Optical Data Processing in the Context of the PICMAR Project

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Abstract *– The inspection of the seafloor is a fundamental task during the implantation, maintenance and dismantling of marine and oceanic infrastructures. The PICMAR project is intended to overcome the existing limitations of the current inspection systems. In the developed framework, the whole sensor-data processing is treated, improving the state of the art in topics such as multimodal data registration and 2D / 3D data blending, and going beyond in others such as automatic data classification and change detection. In this paper, the image processing pipeline is explained, involving preprocessing, geometrical and photometrical registration and change detection, and some of the obtained results are shown.*

Keywords *– Underwater inspection, image mosaicing, data classification, multimodal information, change detection.*

1. INTRODUCTION

The main objective of the PICMAR (Intelligent Platform for the Multimodal Characterization of Seafloor and Underwater Infrastructures) project, funded by the Ministry of Science and Innovation, is to overcome the limitations of current systems to perform the inspection and management of seafloor and underwater infrastructures.

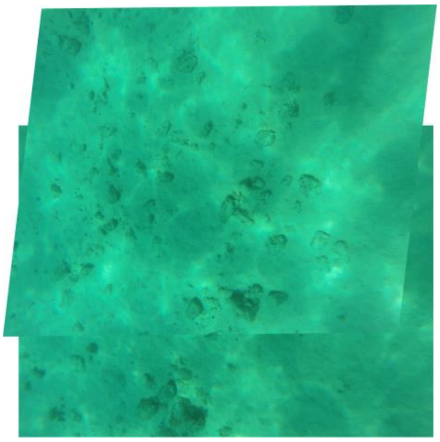
To achieve this goal, the use of multimodal information, coming from optical and acoustic sensors, namely high-resolution camera, side-scan sonar and multi-beam sonar, is proposed. The data acquired by each of the sensors is used to generate 2D and 3D representations of the seafloor, which can be later studied by the scientists. Moreover, this information is acquired and registered on a common georeferenced frame, allowing the association of the different sensors data, in order to improve the accuracy in tasks such as seafloor classification or change detection.

This paper focuses on the 2D processing of the optical data, which is used for mapping and change detection purposes.

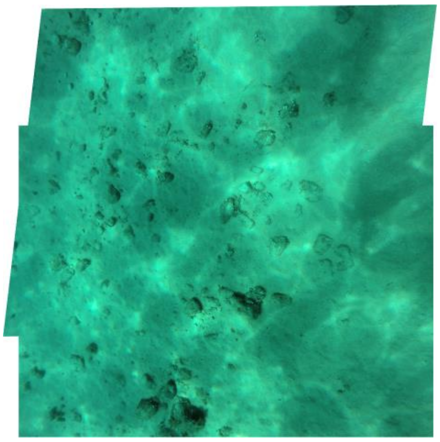
2. UNDERWATER 2D MAPPING

The underwater phenomena affecting optical images, such as light attenuation and scattering [1], constrains their acquisition, which has to be performed at few meters of the seafloor. Consequently, surveying extensive areas requires the combination of sequences of images into a common reference frame, that is, the generation of photo-mosaics [2]. Different optical surveys of a given interest area acquired at different times can be then used to detect changes in the scene.

As a first step of the mosaic generation pipeline, the images are preprocessed to compensate some lighting effects, such as non-uniform illumination and sun flickering artifacts. When a survey is performed at a certain depth, were sunlight cannot reach the seabed, the use of artificial lighting is required. In this case, non-uniform illumination is a common artifact, which causes the images to show a brighter area where the light sources are pointing, while showing a darker appear in the rest. A depth-dependent adaptive method [2], which compensates this illumination oscillations depending on the distance of the camera to the seafloor, has been used. On the other hand, when the images are acquired in shallow waters, and sun flickering artifacts, due to the refraction of the sunlight rays in the water medium induce patterns of concentrated light in the seafloor. A sun-flicker compensation algorithm [3] is applied in that case, to reduce the noticeability of the artifact.



(a)

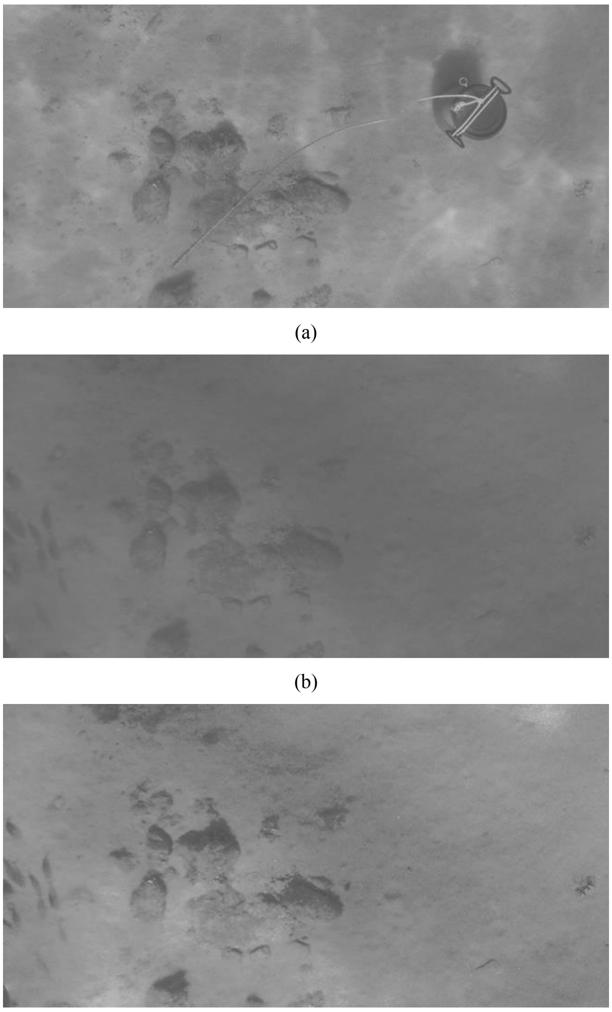


(b)

Fig. 1. Registered image pair before (a) and after (b) photometrical registration and blending. The image boundaries are imperceptible and the detail of the resulting mosaic is enhanced.

A method to improve the sharpness of the images, which may show strongly blurry appearance due to the scattering caused by the presence of particles in suspension in the medium, is also applied to the acquired images [2], to enhance and equalize their detail level along the sequences.

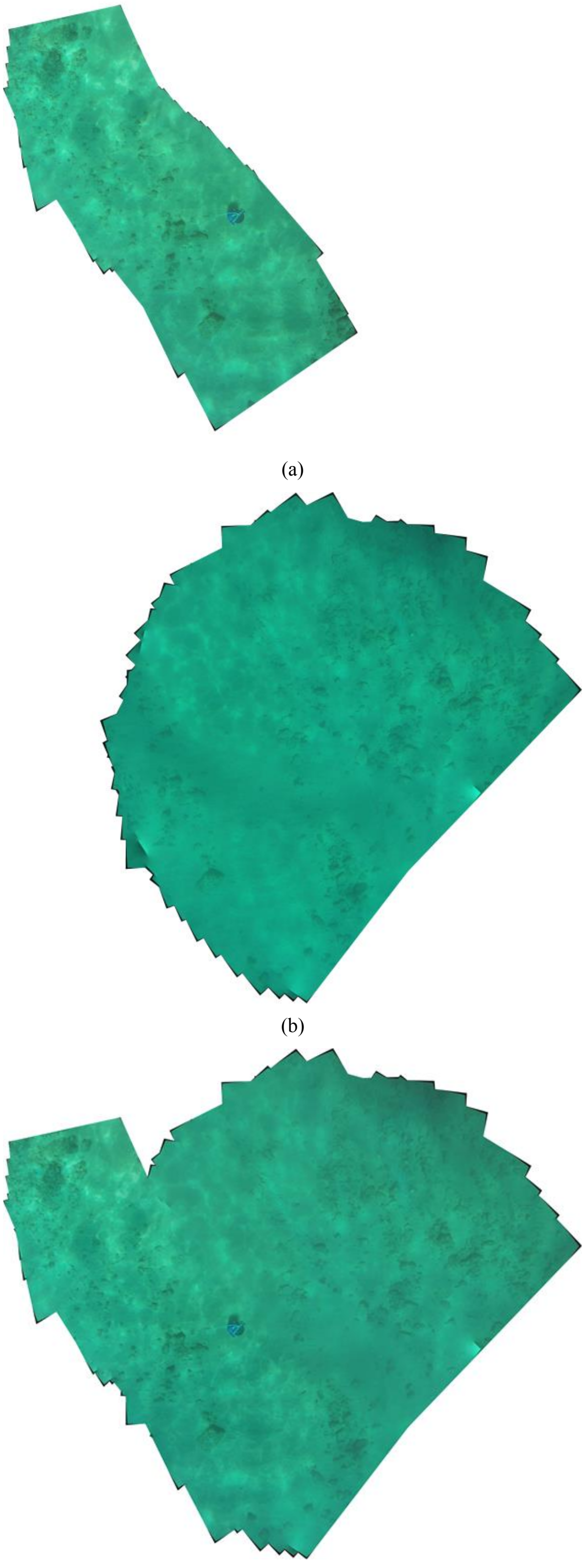
The optical image surveys are then geometrically aligned. First, a pair-wise registration of consecutive images based on features [4] is performed, which allows obtaining a first estimate of the trajectory followed by the camera. If the acquisition setup allows storing geospatial information synchronized with the image acquisition, this data can be used to perform this initial trajectory estimation, and pair-wise registration is applied to refine the initially recovered path. Second, the trajectory estimate is used to identify overlaps between non-consecutive images in the whole sequence. This information, known as loop-closure, is used to apply a global alignment method [5], which allows to improve the consistency of the recovered path.


(a)

(b)

(c)

Fig. 2. Interest area mapped in two consecutive surveys (a and b), and appearance of the second survey map (c) once the equalization with respect to the first survey has been performed. The images are represented in grayscale, given that the differences are found on a single channel.


(a)

(b)

(c)

Fig. 3. Optical mosaics of an interest area corresponding to two different surveys, performed before (a) and after (b) the recovery of a test barrel from the seafloor. Both are combined, after geometrical and photometrical registration, into a single common mosaic (c).

Next, an image blending method [2] is applied on the generated mosaic, to improve its appearance (see Figure 1). A technique based in two main steps is used. In a first step, the seam where the images should be cut in their common overlapping areas is optimally found, based on photometric differences criteria. In a second step, a transition smoothing method on the gradient domain allows reducing the visibility of those seams. The information in a narrow area around these seams is fused, in order to suppress the noticeability of the transition between images. The benefits of image blending are twofold. On the one hand, it allows providing the mosaic with a continuous and consistent appearance. On the other hand, the level of contrast of all the images is adaptively enhanced, depending on the neighboring ones. Both improvements are intended to provide the scientist with and informative representations of the seafloor, easier to interpret than the original isolated images.

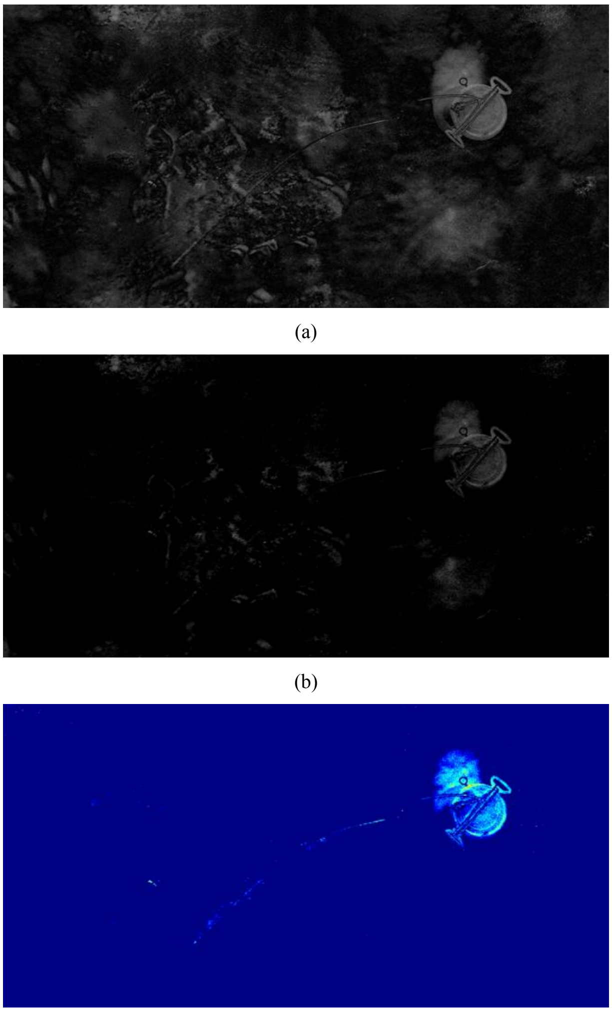
Finally, the photo-mosaics of the different surveys performed in a given time lapse are registered both geometrically and photometrically. The geometrical inter-mosaic registration is performed using the features detected during the generation of the initial mosaics, by looking for correspondences between overlapping images corresponding to different surveys [6]. The georeferenced information of the datasets is used to align all the generated mosaics into a common reference frame.

The photometrical registration is carried out using a histogram specification method, aiming to equalize the global appearance of all the photo-mosaics [7] of the different surveys. Changes in the illumination conditions during the acquisition, the turbidity of the water medium or even the distance from the camera to the seabed may lead to mosaics with significantly different appearances, making the photometric registration an unavoidable step.

The inter-mosaic registration allows conditioning the acquired data to enable the search of differences between surveys (see Fig 2).

3. CHANGE DETECTION

Once two (or more) different surveys have been registered, a change detection algorithm [8] is applied on the interest areas in order to determine the variations of the scene in a given time lapse (see Fig. 3). This detection is carried out in the grayscale representation of the mosaics, and is performed in two steps. Firstly, the method looks for pixel-wise differences between the compared areas, based on photometric criteria, and using the information of each of the pixels and its neighboring ones. Secondly, the results of the first step are refined, to discard non-significant or wrongly detected changes. These may be due to residual illumination variations which have not been correctly compensated in the previous preprocessing steps, or to geometrical registration inaccuracies, due to excessive relief in the scene or the presence on this one of too many dynamic elements, among others. In that sense, the accuracy of the registration steps (both geometrical and photometrical) between the mosaics is crucial to obtain consistent results.


(a)

(b)

(c)

Fig. 4. Result of the applied change detection algorithm before (a) and after (b) the histogram equalization between the surveys, and final (refined) result (c) of the detection (represented in pseudocolor). Both the barrel and the cord used to deploy it have been successfully located and segmented.

4. RESULTS

The developed pipeline has been tested on a real controlled scenario, on the surroundings of the Blanes (Spain) harbor, surveyed with a high-resolution (Full HD) video camera, before and after the deployment of a barrel at a random location within an interest area. The two image sequences were used to generate a photo-mosaic of each of the surveys. Then, both mosaics were registered, both geometrically (see Figure 3) and photometrically (see Figure 2). Finally, a change detection algorithm [8] was applied on the commonly imaged areas to detect the significant scene variation caused by the presence of the barrel (see Figure 4). The barrel, and the cord used to deploy it, were successfully located and segmented.

5. CONCLUSIONS

The obtained results demonstrate that the proposed pipeline is appropriate to process optical data from different surveys in order to consistently detect changes within the monitored areas. After geometrical and photometrical registration, some artifacts, due to different reasons, such as lighting artifacts or geometrical registration inaccuracies, may arise during the change detection step. Nevertheless, the impact of those is not significant and can be compensated, and a correct segmentation of the differences along the time between the interest areas can be successfully found.

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