FEASIBILITY STUDY OF BUILDING SEISMIC DAMAGE ASSESSMENT USING OBLIQUE PHOTOGRAMMETRIC TECHNOLOGY

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ABSTRACT

In this paper, the feasibility of building seismic damage assessment using oblique images is discussed. Firstly, some geometric features of buildings are selected and analyzed according to the universal geometric characteristics of most buildings. Secondly, the parameters of each geometric features are calculated by the method of photogrammetry. Finally, the results of parameters calculation are analyzed and discussed. The results show that more information of building can be obtained from oblique airborne images than from vertical images. Furthermore, these information can reflect the conditions of buildings correctly and effectively in three dimensional (3D) space. The conclusion is drawn that it is feasible and potential to conduct building seismic damage assessment based on oblique airborne images.

Index Terms - Oblique airborne images, Three dimension features, Building damage assessment

1. INTRODUCTION

Currently, many methods of assessment on building seismic damage have been proposed. For example, seriously collapsed buildings can be extracted from remote sensing images based on spectral features [1-3]; SAR images have also been used to extract damaged buildings [4,5]; DSM obtained from digital aerial images is another kind of data to assess building seismic damage based on elevation change [6]. These approaches have one problem that the damaged building can only be detected in vertical image when they are collapsed but not when they are just tilted or cracked. The employment of oblique photogrammetric technology can solve this problem to a certain extent. Some applications of oblique images have been proposed. For example, walls can be extracted from oblique images and the building outlines can also be verified using oblique images [7-9]. Several methods of assessment on building seismic damage based on oblique images have also been proposed. Most of these methods are based on oblique image classification and point clouds calculated by photogrammetry [10, 11].

Oblique photogrammetric technology is a new developed high-tech in international surveying and mapping field [12]. Generally speaking, it can obtain images from its five sensors oriented at different directions (one vertical direction and four tilted directions) at the same time [12]. Compared with vertical images, oblique images have the following advantages: (1) More detail information (top and side information) of building can be achieved from the oblique images due to the multiple viewpoints and perspectives of the sensors [9]; (2) The oblique images are characterized by high spatial resolution and relatively large field of view angle [13, 14].

Feasibility of using geometric information obtained by oblique photogrammetric technology to assess building seismic damage is discussed in this paper. For a certain building, the first step to assess whether it was damaged by oblique photogrammetric technology is to preliminarily select images in which the phenomenon of mutual occlusion is relatively mild; Secondly, several proper geometric constraints, such as length, width, height, angle and direction should be selected and determined to create the assessment rules; The third, is to calculate the selected geometric parameters of target building in these images; Finally, damage situation can be assessed based on the parameters and the rules proposed above. The validity of damage assessment results relies on the rationality of damage assessment rules directly, the reliability of damage assessment rules has been tested based on not damaged buildings in this paper.

2. DATA AND METHODS

2.1. Data

Images used in this study are captured by SWDC-5 which is composed of 5 Hasselblad H3D cameras, one of them is vertically oriented and others are tilted with an angle of 45°. There are also a navigation and positioning system (composed of IMU and GPS) installed on cameras, so the angle of tilt and the exterior orientation of images can be obtained when the camera is imaging[15]. The resolution of images is close to 10 cm when the photographic flying height is about 850 m.

2.2. Methods

2.2.1. Damage assessment rules

Points, lines, polygons (mainly refer to rectangles), planes, etc. are all geometric features on the outer surface of building. These features meet certain geometric constraints when the building is not damaged, but some or all of them may change when the building is damaged，as is shown in Tab. 1 and Fig. 1.

2.2.2. Parameters calculation

The 3D coordinates of the feature points were calculated using two types of unknowns alternating iterative method in this study. The absolute accuracy of 3D coordinates was not high enough due to the errors in exterior orientation and the lack of control points, but this did not affect the subsequent calculation, because the damage assessment parameters express the relative positional relationship of those feature points. After the calculation of 3D coordinates of the feature points was completed, various parameters of other features could be calculated from the 3D coordinates so as to analyze and assess damage.

Tab. 1. Principle of feature selecting and rules of assessment

Geometrical features	Principles of visual selecting	Characterizations of not damaged buildings	Rules of assessment on damage building
Point	Points located in the same elevation	Differences(δ) between calculated values of point elevation: $\lvert\delta\rvert \le e_1$	$\lvert\delta\rvert > e_1$
Line	Lines parallel or perpendicular to the ground （other lines）	The angle (α) between direction vector of line and normal vector of the ground: α =90° or 0°	$\lvert\alpha - 0\rvert > e_2$ or $\lvert\alpha - 90\rvert > e_2$
Polygon(Rectangle)	Polygons with geometrical constraints	Opposite sides of rectangle: $l_1 = l_2$ corners: $\gamma = 90$ °	$\lvert l_1 - l_2\rvert > e_3, \lvert\gamma - 90\rvert > e_4$
Plane	Planes parallel or perpendicular to the ground （other planes）	The angle(β) between normal vectors of a wall and the ground: β =90°	$\lvert\beta - 90\rvert > e_5$

Notes: followings are reference values of various thresholds according to the data precision and experience: e_1=0.2, $e_2 = 0.5, e_3 = 0.2, e_4 = 0.2, e_5 = 2$

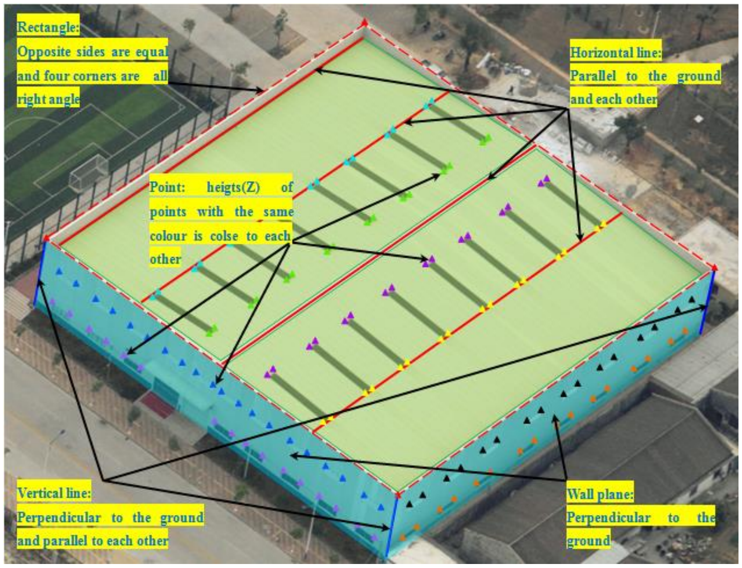

Fig. 1. Geometric features on the outer surface of building

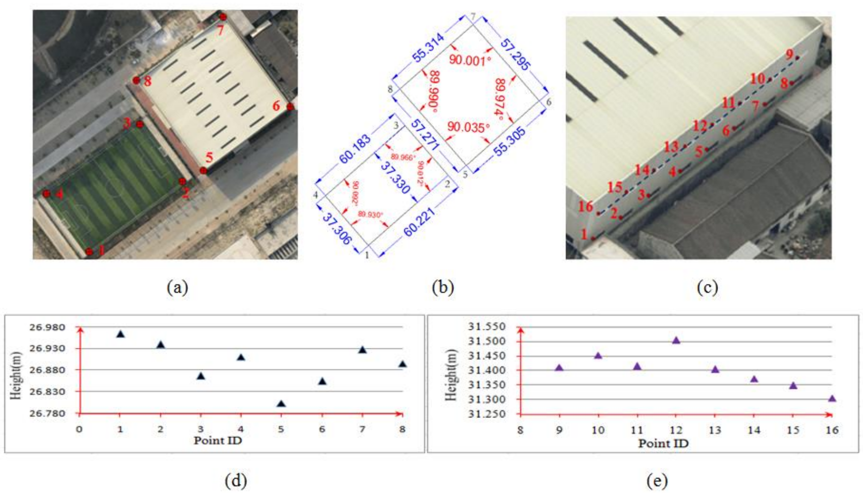

Fig .2. Study areas and calculation results; (a) feature points of ground objects in vertical image; (b) the projection of ground objects on X-Y plane; (c) feature points of the wall in oblique image; (d) and (e) are height diagrams

3. EXPERIMENT AND RESULTS

Two experiments have been conducted on undamaged building in order to test the reliability of damage assessment rules in this section. Experiment one: as shown in Fig.2 (a), there are a football field and a building in study area one. The coordinates of feature points on these ground objects are calculated and projected to X-Y plane as is shown in Fig.2(b), rectangular profiles of the ground objects are meeting following rules: $|l_1 - l_2| < 0.2, |\gamma - 90| < 0.2$. Experiment two: study area two in Fig.2(c) is a wall of the building. Two groups (Point ID: 1-8, 9-16) of feature points which are located in the same elevations respectively are selected and calculated. The maximal differences between height values of points at the same group is less than 0.2 m ($|\delta| \le 0.2$); the angle (α) between dotted line and normal vector of the ground is 90.122° ($|\gamma - 90| < 0.5$); the angle between normal vectors of the wall and the ground is 91.279° ($|\beta - 90| < 2$).

As can be seen from the results above, the various parameters of damage assessment satisfy the various geometric constraints of undamaged building, so the damage assessment rules are reliable.

4. CONCLUSION AND DISCUSSION

As can be seen from the experiments, it is feasible to assess building seismic damage by comprehensive utilization of damage assessment rules based on oblique photogrammetric technology. This technology is well applied in the assessment of those buildings which are tilted and cracked but not damaged completely. However, the feasibility of this approach is validated from the perspective of geometry, and the side texture information is not considered. More experiments on damaged buildings to enrich the parameters, refine the rules of damage assessment and improve the accuracy of damage assessment are required in the future.

5. ACKNOWLEDGEMENTS

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