The Research on Integrated Production of Large Scale 3D Products Based on Mass Multi-angular Images

Caihuan Wen* and Wendong Wang
Department of Chief Engineer Office, Hebei Institute of Surveying and Mapping of Geology, Langfang, China

*Corresponding author email: hbsdzchyzgb@163.com

Abstract. Aim at the problems of high cost and low efficiency of traditional large scale 3D (three-dimensional) products acquisition methods, this paper provides an integrated production of large scale 3D products based on massive multi-angular Images. Firstly, multi-angular images were obtained according to oblique photogrammetric technique. After the operation of aerial triangulation and 3D construction, the real 3D model is achieved. On these base, integrated production of large 3D products were done. Through the statistical analysis of 3D products accuracy, its precision completely meets the requirements of large-scale data specification, which provides a technical guarantee for rapid and efficient data revision of basic geographic information.

1. Introduction

With rapid development of economy and society, demands of accuracy and effectiveness of basic geographic information data in planning, construction, transportation, environment, public services and other application field are getting higher and higher. Traditionally, the method of using total station and GPS (Global Position System) RTK (Real Time Kinematics) technology is adopted for large scale DLG (Digital Line Graphic) production. The method of aerial photogrammetry basing on full digital photogrammetric system is usually applied in large scale DEM (Digital Elevation Model)and DOM (Digital Orthophoto Map) production[1]. Meanwhile, with development of satellite sensors, multi angle observation satellite can provide multi angle observation data which provides more choices for DEM and DOM production[2-3].

Oblique photogrammetric technique is a new aerial photogrammetry technology developed in recent years. With the emergence of UAV (Various Unmanned Aerial Vehicle) oblique photogrammetric systems, the acquisition of multi-angular images becomes fast. With the development of computer cluster, GPU (Graphics Processing Unit) and automation technology, 3D (three dimensional) modelling of massive multi angle image becomes more and more intelligent, automatic and efficient[4]-[7].

At present, the 3D model constructed using massive multi angle image has been widely used in various fields, such as digital city, urban planning, power line detection, and scenic spot display[8]-[12]. There are also some unities to carry on preliminary discussion on spatial information acquisition based on 3D model[13]-[16].

In this paper, an integrated production of large scale 3D products based on massive multi-angular images is proposed which has not been proposed before. First, multi-angular images are obtained according to the oblique photogrammetric technique, and 3D model is automatically built on
application of cluster and automation technology. On these base, integrated production of large 3D products are acquired.

The paper is organized as follows: Key technologies are introduced in section 2. Section 3 deals with the experiment. Final conclusion is drawn in section 4.

2. Key Technologies

2.1. Mass Multi-angular Images Acquisition

Mass multi-angular images are obtained by oblique photogrammetric technique, which overcomes the limitations of vertical photogrammetry by carrying multiple sensors on the flight platform and simultaneously taking ground image from the front, back, left, right, and vertical angles. Therefore, it can obtain more abundant image data with geographic information embedded by position technology to comprehensively reflect the situation of land features.

Before oblique photography, following work should be done: aerial photography division, design of route, elevation, overlap. At same time, image control points are layout and measured which can provide accurate spatial positioning information for multi-angular images, so that a measurable 3D model can be built.

The ground resolution of image is an effective factor for the accuracy of 3D model which affects the accuracy of 3D products. The relationship between ground resolution and flight height can be formulated as follow\(^1\):

\[ \frac{f}{H} = \mu/GSD \]

Where \( f \) is the focal length, \( H \) is the flight height, \( \mu \) is the pixel size, and \( GSD \) is the ground resolution.

Therefore, high-resolution images can be obtained by designing reasonable flight considering the actual terrain.

The accuracy of image control points can strongly influence the accuracy of 3D model which affects the accuracy of 3D products. GPS RTK technology is used to image control points survey for two observation. The precision of image control points is as follows: plane error is not more than 2 cm, height error is not more than 3 cm. The average value of the two observation results is taken as the final result of image control point.

2.2. 3D Modeling

Based on geometric relationship of image coordinate and its ground coordinate, aerial triangulation is adopted for adjustment computation, consequently, orientation elements, the plane positron and elevation of extension points are determined. There, the bundle block triangulation method based on ContextCapture \(^1\) software is used, which includes relative orientation, image control point measurement and absolute orientation.

Firstly, the inner orientation elements of each camera in a small area are calculated, and then imported into whole project for free network adjustment which can improve the precision of relative orientation. Then, image control points measurement are performed. Each image control point is distributed in different perspectives. Each perspective has at least three or more photos. The image where the image control point located is clear, and the position of the image control point is close to centre of the image. After those above work, the adjustment calculation is carried out to complete the absolute orientation. Therefore, exterior orientation elements and relationship between each image were determined.

It's important to note that during process of aerial triangulation, the mean square error of control points can be achieved in less than 1 pixel by optimization and adjustment of image control point measurement, which in thus improves the accuracy of the aerial triangulation.

After the aerial triangulation, ContextCapture software was used to obtain a large number of high-density point cloud data through dense matching of oblique images. Then an irregular 3D mesh model was constructed, optimized and simplified and the textures were automatically mapped on the mesh model\(^2\). Finally, a clear, realistic 3D model was generated.
In order to improve modelling efficiency, multiple servers were employed for cluster processing and parallel processing of 3D modeling of tiles data.

2.3. 3D Products Generation
After the real 3D model built, high-precision orthophoto is outputted into blocks. On this basis, the remote sensing software is used to mosaic block images, and then re-sample according to grid size to generate large scale DOM. The traditional aerial photography method to generate DEM by restoring stereo image pairs is time-consuming and laborious, using stereo glasses, hand wheel and foot disk and other equipment to collect feature points and lines. There, without any equipment such as stereo glasses, hand wheel and et on, the EPS 3D survey system is used to collect feature point and line according to the real 3D model so as to construct triangular network to complete the DEM production. 
(1) The elevation points and contours with a certain grid spacing are automatically extracted based on the 3D model.
(2) Above extracted elevation points and contours are check in 3D model. Meanwhile, the missing points that reflect the geomorphic features are collected.
(3) Noticed that, it is close to ground in collecting points to avoid large errors.
(4) when the terrain changes greatly, the characteristic lines are collected.
EPS platform is used to import the OSGB (Open Scene Graph Binary) 3D model format. The realistic 3D model and the orthophoto window linkage mode is used for digital collecting such as houses, roads, rivers etc., as well as attributes is assigned which finishes the DLG production.
(1) Feature points such as manhole covers and tweezers are collected at the central location according to the central positioning method.
(2) Feature lines such as roads and rivers are identified by using a direct method based on the 3D model combined with texture information, so as to quickly get the plane position and elevation information.
(3) Polygons such as vegetation, are recognized by using direct method to judge the vegetation area with the 3D model of oblique photogrammetric combined with texture information.
(4) Residential areas are acquired according to the specific situation of residential buildings in 3D model. The independent buildings are identified by automatic searching of building edges. The dense buildings are collected by intersection method and distance extension method. The buildings with clear top and unclear boundary are recognized by 3D model combined with orthophoto. The storey and structure of buildings are identified at same time.
(5) For the occlusion areas in the 3D model, supplementary field surveying is performed.

3. Experiment

3.1. Test Area and Multi-angle Image Acquisition
The research area is a small county with 31.88km². The traffic in the region is very developed, with many highways and various grades of highways, which brings some difficulties to the surveying and mapping work. With tight duration and heavy task, it is impossible to complete the task using traditional ways.
Five tilt cameras with 42.4 mega-pixel sensors assembled on an UAV were used for oblique photography. The camera parameters are shown in Table 1. According to the shape and scope of the area, the number of aerial photography zones was 9, the flight route of UAV was along the north-south direction with a forward overlap on 80% and a side overlap on 70%. According to the condition of the tallest building in the survey area, the flight altitude is 200 meters.
The image control points are arranged in advance, measured by GPS RTK technology. The total of 264 image control points were completed, the coordinate system was CGCS2000, and the central meridian was 117 degrees. The total number of multi-angular images is 65195, and the model resolution is 3.9cm, up to 2.4cm.
Table 1. Camera parameters.

| parameter  | Camera 1        | Camera 2        |
|------------|-----------------|-----------------|
| Camera tape| SONY5100        | SONY RX1        |
| focal length| 25mm            | 35mm            |
| Image size | 6000*4000       | 7952×5304       |
| CCD size   | 23.5*15.6mm     | 35.8*23.9mm     |
| Pixel size | 3.9um           | 4.5um           |

3.2. Integrated Production of Large Scale 3D Products

The massive multi-angle images are partitioned according to the distribution and cluster computing capabilities. 6 partitions are divided with about 10,000 photos each pieces. Aerial triangulation is carried out for each zones. The ContextCapture software was used to import the original image, camera parameters and POS (position and orientation system) file. The software automatically finished the process of key points extraction, image pairs selection, exterior orientation elements initialization, tie points matching, bundle adjustment and then complete the aerial triangulation.

The max re-projection error is 0.76 pixels, the max plane error of the control point is 0.012m and the max height error is 0.018m.

After aerial triangulation, the 3D model was produced by using ContextCapture software for automatic texture mapping, and the 3D tile with clear texture was output. There, the tile size is 200m, with a total of 1570 tiles.

Based on the 3D model, 3D products is carried out. A total of 1: 2000 DLG products of 20 square kilometres are generated, equivalent to 20 standard map sheets, 1: 500 DEM products of 4 square kilometres are generated, equivalent to the 66 standard map sheets. A total of 1: 2000 DEM was completed, 45 square kilometres, equivalent to 45 standard map sheets. A total of 1: 1000 DOM was completed, 45 square kilometres was completed, equivalent to 156 standard map sheets.

3.3. Quality Inspection

The field scattered points are used to check the accuracy of DLG and DEM. By using precision statistical method of measurement data, the median error was calculated as formula (2):

\[ m = \sqrt{\sum \Delta_i^2/2n} \]  

Where \( m \) is the median error, \( n \) is the number of points, \( \Delta_i \) is the relative error.

About 30% of the DLG products are randomly selected. A total of 294 planar points and 208 elevation points were checked. After calculation, the median error of the point is 13.9cm. The median elevation error is 11.7cm.

About 30% of the DEM products, about 12 sheets, are randomly selected. A total of 653 elevation points were checked, and the elevation median error was 14.4cm.

About 30% of the DOM products, about 40 sheets, are randomly selected. The method of nesting with DLG was used to check the geometric accuracy. The nesting accuracy was higher than 2 pixels, and no significant deformation or deviation was found.

After quality inspection, 3D products meet standard requirements.

4. Conclusion

In this paper, UAV oblique photogrammetric technique is used to obtain massive multi-angle images, and cluster technology is used to automatically establish of high-precision 3D real scene modeling. On these base, integrated production of large 3D products are acquired. Through the statistics of quality inspection results, 3D products completely meets the requirements of specification.

Compared with traditional aerial photogrammetry, this method breaks away from stereo glasses, hand wheel and trundle and other equipments, and overcomes various disadvantages such as high cost, time
and labor consuming and difficulty in getting started, which becomes a new method of 3D products acquisition. Compared with conventional field data collection, this method greatly reduces field working time, has the advantages of higher automatic level, saving labor, easy operation, high efficiency and wide measuring range, and less influenced by human factors especially in the land expropriation and demolition areas with high sensitivity of residents, which will provide powerful technical guarantee for high efficiency and precision of 3D products acquisition. It can be seen that the massive multi-angle images obtained by oblique photography can not only obtain the real 3D model, but also achieve the integrated production of 3D products with high efficiency and accuracy.

Acknowledgments
The authors are grateful to Xiaodong Wang in Hebei Institute of Surveying and Mapping of Geology for his valuable help and constructive advices, and thanks to “S&T Program of Hebei bureau of geology and mineral resources exploration” for financial support with NO-454-0601-YBN-191V.

References
[1] Dongling Ma, Ning Ding T 2009 Method for Gaining 4D Product Effectively By Using Full Digital Photogrammetric System (Geospatial information vol17) pp 69-71
[2] Qinghua Chen, Xiaoyi Chen T 2015 The Research on Producing DSM, DEM, with Multi-Angular Satellite Image (Geomatics & spatial information technology vol38) pp 168-169
[3] Shizhen Jia, Weiliang Zhao T 2016 DEM Produced by Multi Angle Imaging Satellite (Geomatics & spatial information technology vol39) pp 145-147;
[4] Shuaishuai Cao D 2017 Application and Experiment of Research on Three Dimensional Modeling Based on UAV Oblique Photogrammetry Technology (Kuming: Kunming University of Science and Technology)
[5] Lin Cao D 2017 Three Dimensional Modeling and Its Precision Analysis Based on UAV Oblique Photogrammetry Technology (Xi’an: Xi’an University of Science and Technology)
[6] Yang Liu D 2016 Unmanned Aerial Vehicle (UAV) Oblique Photogrammetric Image Processing and 3D Modeling (Shanghai: East China University of Technology)
[7] Guohai Xu, Lili Ning T 2016 Analysis in method of Digital city 3D modeling (Science & Technology Association Forum vol4) pp 19-20
[8] Lin Zhao T 2017 Study on 3D digital city modeling on basis of oblique photography measurement technology (SHANXI Architecture vol43) pp 197-199
[9] Li Guan, Yanjie Ding, Hui Zhang, etc T 2017 Key Technologies research and application of 3D modeling for digital city construction (Bulletin of surveying and mapping vol 2) pp 90-94
[10] Ling Cheng T 2017 Application of Oblique Photogrammetric Technique in 3D city modeling (Jiang xi ce hui vol12) pp 2-3
[11] Mingming Jiang T 2017 The 3D Digital City Modeling Based on Tilt Photogrammetry Technology (Geomatics & Spatial information technology vol40) pp 189-190
[12] Yong Feng T 2013 Study on the Modeling Technology and Application of 3D Digital City (Geomatics & Spatial information technology vol36) pp 71-74
[13] Yanmei Yang, Lei Shi, Shoumin Zhang, etc T 2017 Experimental Study of 3D Digital Mapping Based on Tilt Photogrammetry (Surveying and Mapping of Geology and Mineral Resource vol33) pp 25-27
[14] Nengguo Li T 2017 Application of UAV Oblique Photogrammetric Technique in large scale Topographic Mapping (CHINA high tech enterprise vol12) pp 279-280
[15] Jing Ma, Ying Shi T 2017 Application of Oblique Photogrammetry in Large Scale Topographic Mapping (Standardization of Surveying and Mapping vol33) pp 46-48
[16] Linghu Jin, Yuejun Zheng, Renbin Yue T 2017 Study on Application of Oblique Photography in Measurement of 1:500 in Building Concentration Area (BEIJING SURVEYING AND MAPPING vol1) pp 178-180
[17] State Bureau of Surveying and Mapping 2010 Specifications for low-altitude digital aerial photography CH/Z 3005-2010 p12
[18] Xinxin Zhang, Dong Wang , Fengwu Zhao T 2017 Fast 3D model production of Real Image Based on A3 Aerial Photography System and Smart3D Software( Urban Geotechnical Investigation & Surveying vol2) pp76-81
[19] Zhuhong Dao, Liuxing Li, Fadong Zou T 2015 Application of Real 3D modeling based on SMART 3d Software (Cities and Towns Construction in Guangxi vol4) pp113-115
[20] Ying LI, Zongjian Lin, Guozhong Su, etc. T 2017 3D model reconstruction based on Smart 3D data(Science of Surveying and Mapping vol42) pp88-93
[21] Juan Cao T 2019 Application of UAV tilt photogrammetry in earthwork calculation(Mine Surveying vol47) pp53-56