EVALUATION OF THE DAMAGES CAUSED BY SEISMIC EVENTS: FIRST TESTS ON SUPPORTING TRADITIONAL MULTISPECTRAL CLASSIFICATION WITH DSM

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ABSTRACT:

Seismic damages, as a roof entirely collapsed on the ground, are very difficult to be found using only multispectral classification algorithms. The availability of high resolution stereopairs from satellite disclose new possible fields of application to estimate changes and transformations of areas following catastrophic events. Combining both techniques it is obviously possible only when stereoscopic and multispectral images are available. In this case, as for all monitoring studies, it is necessary to compare the present situation to the pre-seismic one.
The pre-seismic situation can be advantageously studied by classic photogrammetric techniques based on aerial frames, that are available in archives managed by photogrammetric companies and local government agencies. But it is also possible to extract the pre-seismic morphology from digital maps, containing the three-dimensional characteristics of the buildings. The present research tries to: a) improve the digital surface model extracted from Ikonos satellite images covering an area of central Italy (Foligno, Umbria), through a pre-treatment of images and a manual editing b) study the best DSM models to improve the detection of height difference, mainly in urban areas, and evaluate the results of the classification of land cover as further data to detect changes in building shape. DSM obtained by three-dimensional maps have been compared with DSM extracted directly from aerial stereo-pairs using different approaches. In the area under study a seismic event happened in September of the '97 causing relevant damages to different urbanized centres of the area.

1. INTRODUCTION

1.1 Site under study

The investigated area presents mountains (mainly in the eastern part), hilly areas and lowlands near Topino river and its tributary Menotre, with heights above sea level varying from 300 to 1200 meters. The area includes some small urban agglomerations, mainly constituted by buildings of two-three floors, and some industrial zones with ample sheds.

Figure 1. Site under study

On September 26th, 1997 a seismic crisis started, lasting up to the first months of 1998, and interesting different municipalities, beginning mainly in Colfiorito and Cesi, with various replicas of notable intensity, particularly that of October 14th, 1997 that interested the territory of Sellano and Preci. The areas hit by this seismic event cover a big part of the regional territory of Umbria, with damages especially in the zones of the Apenninic chain, in the towns of Colfiorito, Tesina, Sostino, La Franca. Following such events a joint project of CNR/GNDT, National Italian Seismic Service and Umbria and Marche Regional Administrations, was started with the collaboration of the Geologists Professional Orders of the involved Regions.

1.2 Aim of the work

In previous papers (Baiocchi, 2008) the possibility to appraise the damages caused by the 1997 central Italy seismic event through comparison of DSM automatically extracted by satellite IKONOS imagery and from aerial photo were experimented. In the present paper has been tested the possibilities to improve the results previously obtained, through use of different approaches and particularly using both the height and multispectral informations.

1.3 Overview

In literature some experiences of comparison of SAR data pre and post seismic event, and a classification of corresponding optic high resolution multispectral images are reported (Stramondo, 2006). Such experiences suggested to the authors to evaluate also the possibility to use the height information automatically obtained from stereoscopic images together with the multispectral information of the same images.

2. EXPERIMENTATION

2.1 Data and instrumentation used

The situation of the area in 2006 has been described through Ikonos panchromatic stereo images of part of the zone interested by the seismic event (an area of around 150 km^2), characterized by a geometric resolution of 1 m, 11 bit of gray depth, standard geometric corrections, and pseudo epipolar geometry. Automatic DSM extraction has been performed through the rigorous photogrammetric model implemented in the PCI Geomatica OrthoEngine software. The GCPs, necessary for photogrammetric orientation of the images, have been measured through a GPS survey in NRTK and rapid static post-processing modes.

The obtained DSM has been validated through comparisons with some checkpoints, with height spot points derived from the 1:5000 scale Regional Technical Map (CTR) and with the results of some kinematic surveys performed during the transfers for measuring the GCPs. Such comparisons reported an accuracy around 2-4 m in height. From the images an orthophoto map was also derived; its planimetric accuracy is less or equal to pixel dimension, therefore inferior to one meter.

The morphology before the seismic event has been derived from 1977 archive aerial images at 1:33000 scale (grey scale), and 1:13000 scale (colour), acquired with a *Wild RC10* camera (with known calibration data), digitalized with a photogrammetric scanner Vexcel UltraScan 5000, at 1200 dpi resolution. Using the software *Socet Set* by Bae System the photogrammetric model has been estimated, then has been possible to extract a DSM representative of the area of study as it was thirty years ago.

2.2 Previous experimentations

Older experimentations (Baiocchi, 2008) showed that the algorithms of change detection individuate many variations happened in the urbanized areas, keeping in mind that post-earthquake effects after about 10 years from the event, are not sufficiently representative of the immediate consequences of the event; many buildings have in fact been reconstructed. Anyway, the test allowed to show that the variations of the urban and road tracks can be easily detected especially using the change detection algorithm on single orthophoto images. The comparison of DSM has allowed anyway to easily underline variations not detectable using only the change detection algorithms.

It is however important to underline that has been possible to compare very different initial data, separately elaborated with different software, getting important information on the changes happened during the years and above all following the seismic period. It has not been possible to observe all the variations caused by the seismic events with the available images, because most of the damages have been repaired in the period between the seismic event and the acquisition of the available Ikonos stereo-pairs, but some methodological considerations on the advantage of combining the two techniques can be done.

The main change detection algorithms are very effective where there is a presence of new buildings, new roads, etc., but not always able to represent with sufficient accuracy the changes occurred in the territory, especially when there are changes in altimetry.

2.3 DSM extraction models comparison

The results of the described DSM comparison were obviously influenced by the algorithms.

Regarding this, the first step of the research is to evaluate the influence of the different models of DSM extraction from aerial and satellite images. In fact DSM extracted using PCI with IKONOS stereopairs showed poor accuracy representing narrow roads in urban areas. For this reason Ikonos stereopairs were also processed with Socet Set models to evaluate if the quality of the DSM can be improved.

From the comparison with height acquired with differential GNSS cinematic surveys in the area of study, the accuracy of the two DSMs seems very similar (2-4 ms). However, the DSM automatically extracted using the Socet Set software in some zones introduces a less discontinuous trend in comparison with the same results obtained with PCI, as shown in figure 2, where a vertical profile comparing the two DSMs is depicted.

Figure 2. Comparison between PCI and Socet Set results

In figure 4 are shown profiles of the DSM extracted with PCI (red), of that extracted with Socet Set (blue) from the Ikonos stereopairs, and of that extracted with Socet Set too but from aerial images (green).

Figure 3. Path of profile 1 - Colfiorito area, satellite image

The DSM extracted with PCI and that extracted with Socet Set have a similar trend and the new buildings, built after 1977, are well represented (orange color circle in Fig. 4).

From a second vertical profile effected in correspondence of the buildings in the historical center of Colfiorito (already present on the 1977 aerial photos)

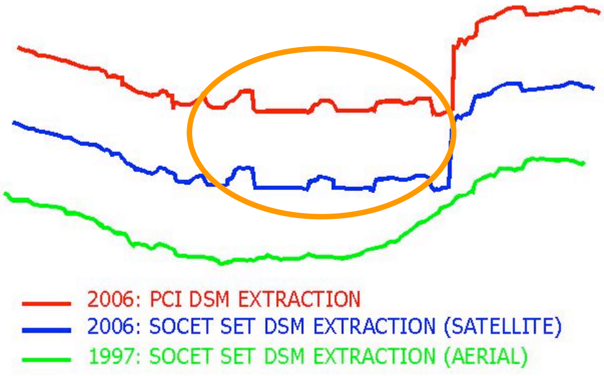


Figure 4. Profile 1

and shown in figure 6, it is possible to observe that the two DSMs extraxcted from satellite stereopairs don't correctly delineate the buildings near narrow roads typical of the historical centers, while the DSM extracted by the images aerial model more accurately such discontinuities (evidenced with a yellow ellipse in Fig. 6).

Figure 5. Path of profile 2

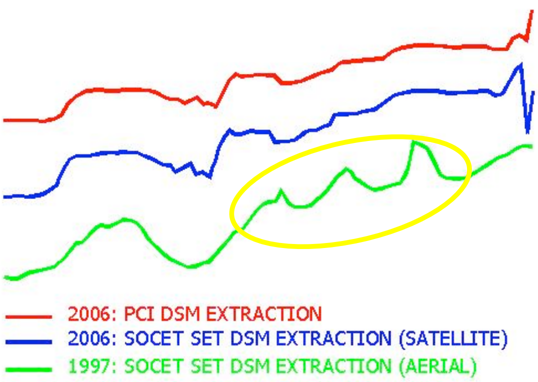


Figure 6. Profile 2 over buildings

These characteristics of the aerial images are very useful to correctly represent the urban areas, and for their proper modeling. On the other hand, aerial imagery need longer time for the acquisition and the elaboration in comparison to the correspondent satellite imagery, and in emergency situations as the seismic events, a rapid elaboration can be of critical importance.

2.4 Satellite imagery pre treatment

To improve the DSM extracted by the Ikonos stereopairs a pre treatment was performed on the raw images. In fact a Sobel filter was applied on the images to better define the radiometric edges and then to extract a new DSM from the filtered images. An increase of the percentage of success was observed in the process of automatic correlation (figure 7), appraisable also as improvement of the quality of the orthorectified images obtained by the same DSM (figure 8)

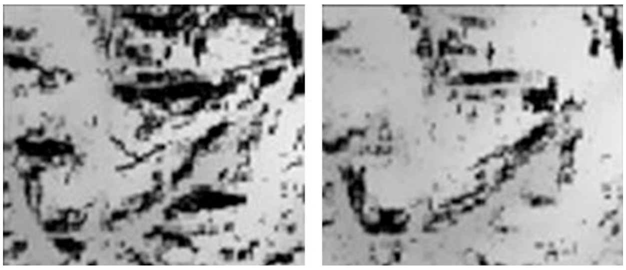


Figure 7. DSM from original imagery (left) and Sobel filtered imagery (right). In black areas were correlation failed

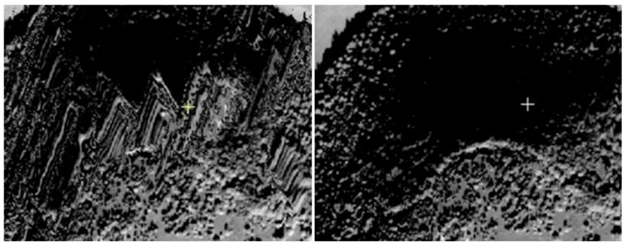


Figure 8. Images orthorectified using DSM from original images (left) and from filtered images (right)

Thus, improving DSM accuracy is not only a critical factor for the surface reconstruction but also for multispectral classification performed on orthorectified images.

3. CHANGE DETECTION STRATEGIES

The principal variations on the study areas from the 1997 seismic event regard mainly buildings, a lot of which have been completely destroyed. As mentioned above, precedent researches demonstrated that building identification using only "classic" change detection or DSM difference techniques show the same limits. For this reason an evaluation of procedure to individualize collapsed buildings using both height and multispectral information was performed.

3.1 Multispectral classification

On the whole area of study, different clippings of the multispectral orthorectified image, representative of different areas interested by the seismic event, were selected. On such clippings a multispectral classification has been effected in the Envi (ITT) environment, using a supervised "pixel based" classification technique, based on a maximum likelihood algorithm, that has allowed the recognition of the most greater part of the present buildings.

During the classification process different classes of coverage of the ground have been individuated as: buildings, asphalted roads, not asphalted roads, shades, different types of crops. The results of the classification have been reported, as usual, in raster file in which each pixel has a digital number representing the class assigned.
From such classification only the class "buildings" has been drawn out and subsequently used to individuate the existing constructions in the area of study.

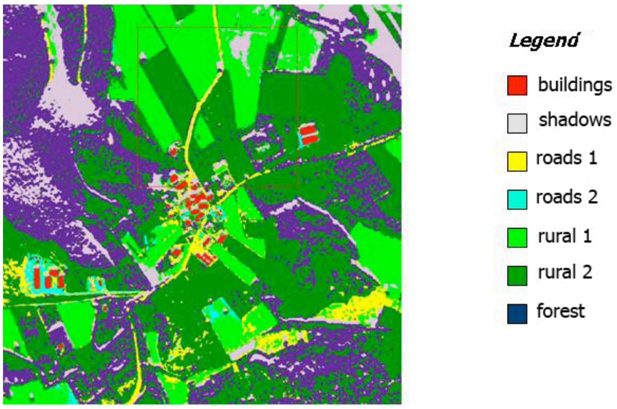


Figure 9. Multispectral classification

In figure 10 is represented an example clipping in which 53 buildings are present, of which 42 were detected using only multispectral classification, with 4 errors of classification on areas with same radiometry of the roofs (yellow squares in Fig. 10) but where there is no buildings.

Figure 10. Errors of multipsectral classification

3.2 DSM difference

To eliminate, or at least to reduce, the errors of classification found on pixels representing soil with radiometric characteristics similar to roofs, a pixel by pixel height difference was performed among the DSM obtained by the Ikonos stereopairs and that extracted from 1:5000 scale cartography. The difference between the two models underlines what is above the ground (so that for example fields and bare soil are excluded because present the same height in the two models), therefore buildings but also vegetation. For the analyzed clipping, 46 buildings of the 53 presents have been individualized and 5 errors have been made in correspondence of the vegetation (yellow squares in Fig. 11).

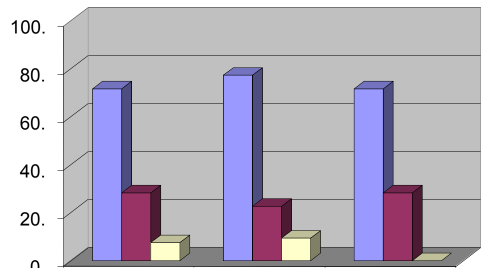
Figure 11. Detection errors considering only DSM and DTM difference

3.3 Using the two techniques together

Subsequently, in GIS environment, the results of the two techniques of individualization of the buildings were combined, to eliminate the mentioned errors, as fields of the same color of roofs for the multispectral classification, or trees for the differentiation between the surface models. In figure 12 are represented the 38 buildings individualized using both techniques without any error. It has to be underlined that some buildings were not detected, as the two with the grey and almost white roof near the center of the clipping, but there is no false detection of building.

Figure 12. Results obtained using both techniques together

So a multispectral classification alone can detect the same number of buildings of the two techniques together, but with a 7.5% of false detections, while a DTM difference detects a little more (around 5 %) buildings than multispectral classification alone but with more false detections.



	Multispectral classification only	DTM onl	Bot
Correctly	71.	77.	71.
Undetecte	28.	22.	28.
False	7.	9.	0.

Table 1. Detection percentages of the different strategies

The strategy of using both techniques together detects the same number of the first strategy but with no false detection.

3.4 Comparison with medium scale cartography

The obtained results have subsequently been compared with the 1:5000 scale vectorial file of the "Technical Map of regional Administration (C.T.R.)" in which the buildings are represented as polygons that are contained in a specific layer. So it's possible to verify the correspondence between the individualized elements and the effectively present buildings in the area of study and it is also possible to individualize the buildings eventually not represented on the map due to lack of updating. So when this method is utilized to evaluate damages after a seismic events, the comparison between existing cartography and the buildings map obtained using both techniques together can give four different results: 1) building show on the classification and on the cartography, 2) building show on the classification but not on the cartography, 3) building not show on the classification but on the cartography, 4) building not show on the classification nor the cartography

Figure 13. Comparison with medium scale cartography

The first occurrence is when a building appears on the classification and on the cartography. It means that a building reported on the cartography is not damaged, or only partially damaged, because the model individuated that it has an height difference from the ground. In the second circumstance the classification found a building that is not on the cartography (as the one underlined in fig. 13). This is because the cartography is not updated but the building suffered no or little damages. The third situation is surely of interest in a case of emergency, because a building reported on the cartography is no more detected by the classification, so it is probably an existing building collapsed. In this case there is a possibility (in our example 28 percent of the buildings) that the classification failed to detect a building that suffered no damage but a quick check on the orthophoto map by the operator can confirm or not the detection. In the last occurrence there is probably no damage because there is no building on the classification and on the cartography. In this case there is a very little possibility that a building newer than the cartography collapsed but anyway the model cannot detect it because is at the level of the ground. In this case the problem of the diction of the collapsed building depends on the cartography updating. Anyway, this last occurrence is unlikely, also because newer buildings usually suffer less damages from earthquake.

4. CONCLUSIONS

The use of satellite techniques can be very useful for the management of an emergency like a seismic event because it can frequently furnish similar results but more quickly. Another advantage of satellite technique is the availability of stereopairs and multispectral images in the same acquisition, frequently not available together using aerial images. On the study area, interested by the seismic event of 1997, "classical" change detection techniques using monoscopic multispectral images detected a big part of the buildings present. The use of DSM extracted from the same high resolution stereoscopic satellite images and DEM extracted from medium scale cartography can detect a slightly bigger number of buildings. Use both the techniques led to a detection of buildings without false detections. After a seismic events the buildings so detected can be considered in a first analysis the undamaged or little damaged ones.

Comparison of the detected buildings with polygons representing buildings on an existing vector cartography of the same area can underline quickly the "missing" buildings: existing on the cartography but not detected on the satellite images. A little percentage of over-detection is possible when a building present on the cartography is not detected on the image but is not actually collapsed; but this can be quickly checked observing the image. There is still a very reduced possibility that a collapsed building is not reported on the cartography because lack of updating of the cartography itself, but this can be avoided only with a continuous cartographic update.

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