rt Anno 2009_Numero 121

rapporti tecnici INGV

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AN EXPERIMENT FOR ZSCAN EFFICIENCY IN SURFACE MONITORING

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Introduction

Several geophysical processes, involving crustal deformation, can be studied and monitored by means of the comparison of multitemporal Digital Terrain Models (DTM) and/or Digital Surface Models (DSM): deformation patterns, displacements, surface variations, volumes involved in mass movements and other physical features can be observed and quantified providing useful information on the geomorphological variations (Butler et al., 1998; Kaab and Funk, 1999; Mora et al., 2003; van Westen and Lulie Getahun, 2003; Pesci et al., 2004; Fabris and Pesci, 2005; Baldi et al., 2005; Pesci et al., 2007; Baldi et al., 2008).

Many techniques, including GPS kinematic methodology (Beutler et al., 1995), digital aerial and terrestrial photogrammetry (Kraus, 1998), airborne and terrestrial laser scanning (Csatho et al., 2005), remote sensors on space-borne platforms, both optical and radar stereo option, satellite SAR interferometry (Fraser et al., 2002), are suitable surveying methods for the acquisition of precise and reliable 3D or 2.5D geo-information. Actually, the technique to capture the evolution of a natural process, rapidly changing the terrain morphology of an area like a volcanic eruption or a rock mass collapse, taking a time of a few seconds or several hours (or more) is the digital photogrammetry. Scientific software exist to manage and process stereoscopic photogrammetric images, requiring professional operators but, recently, more friendly applications are developed to facilitate and make fast but efficient the analysis.

1. ZScan methodology

The photogrammetry is a technique which allows the definition of shape, size and position of objects using images taken from different points of view. Images can be acquired by analogic or digital cameras; because digital photogrammetry processes numeric images, the available film frames must first be digitized and translated from a continuous to a discrete data set. At the same time the intensity of the signal is given by a grey or color scale assigned to each pixel. In general, using the metric properties of an image, together with the coordinates of several Ground Control Points (GCP), the geometry and the position of an object can be described in a defined reference frame. The processing of stereo digital images can be automated using image matching procedures, based on well defined techniques relative to shape or grey/colour intensity for the same zones (Kraus, 1998).

ZScan is an innovative and complete measurement system for the accurate acquisition and management of point clouds; it is composed of a photogrammetric device with one or more (ZScanTer) calibrated cameras installed on a mechanical apparatus and of a special software for automatic image processing based on multi-focal analysis (Hornung and Kobbelt, 2006; Kolev and all., 2007; Labatut and al., 2007; Sinha and al., 2007; Furukawa and al., 2007). Actually, the mechanical support is an aluminium bar 1 m (or 0.5 m) long) especially designed to accommodate with high accuracy cameras on well known relative positions in terms of baselines and orientation to make simple the automatic registration and processing of images. The system is generally mounted on a tripod and equipped with a tilt head to choose for an optimal instrument stationing. Figure 1 shows an example of the basic system configuration, and a specific application (see below) with two cameras installed on known relative positions on the bar and the tilt was chosen to provide a good field of view. The acquisition can be executed using a single camera moved on calibrated positions or with two or three cameras in contemporary acquisition; in the first case three shots sequence are executed from three different known positions along the bar while, in the second case, three simultaneous shots are done.

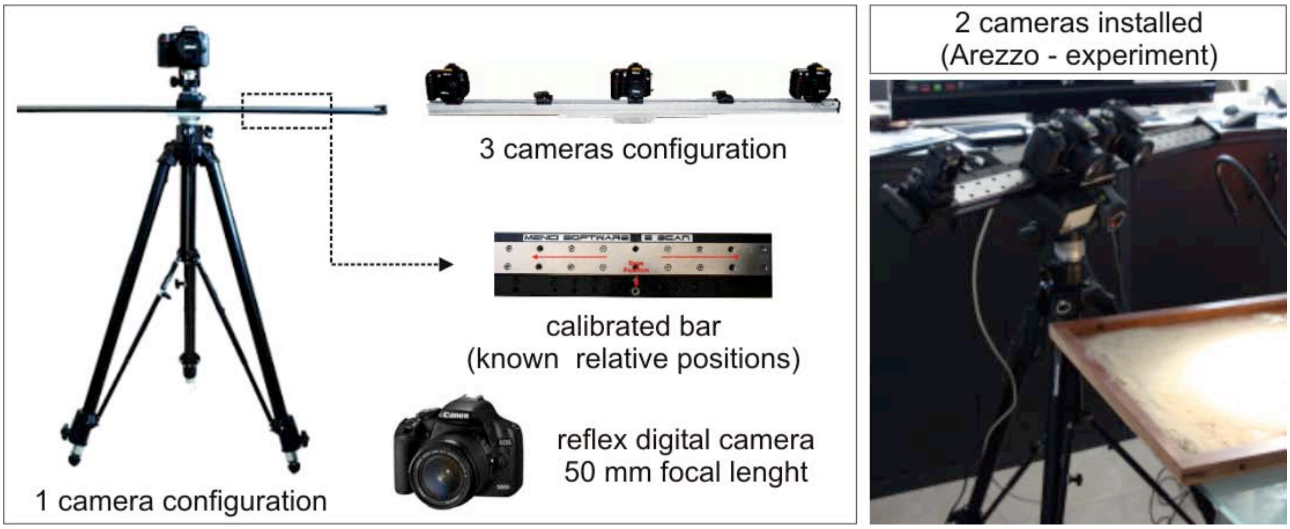

Figure 1. ZScan system. A particular of the calibrated bar and a real example while using ZScan.

The process duration takes just a few seconds time for image acquisitions leading to a real time point clouds acquisition and model (DTM) creation. Also multitemporal image pairs (or triplets) can be acquired and processed to capture the dynamical evolution of object in movement. The system works following simple steps; the images are imported into ZScan software, the user defines the interested area (a part or a complete image area) for point clouds and the generation of point clouds or DTMs is provided in real time introducing the geometrical parameters and information for program correct run, that is, relative cameras baseline and camera calibration. So, the ZScan software starts and processes data providing multitemporal DTMs. ZScan system is characterized by all the advantages of terrain surveying throughout stereoscopic image processing that is digital photogrammetry for DTM generation with high emphasis on the automatic analysis. This peculiarity makes the system suitable for high speed surface monitoring with or without the supervision of an expert user. Briefly, triplets or images couples are grouped taking into account the known cameras relative positions; nevertheless the software allows the alignment correction between images due to possible not-orthogonal errors caused by solid bar deformation. The final generation of the point cloud from image processing, needs the definition of an adequate grid-pass respect to object morphology, precision, processing time, working range and camera characteristics; the pixel size on the ground is automatically computed and the correlation between images is computed using the calibration certificate of the metric cameras. The actual ZScan is conceived to work well on moderate ranges (a few or some tens of meters) but it could be upgraded and improved for a wider application field.

In the context of a collaboration between INGV, UNIBO and Menci, aimed to extend the method to long range field monitoring, moved the cited institutes to test the ZScan system and to conceive the appropriate modifications for physical surface monitoring on both volcanic areas and in areas subjected by relevant mass movements due to hydro-geological causes (the work to draw up a definitive agreement document is in progress; for more details, please contact pesci@bo.ingv.it). The idea is to generate an integrated system based on both TLS, GPS and ZScan technologies. The relative position between calibrated photogrammetric cameras can be well known apriori or can be acquired after the multitemporal images acquisition by means of both GPS and laser scanner measurements. In this way, the observed areas and the acquired images will be automatically processed into the WGS-84 reference frame. The very accurate knowledge of relative camera position is needed for the optimal operative sequence of ZScan software. At first, some experiments are needed to validate ZScan for rapid surface monitoring.

2. Experiment

The first experiment was performed on July 2009 at Menci srl laboratories in Arezzo city. A model of a volcano, composed of two parts, was used. The first part was solid clay stable and fixed material, while the second one was made of unstable material like sand. A simple mechanism was adopted to move the sand simulating a terrain movement and collapse; a blown balloon, connected to a thin kane was, inserted beneath the sand and was slowly deflated by user (Figure 2).

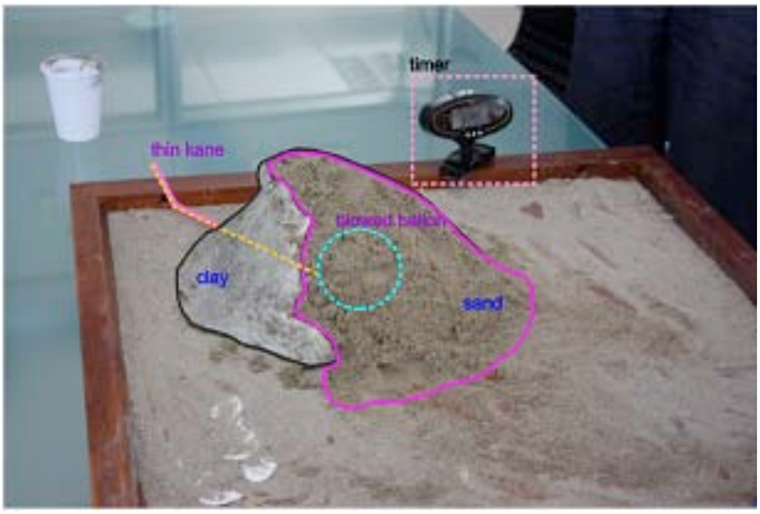

Figure 2. The in scale apparatus of about 30 cm x 30 cm x 15 cm size.

The choice was to test the system on bad conditions due to the homogeneous colour of used material and, therefore, a more difficulty in automatic images processing. The dynamical sequence was to simulate a sort of degassing phenomena leading to surface variations and mass collapses; it was captured with 1s time interval between scenes (singe shots).

Figure 3 shows the ZScan system during the experiment mounted near the in scale apparatus to simulate volcanic collapse and figure 4 shows two images of the model captured by CAM1 and CAM2 at the first instant of the dynamic evolution.

Figure 3. ZScan system and in scale model from different point of view.

Figure 4. The first images contemporary acquired by the two cameras.

The complete phenomena sequence is represented in Figure 5, showing the images captured by CAM1 and the corresponding extracted DTMs, automatically created in real time by ZScan (Figure 6). 3D models got during the eight steps of sequence have an average resolution of 1.5mm (Ground Sample Distance). This resolution is obtained using a 10 pixel step for model generation (every 10 pixel on picture a 3d point is generated on model). By reducing that step to 3 is possible to generate 3d models up till 0.5 mm resolution. Not ever it is the best solution: higher resolutions mean bigger file sizes and sometimes redundant 3D information. The average number of points of each model is 15000 points. The resolution value is related to several parameters: acquisition distance (in the experiment 60 cm), the type of lens, camera sensor resolution.

The fixed position of cameras assured the common and stable reference frame making possible the definition of surface variation models (Figure 7) by means of difference between subsequent DTMs (in terms of time). In particular, vertical mass variation of the order of 4 cm are obtained.

3. Conclusions

An experiment to check for ZScan system efficiency in terrain monitoring was realized using a simple apparatus simulating the collapse of a volcanic area. The dynamical sequence was realized deflating an internal ball and the images were acquired with 1 s time step and the adopted automatic software and device allowed an immediate and totally automatic definition of accurate digital models. The accuracy depends on survey qualities: chosen baseline, subject surface properties, illumination, static or dynamic conditions, maximum resolution achievable. In the experiment conditions we got an average Z resolution of 0.3 mm using a 160mm baseline.

The results demonstrated that this methodology allows an efficient acquisition of dynamical processes and model restitution and encourages researcher to export the method in the long range application field for instable physical surface monitoring. The work is in progress to create an integrated measurement system able to capture dynamical phenomena in fast evolution like, for examples, lava/ debris flow.

Figure 5. Images from CAM1 acquired at 1 s sampling rate.

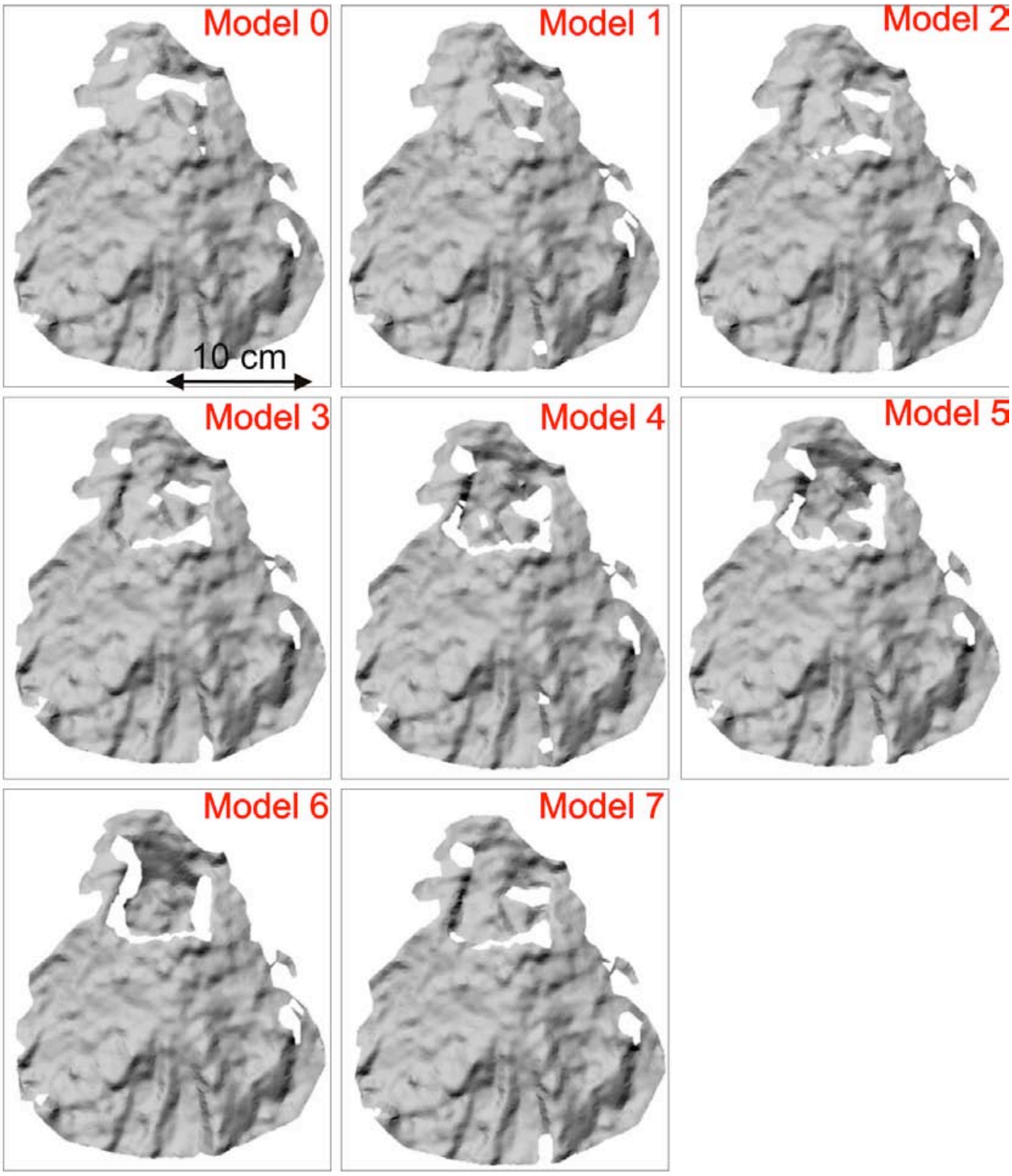

Figure 6. Models automatically provided by ZScan software from stereoscopic image pairs analysis. The derived points (point clouds) are used to create multitemporal DTMs.

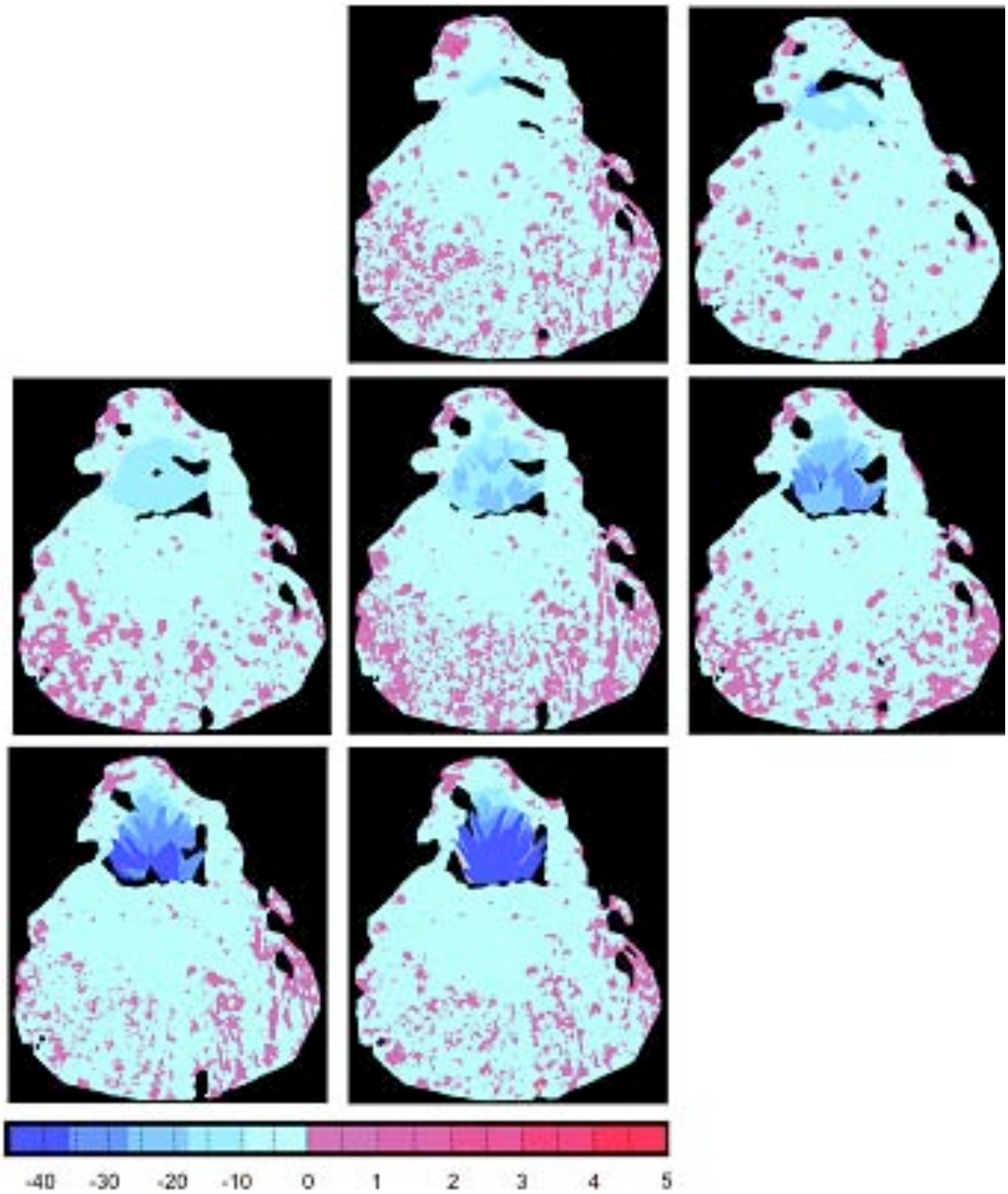

Figure 7. The surface variation maps (mm) by direct comparison between models pairs shown in figure 6.

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