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Action camera for metric archaeological documentation in narrow spaces

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***Abstract* – In this article we develop a case study in order to obtain orthophotos to a wall surface of "Villa di Giulia Felice" in Pompeii. Given the length of the section and a very small distances to the object, it was necessary to test the use of an action camera: a "GoPro Hero 3 Black". The distorting effects are the factors that characterize this type of camera and they are caused by the wide-angle lens mounted on it. For this reason, the "GoPro Hero 3 Black" is not particularly suitable for photogrammetric purposes. The photos were processed in different software and the 3D models obtained were compared in terms of geometric and radiometric information.**

I. INTRODUCTION

The realization of photoplan is often required in Archeology to collect chromatic and metric information in a single file.
However, it is not always possible to use the non-conventional photogrammetry due to intrinsic (e.g. non-planar surfaces) and/or extrinsic (e.g. reduced distance to the object) conditions. The use of multi-image photogrammetry is a possible solution; acquiring more images, relying on the parallel or convergent axes, in respect of the theoretical principles of the discipline, process them through algorithms based on collinearity equations and scale them with the topographic points of support.
The final output obtained is a photo-realistic 3D model, suitable to generate metrically correct orthophotos that can be verified only with accurate topographic surveys.
In this paper, we develop a case study in which we consider the problems afore-mentioned and it was necessary to test the use of an action camera. We show the following steps: (i) the photographic acquisition, (ii) the processing in different software (Agisoft PhotoScan 1.0.4, Pix4dMapper 1.4.46 and the service cloud Recap 360 Photo Autodesk) considering the photogrammetric restitution, and (iii) the effectiveness of the metric method and the infographic performance (Fig. 3). In addition, all the images were 'corrected' by distorting effects, through the filter "lens correction" of Adobe Photoshop version 8.2, recently released for the type of camera used (Fig. 2). The models obtained from the filtered images were compared with unfiltered images to highlight advantages and / or disadvantages that this step can bring to the result for documentation of narrow spaces.

II. PHOTOGRAMMETRIC ACQUISITION

The project involved the use of an "action camera", a GoPro Hero 3 Black. The distorting effects are the factors that characterize this type of camera and they are caused by the wide-angle lens mounted on it. For this reason, the use of these shots is not particularly suitable for photogrammetric purposes. [*Kim et al., 2014*].
This type of camera are tested in order to obtain an orthophoto of a perimetric wall, on the east side of "Villa Giulia Felice"in Pompeii.
Given the very small distances to the object (0.7- 0.9 m), the length (about 20 m) and the height of it (about 4 m), the wide-angle optics mounted on it is an advantage in the acquisition phase of the images; indeed, this type of lens increases the angle field and consequently the visual field. Sometimes, in photogrammetry, the increase of the visual field may be advantageous because it decreases the number of photogrammetric shots carry out. Further advantages the use of GoPro Hero 3 Black are its small size and low weight of the camera body, which facilitate the photographic acquisition in narrow spaces. On the other hand, the wide-angle lenses are more exposed to distortions, generating distorting effect known as "barrel distortion" [*Balletti et al., 2014*], especially at the extremes of the frame (an example is shown in Fig. 1).
The strong distortion effects are accentuated due to the very small distances to the object; for this reason the shots are not particularly suitable for photogrammetric purposes. However, some software on the market are able to process photos with wide-angle lenses distortions, because inside the calculation algorithm, they already have the parameters of the camera, and therefore they are able to eliminate them in post-processing.
The acquisition project of the shots included the use of a telescopic pole to obtain the photos for the entire height

of the wall. We have acquired 321 images in 11 horizontal strips with overlapping of 80%, with parallel axis camera and without the use of additional converging shots. The essential element, for the correct metric of 3D final model, is the use of topographic points of support in the absolute orientation phase; in particular, we have used 14 topographic points well distributed on the investigated wall (about one point per 5 m^2, Fig. 4). The overabundance of control points allows a better control on the error dispersion over the entire wall surveyed [*Fiorillo et al., 2012*]. The processing steps, in each software used, were then analysed, separating the filtered and unfiltered images processing.

Fig. 1. Deformations due to the wide-angle mounted on GoPro Hero 3 Black.

Fig. 2. Elimination of deformations through Adobe Photoshop filter.

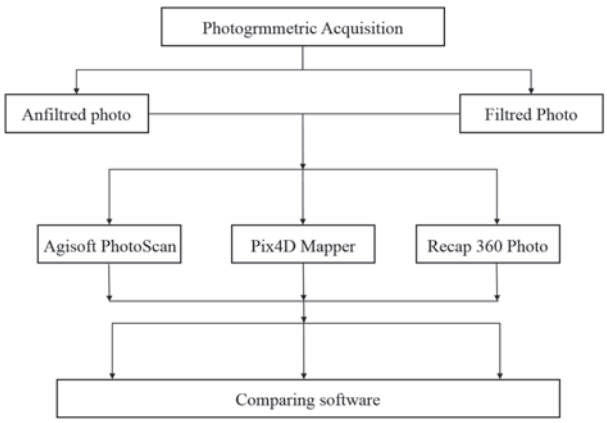

Fig. 3: Activity flow chart.

III. DATA PROCESSING

A possible approach to reduce these distortions is to apply the filters before the photogrammetric processing. It is possible to eliminate the distortions from each single shot knowing the type of lens mounted on the camera. *Adobe Photoshop* version 8.2, recently released, has incorporated in its function "correction lens" the camera used. The images, obtained in the acquisition phase, were filtered in Photoshop to eliminate the distortion effects caused by the wide-angle and subsequently processed in photogrammetric software afore-mentioned.

III.A AGISOFT PHOTOSCAN

Agisoft PhotoScan is an advanced solution photo-modelling to obtain high quality 3D models from images. Based on the latest multi-view 3D reconstruction technology, it operates with arbitrary images and it is efficient in both controlled and uncontrolled conditions. Both the images alignment and the 3D reconstruction are fully automated. The photo processing is based on 4 consecutive steps: (i) *Align photos* (in which takes place the calculation of internal and external orientation parameters and the creation of sparse cloud), (ii) *Build Dense Cloud, (iii) Build Mesh* and (iiii) *Build Texture*. In Agisoft PhotoScan, two different projects were created, one originated from unfiltered images and one originated from filtered images by the filter of Photoshop. The results show that the software can align a number of shots higher to the processing of filtered images, with respect to unfiltered shots. With filtered images, all the shots were aligned (321/321; 100%), while the processing with unfiltered images has aligned, 243/321 images (about 75%). The model generated from unfiltered images presents some information gap due to reduced number of photos aligned with respect to those incorporated in the project. Furthermore, the software gives us a report of the errors with respect to topographic control points, which results to be a benefit during the metric control of the 3D model. The topographic points are manually inserted by the user, identifying the pixels that represents the topographic points in every image; associating the topographic point and its coordinates to pixels, the software project it on the cloud and calculate the metric error (in X, Y, Z), for each control point inserted. In Fig. 5 and 6 the errors calculated in PhotoScan are represented, in the Z direction (height of the wall) and Y (longitudinal axis of it) for the project with the unfiltered images (blue) and the project with filtered images (yellow). It can be noted the errors in the model with unfiltered images are always greater than the model with filtered images. For the model generated from unfiltered image the average error in the Y direction is approximately 0.26 m while for the model generated from filtered images it is approximately 0.01 m. In the Z direction, the respective metric errors are 0.22 m and 0.01 m. In Fig. 7 and 8 the orthophotos obtained from the respective models are shown.

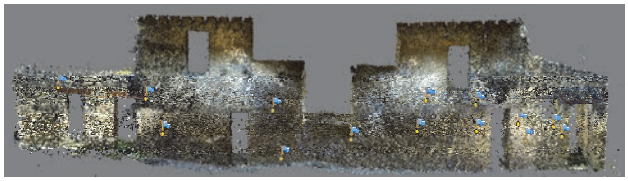

Fig. 4: Topographic points in Agisoft PhotoScan.

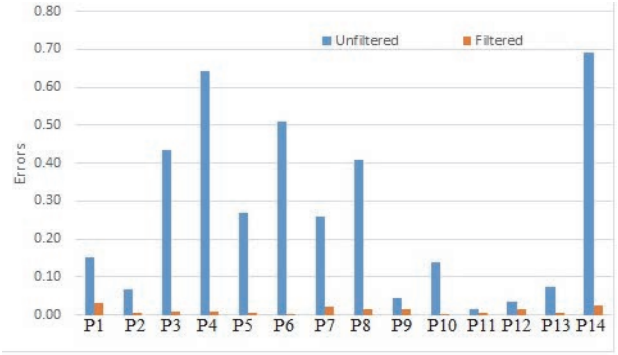

Fig. 5: Error in the Y direction in PhotoScan.

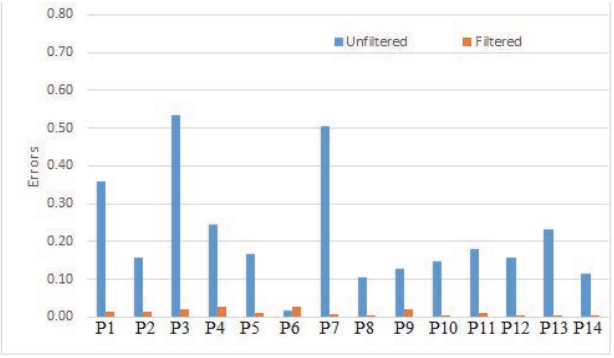

Fig. 6: Error in the Z direction in PhotoScan.

Fig. 7: Orthophoto and top view from filtered images in Agisoft PhotoScan.

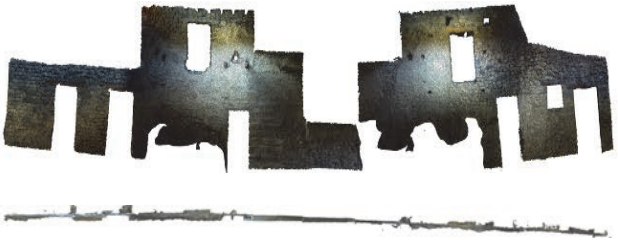

Fig. 8: Orthophoto and top view from unfiltred images in Agisoft PhotoScan

III.B PIX 4D MAPPER

Pix4D Mapper is a software that processes the photos acquired from the ground or UAV, to get digital 3D models and orthomosaics that can be used in a wide range of applications. The GoPro model has been inserted in the latest versions of Pix4D Mapper; knowing the parameters of the camera used, the software is able to eliminate the distortions, caused by the wide-angle lens, in post-processing.

It, as Agisoft PhotoScan, is a software that automatically processes the images, according to a flowchart based on 3 steps: (i) *Initial process* (in which takes place the calculation of internal and external orientation parameters and where you can choose full or reduced resolution of the image), (ii) *Point Cloud and Mesh* (this step generates the dense cloud of points, the alignment of the photos and subsequently the generation of the 3D model with texture) and (iii) *DSM orthomosaic and index* (this phase generates the orthophoto, according to resolution requested by the user and error report calculated by topographic control points inserted on the photos).

Both filtered (in Adobe Photoshop) and unfiltered images were processed also in Pix4D. The insertion of the topographic control points is identical to Agisoft PhotoScan. The metric results, calculated according to the 14 topographic control points, are shown in Fig. 9 and 10. It can be noted that the metric errors of the filtered images are higher than the unfiltered images, directly obtained from GoPro. The main reason is that the algorithm in Pix4D is optimized for the kind of action camera tested; with the filtered images, the algorithm applies the filter a further, so the benefits, obtained from filtered images, are vain. The graphs show that the algorithm works well with the unfiltered images, it to aligns 269/321 (about 84%); the average error on the points is about 0.006 m in the Y direction and 0.01 m in the Z direction. For the model generated from filtered images the number of aligned photos increases (311/321, 96%) but their average errors are to 0.52 m in the Y direction and 0.02 m in the Z direction. In Fig. 11 and 12 the orthophotos obtained from the respective models are shown.

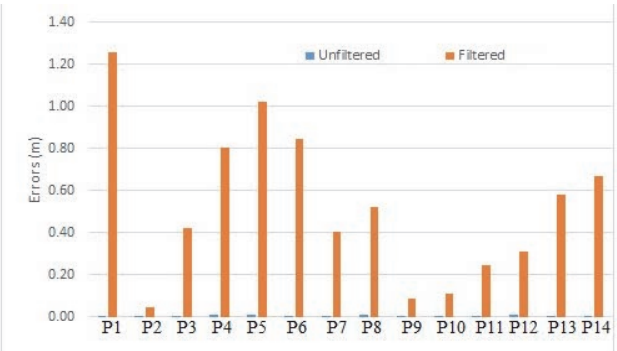

Fig. 9: Error in the Y direction in Pix4D Mapper.

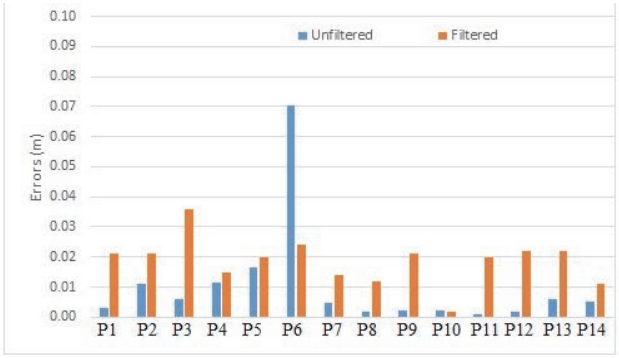

Fig. 10: Error in the Z direction in Pix4D Mapper.

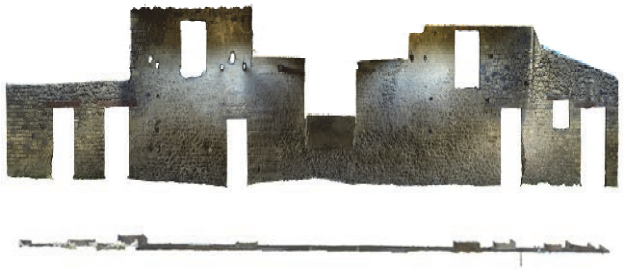

Fig. 11: Orthophoto and top view from filtered images in Pix4D Mapper.

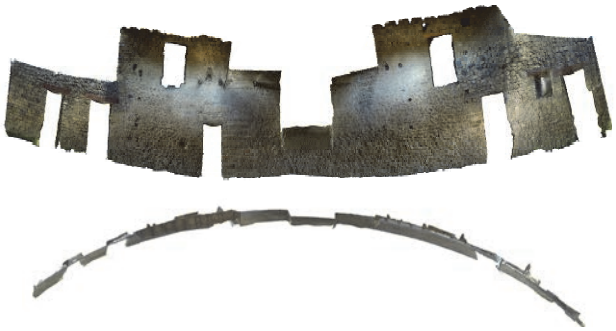

Fig. 12: Orthophoto from unfiltered images in Pix4D Mapper.

IIII.B RECAP 360 PHOTO

Recap Photo, cloud service of the Autodesk 360 in free version educational, allows the reconstruction of 3D mesh (of objects, buildings and land) from digital photos. In the trial version, it is possible to insert maximum 50 images, in educational version maximum 250 images. The imported shots are processed in cloud; the non-aligned shots can be manually collimated by the user through the identification of at least three homologous points between consecutive images (*manual stitching*). This operation is also necessary in the absolute orientation and in the insertion of the topographic control points, to obtain an object in real size and shape [*Buscemi et al., 2014*]. We have processed the images obtained from Photoshop filter and unfiltered images to underline the differences between the two models. 321 images were not processed due to the limit of number of images in the educational version; the images with greater overlap were eliminated; therefore we have processed 247 images (both filtered and unfiltered), remaining under the maximum number of images that can be processed. Recap 360 Photo does not provide any report of the metric control of 3D model returned, so it is not possible any metric analysis about it. In Fig. 13 and 14 the orthophotos obtained from the respective models are shown. It can be noted that the model obtained from unfiltered images, has significant information gap, but it maintains the planarity of the wall surface, contrary to the model obtained from filtered images in Photoshop that has a lot of metric information of the wall surface but does not maintains its planarity. In the last model, it is also possible to note gross errors in the alignment phase.

Fig. 13: Orthophoto and top view from filtered images in Recap 360 Photo.

Fig. 14: Orthophoto and top view from unfiltered images in Recap 360 Photo.

IV. RESULTS AND CONCLUSIONS

The filter "lens correction" of Adobe Photoshop can be a useful tool when the software operates with algorithms in which the distortions, deriving from this kind of action camera, are not implemented. In Agisoft PhotoScan, for example, the processing of unfiltered images has any problems in the alignment phase: it does not maintains the planarity and it makes high metric errors with respect to control points. Conversely, processing of filtered images, improves the metric quality of the model and the planarity of the surface is maintained. In the model

generated from unfiltered images the average error in the Y direction is approximately 0.26 m, while for the model generated from filtered images it is approximately 0.01 m. In the Z direction, the respective metric errors are 0.22 m and 0.01 m.

It is be noted that in the latest version of Agisoft PhotoScan (1.1.6) was implemented a function to eliminated the distortions of the images obtained from GoPro, in post-processing (as in the tested version of Pix4D).

In Pix4D Mapper, the situation is reversed: the algorithm is calibrated for this specific type of camera, so the processing of unfiltered images provided excellent metrical results, where the average error is often less than the cm with respect to control points, and excellent results in infographic quality of the 3D model.

Instead, using pre-filtered photos in Photoshop, the algorithm provides metric results with high errors and it does not maintains the object planarity. Therefore, the use of filter of Photoshop in Pix4D Mapper is useless, because the calculation algorithm implemented in it operates well with unfiltered images. In the 3D model generated from unfiltered images the average error in the Y direction is approximately 0.006 m while for the model generated from filtered images it is approximately 0.52 m. In the Z direction, the respective metric errors are 0.01 m and 0.02 m.

The processing in Recap 360 Photos showed that the filter of Adobe Photoshop worsens the alignment phase. It does not maintain the planarity and it aligns erroneously a high percentage of photos. The use of unfiltered images allows maintaining the planarity, but it is able to align a low number of photos, generating some information gap.

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