Integration of Image Processing Tools for Monitoring Breakwaters Models

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Abstract

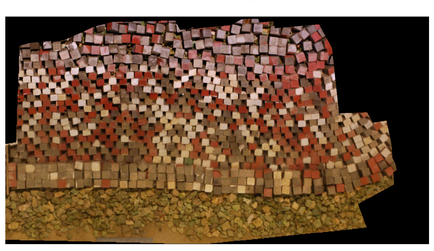
The protection of ports in coastal areas exposed to the action of the sea is carried by sea hydraulic structures (breakwaters) which are exposed to the influence of sea waves. The monitoring of the surface plates movement, constituting the protective mantle and the superstructure (concrete structure) is made by visual comparison of images obtained during follow-up visits. No quantification of these shifts is yet performed. In the design phase of a port protection structure, models are built to study the effect of waves on the protection blocks. During the testing phase waves are generated and periodically are measured the effects of waves in the model.
Presently, photogrammetric monitoring of the model ports is being held, including the use of orthophotos and point clouds to measure displacements of protection blocks. With these methods there were obtained results of the change in overall topography of the model structure. However the real 3D motion of each block is indeterminate due to the absence of data on the geometry of the blocks. The extraction of these geometric data from the images, along with the spatial data of the point cloud, will deepen knowledge of the intended movement.
This work presents an alternative monitoring solution based on image segmentation in order to obtain displacements of the model protection blocks so to monitor its development over time. Time sequence orthogonal images were obtained during the action of blocks movement. In this study, blocks are identified in the image and shifts are quantified. Validation is held by crossing image segmentation results with point clouds data obtained in laboratory by photogrammetric methods at the same moment images were taken. The present study intends to show the positive contribution of image processing techniques for the laboratory monitoring of breakwater models.

Image and Point Cloud data

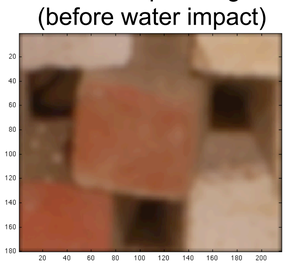
- Ortho-images (RGB) and Point Clouds (PC) acquired by photogrammetric methodologies before and after water impact.

Ortho-image 1

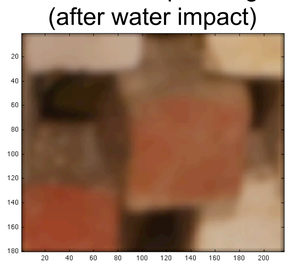
Ortho-image 2



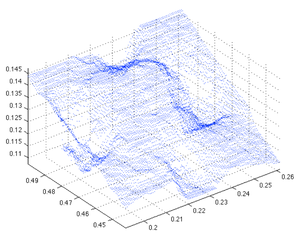
First sample image (before water impact)



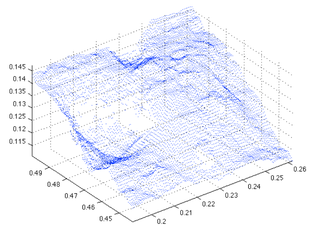
Second sample image (after water impact)



Point Cloud (PC) 1

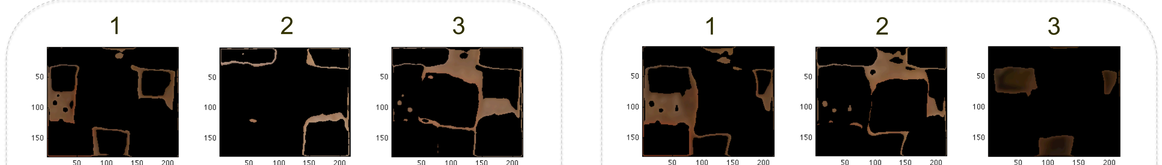


Point Cloud (PC) 2



1. Image segmentation by K-Means clustering

1.1 Application of color K-Means clustering (6 clusters) to both RGB images, in order to find markers for the block top surfaces.



RGB clusters / First image

RGB clusters / Second image

1.2 Block markers selection by a statistical-basis approach:

- Computation of pixel *Average* and *Standard Deviation* (STD) for the three 8-bit image components of all six clusters;
- Computation of the difference between the maximum STD and the minimum STD in each cluster.

$$d = \max\left[std(R); std(G); std(B)\right] - \min\left[std(R); std(G); std(B)\right]$$

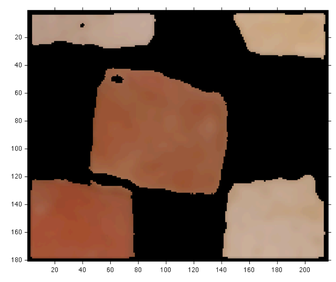
	FIRST IMAGE						
	AVERAGE			ST. DEVIATION			
Cluster	R	G	B	R	G	B	d
1	92.02	59.46	39.08	10.69	8.65	7.11	3.58
2	149.90	114.94	89.83	10.14	8.35	10.50	2.15
3	120.95	84.20	60.65	10.17	6.47	7.16	3.70
4	48.07	29.63	18.29	13.23	8.00	4.81	8.42
5	139.39	71.44	47.13	5.32	6.82	5.49	1.50
6	182.34	149.10	122.46	8.15	7.67	9.03	1.36

	SECOND IMAGE						
	AVERAGE			ST. DEVIATION			
	R	G	B	R	G	B	d
	86.91	54.79	35.09	10.98	8.12	6.29	4.69
	114.43	77.75	51.99	9.62	5.93	8.00	3.69
	44.22	28.49	17.36	11.62	6.79	4.52	7.10
	183.78	150.35	116.66	9.76	10.21	10.10	0.45
	147.96	111.71	82.68	9.36	10.78	11.68	2.32
	136.83	67.06	42.00	5.62	7.48	6.16	1.86

1.3 Merge clusters agree the following criteria:

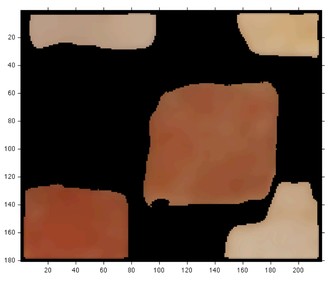
$$d \leq 2$$

Block markers before water impact



Clusters 5 and 6

Block markers after water impact

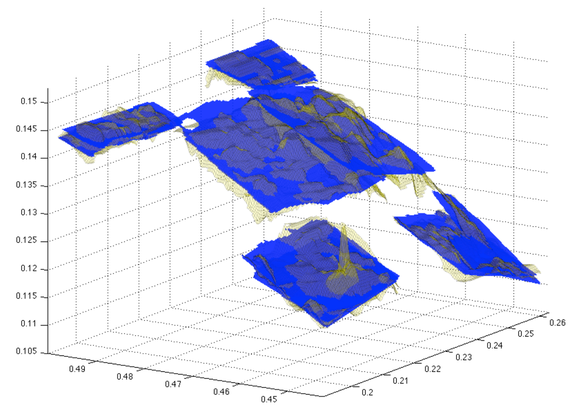


Clusters 4 and 6

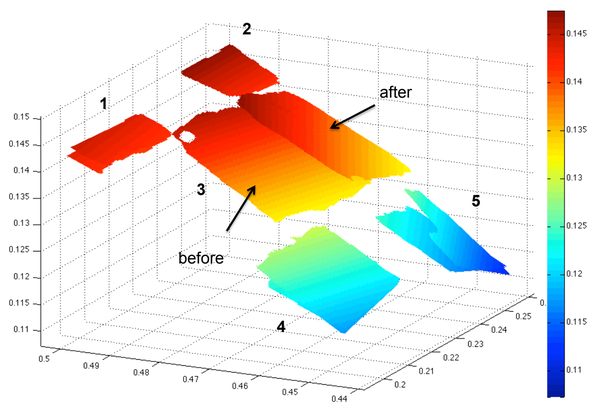
2. Least-Squares adjustment

2.1 Selection of PC1 and PC2 values corresponding to previous image regions.
2.2 Application of the least-squares adjustment to the PC data of each single region of both images. The mathematical model is the equation of a 3D plane:

$$z = c_1 x + c_2 y + c_3$$



Plane surfaces adjusted to PC 1 and 2 data sets



Superimposed view of the estimated top surfaces of five blocks, before and after water impact (height in meters)

3. First results and future developments

3.1 Block displacement evaluation.

The evaluation of block's displacement is made by estimating following parameters for each pair of homologous planes:

i) Centers of mass $CM_i(X_i,Y_i,Z_i)$ and $CM_j(X_j,Y_j,Z_j)$.
ii) Angles of rotation $(\omega_i,\varphi_i,\kappa_i)$ and $(\omega_j,\varphi_j,\kappa_j)$ in the 3D space (κ not yet been tested).

	FIRST IMAGE			SECOND IMAGE		
Block	X1	Y1	Z1	X2	Y2	Z2
1	0.201	0.452	0.123	0.201	0.451	0.122
2	0.212	0.496	0.142	0.214	0.495	0.142
3	0.222	0.472	0.139	0.236	0.469	0.140
4	0.250	0.452	0.118	0.255	0.450	0.117
5	0.250	0.495	0.144	0.253	0.495	0.143

	FIRST IMAGE			SECOND IMAGE		
Block	ω	φ	κ	ω	φ	κ
1	-30.1	9.3	0	-21.5	7.7	0
2	-21.5	0.1	0	-20.5	-2.3	0
3	-27.8	7.7	0	-24.2	-12.4	0
4	-26.1	-12.1	0	-37.9	-18.2	0
5	-27.8	-0.1	0	-22	-2.9	0

Left table: Centre of Mass coordinates of blocks. **Right table**: Rotations in X (ω) and Y (φ) , in relation to the horizontal. The rotation in Z (k) has not been estimated.

3.2. Modeling the breakwater: The real world block samples for this experiment are cubes with an edge length of 32 millimeters. This knowledge, in addiction to previous mentioned parameters, will allow to create a simple 3D space model of the cubes displacement.

3.3 The main objective of this presentation is to use image data in addition to point cloud data to improve breakwaters models monitoring. For that, two main tasks are suggested:

i) Image segmentation of the top surfaces of the blocks before and after water impact. Blocks are often coded with colors according to several attributes (weight, density, position and others). The proposed K-Means clustering method proves to be quite effective in this task.
ii) The application of least squares to the point cloud data located in those image regions, give a proper estimation of blocks' surface status (position and rotation).

From what has been tested so far, integration of the two data sources proves to be an asset to the monitoring work of the breakwaters models. The next step is the 3D modeling of displacements, thus approaching the methodology of experimental work.