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Concrete Block Tracking in Breakwater Models

(paper 8550)

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Objective

The following presentation will describe a methodology to characterize regular blocks' motion, by using both registered Depth and RGB image data sets of rubber mound breakwater models.

The aiming is to obtain the location of blocks' geometric center, at different instants, to monitor and analyze the breakwater behavior, after water action.

For this purpose, sample data were selected at different instants, between which changes were made on the target coverage, and then used to test the proposed approach.

A set of results and a brief discussion will be presented at the end.

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Motivation

The Harbours and Maritime Structures Division of the Department of Hydraulics and Environment (NPE) of *Laboratório Nacional de Engenharia Civil* (LNEC) frequently uses physical models of breakwaters, build inside water basins (complete model) or wave flumes (a section of the model) to study if the structure fulfils the safety requirements.

There is large interest in detecting changes of models of breakwaters quickly, accurately and economically:

- Quickly, to reduce the periods in which the model is "stopped".
- Accurate, to have confidence in the data that is obtained.
- Economic, to manage and use, as much as possible, the available resources of the institution.

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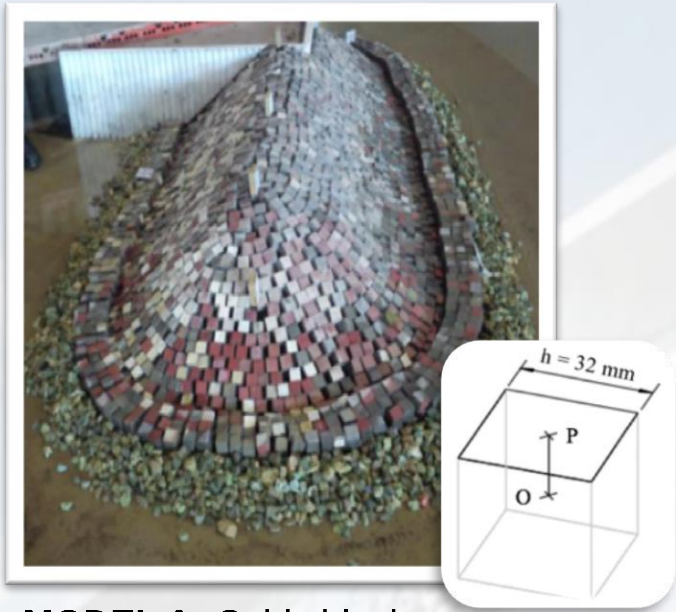
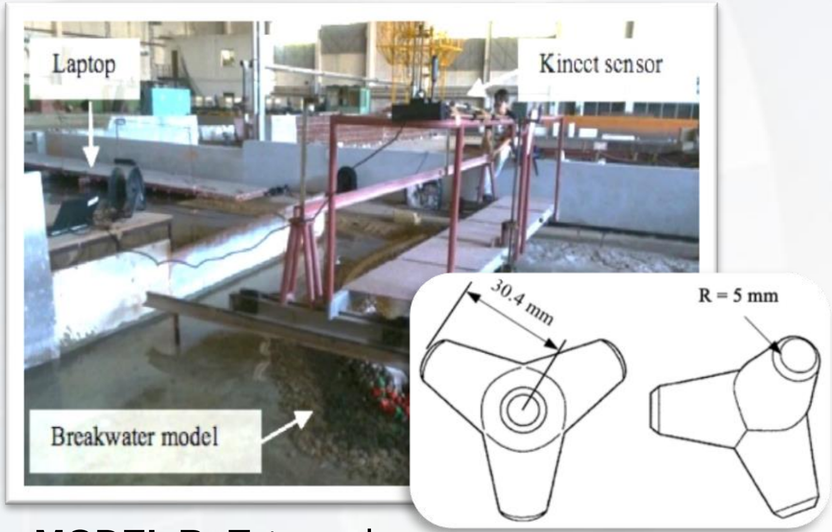
Rubber mound breakwater models: a visual perception



MODEL A: Cubic blocks



MODEL B: Tetrapods

All the blocks of concrete are of <u>known</u> dimensions

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Capturing hardware and data products

	BREAKWATER MODEL A	BREAKWATER MODEL B
Camera device	Nikon D200	Kinect V2 RGB-D, plus USB adapter
Computer	-	Laptop Intel Core I5, 3.0GHz, USB 3.0

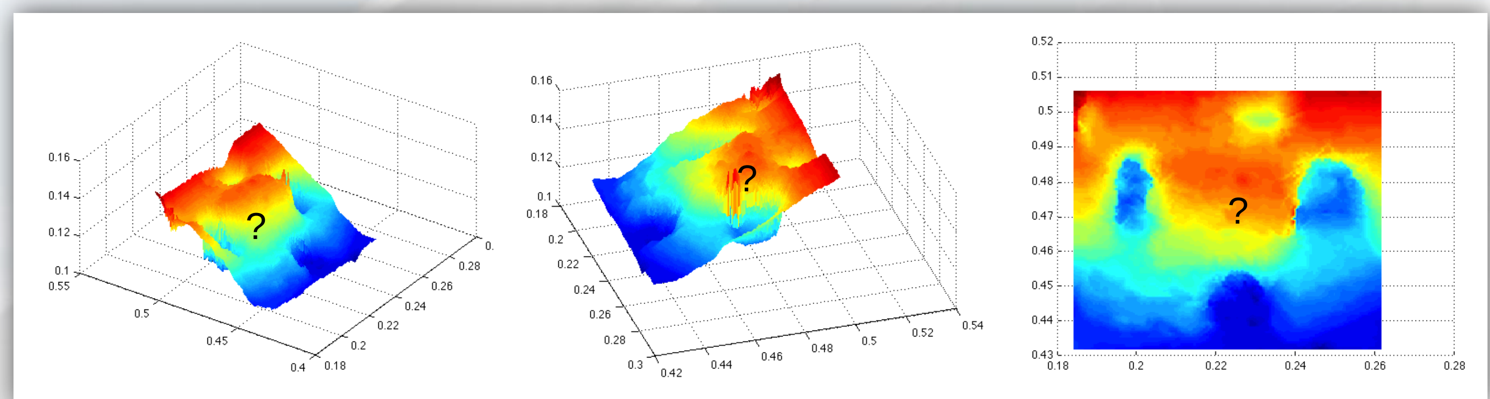
Image data	RGB images	RGB images
Depth data	Obtained by photogrammetric post processing	Obtained directly from the device during the experiment

Microsoft Kinect V2

Brief consideration on point clouds

Question: Can the (X,Y) plane coordinates of a certain block’s 3D point be properly located, over a depth map?

Our answer: Not really. In fact, it is difficult to recognize either the vertices and the edges of its most exposed face (the top face).

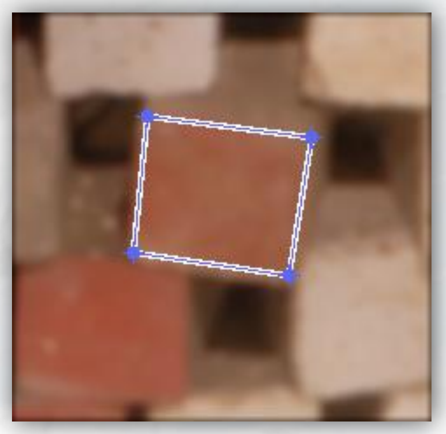


3D view 1 | 3D view 2 | Top view

Brief consideration on RGB images

Question: Can the Z coordinate of a block's 3D point be obtained from mere RGB image data?

Our answer: No. On the other hand, a clear delimitation of a block's top face can be easily obtained from the image.



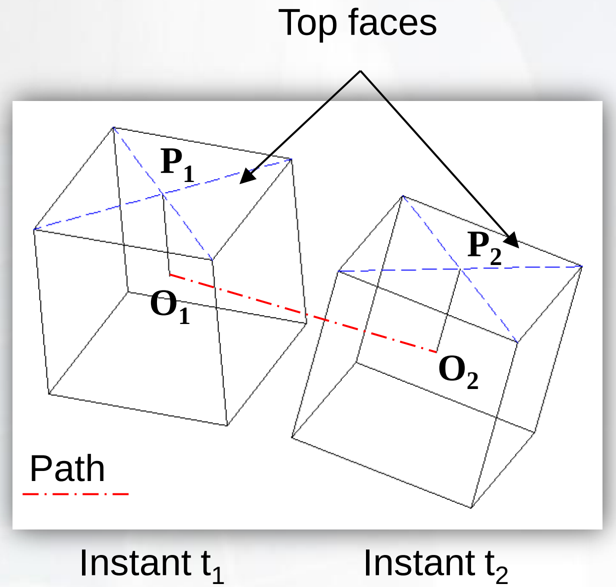
Resolution procedure overview

Assuming that it is known,

i. The 3D location of the point P(X_P,Y_P,Z_P), *i.e.* the center of the top face of the block;
ii. And the block's true dimensions,

The 3D location of the geometric center $O(X_O,Y_O,Z_O)$ can be obtained by common tridimensional geometry.

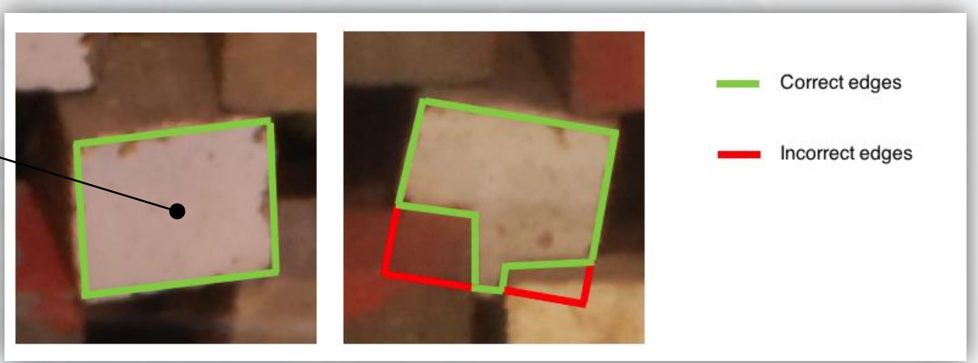
Therefore, the motion path of the point *O*, i.e., the center of the block, can be mapped in the 3D space, given its location at several instants.



3D location of the point $P(X_P, Y_P, Z_P)$

The point P is wanted to be located in the centre of the top face of the block, which is previously segmented from the RGB image. This binary mask has to be representative of the entire face, and not be partial (hidden block scenario).

Centre point of the 2D segmented shape

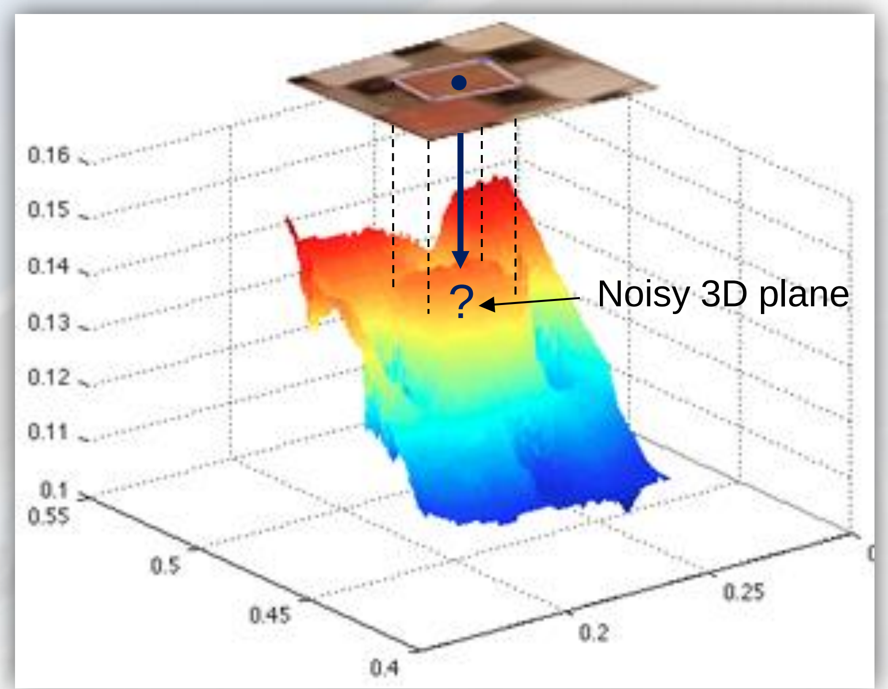


Entire block scenario

Hidden block scenario

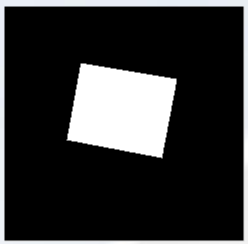
3D location of the point $P(X_P, Y_P, Z_P)$ (cont.)

The next step aims to find an estimation for the Z_P coordinate.

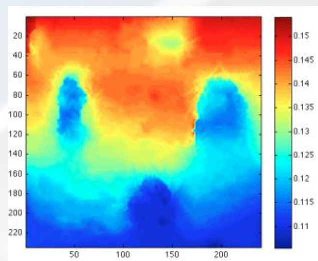


3D location of the point $P(X_P, Y_P, Z_P)$ *(cont.)*

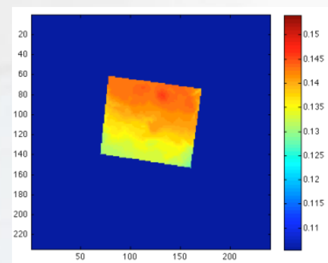
The depth values that match the top face image are obtained by crossing the segmented binary mask with the depth data.


Binary mask

×


Depth Map

=


Top face depth points

Given that those points are not coplanar, the proposed resolution is to estimate the best fitting plane by Least Squares Adjustment, from the selected depth values.

The Z_P value is given the depth value of the middle point of the estimated plane.

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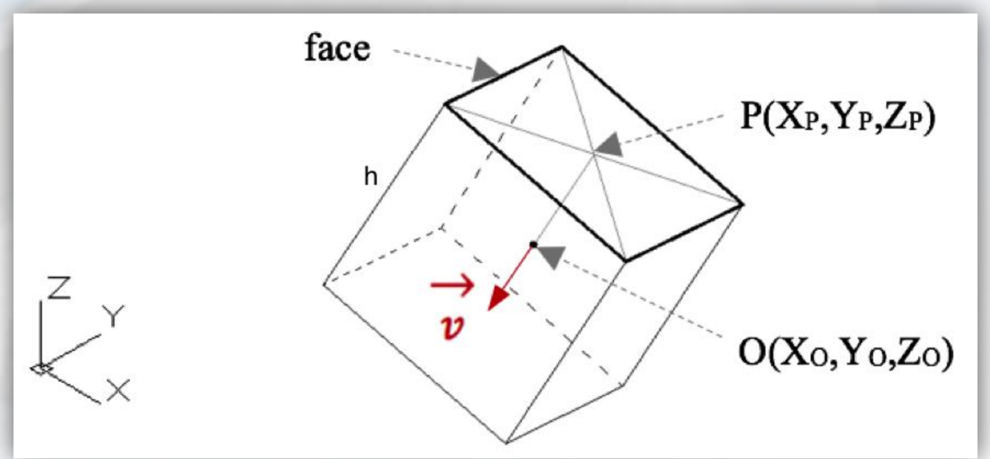
Estimation of the Geometric Centre of a block, $O(X_O, Y_O, Z_O)$

Centre of the block

$$\begin{cases} X_O = X_P + k \times a \\ Y_O = Y_P + k \times b \\ Z_O = Z_P - k \end{cases}$$

$$k = \frac{h}{2}$$



- The director vector $\vec{v}(a, b, d)$ is perpendicular to the estimated plane (the length of $\overline{PO}$ is equal to $k = h/2 = 0.016$ meters).

Case studies

The following slides show the results of the implemented method, for two different case study blocks:

1. CUBE

2. TETRAPOD

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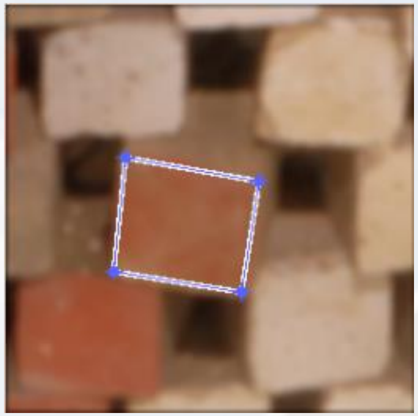
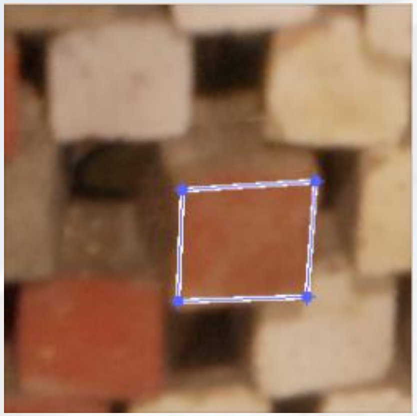
Results (cube example 1)

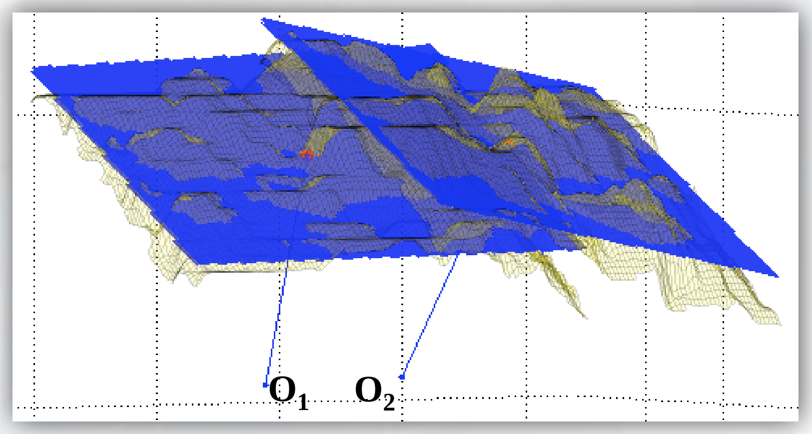
- The block unit moves to another location and changes orientation



Before



After



Coordinates of the GC, and displacement (meters)

CUBE	Geometric Centre			Displacement			Distance
GC	X	Y	Z	dx	dy	dz	D
O_1	0.2241	0.4809	0.1231	0.0084	-0.0044	0.0004	0.0095
O_2	0.2325	0.4765	0.1236				

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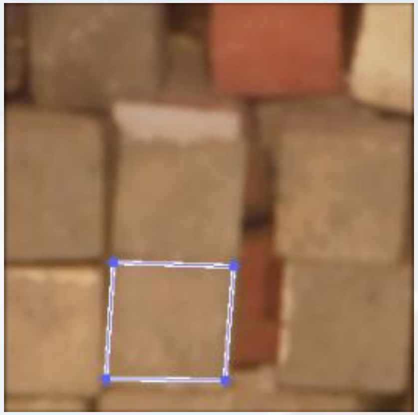
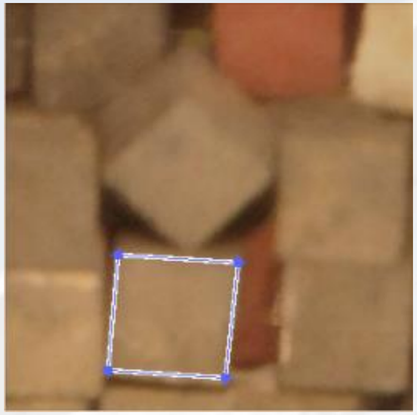
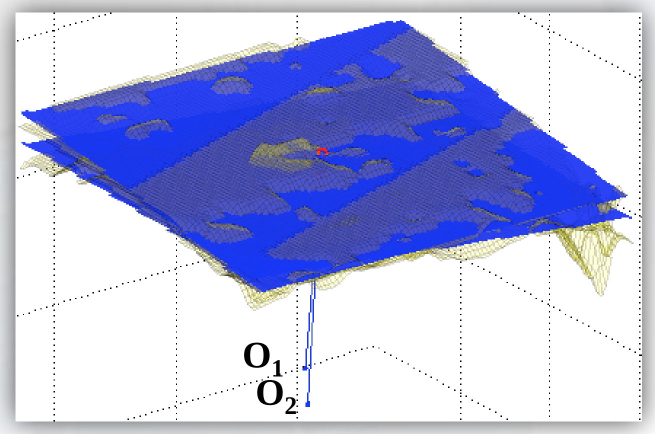
Results (cube example 3)

- The block stands almost in the same position


Before


After

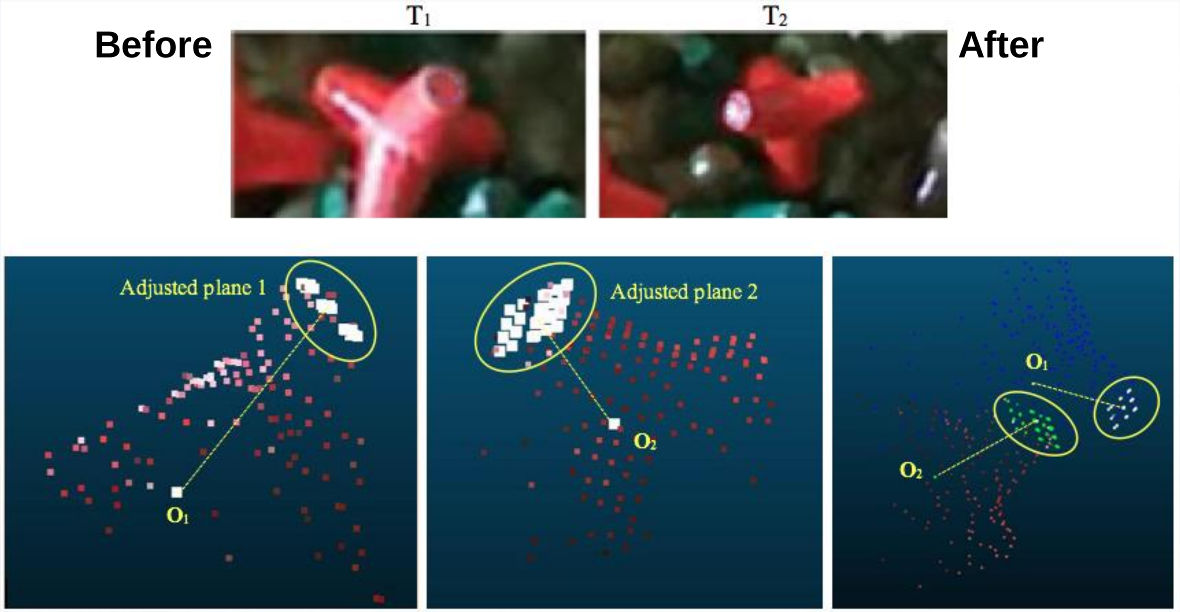


Coordinates of the GC, and displacement (meters)

CUBE	Geometric Centre			Displacement			Distance
GC	X	Y	Z	dx	dy	dz	D
O_1	0.1632	0.2722	0.0628	-0.0004	-0.0008	-0.0022	0.0024
O_2	0.1628	0.2714	0.0606				

Results (tetrapod example 1)

- The block rotates and moves



TETRAPOD	Geometric Centre			Displacement			Distance
Instant	X	Y	Z	dx	dy	dz	D
T_1	0.153	-0.013	1.221	0.031	-0.008	0.025	0.041
T_2	0.184	-0.021	1.246				

Discussion and Conclusions

1. The innovative proposal of point cloud adjustment, driven by the segmentation of block imagery data, proves to be an asset to block geometric centre estimation and tracking. It depends, although, of a clear identification of the target plane faces of the blocks, on the images.

2. The Kinect V2 with RGB and Depth sensors, proves to be an asset concerning surveying cost and quickness. However, it should be noted that the optimal distances from the object, for a higher accuracy, stand between 1 meter and 2 meters, which may work against the small dimensions of some blocks faces.

3. Based on the preliminary results the functional approach aiming the estimation of block's location, achieves the main objective proposed at the beginning of this presentation.

Future improvements

1. Image processing development aiming the selection of the blocks' faces. To optimize this procedure, the blocks' colour standardization is also under discussion.

2. The location of point O is computed from the location of the shape's middle point P, which depends of its proper shape definition. When one block is partially hidden by another, that is not possible. This situation is also a top concern that is under study.

3. Extend the approach to a real scenario breakwater, is a project to develop at medium term.

4. Deeper study of the Kinect V2 RGB-D camera for monitoring breakwater models.

Thank you for your attention

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