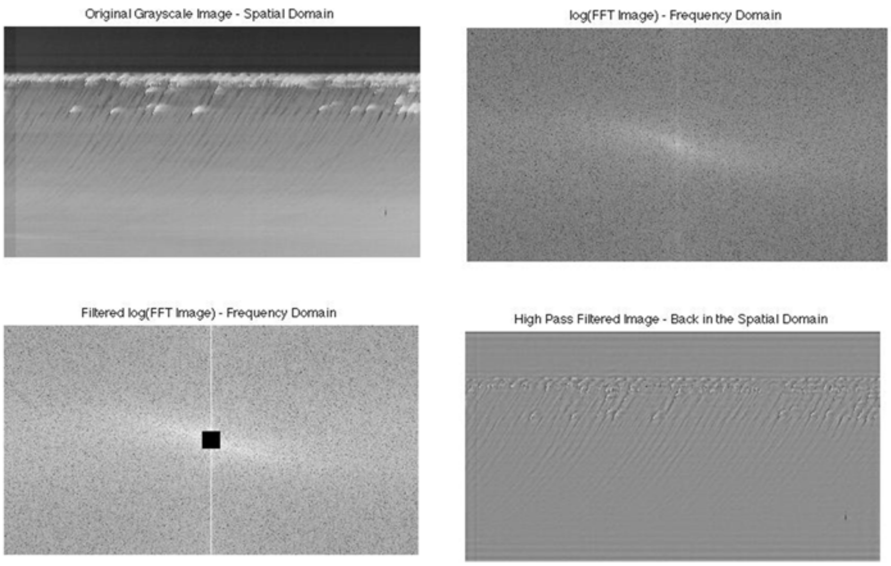

Figure 3: Application of a high-pass filter in the frequency domain to a time-stack image. (Source: self made)

After getting the edges of the image from time-stacks, it was easy to segment the waves. It was segmented with a normal high-pass filter on the median grayscale of the image. A binary image of segmentation of the wave itself was obtained, where the white area corresponds to the wave and the black area corresponds to the separation between one wave and the next.

Finally, the average width of the waves was calculated. To obtain this measure, a horizontal line was defined in the same way as in the methodology to obtain the wave speed. With a horizontal cut line representative of the swell, an algorithm was programmed that traversed the line, saving the width of each wave to finally calculate an average of these. This last value is used to obtain the wavelength, the period and the frequency of the swell.

4. Experiments and results

Images averaged over time

The techniques described in the methodological section were applied to a series of nine images. They were chosen so that there was a wide range of lighting characteristics and weather conditions to make the experiment as representative as possible.

To estimate the functionality of the method, a group of ideal binary images was used for comparison with the images resulting from the experimentation. For the coastline it is compared that it is within a delimited zone, and for the breaker that it adjusts to the shape of the dissipation zone in each case. Ideal binary images were created on expert judgment.

Figure 4: Ideal binary images for comparison with the results of the experiment. Coastline region (left) and surf zone (right). (Source: self made)

It is shown in Figure 5 an example of the coastline and the surf zone determined for one of the treated images.

Figure 5: Determined coastline represented on the original image (left) and determined surf zone represented on the original image (right). (Source: self made)

The results are presented in the Table 1 where the true positives (VP) and false positives (FP) are shown for both the shoreline and the break zone, as well as the VP rates and FP rates for the break zone. This is because for the coastline it is verified that it is within a selected zone, while for the surf zone the real shapes are compared with those found in the experimentation.

COAST LINE									
	Img1	**Img2**	**Img3**	**Img4 Img5**		**Img6**	**Img7**	**Img8**	**Img9**
VP	8567	9311	8626	8713 8979		8690	8583	8582	8745
FP	0	0	0	31 0		0	0	0	0

BREAKER AREA					
	Image 1	**Picture 2**	**Picture 3**	**Picture 4**	**Picture 5**
VP	58081	90161	71261	137434	162798
FP	10732	18595	16934	20912	25353
VP rate	0.700717	0.775112	0.816539	0.874885	0.875333
FP rate	0.00559	0.009685	0.00882	0.010892	0.013205

BREAKER AREA				
	Picture 6	**Picture 7**	**Picture 8**	**Picture 9**
VP	156357	78328	124363	98129
FP	33001	34111	10427	19916
Rate VP	0.924927	0.872638	0.807049	0.86668
Rate FP	0.017188	0.017766	0.005431	0.010373

Table 1: Results of the comparisons of the ideal binary images with the segmentations resulting from the experiments

In view of the results, for the coastline only in one of the experiments an error appears in its determination (Image 4), being a good result that for the eight remaining images a percentage of 100 is reached. %.

Regarding the break zone, the results are not so good but detection percentages of between 70 and 92% are reached, with an average of 83%, which can be considered acceptable and a good approximation.

Time-stack images

To test the results obtained with the processed images, mainly 2 stack-time images were used to program the algorithm and experiment with its effectiveness.

By calculating the wave speed and its wavelength, the following wave segmentation was obtained.

Figure 6: Wave segmentation in a time-stack image. (Source: self made)

It was not possible to obtain the real data since the areas where the images were taken are not registered in the meteorological sites. Even so, experiments were carried out and the results obtained were as follows.

Image	Speed (px / sec)	Wavelength
stack2	2.2784	9.1926
stack3	0.1425	10.0932

Table 2: Wave parameter results.

The results obtained are within the normal range of wave speed and wavelength according to the nearby coastal areas, so we can say that the results are acceptable.

5. Conclusions

This work presents a proposal for processing images of coastal areas in order to extract data from the waves and the surf at a specific time. The implementation of techniques such as Otsu segmentation, frequency filters, Hough transform or Canny edge detection were effective to attack this type of problem. It was possible to identify both the positions of the coastline and the break zones in different wave conditions as well as the most important parameters of the coastal zone with the methodology described.

The results for the identifications were good with a higher precision in the detection of the coastline. Regarding the results for the wave parameters, they are within the real normal ranges, so we can say that the algorithm presents a good relative performance. For these last data to be conclusive, they must be supported by field measurements of the real parameters at the time of obtaining the image.

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