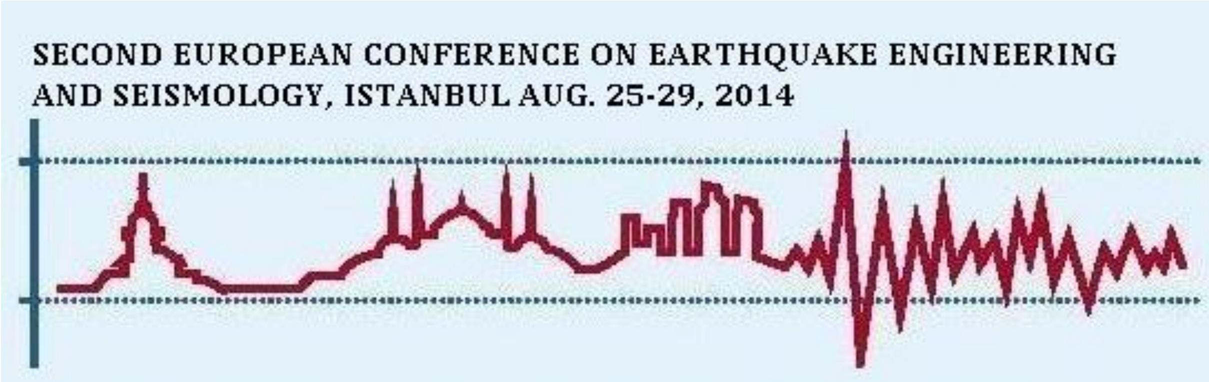

DETECTION OF BUILDINGS HEIGHT USING SATELLITE MONOSCOPIC IMAGE

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ABSTRACT

Just after a natural disaster occurrence, like earthquakes, the remote sensing remains often a substantial way to detect the extent of this disaster on the affected area. It allows the implementation of a real time post-disaster management plans, mobilization of emergency, coordination of seeking and rescue, mapping the extent of the damage.

With the advent of the very high resolution satellites, the opportunities to improve the frequency and quality of urban data have emerged. The very high resolution satellites, whose discrimination power of objects on the ground can help to quickly develop useful tools to various stakeholders in the post disaster crisis.

This paper aims to develop an automatic technique for the detection of buildings height, based on the analysis of buildings shadow derived from panchromatic Quick Bird images. This method can be used for the detection of post-earthquake building damages.

INTRODUCTION

The post seismic crisis management assumes that the access to reliable and continuously updated data will be available shortly after the event. In developing countries, like Algeria, these data are rarely available quickly after the earthquake occurrence, because the traditional means of collecting information are, in one hand expensive, and in the other hand, the collected data take a long time to be used by the post-disaster managers.

The satellite images can constitute solutions for the response to such a need.This data type is mainly used to improve the frequency and quality of urban data and especially to reduce the cost of information. The very high resolution satellites can help to quickly develop useful means to various stakeholders in the post earthquake crisis.

The remote sensing techniques provide information to broad coverage, allowing the identification of the measured objects (buildings). In case of earthquakes, this information is used to detect and identify the seismic vulnerability of buildings.

In the literature, several studies have been developed for the building damage extraction from radar and optical images. The techniques used in the field of radar, allow evaluation and detection of relevant objects on the studied area (Stramondo et el 2006; Blaz et al 2010; Dell'Acqua et al, 2010). Their main advantage is being independent of weather, but such images are difficult to be interpreted. Radar images are based on average differences between areas, and have different behaviour according to the average radiometry of the area, which induce some errors in the interpretation. In fact, in the most cases, these techniques provide noisy results.

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On the other hand, optical images are easier to be interpreted and objects are more realistic, but they have the disadvantage to be dependent on weather. This type of images is often used in an analogical manner for the detection of earthquake damaged buildings (Tong et al, 2012), however this method is dependent on the skill of the photo-interpreter. The methods which use shadow changes, after partial or total collapse of a building, have been investigated also by (Mansourian et al, 2006;Yamazaki et al, 2009; Li et al, 2011; Meslem et al , 2011). The disadvantage of these methods is that, they still depend on the skill of the imagery interpreter. Automatic methods were developed using stereoscopic images to generate DEM (Digital Elevation Model). These methods allow damage building identification through the difference between the building heights (Turker et al, 2005; Tong et al 2012), however the big disadvantage is the high cost of images.

Other methods for post earthquake damage assessment, based on the building shadow do exist. They used panchromatic images which are less cost. In [Vu et al, 2004], the main cause of errors in this method results from the consideration that pre-seismic and post-seismic images are identical, and that, they do not depend on time or seasons where they have been taken. Consequently the sun azimuth angle which changes with seasons and hours, is not taken into account, this leads to some errors.

Within this study, an automatic method is developed based on the building shadow to detect post earthquake damages, using panchromatic Quick Bird images.

DEVELOPED METHOD

The indicator of damage is the height of buildings, so hereafter this parameter is considered and an automatic method for the determination of the height of buildings is developed. This method is based on the determination of the height of the building from its shadow, and has the main advantage to be independent of time and seasons of shooting the satellite image and from the skill of the interpreter.

The main steps of the method are:

<u>Step 1: Extraction of the building shadow</u>

The extraction of building shadow can be performed through the use of a panchromatic channel or multi spectral bands. In the present study, the panchromatic channel is used because it is sensitive to all the wavelengths of the visible spectrum. This is not the case of multi spectral bands which is sensitive to only some wavelengths (blue, green, red and infrared). The panchromatic channel has also the advantage of having a higher resolution (pixel dimension) than multi spectral bands (In the case of a Quick bird image the resolution is 0.6m, better than multi spectral bands which have a resolution of 2.4m). This leads to reduce the calculation error on the building height. To do this, two operations must be performed:

a) Determination of the scene orientation:

Usually the direction of true north is not identical to the image north (or image column axis). Therefore, the rotation angle (Rn) between the true north and the north of image has to be calculated. Rn is calculated by latitude and longitude coordinates of the 4 corners of the image specified in the metadata in order to extract the true shadow orientation.

b) Threshold operation:

Roof of the building must be choosen; This operation has the goal of reducing the amount of information present in the image and keep only relevant information. The frequency appearance of the different levels of gray within a single channel image on a dimension histogram can be observed (Figure 1).

From this histogram, segmentation can be performed using a thresholding tool. The pixels are then classified on two categories and a black and white image is created. To extract the shadow, radiometric lower values is chosen. By this way, buildings shadow can be separated from other theme present on the image.

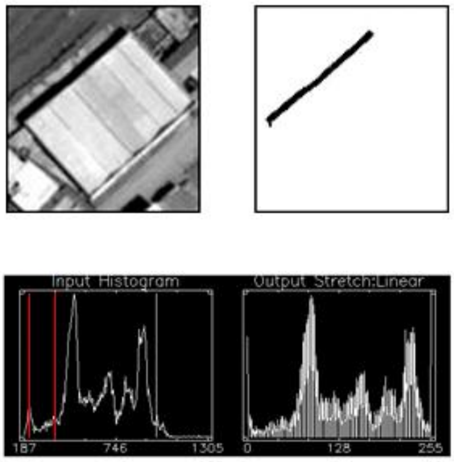

Figure 1. Thresholding operation

Step 2: Transformation of the shadow in ASCII Format

In a second step, the resultant image of the "thresholding" will be transformed into a matrix in order to extract the size of building shadow. It will be saved as an ASCII format to allow the extraction of the size of the shadow using a developed Matlab program.

Step 3: Calculation of the building height

The calculation of the building height needs two further substeps which are described as follows:

a) Automatic calculation of the shadow dimensions

A shadow matrix is obtained from the previous step. Then the shadow line “S” is extracted from this matrix using a developed routine under Matlab software.

As shown in figure 2, the shadow line can be calculated from equation 1.

$$S = R * n_k \qquad (1)$$

Where S is the length of the shadow line; R is the pixel size and n_k is the rank of the shadow line matrix. With S the shadow line, showed on figure 2.

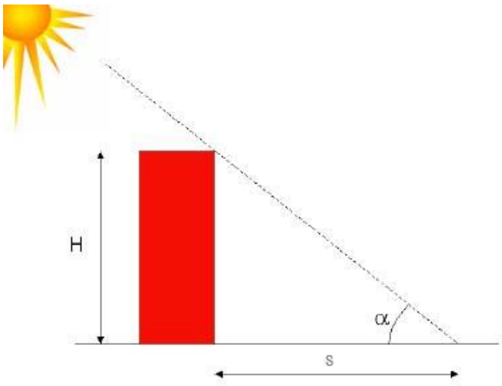

Figure 2. Building height

b) The calculation of the building height will be performed automatically on the Matlab software incorporating the sun elevation angle α at the time of shooting by the satellite sensor (Figure 2). This information exists in the metadata of the satellite image. The height building (H) is then determined using Equation 2:

$$H = S * \tan\alpha \qquad (2)$$

VALIDATION

In order to validate the developed method and to show its efficiency, twenty buildings were considered. The determined heights were compared to those measured in situ. These buildings are localized in the region of Tipaza (Figure 3), located 50 km West Algiers (Algeria).

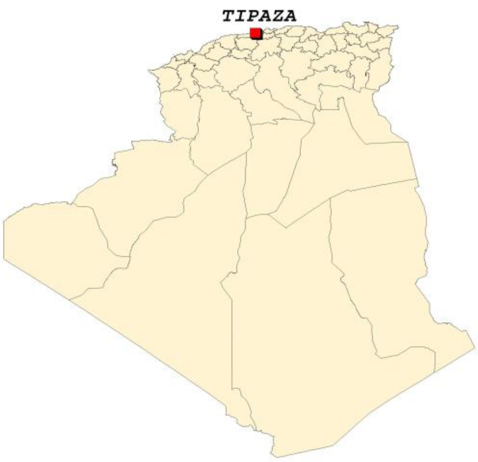

Figure 3.Tipaza Localization

A Quick Bird satellite image was used (Fig. 4). It was taken on April 30th 2006 with a sun elevation angle of 67.3°. The considered buildings are indicated in figure 4:

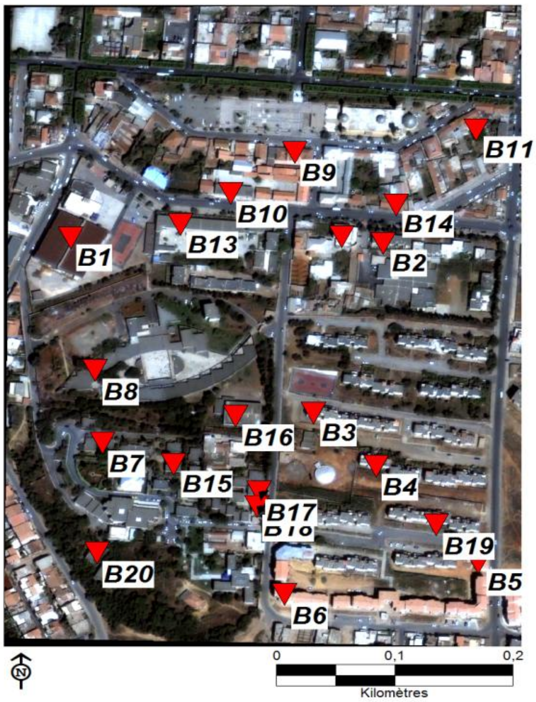

Figure 4. Studied buildings

In Table 1, H in situ is the height of the building measured in situ, and H1 is the height of construction determined using developed method. The determined heights and calculated errors (E) are also shown in the same table.

Table 1. Studied Buildings Height

Building	H in situ(m)	S1(m)	H1(m)	H-H1(m)	E(%)
B1	10	4.2	10.04	-0.04	0.4
B2	8.95	4.2	10.04	-1.09	12.2
B3	12.7	5.4	12.90	-0.2	1.6
B4	12.7	5.4	12.90	-0.2	1.6
B5	17.5	7.2	17.20	0.3	1.7
B6	20	8.4	20.07	-0.07	0.4
B7	4.2	1.8	4.30	-0.1	2.4
B8	5	1.8	4.30	0.7	14
B9	8.5	3.6	8.6	-0.1	1.2
B10	8.5	3.6	8.6	-0.1	1.2
B11	5.3	2.4	5.7	-0.4	7.5
B12	10.4	4.2	10.04	0.36	3.4
B13	6.5	3	7.17	0.79	12
B14	13.7	6	14.34	0.64	4.6
B15	7.1	3	7.17	-0.07	0.9
B16	12.5	5.4	12.90	-0.4	3.2
B17	4.2	1.8	4.3	0.1	2.3
B18	7.2	3	7.17	0.03	0.4
B19	12.7	5.4	12.90	-0.2	1.6
B20	7.2	3	7.17	0.03	0.4

As we can notice, that the maximum error rate is around10% so that results are acceptable. The obtained results are quite satisfactory, and allows to apply the method to the detection of building damage after an earthquake.

APPLICATION

Two buildings damaged by Zemmouri earthquake (May 21st, 2003) were studied to show the efficiency of the developed method. The considered images dates on 13th May and 23rd May 2003, with a sun elevation angle of 65,3° for the first image and 68,4° for the second one. The studied buildings A and B are showed on Figure 5.

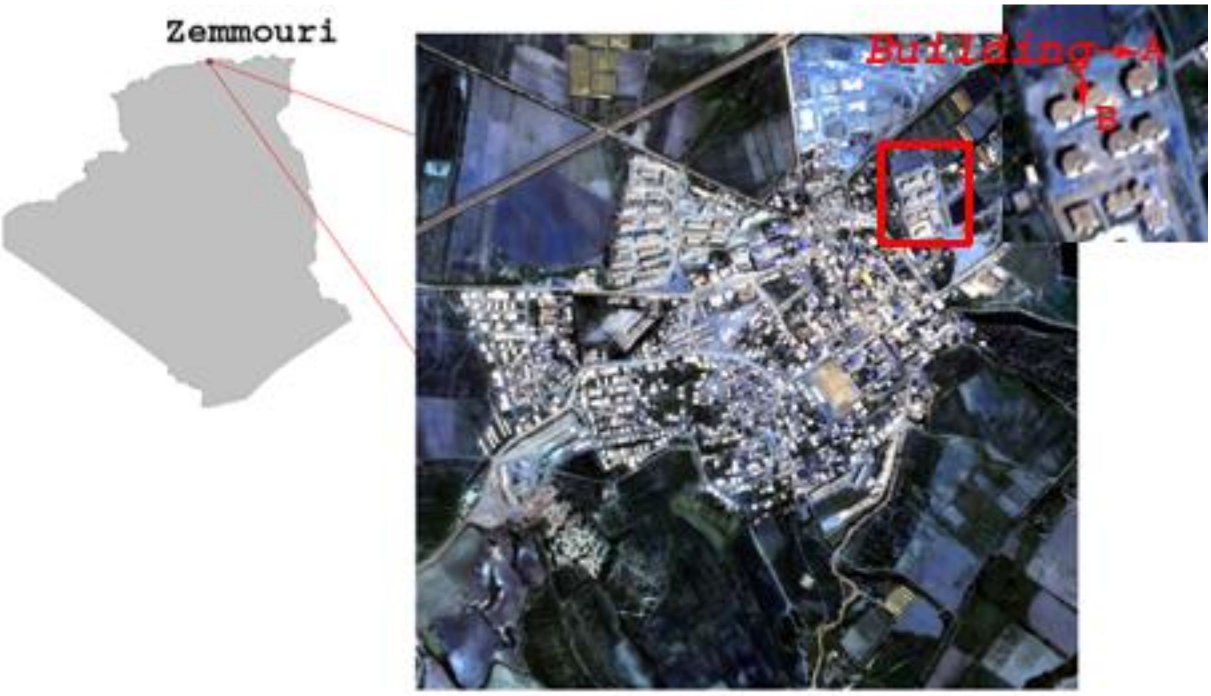

Figure 5. Buildings localisation

Figures 6 and 7 hereafter showed the extraction of buildings A and B and the thresholding operation leading to buildings shadow identification.

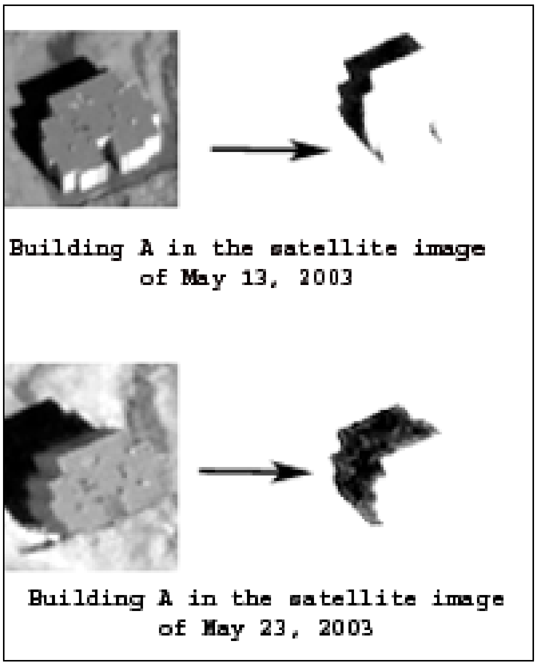

Figure 6.Extraction of building shadow in A

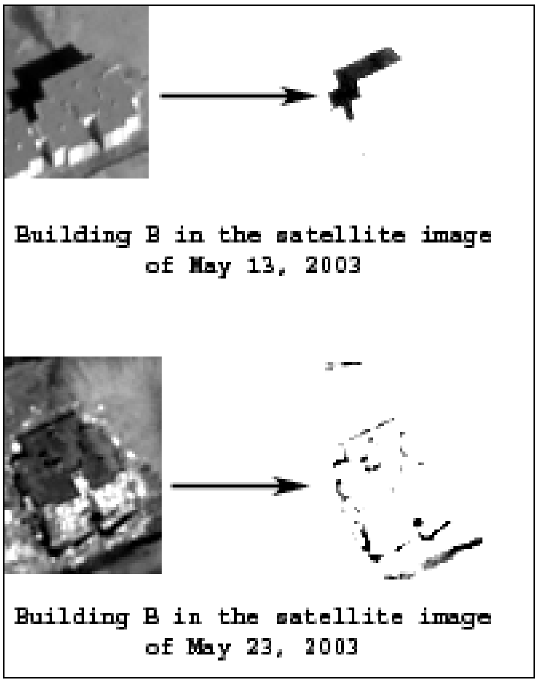

Figure 7. Extraction of building shadow in B

Figure 8. Pictures of damaged buildings A and B [courtesy of the National Centre of Earthquake Engineering]

Table 1. Application results

			Building A		Building B	
İmage	Date	Sun Elevation Angle	S_A (m)	Height (m)	S_A (m)	Height (m)
İmage1	13 May 2003	65.3	7.2	15.6	7.2	15.6
İmage2	23 May 2003	68.4	5.4	13.6	0.6	1.5
Diffence height				02.0		14.1

The difference between the two determined heights before and after the earthquake are calculated (Table 1) for buildings A and B. It showed that there is a great difference between the two heights, so the buildings have experienced great damages. Building A is less damaged than building B. The difference in building height in case of building B is too important (arround 90% of the height), so it is easy to conclude that the building collapse.

This result is in adequacy with the in situ ascertainment (Figure 8) where building B collapsed and building A suffered heavy damages.

CONCLUSIONS

In this study building heights analysis is performed. These heights are identified from an automatic procedure. This procedure use building shadow and sun elevation angle extracted from monoscopic satellite image. The results are in accordance with in situ observations. In case of an urban area where buildings are juxtaposed, the procedure need to be improved again. However, the developed method can be easily used for emergency and rescue operations in case of an earthquake.

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