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New Method for Surveying and Mapping Architectural Plane In-house with Laser Reticule Images

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Abstract Surveying and mapping the appearance of architecture plane is a supporting technology of historic buildings. To meet the need of plan survey in-house, a new close-range photogrammetry method was developed by laser reticule system. With the help of the system, two parallel level lines and eight vertical laser lines can be marked on the surface of inner walls. When the relationship between the distance from a vertical line and the length of the same line on an image picture is studied, the spatial location of room corners and some characteristic points on the images can be determined. Based on the photogrammetry and plane table operation method, architectural plane mapping can be done easily following a set of laser reticule images which were shot in situ closed by a non-metric digital camera. More details of historic buildings can be recorded on drawing sheets and images monogamy at the same time by using the proposed method, which are the basic information for the structural analysis of historic buildings.

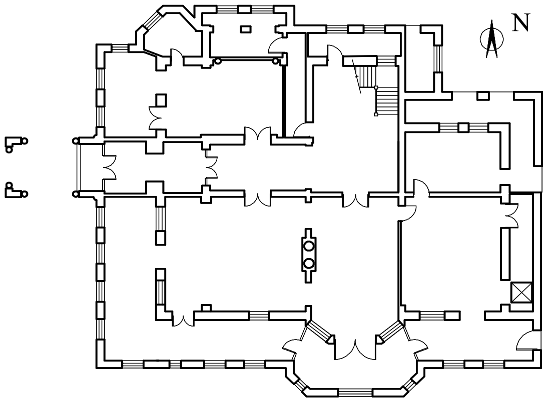
Keywords: Surveying architectural plane in-house, laser reticule system, non-metric digital camera

Introduction

As a symbol of ancient civilization, there are more than 50 billion square meters existing buildings in China and lots of structures built with traditional materials still exist and remain in service nowadays. Some of them are considered as integral parts of the important features of cultural heritage. From the beginning of last century, many distinguished buildings were built along the Huangpu River in Shanghai (Fig. 1). There are 2138 historic buildings in 632 zones that are protected by the government of Shanghai (Lu and Gu 2008). Based on the investigations from 2002 to 2004, mechanical behavior of 58% of those buildings was confirmed to have been deteriorated. In order to protect them, the first and most important step is the documentation of the current status of the structures. In most cases, the original design documents are not available, so in situ measurements are necessary to get the basic information for the structural analysis to protect these distinguished buildings.

Figure 1: Fourteen historic buildings in the Bund of Shanghai

Limited by different kinds of architectural styles and construction methods, the plane layout of historic buildings are usually complex and subjected to changes (Gu and Li 2007). The axial lines of the architectural drawings are always not clear and curved (Fig. 2). Therefore, the commonly used tapes or plummets to make measurements by hand are usually not sufficiently accurate and very time-consuming. These techniques require substantial effort and do not give satisfactory results about the structure's geometry and materials properties. More information may be discarded in these traditional methods. For example, masonry structures with out of plane deformations or moldings, often seen in historic buildings, may not be recorded in documents.

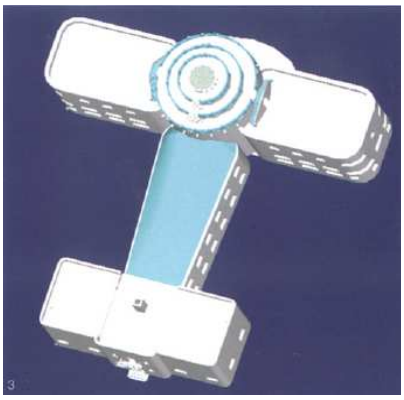


(a) Plan view of ground floor

(b) Elevation view of northwest corner

Figure 2: Former Consulate of the United Kingdom in Shanghai, China

Nowadays the rapid advance in digital image acquisition systems and many powerful graphics workstations make new methods for digital documentation of buildings feasible (Athanasios 2007). Close-range photogrammetry (Wu and Huang 2006) and 3D-laser scanning techniques (Shang and Kong 2006) have become very important measuring tools in heritage applications (Fig.3), where intervention and manipulation might be kept to a minimum.



(a) Obtained by close-range photogrammetry

(b) Obtained by laser scanning

Figure 3: 3D models obtained by non contact surveying methods

As a non-contact surveying technique, close-range photogrammetry is used to obtain scaled 3D digital models of target objects from a network of multiple photographs taken from different and convergent perspectives. It differs from traditional photogrammetry in the size of the object to be measured and the distance from the camera to the object. Using a pre-calibrated camera, the position from where the images were taken can be computed by taking measurements of a number of control points. Once the images are oriented, 3D information of measured points can be obtained by matching corresponding points in the images. With the help of computer, highly complex matching algorithms can be used to automatically detect matches. The problem with this technique is that it requires good lighting and sufficient texture. If these requirements are not met, the automatic matching algorithms fail to compute proper corresponding points. Therefore, this technique is not useful when working in an interior area of the building with low-light conditions (Julia et al. 2009).

Recently, laser scanning is getting more and more attentions for its relevant simplicity and speed. Laser scanning analyzes an object by measuring thousands of points with high accuracy in a relatively short period of time. After an extensive processing phase, the collected data can be used to construct digital, two-dimensional drawings or 3D-models, which are useful for a wide variety of applications.

Like cameras, they are line-of-sight instruments; therefore, to ensure complete coverage of a structure, multiple scan positions are necessary to capture the whole vault without having any shadows or occlusions. Therefore, combining the point clouds and filtering redundant points needs high-speed computer and special software (Luc and Bjorn 2009). For scanning with laser, cracks and materials of buildings might not be able to be distinguished by using this method.

To use non-contact surveying method in the protecting operations of historic buildings, it must be simple and accessible to people with no special background knowledge of photogrammetry (Jaime, Maria and Pedro 2008). Low-cost close-range photogrammetry has been studied during the past years by various researchers, who aimed to bring photogrammetry closer to nonspecialized users. Because pattern recognition techniques are not reaching the acme of perfection, operator interaction cannot be avoided. In that case, surveying and mapping plane by images and plane table operation may be a practical and effective choice.

Methodology and Equipments

The method proposed in this paper was developed based on digital cameras and laser reticule system to meet the need of in-house plane survey (Fig.4). The camera is an inexpensive non-metric digital camera with fixed focal length. The laser reticule system is composed by two laser generators, which can emit a horizontal circumferential laser beam and two vertical orthogonal intersection laser beams at the same time. The laser generator is autoset level and is mounted on a steel frame at different levels by special thread. With the help of a holder, a digital camera is fixed in the middle of two laser generators. All equipments should be fixed on a measuring tripod in situ.

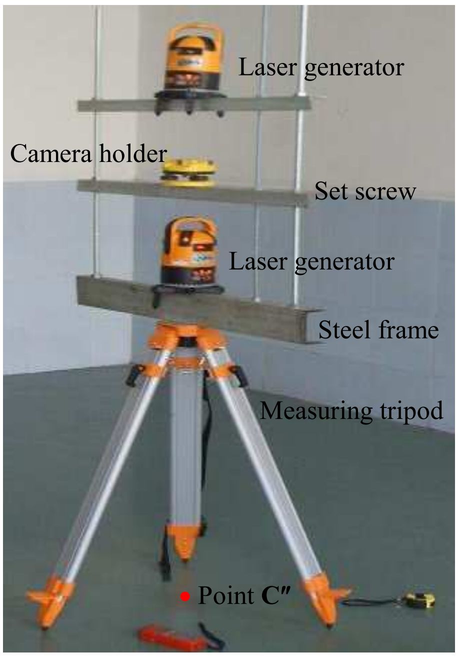


Figure 4: Equipments of the new method

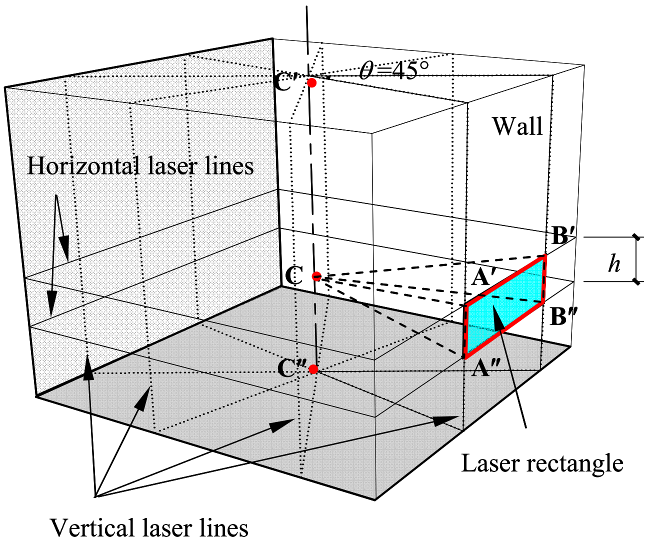


Figure 5: Laser lines on the inner walls

Adjusting the set screws and the direction of vertical laser beams, when the centers of camera (Point **C** in Fig. 5) and the two generators are on the same vertical line **C′-C″** and the lens of the camera is at the half-height of the two horizontal laser beams, the equipment for surveying is set up. It can produce a laser beam net which is made from a pair of horizontal parallel and eight vertical lines and project the net on the inner walls. In order to simplify the data processing, it is an advisable choice to adjust the intersection angle θ of the two laser beams to 45°. Hence, when the laser beams are stabilized, eight continuous rectangles can be marked on the walls. The digital camera can take eight images of the walls on the platform (Fig.6).

Determination of the Distance between the Vertical Line and the Camera Center

Measurement process is the key technique and will significantly influence the accuracy and the speed of the surveying. Based on the geometry, when the two sides and the intersection angle of a triangle are determined, the spatial location of the third side can be determined uniquely. Hence, if we know the length s from the camera center to points **A** and **B** on the wall and the intersection angle is 45°, the spatial location of the line **A-B** in the same horizontal plane can be determined and mapped in the plane(Fig.7).

Since the vertical distance h between two horizontal parallel lines is a definite value, we can calculate the horizontal distance from the half-height point **A** of vertical line **A′-A″** to the camera center point **C**. According the lens equation and assignment test, when the vertical distance h=600mm, the horizontal distance s from point **A** to the Samsung camera center point **C** can be determined using Equation (1).

$$s = h \times d / l = 725.8 / l \qquad (1)$$

where, s is the distance from point **A** to **C** , h is the vertical distance between two horizontal parallel lines, d is the fixed distance from image to **C**, l is the length of **A′-A″** measured in images.

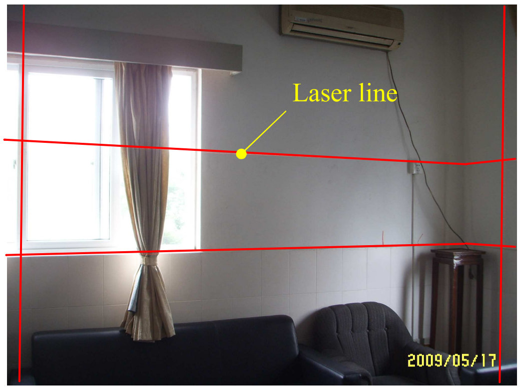


Figure 6: Image of a living room

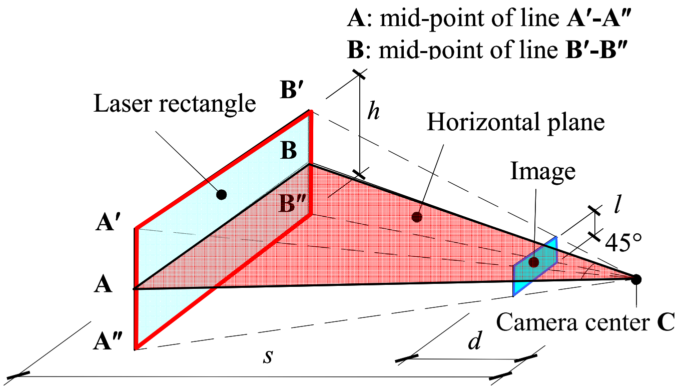


Figure 7: Determination of the distance

Mapping Architectural Plane In-house with Images

Since the horizontal laser beams can always be kept horizontal by the system, plane figure can be mapped from eight images in 9 steps as follows.

1. Install the system and mark point **C″** on the floor of the room under consideration.
2. Take digital images and transfer into computers.
3. Use AutoCAD or similar software to draw two cross-hairs at a same center point. The intersection angle between one line with the other should be 45°(Fig.8). The intersection point of the four lines is defined as **C** on the plane view.
4. Insert image photo into the CAD drawing using a scale of 1:1.
5. Measure the distances of two vertical lines to the horizontal laser lines directly on the image and calculate the actual distances s_A and s_B from the camera center **C**.
6. Mark **A** and **B** on the line with s_A and s_B from point **C**.
7. Rotate and zoom the images by proper scale and angle to meet point **A** and **B** in the plane (Fig.9).
8. According to the plane table operation method, determine the location of every visible point in the digital images.
9. Repeat the process from step 4 to step 8 until all the eight images of a room have been recorded and combined together.

With the help of the overcastting staff stand at point **C″**, which is visible and is marked by another two horizontal laser beams, another plane of the indoor can be connected to the room whose point is

C″. In this way the in-house plane figures of every floor can be mapped with common points and straight lines from one room to another.

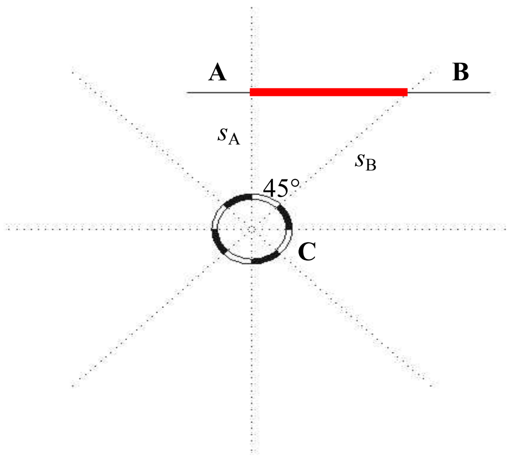


Figure 8: Draw cross-hairs and mark points

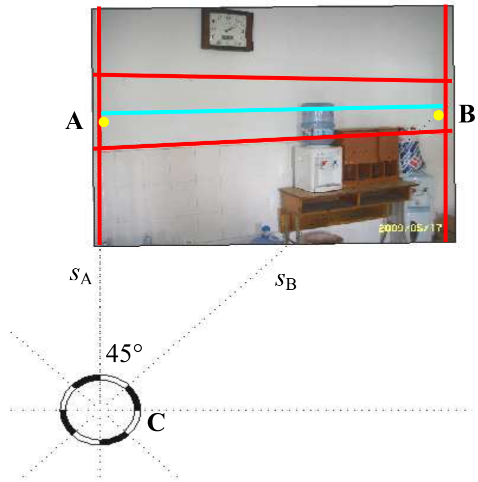


Figure 9: Draw plan with image

Verification

To prove the suitability of the new method, tests were carried out using the following instruments:

1. Samsung i5 digital camera: Fixed focal distance (7mm); Format (2048×1536)pixels;
2. LaiSai Line Laser : LS616 Self-leveling Laser Level
   Four Cross-Lines & Plumb Beam(3V-2H-1D);
   Laser wavelength: 635 nm; Laser class : Class II;
   Accuracy : ±1 mm/5m; Self-leveling range: ±3°
3. Leica DISTO A3 Laser meter.

Supporting point **C** is the origin of the coordinate system. The comparison results obtained from the measurements are shown in Table 1 and Fig.10. It can be seen that the precisions obtained can meet requirements for all the compared rotation positions. The comparison results indicated that the mechanical and dimensional stability of the system can be assured.

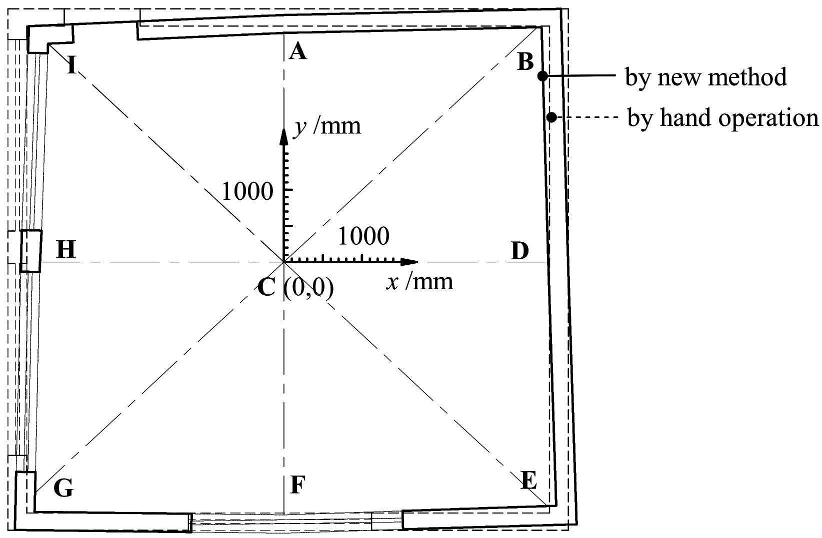


Figure 10: *Plans drawn with the new method and the hand operation*

Conclusions

A simple close-range photogrammetry system to measure flat objects is presented. It is an inexpensive and easy system to use and does not require ground control points as used in topographic methods. The system and the measuring method described in this paper were proved to be useful and easy to apply for the surveying operations in the field. Using this kind of method, measurements can be made in situ and transferred to computers for later analysis. The precision in determining the object plane can be further improved if the lens distortion can be mitigated. With this method it is possible to simultaneously survey different types of information, such as cracks or inclination of members, as long as they are visible to the camera.

Table 1: Camparison results between new method and hand operation

Point	*Coordinate by new method*	*Coordinate by hand measure*	*Relative error to length of side*
A	(+0000, +3165)	(+0000, +3259)	(±0.0%, +1.4%)
B	(+3298, +3245)	(+3398, +3259)	(+1.5%, +0.2%)
D	(+3383, –0001)	(+3398, –0001)	(+0.2%, ±0.0%)
E	(+3486, –3365)	(+3398, –3462)	(+1.3%, –1.5%)
F	(+0000, –3490)	(+0000, –3463)	(±0.0%, +0.4%)
G	(–3190, –3449)	(–3290, –3463)	(–1.5%, –0.2%)
H	(–3190, +0000)	(–3290, +0205)	(–2.5%, +3.0%)
I	(–3018, +3018)	(–3290, +3259)	(–4.1%, ＋3.6%)

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