UAV flight plan software: first implementation of UP23d

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Abstract. UAVs flight are actually planned only on the experience of pilots, acquiring most of time three or more time the images needed. This is a time consuming and autonomy reducing procedure. These last two aspects are strategic when extensive survey are needed as in the case of large city center and thus when in emergency situations. For example: historic center of L'Aquila city suffered big damages from the well known main seismic event on 6th April 2009. Causes and modality of the collapse of some buildings are still under investigation. The earthquake caused more than 300 fatalities, thousands of injuries, extensive and severe damage to buildings, structures and infrastructures. About 16.000 buildings are completely or partially destroyed: about 80,000 residents were evacuated and more than 25,000 remained homeless. During the emergency a continuous monitoring of all building is crucial in order to guarantee that each structure at least will not worsen its stability until the final reconstruction is completed. To achieve a complete reconstruction a detailed survey of all building is performed using different techniques and sensors, between them the geomatic techniques as total stations, near photogrammetry, and laser scanners. Even if all these techniques can perfectly respond to many crucial post hazard needs, there are still many monitoring that cannot be completely carried on with traditional techniques. Some difficulties are related to the morphology and the architectural particularities typical of medieval city centers like the one of L'Aquila. For these reasons, in this work, a survey methodology using multirotor UAVs (Unmanned Aerial Vehicles) is proposed; UAVs are fully remote controlled and so they will allow high quality photogrammetric image capturing roofs and facades of structures in urban centers. In particular we'll illustrate a scientific package that was implemented specifically for this task of planning the flight to improve the optimization of the path to obtain a stereoscopic vision.

Keywords. UAV, earthquake, flight planning, L'Aquila, photogrammetry, UP23d.

1. Introduction

The continuous evolution of techniques and methodologies of digital survey, and three-dimensional modeling, has led to an interest in innovative techniques.

In this work a new surveying methodology, using multirotor UAVs (Unmanned Aerial Vehicles), will be illustrated. UAVs are aircrafts usually remotely piloted from a ground station, and represent the last frontier for the acquisition of the territory with high resolution and low-altitude flight. Their possibility to install different sensors make them usable in urban areas, for analysis of risk environment and for the estimation of the changes of land use, as an example. This innovative methodology, subject to constant scientific research, was selected and tested in this paper for a documentation of the damage caused in the historic center of L'Aquila earthquake of April 2009. In particular, a comparison of obtained DSMs processing images acquired through UAV, by using two different software PCI Geomatics 2012 and Agisoft PhotoScan.

2. Acquisition of UAV images

A correct photogrammetric survey, needs a suitable number of high quality acquisitions with the correct geometry [1]. To guarantee this quality the whole flight and thus the acquisition points have to be spatially distributed maintaining definite geometric characteristics as equal and correct air base and correct interaxes [2]. Considering as a guideline, the case of a traditional aerophotogrammetric acquisition, a flight is planned according to predetermined rectilinear paths parallel to each other; during the flight, images are taken in succession at regular time intervals, forming what commonly is called a 'swath'.

According to these parameters, each frame covers the previous by a quantity of at least 60 - 80% of the image size. The overlap between two successive images and relating to the same strip is defined as 'longitudinal overlapping'. Considering then two adjacent strips, parallel to each other, the frames are acquired in order to guarantee a 'transverse overlapping', equal to at least 20-30% of the size of the image as reported in figure 1.

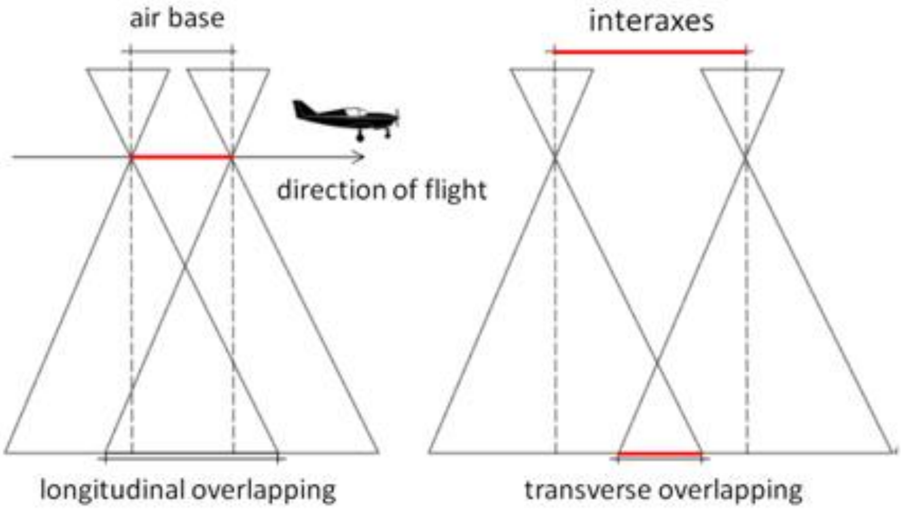

Figure 1. Air base, longitudinal overlapping and transverse overlapping in planning a flight

3. Scope and goal of UP23d software

Currently the flight plan is projected during the flight mainly based on the experience of the UAV pilot, for this reason a software was developed to model the flight plan of the UAV optimizing acquisitions, evaluating at the same time if this approach is correct also for the multirotor UAVs using amateur or semi-metric cameras [3]. The aim is obviously to obtain only the frames needed to reconstruct the stereoscopy and to obtain geometrically correct reconstruction of the objects observed to reconstruct a DSMs or to perform a stereo restitution [4].

The software 'UP23d' (UAVs planner to 3 dimensional acquisitions) that was developed, requires as input data the extension of the area to be acquired, the optic parameters of the camera installed on the drone and the desired final scale of the acquisitions. From these first input data the package suggest a flight altitude, which is proposed to the user which is free to edit if it's not suitable for the area to be investigated, for example if there is an obstacle higher than the surrounding territory.

Once individuated the flight height and consequently, the final scale obtainable (considering as guideline the classical aerophotogrammetric scale parameters), the values of longitudinal and across overlap have to be inserted in the software to allow the evaluation of the airbase needed to assure a correct stereoscopic restitution. After this step the software calculate the waypoints and footprint of each acquisition. As output the software returns the coordinates of the points where the UAVs has to stop to acquire the images; also a vector files of polygons that shows footprint of each frame is produced [5].

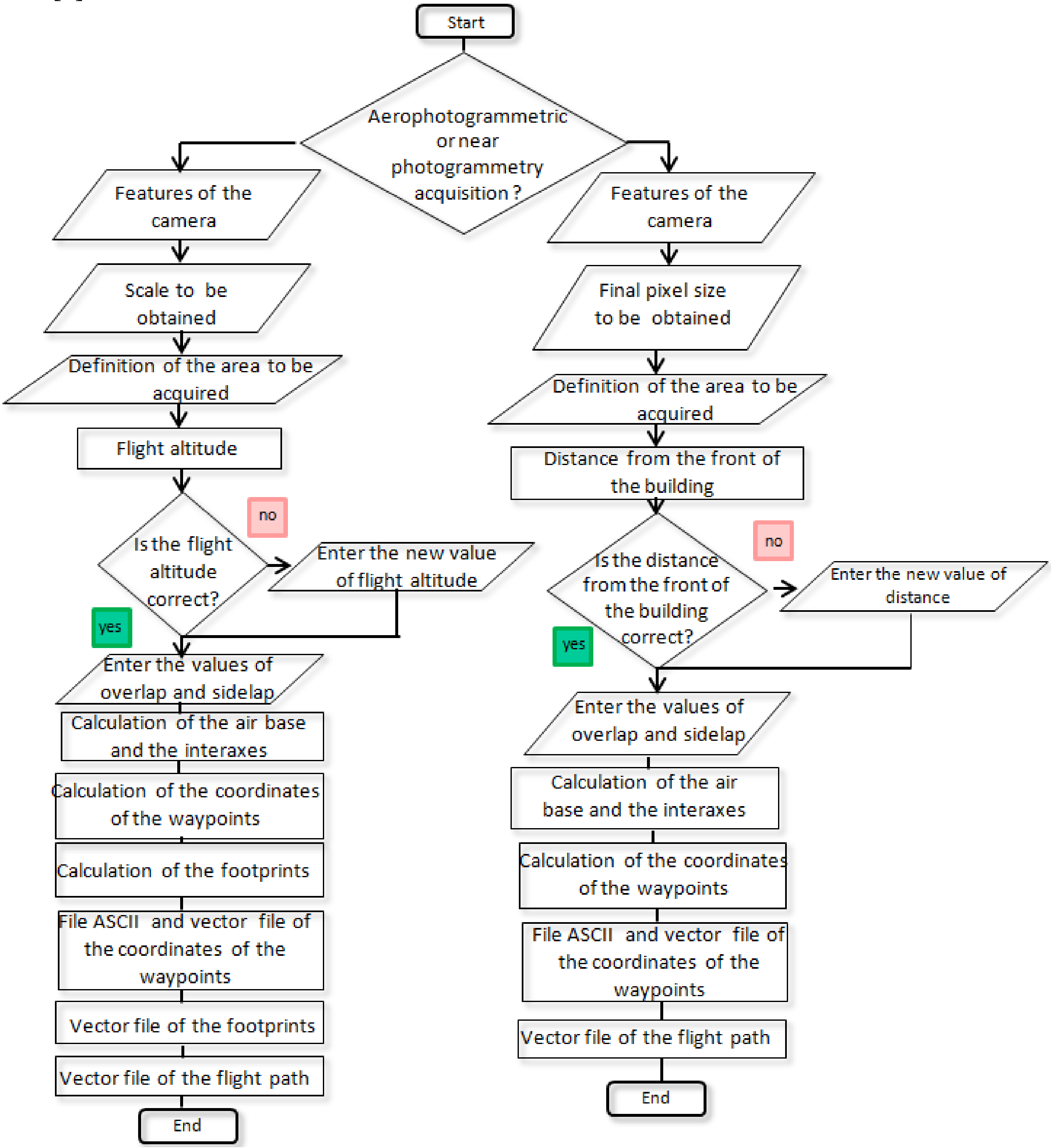

Figure 2. Flow chart of the software UP23d

At its end the program creates a report file, which also contains the intermediate results that were estimated during its execution.

In a post seismic environment UAVs can also be used to acquire front of buildings for near photogrammetry, in this case the package works in a slight different way as shown in figure 2.

As for the aerophotogrammetric survey, in this case as input data the size of the area to be acquired, the optic parameters of the camera installed on the drone and the dimension of the pixel in the acquisitions are needed.

4. Experimentation performed

To realize this experiment a typical European square with historic-monumental buildings was chosen: ‘Piazza del Palazzo’ in L’Aquila city [6]. Its dimensions are approximately 60 meters long to 38 meters wide covering a total area of 2500 square meters and surrounded by the public library, the city hall ‘Palazzo Margherita’ with its 40 m height bell tower (Fig.3).

Figure 3. The test area: Piazza Palazzo.

This test in the historic center of L'Aquila for this project is the result of a collaboration between Engineering Faculty of L’Aquila, Engineering Faculty of Rome ‘La Sapienza’ University and the IPT company of Rome, that provided a Mikrokopter platform in Okto configuration, including all on board sensors like Reflex Canon EOS 550D and GNSS navigation. The choice of this platform was made trying to achieve excellent flying characteristics of stability even in presence of wind or other non optimal climatic conditions and according to the payload specified by the manufacturer, which allows carrying a reflex digital camera like the EOS 550D. On this UAV takes off, the mode of autonomous flight can be activated but, in this case, all the 15 acquisitions were performed in ‘manual’ modality.

From this first analysis, we can note, that the number of acquisitions executed by the pilot was extremely redundant and this (as we explained) is presently the most diffused way to acquire.

To simulate an acquisition based on our planning software we looked for two acquisitions that reconstruct the geometry calculated by the software UP23d. So some stereopairs were found that have nearly the same geometry planned by the software (Fig.4).

Figure 4. In purple the trajectory planned by the software UP23d in green the actual 'manual' piloted path

5. Results

The extraction of a DSM from a photogrammetric survey need at least a pair of frames, with a minimum overlap of 60%, as the stereoscopy required to 3D survey is realized only, as it is well known, in this area of overlap. In this case, we have considered the two acquisitions between those made by the pilot UAVs, that come closest to those indicated by the software UP23d. In the present case, the frames which form a stereo pair, are chosen with a distance between the air base equal to approximately 39 m. and consequently with an overlap of 62%.

5.1 Tests performed in PCI Geomatics 2012 environment

A first processing was performed with the software Geomatics 2012 by PCI, based on the photogrammetric Toutin model. The treatment of the information content of aerial images acquired with the UAV and the extraction of their metric characteristics requires some preliminary steps, such as camera calibration. PCI Geomatics 2012 does not perform automatically calibration, the parameters must be entered manually. For this reason, the camera calibration has been realized through the use of software Photomodeler, which allowed to obtain the parameters which enable to the mathematical model to calculate the internal orientation and then to identify the relationship between camera and frame.

To take advantage of stereoscopic vision for the extraction of DSM is necessary to reconstruct the geometry of the two images in relation to the surface, calculating position and orientation of the camera relative to the ground at the time of acquisition. For this task the first step is to collimate an adequate number of Ground Control Point (GCP). In this experimentation 21 control points were detected in total, acquired by a GNSS RTK survey. After entering the GCPs is necessary to orient the two images in order to reconstruct the mutual position at the time of acquisition, through the identification of TPs (Tie Points). In this case the TPs were entered manually, because the images showed many shaded areas and deep parallax effects that led the automatic insertion algorithm to a big number of mismatching.

The DSM obtained through the use of PCI Geomatics 2012 is shown in figure 5 where the big precision of the central part of the DSM can be observed

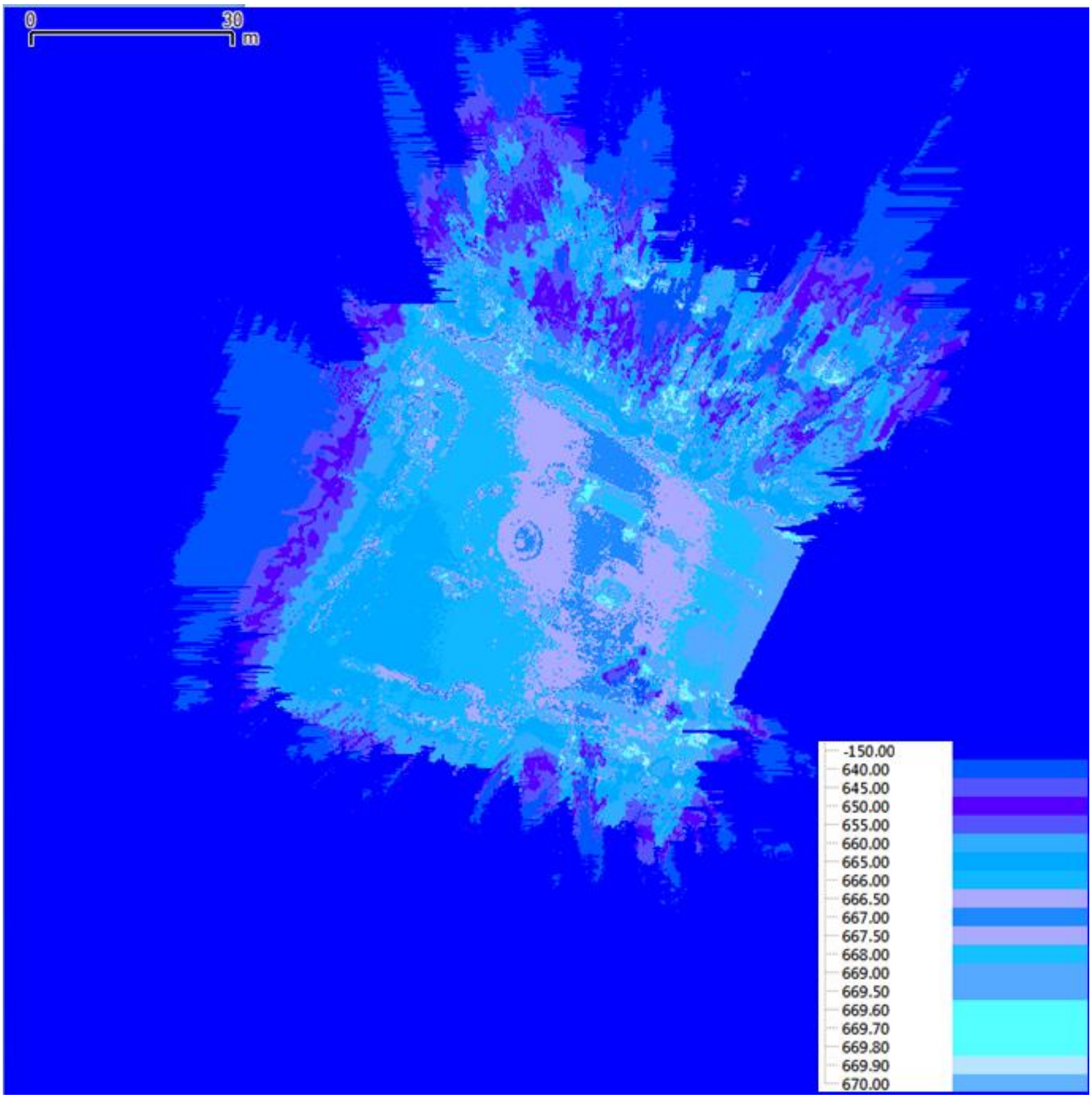

Figure 5. DSM resulting from the process of automatic extraction performed by PCI Geomatics 2012

5.2 Tests performed in Agisoft PhotoScan

Agisoft PhotoScan is an advanced image-based 3D modeling solution aimed at creating professional quality 3D content from images. In this software, differently from PCI Geomatics, both image alignment and 3D model reconstruction are fully automated.

Generally the final goal of photographs processing by Agisoft PhotoScan is to build a textured 3D model. The procedure of photographs processing and 3D model construction includes three main stages:

- The first stage is photographs alignment. At this stage Agisoft PhotoScan searches for common points on photographs and matches them, as well as it finds the position of the camera for each picture and refines camera calibration parameters. As a result a sparse point cloud and a set of camera positions are formed;

- The next stage is building geometry. Based on the estimated camera positions and pictures themselves, a 3D polygon mesh, representing the object surface, is build by Agisoft PhotoScan.

- After the geometry is constructed, it can be textured and / or used for orthophoto generation.

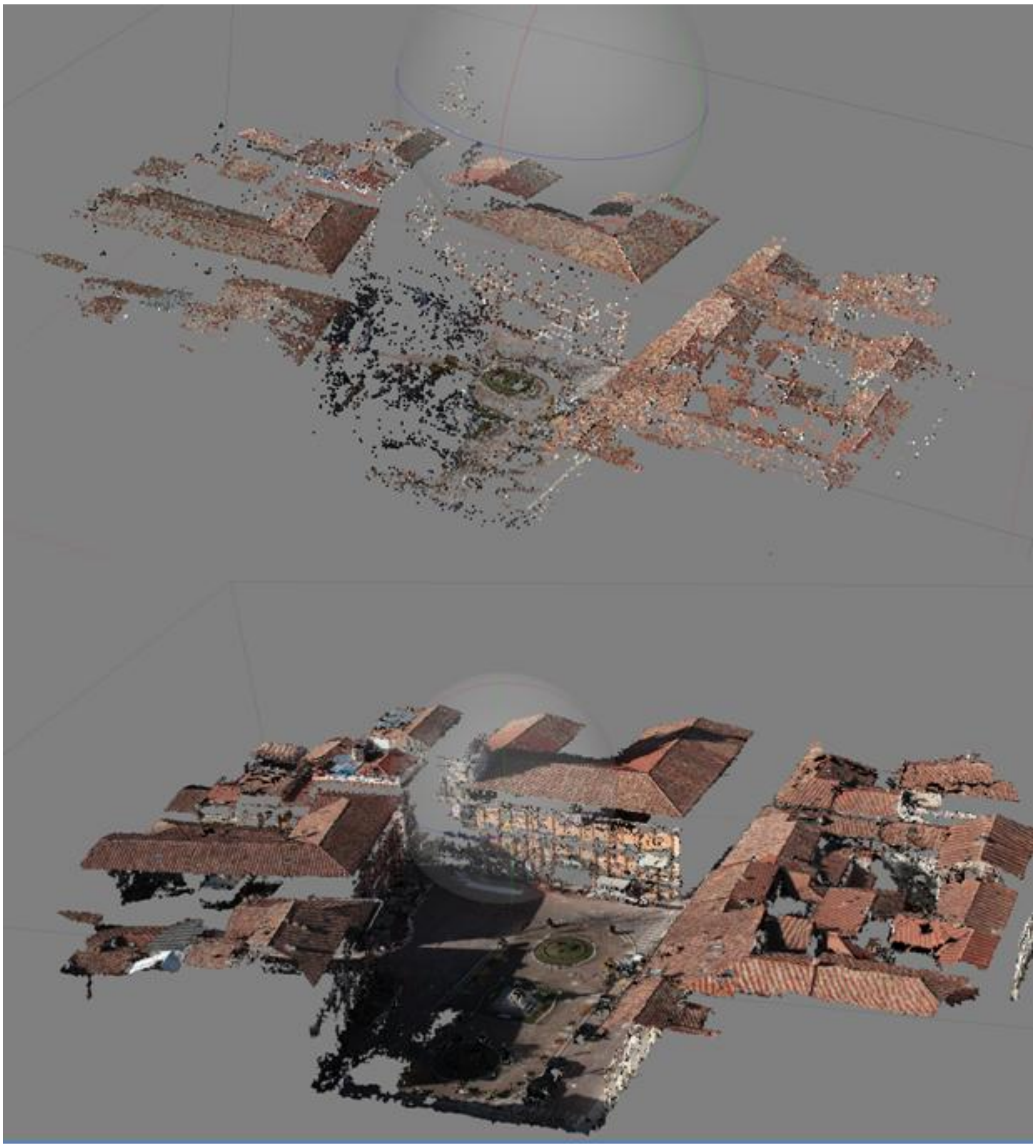

Figure 6. The procedure of photographs processing and 3D model construction in Agisoft PhotoScan

In figure 6 we can see the first stage of alignment of the photographs, and the final step of construction of the texture.

While carrying out photos alignment, the Agisoft PhotoScan software estimates inner camera orientation parameters, including nonlinear radial distortions. Normally this data are estimated automatically starting from information contained in the EXIF metadata.

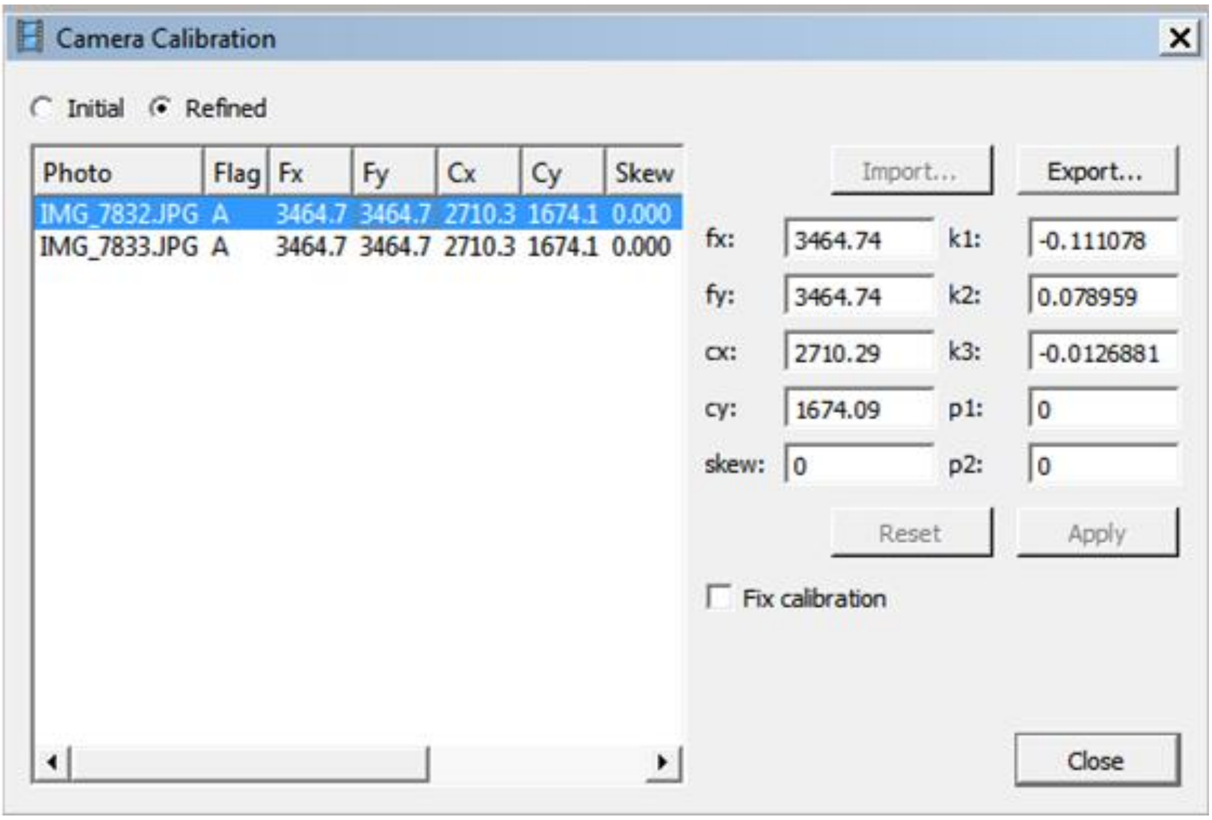

Figure 7. Camera calibration in Agisoft

The calibration parameters automatically calculated are;

- fx and fy : focal length in x- and y- dimensions measured in pixels;
- cx and cy: principal point coordinates, i.e. coordinates of lens optical axis interception with sensor plane;
- k1,k2 and k3 : radial distortion coefficients;
- p1 and p2 : tangential distortion coefficients;
- skew: transformation coefficient.

At the end of these operations have been included 21 GCPs, and then proceed to the extraction of the DSM.

The DSM obtained through the use of Agisoft PhotoScan is shown in figure 8.

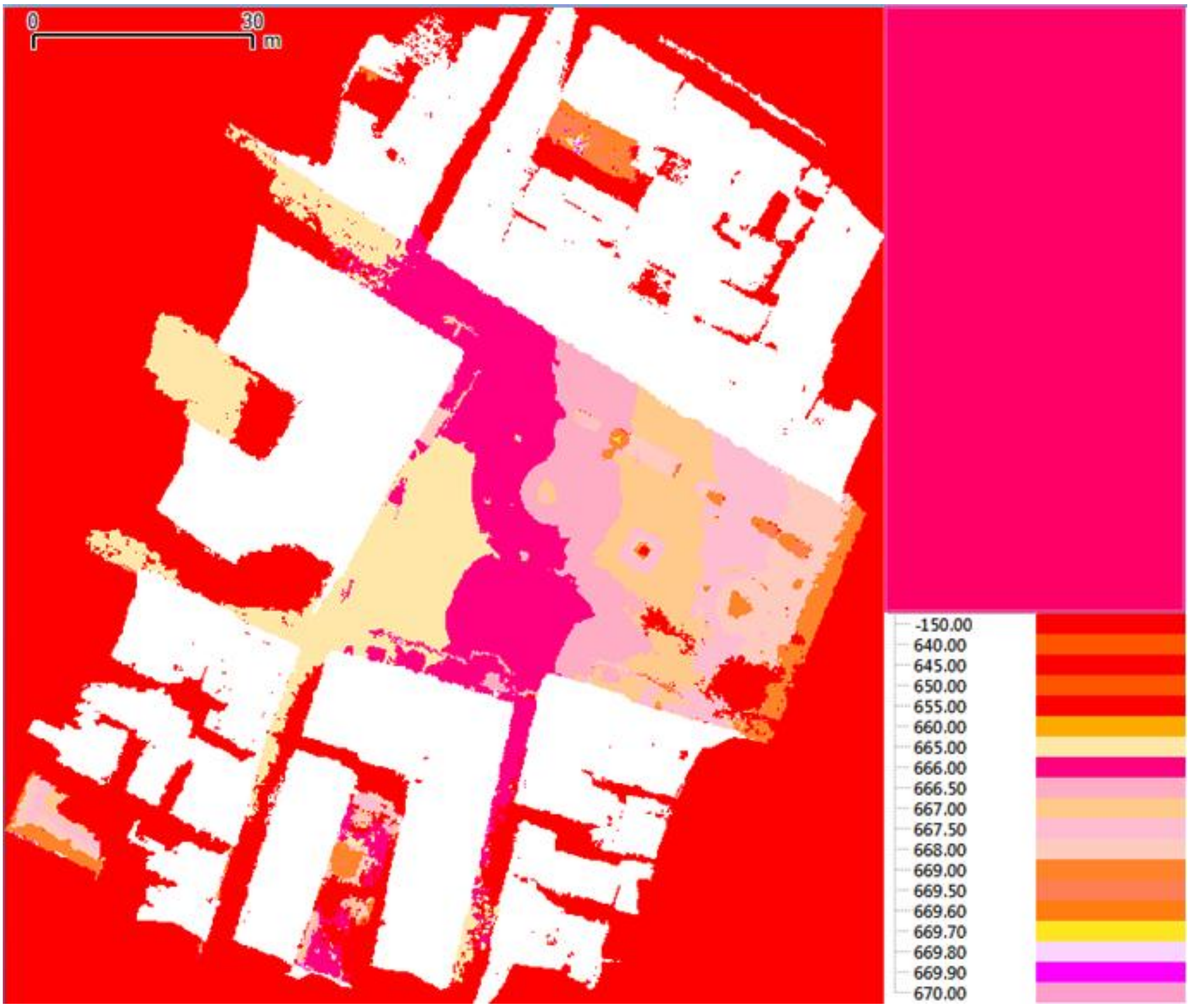

Figure 8. DSM resulting from the process of automatic extraction performed by Agisoft PhotoScan

5.3 Comparison between the obtained DSMs

In order to compare the obtained DSMs through processing with two different software, these have been implemented within the GIS open source software QGIS. Inside this package the module 'Raster Calculator' allows to perform calculations between existing raster files pixel values.

In this case the DSM obtained in PCI Geomatics 2012 was subtracted from the Agisoft PhotoScan DSM, obtaining a difference raster as shown in figure 9.

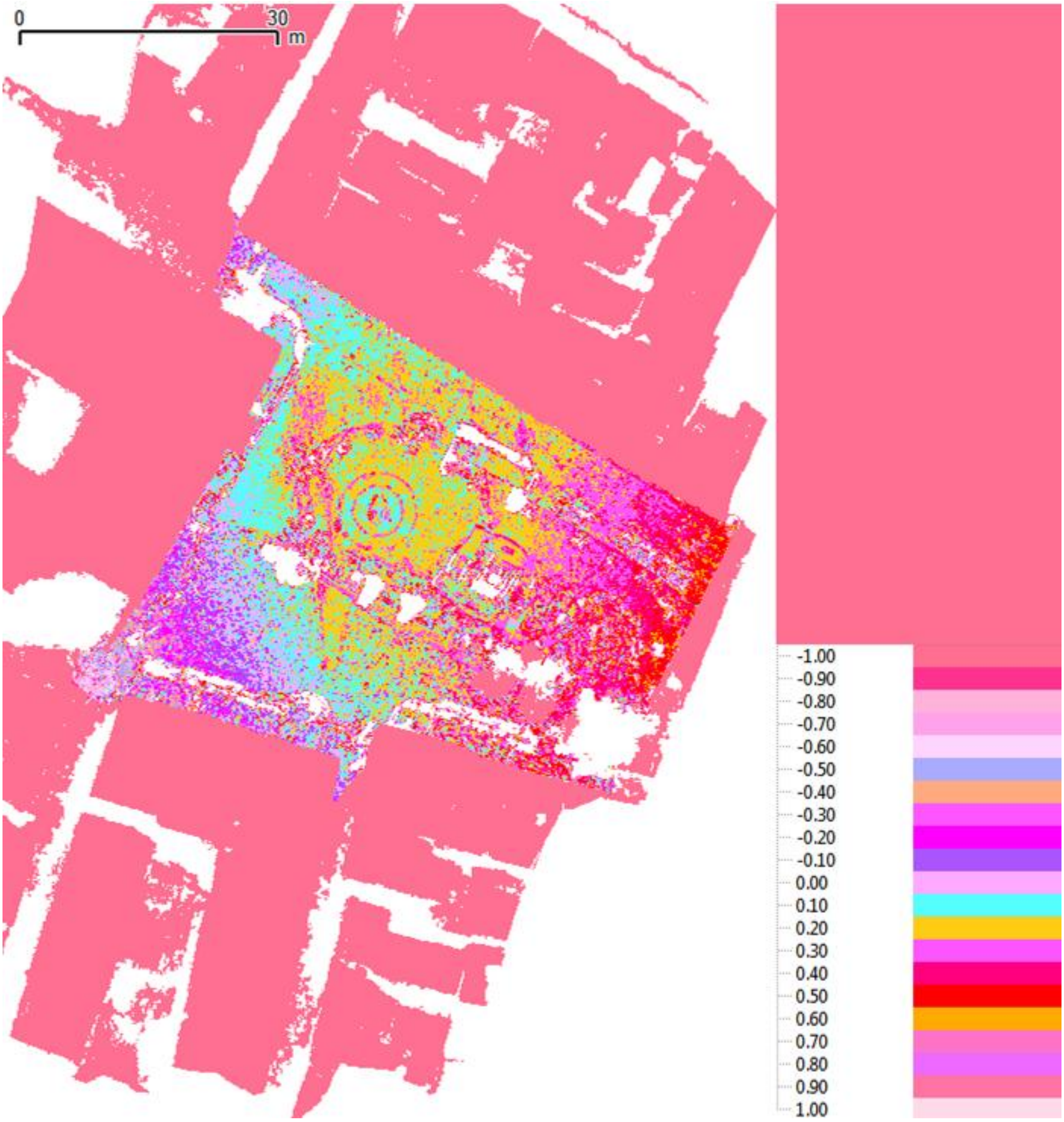

Figure 9. Raster obtained from the difference of the DSM processed by PCI Geomatics 2012 and the one obtained by Agisoft PhotoScan

To evaluate the differences between the results obtained with the two software, a set of nicely distributed points (560) was considered in correspondence of whom were evaluated the height differences between the two DSMs (Fig.10).

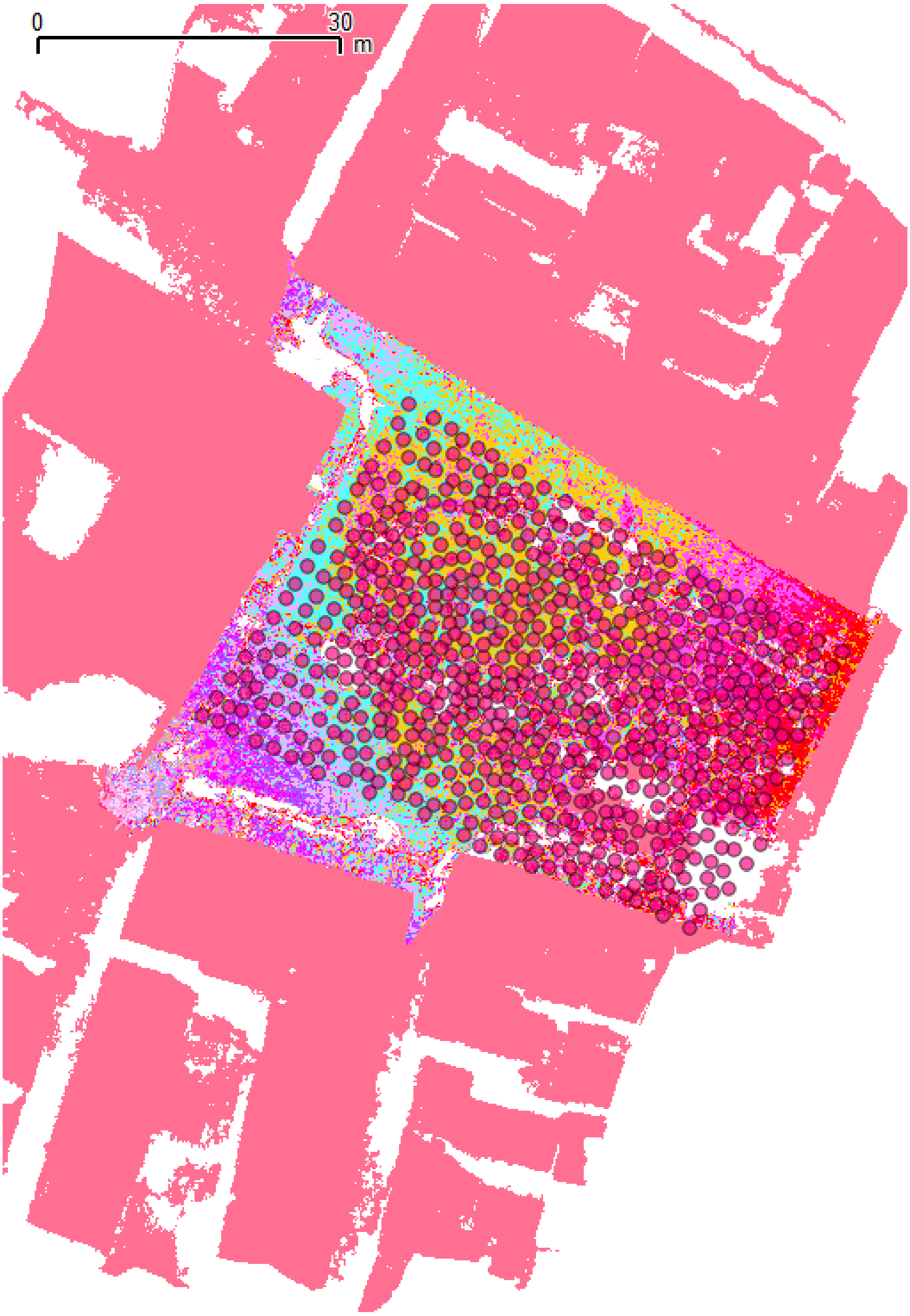

Figure 10. Points with respect to which calculates the differences in height between the two DSM

The results obtained were then plotted in a histogram, as shown in figure 11. The histogram has been built considering a range from -1 to 1 meter, with a step of 0.2:

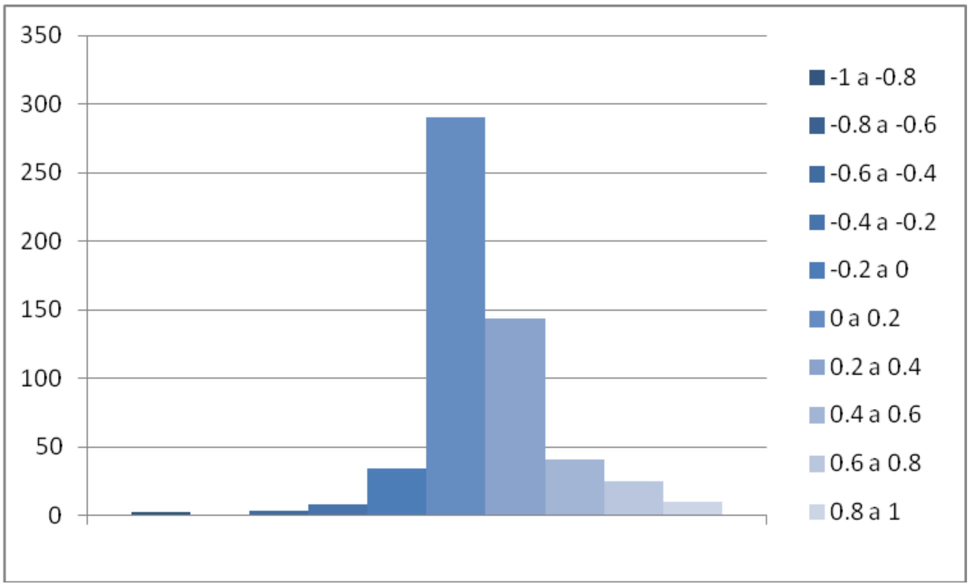

Figure 11. Histogram of the difference in height built considering a range from -1 to 1 meter

This first histogram shows that most of the height differences are included in class that goes from 0 to 0.2 meters with a notable positive bias. For this reason, we wanted to investigate how the differences within this class of share are distributed (Fig.12).

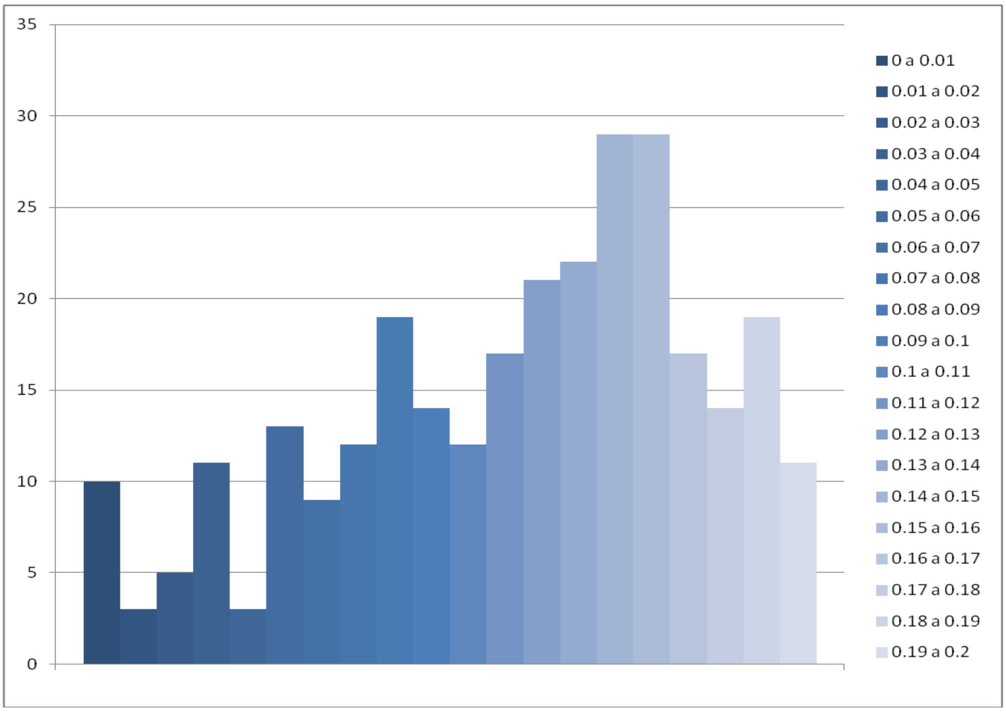

Figure 12. Histogram of the difference in height built considering a range from 0 to 0.2 meter

On figure 12 it seems that the most populous classes are 0.14 to 0.15 and 0.15 to 0.16 suggesting a sistematic bias around 15 centimeter higher for the PCI DSM. It has to be investigated which is the most accurate DSM comparing with an independent set of points with higher accuracy as LIDAR acquired points.

6. Conclusions

In this work, the advantages of the use of UAVs in the case of post-earthquake surveys scenarios, were tested. UAVs given the opportunity to fly, at low cost, nearby the objects we are interested to survey and for reconnaissance operations also in inaccessible areas. In this paper, some first results confirmed that the geometric conditions hypothesized are correct to automatically extract DSM in two of the most diffused photogrammetric software but further and more extensive test have to be performed. The two DSMs obtained through the use of two different software, PCI Geomatics and Agisoft PhotoScan were also compared showing a general good fit. These two software operate in a very different way, in fact the first requires the manual entry of calibration parameters, the second extracts them automatically, starting from information contained in the EXIF file.

At the moment, although the results between the two software appear comparable, a significant bias can be hypotized but presently not individuated. For this reason, a laser scanning survey is in progress actually, and comparing it with the obtained results, it will be possible to have a correct evaluation of the accuracy.

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