3D Indoor Model Reconstruction Using A Panorama Equipment

Ting-Chun Lin[1] and Fuan Tsai[2]
[1] Master Student, Department of Civil Engineering, National Central University,
No.300, Jhongda Rd., Jhongli City, Taoyuan County 32001, Taiwan,
E-mail: suaygiho@hotmail.com
[2] Professor, Center for Space and Remote Sensing Research, National Central University,
No.300, Jhongda Rd., Jhongli City, Taoyuan County 32001, Taiwan,
E-mail: ftsai@csrsr.ncu.edu.tw

KEY WORDS: Single Image Reconstruction, Image Stitch, Vanishing Point, Indoor Building Model

ABSTRACT: Panorama equipments are suitable for indoor building model reconstruction. This research utilizes vanishing point detection to obtain the metrology of individual panorama images. In addition, multiple images are stitched to increase the efficiency of model reconstruction. The proposed procedure is divided into four parts, including equipment setting, image stitching, vanishing point detection, and model reconstruction. The verification of the results is achieved using total station measurements to determine the accuracy of the model.

1. INTRODUCTION

Nowadays, the three-dimensional building models have become more and more popular in urban or land planning, city tours, car navigation and other applications. Cyber city is a major trend for city management and planning in future (Gröger et al., 2008). In addition to the appearance of buildings model, roads, vegetation, it is progressing to provide indoor visiting, interior scene reconstruction and the application of indoor planning decisions recently. Currently two popular three-dimensional building model reconstruction methods can be broadly divided into LiDAR (laser scanning) and image-based approaches. When the density of point cloud is high enough, LiDAR can generate highly accurate results, but it requires a huge amount of computation, bulky and expensive equipment. On the other hand, image-based methods such as multi-image overlap and video images are relatively inexpensive, lightweight and easy to carry out, but also can provide further environment visual information.

Panorama equipments are commonly used for outdoor long range shooting. However, when used in an indoor environment, it can capture the whole interior space and has more advantages than using CAD data and BIM (building information model) for indoor model reconstruction. In this study, the GigaPan EPIC PRO equipment is used. It can carry 4.5 kg of cameras and lenses with a strong structure and can be set up on a general common tripod. When using this equipment, the user only needs to set the shooting range and order; image data can be automatically acquired.

There are many panorama stitching software can connect hand-held shooting of images into a large high-resolution figure and satisfy the visual needs. However, if the camera is set up on the panorama equipment, all images will have the same center of projection. According to this principle, the photos acquired by a panorama equipment can be used for single image reconstruction with vanishing points algorithm. In this context, these geometric relationship outcomes will be more reliable for spacing analysis and other use after the model has been constructed (Vouzounaras et al., 2011).

2. METHODOLOGY

2.1 Instrument Calibration

In this research, the equipment used included a Canon EOS 5D Mark II camera with Canon EF 24-70mm F2.8L II USM lens and a GigaPan EPIC PRO, as shown in Figure 1. Six camera lenses have been calibrated to choose the one which has the minimum principal point deviation and lens distortion. After that, determining the location of the nodal point is a necessary step to make sure the imaging center is located on the three axis of the GigaPan EPIC PRO. There are two common methods to determining the nodal point location, which are conventional approach and laser method. Both of the above methods were used in this research.

Figure 1. research equipment: Canon EOS 5D Mark II、Canon EF 24-70mm F2.8L II USM and GigaPan EPIC PRO

The conventional approach is a simpler method for determining the Nodal Point. There is an object near the lens and align it with a more distant object as illustrated in Figure 2. If the camera is rotated about the front nodal point, the two objects will be aligned when they are in the center of the image and also when at each side of the image. If the objects are aligned when in the center of the image, but appear to separate as the camera is rotated then the rotation is not about the nodal point. On the other hand, the laser method is a more innovative and inspired one. When the laser beam travels along the path of a ray that meets the nodal point, a very bright spot is seen on the surface placed behind the lens and the ray can be drawn on the paper. These rays can be constructed for a variety of angles of incidence and the nodal point are determined accordingly.

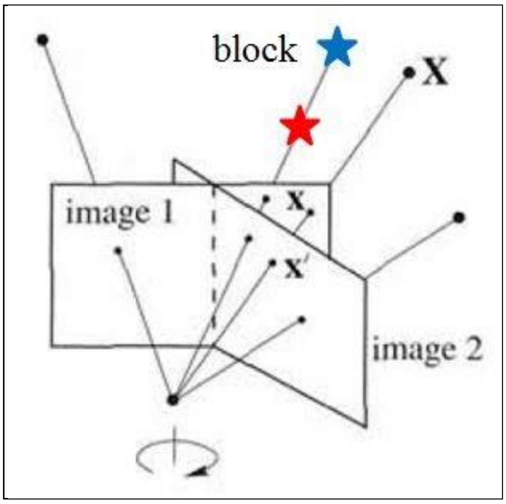

Figure 2. the idea of nodal point.

2.2 Image Processing

Image pre-processing steps consist of lens distortion collection, image stitching, image segmentation and edge feature extraction. Lens distortion correction reduce the parts of the image was not proportionally imaged. Stitching multiple images can increase the information available for building indoor models. Scale-Invariant Feature Transform (SIFT) with Random Sample Consensus (RANSAC) is applied to get the feature points and perspective transform is used to stitch the images in this step. The features can be extracted from the image even under different image scale, rotate, noise and illumination when using SIFT algorithm (Lowe, 2004). Image segmentation is performed before the canny detector to exclude common indoor repeating texture. The purpose of edge feature extraction is to obtain the segments on images. This study uses Canny edge detection algorithm to get the edge features. It considers good detection, good localization and minimal response requirements to get the best edges (Canny, 1986).

2.3 Vanishing Point Computing

A vanishing point is the point in the perspective space where a group of parallel lines in the object space converge. Continue the previous step, save the edge lines information as the binary image. Then convert the coordinates into Hough space of each point to select the best linear feature connection with its linear parameters by voting mechanism. After that, candidate locations of vanishing points will be acquired when these linear characteristic equation rendezvous. Where every two arbitrary characteristic line will intersect to a point, on each axis will get a point group.

Mean-shift is then used to identify the most representative point in each group point. Comply with the above steps, the three vanishing point intersected by the parallel lines along three axis will be obtained (Chang and Tsai, 2012).

2.4 Model Reconstruction

After finding out the vanishing points, the model can be constructed according to vanishing point geometry principles. Once there's a reference height in one dimension, using simple proportional relationship can calculate the relative height of the other objects like Figure 3. After the reference height calculation along three main directions, the model is completed.

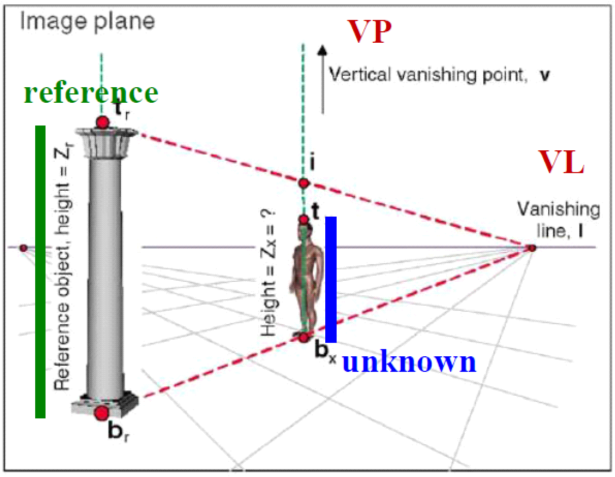

Figure 3. reference height proportion method schematic (Criminisi, 2002)

3. EXPERMENTAL RESULTS

The study area of this research is the Building of Graduate Institute of Environmental Engineering, National Central University in Taiwan. The validation data were measured in situ using a total station. Figure 4, Figure 5, Table 1 and Table 2 show the verification results. Figure 6 displays the reconstructed model.

Figure 4. Verification measurements (vertical features)

Table 1. Model Checking

(m)	in suit	model
A	1.212	1.203
B	1.253	1.243
C	1.280	1.243
D	1.028	1.075
E	1.425	1.419
F	0.582	0.453
G	0.490	0.452
H	3.270	3.264
I	1.296	1.269
J	1.295	1.215
K	1.293	1.277
L	1.292	1.303
M	1.290	1.294
N	1.293	1.311
RMS error: 0.046 (m)		

Figure 5. Verification measurements (horizontal features)

Table 2. Model Checking

(m)	in suit	model
A	1.000	1.002
B	1.096	0.831
C	1.045	0.969
D	2.258	2.244
E	2.355	2.250
F	0.132	0.086
G	0.107	0.074
H	1.061	1.112
I	2.093	2.002
J	2.133	2.101
K	1.883	1.668
L	2.401	2.270
M	2.704	3.344
N	0.753	0.880
O	0.750	1.080
RMS Error: 0.216 (m) Quit data M: 0.144 (m)		

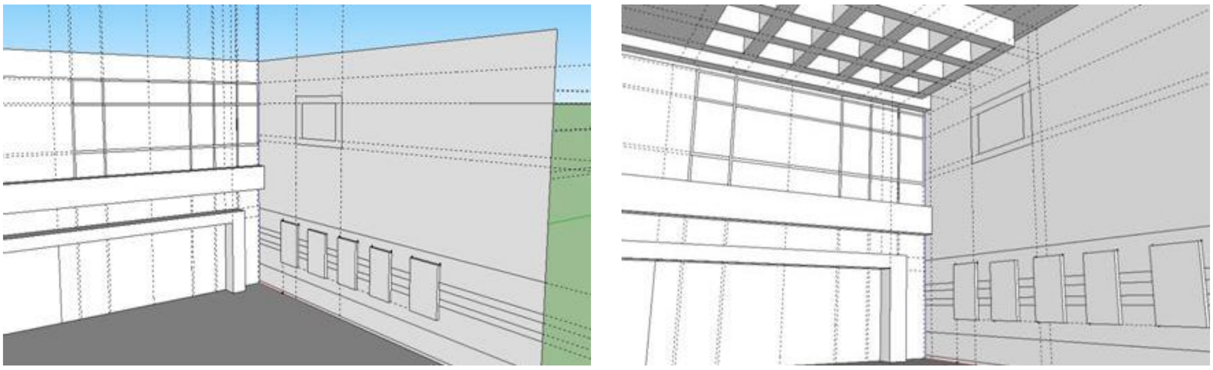

Figure 6. Reconstructed model

4. CONCLUSIONS

In this research, panorama equipment and vanishing point geometry principles were used to reconstruct the indoor building model from perspective projection images. The proposed method stitched multiple panorama images acquired using a consumer digital camera mounted on a GigaPan EPIC Pro robot. Vanishing point algorithms were utilized to compute 3D metrology of identified features and to reconstruct the 3D model of an indoor environment. The reconstructed model was validated with in situ measured data and to evaluate the accuracy of the reconstructed model. According to the verification results, the error can be control in cm level. If there is a good intersection condition of line segments, the error can be less than 5 cm.

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