Research on 3D Modeling Technology Using UAV Tilt Photography

Chin-hsiung LEE
College of Robotics, Fuzhou Polytechnic, China

Keywords: UAV, Aerial photography, Tilt photography: Smart3D, 3D modeling.

Abstract. With the rapid development of drone technology, UAVs have been widely used in military, agriculture, measurement and electric power transmission inspection fields. They are particularly useful in the field of aerial photography due to multiple advantages. The drones are light, flexible, easy to operate, with strong applicability and relatively low cost, and help human avoid dangers of working at height. UAV aerial photography technology can rapidly acquire image data, and then use the Smart3D platform for high-precision, high-efficiency real-time 3D modeling. Smart3D has the advantages of high automation, fast modeling, high positional accuracy, and reliable geometry and texture accuracy for large-scale real-world modeling.

Introduction

In the past, traditional outdoor large-scale 3D modeling techniques are usually based on manual measurement modeling. The outsiders would first manually measure the photos to obtain the structures and texture of the outdoor building. Then, the internal staff would establish a white model based on the orthophotoimage and the relative vector data of the survey area. By measuring the texture obtained from the photograph, the detailed structure of the model is analyzed. Finally, the post-processed texture is pasted on the white model. Although the traditional manual modeling method is able to establish the complete model, it cannot meet current needs of large-scale rapid modeling due to high production cost and complex processes. With the advancement of UAV application technology, it is more convenient and faster to acquire ground map by UAV than by the traditional method. It can be used not only for data acquisition, orthophoto mapping, digital line mapping and other traditional two-dimensional mapping work, but also for the current popular three-dimensional modeling work through the server platform.

Compared with traditional measurement methods, UAV aerial photography has high security and high maneuverability. However, if the UAV aerial photography is equipped with an inappropriate camera, it will be easily affected by terrain change or UAV attitude instability in the process of shooting, which will cause distortion or large rotation angle of the acquired image, and lead to poor three-dimensional modeling results. In recent years, due to the development and application of tilt photogrammetry technology, the field of aerial photography and mapping has become more powerful, which greatly promotes the improvement of three-dimensional modeling technology. It has the characteristics of high efficiency of data acquisition and automation of modeling process by using the image of tilt photography for three-dimensional modeling. Moreover, the established three-dimensional model has high accuracy and good texture adhesion, which reflects the detailed features of the surface of objects in detail, making UAV tilt photography aerial photography widely used in three-dimensional modeling of outdoor scene [1].

This research is based on UAV aerial image data, and produces the three-dimensional model of outdoor scene on the server platform by means of multi-program data processing and computer software operation technology. In the process of image processing of three-dimensional real-world modeling, aerial images store a variety of data. The two-dimensional information includes the physical characteristics of common objects in multiple images and their corresponding geometric relationships. Therefore, the software can use image matching technology to find homonymous points and realize aerial triangulation calculation. Among various aerial photography techniques, tilt photography is a novel high technology developed in recent years. By carrying multiple lenses on the
same UAV platform and collecting images from different angles such as vertical and tilt, the more complete and accurate information of ground objects can be obtained. The three-dimensional modeling technology based on Smart 3D is developed on the basis of the principle of tilt photography. The technology research is to use Smart 3D software to process image and build three-dimensional model after obtaining map data by UAV aerial photography. The software is used to complete the research of UAV campus aerial photography and three-dimensional modeling [2].

**Tilt Photography**

Different from traditional orthophoto and CAD modeling, tilt photography uses multi-view lens. It consists of a positive camera and four tilted cameras with a tilt angle of $40^\circ$~$45^\circ$ as shown in Fig. 1. Using the vertical camera to get the image of the top of the object and the tilted camera to get the texture of the side of the object, we can produce the real face of the object from all directions. Tilt photogrammetry combines traditional aerial photography and close-range measurement technology to make up for the shortcomings of orthophoto image, which is limited to shooting from a vertical angle. By mounting multiple cameras on the UAV at the same time, images are collected from five different perspectives: vertical, front view, left view, right view and rear view. Through efficient digital image acquisition equipment and high-precision background image data processing, more accurate and vivid three-dimensional model can be obtained than traditional photogrammetry.

![Figure 1. Tilt photographic view.](image)

At the same time, when UAV takes aerial photographs, an on-board POS system is placed above the camera, which can acquire the POS system observation value at the moment of tilt photography and serve as the initial exterior orientation element of multi-angle tilt image. Therefore, by using the technology of three-dimensional modeling of tilted images and automatic aerial triangulation processing of vertical and multi-angle tilted images, only a few ground control points and manual intervention are needed, a large number of encrypted points can be obtained, and then TIN triangulation network can be constructed to generate white models. Finally, through texture mapping, the corresponding relationship between two-dimensional texture space points $(u, v)$ and three-dimensional object surface points $(x, y, z)$ is established to obtain real three-dimensional scene reconstruction [3].

In the process of image data processing, aerial triangulation (referred to as aerial triangulation encryption) is an important part of three-dimensional modeling. Aerial triangulation encryption includes image matching, absolute orientation, measurement adjustment and output of results. The
spatial triangulation uses the coordinates of control points measured by RTK, and uses the beam method to adjust the regional network, and calculates the interior and exterior orientation elements. After completing the aerial triangulation encryption, it can display important data such as relevant airstrip information, UAV flight status, and image relative position and so on.

Three-Dimensional Modeling Process

In recent years, tilt photography has been widely used all over the world. The method and software of 3D modeling using tilt images are constantly being optimized. This technology research uses UAV aerial photography, tilt photogrammetry technology to obtain image data, and Smart3D software platform is selected to carry out three-dimensional modeling of the campus scene [4]. Smart3D is a set of three-dimensional model solution that can automatically generate high-resolution texture using acquired aerial image data with only a small amount of manual intervention. The principle of Smart3D modeling is to extract feature points by inputting a group of tilt photographic digital images. The matching pretreatment is realized by feature point matching. Then, a robust three-dimensional reconstruction intensive algorithm based on the regional network combined adjustment method is used to generate a large number of connection points for three-dimensional reconstruction. Finally, a three-dimensional model is generated by seamless texture mapping and texture mapping packaging [5-6]. This three-dimensional modeling process is illustrated in Fig. 2.

![Three-dimensional modeling process diagram](image)

Figure 2. Three-dimensional modeling process.

Detailed steps are as follows:

1) **Image data preparation and inspection.** The camera used for aerial photography should be calibrated to obtain the internal orientation elements of the photograph and the objective lens distortion parameters of the camera before acquiring the image. After completing the image document pre-operation, the POS information of UAV should be checked. Because the acquisition of image data is the most critical step in three-dimensional modeling, the results of three-dimensional reconstruction are usually directly related to the acquired image data.

2) **Data loading and aerial triangulation operations.** According to the results of photogrammetry and the principle of multi-view geometric reconstruction, the modeling software calculates the spatial information of each photo, and then carries out orientation operation. Then a certain number of control point coordinates are obtained by conventional measurement methods, and regional network adjustment is carried out to identify the ground control point identification in the photos. In the process of aerial triangulation operations, feature points are extracted, matching algorithm is used to find the same name image points, and the external orientation elements and a large number of dense connection point coordinates of each photo are obtained.

3) **Reconstruction generation.** This part calculates the correlation between images, and then links all feature points in each image to form connection points. The corresponding three-dimensional
coordinate values are calculated by triangulation, and the overall optimization is carried out by cluster adjustment. By restoring the orientation elements of the image sequence and traversing the matching relationship of each pixel, the disparity map of the matching relationship between views is obtained, and then the matching pixels are intersected in front of each other through the known orientation elements.

(4) Grid generation and texture mapping. After the generation of dense point clouds, the known discrete dense point clouds are partitioned by Delaunay method to construct triangular meshes. After mesh generation, texture mapping is performed to establish the primary three-dimensional model.

(5) Model output. After texture mapping is completed, the main outputs are Digital Orthophoto Image (DOM) and digital three-dimensional model. When exporting, the resolution, projection type and image size can be set. The three-dimensional model generated by Smart3D can refer to OS-GB, OBJ, Max and other formats. For the three-dimensional model with tiling, an S3C index file can be opened in the same reference frame.

In order to practice UAV aerial photography for campus three-dimensional modeling, this technology uses Lanyu 1800 fixed-wing UAV. The mounted aerial photography equipment is LY2.0, an aerial camera independently developed by Lanyu, with 5 lenses, 13.2*8.8 mm sensor size, 2.4 um pixel spacing, a total number of pixels over 100 million, a focal length of 35 mm and an average aerial height of 200 m. The project covers an area of 740,000 square meters. The model projection coordinate system uses 84 coordinate system. Through conventional measurement technology, 9 ground control points around the campus are obtained, and aerial photography work is carried out on the campus. After acquiring the image data of campus aerial photography, the Smart 3D software platform is used for subsequent three-dimensional modeling.

Summarizing the three-dimensional modeling process of this technology research includes three major steps: The first step is aerial triangulation encryption. The software is used to match the image from multiple angles and the same name points, and then calculate the exterior orientation elements to get the flight information of the airstrip and UAV, the position density of aerial triangulation and the relative position of the image. The second step is to add control points and encrypt empty three images again to make the generated model more accurate and to check out the problems of other images. The last step is to build a model to cover texture output. The related modeling process and output results are detailed in Fig. 3.

![Figure 3. Output of 3D modeling.](image)

Summarizing the above technical practices, we can see that in this study, we use Smart 3D software to realize real scene three-dimensional modeling. The whole data processing process is fully automated from empty three blocks to fusion combined adjustment, which reduces the workload of artificial disassembly to the greatest extent without additional manual intervention. It also reduces the
error caused by the edge of measuring area, solves the technical bottleneck of data processing in a single project, and provides solutions for rapid modeling of large-scale data. At the same time, it verifies the advanced and efficient features of the spatial-three distributed algorithm of Smart3D software, which is of indicative significance for large-scale tilt modeling projects.

**Conclusion**

This technology applies UAV aerial photography tilt photography technology to obtain tilt image data, and then uses Smart 3D platform to quickly carry out three-dimensional campus scene modeling. The results show that the processing method of 3D scene modeling based on UAV tilt image has the advantages of high automation, fast modeling and high accuracy, and can adapt to the characteristics of complex three-dimensional scene. In particular, the three-dimensional modeling of Smart 3D platform based on UAV tilt image can not only get the monolithic three-dimensional model, but also ensure the refinement of large-scale three-dimensional model. It solves the problems of slow data acquisition, long modeling time and low precision of traditional three-dimensional modeling technology. It provides a new scheme for the construction of three-dimensional models in the fields of geographic monitoring, disaster prevention and control.

**Acknowledgement**

This work was supported by Scientific Research Startup Foundation of Fuzhou Polytechnic under Project Number RCQD201802 and Scientific Research Project FZYKJJJC201801 of Fuzhou Polytechnic.

**References**

[1] Z. F. Ren, Research on 3D Reconstruction Technology of Outdoor Scenes from UAV Aerial Image, J. Remote Sensing and Aerial Photography. 3 (2017) 71-73.

[2] X. L. Song, X. R. Ruan, R. F. Ma, W. Zhang, W. Zhang, L. L. Ding, X. Lei, C. Y. Xie, W. Chen, Z. W. Wang, M. J. Ye, Three-dimensional Modeling of UAV Tilt Photogrammetry Based on Context Capture, J. Science and Technology Economic Guide. 26(21) (2018) 7-12.

[3] X. Xiao, Application of UAV Low Altitude Photogrammetry in Urban Renewal Survey, J. Innovation and Application of Science and Technology. 29 (2018) 177-178.

[4] Y. X. Kang, W. G. Sang, N. Li, Y. B. Li, Data Processing and Application of Unmanned Aerial Vehicle Low Altitude Photogrammetry, J. Surveying and Mapping Bulletin. S1 (2017) 62-65.

[5] L. X. Xie, G. Wan, X. F. Cao, Q. H. Wang, Design and Implementation of a Rapid 3D Reconstruction System for UAV Sequence Images, J. Computer Technology and Application. 43(6) (2017) 134-142.

[6] H. J. Lu, 3D Modeling and Application of Unmanned Aerial Vehicle Tilt Photography, J. Shanxi Architecture. 44(16) (2018) 80-81.