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Construction and Accuracy Test of a 3D Model of Non-Metric Camera Images Using Agisoft PhotoScan

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Abstract

This paper aims to provide a method of constructing and testing the accuracy of a three dimensional (3D) model for non-metric camera images using Agisoft PhotoScan to solve the problems regarding large investment, long processing periods and high technical difficulties. On the basis of data pre-processing, this software presents a way of orientating data, extracting point clouds, building Triangulated Irregular Networks (TIN), Digital Elevation Models (DEM) and producing Digital Orthophoto Maps (DOM). From these networks, a 3D model of the research area can be established. The experimental results show a highly precise 3D model can be rapidly established using this method. The construction time is shortened and the relevant investment required to produce the map is reduced. This method is a robust and relatively quick approach to build 3D models which is relevant for many applications.

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Keywords: Agisoft PhotoScan; Non-metric camera; 3D model construction; Accuracy test

1. Introduction

Reconstructing original 3D models of space objects based on the two-dimensional images obtained from different points of sight has been a hot research area in the field of photogrammetry and computer vision[1]. In

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practice, 3D models can visually, efficiently and practically reflect the basic geographical information of real surface features which change traditional models and greatly improve the efficiency of work and research. However, only accurately measured 3D data of the target feature can be used for the subsequent construction of three-dimensional structure models and rapid response manufacturing. Strategies to improve the efficiency, convenience and accuracy of 3D data for target objects have attracted much interest as a hot research topic[2,3]. At present, three dimensional modeling is a complicated process which involves a long work cycle, and has very high for example, the use of 3D Laser Scanners. There is significant scope and potential for the development of novel solutions that will improve the efficiency, speed and quality of the process but these remain to be fully developed.

The rapid development of digital camera technology in recent years has significantly increased the quality and resolution of photographic images. The higher cost performance of digital camera products provides 3D modeling with a broad developmental space. Further progress has also been made in the application of one or several common Charge-coupled Device (CCD) digital cameras in different positions and angles to obtain an image or a collection of images that can be reconstructed to generate three-dimensional models of targets.

Using the Dream Park 3D rock landscape in Jiangxi province of China as an example, the Agisoft PhotoScan software is used to process the pictures captured using a non-metric digital camera from multiple angles. A multi-view, three-dimensional reconstruction technique was adopted to establish a 3D model. Local point cloud data are firstly obtained after processing the point cloud data to generate a TIN which is used to build the texture atlas. Finally, a Digital Elevation Model (DEM) of the research area is produced. When combined with the orthoimage, the 3D model is then rebuilt to realize the representation of the three-dimensional geometric scene.

2. Introduction of 3D reconstruction based on images and relevant software

2.1.3D reconstruction based on images

In digital image processing, three-dimensional models is reconstructed on the basis of spatial geometric information of the target object which is obtained from one or several images taken by a non-metric camera achieved using several methods as follows: firstly, using light and shading to present a 3D shape of a target, the main task of which is to restore the three-dimensional geometric information of the target based on one or several pictures [4,5]; second, another approach is Binocular stereo vision method which simulates the structure of the visual space of human beings. By using two CCD cameras of the same performance in fixed relative positions, one scene can be captured from two images for 3D reconstruction. Considering whether the digital camera parameters are known or not, reconstruction of the geometric information of the 3D scene can be classified the known and unknown parameters[6].

2.2. Introduction of 3D reconstruction software Agisoft PhotoScan

Agisoft PhotoScan is a 3D scanning software package developed by the Agisoft company, Russia. It is an advanced 3D modelling package based on image data processing. It uses the latest 3D reconstruction technology from multiple views which can process any picture taken by a non-metric camera with data ranges from small sculpture to mass data captured from Unmanned Aerial Vehicle (UAV). It can process a series of images to produce a high quality Digital Orthophoto Map (DOM) and Digital Elevation Model (DEM) from which a 3D model can then be built. 3D scenes have wide applications in many fields, such as the protection of cultural relics, industry, archaeology, biology, medicine and some military application[7]. The advantages and disadvantages of the software are as follows:

(1) Advantages of Agisoft PhotoScan

Agisoft PhotoScan can automatically construct 3D models throughout the whole course without setting initial values and control points and so it is very convenient for users. Photos can be taken at any position and at any angle with only one pre-condition, that there exist corresponding points between two adjacent pictures of the target. In comparison to constructing 3D models of surface features using a 3D Laser Scanner, this method is highly efficiency and has low cost.

(2) Disadvantages of Agisoft PhotoScan

Agisoft PhotoScan requires a high performance computer which is capable of graphics processing. The construction speed of the three-dimensional model depends on the number of photos and other corresponding parameters such as RAM. The larger the amount of processing data, the longer the time to build the three-dimensional model. The accuracy obtained from the above method is lower than that from a 3D Laser Scanner, therefore, a 3D Laser Scanner is still necessary for 3D measurements which require a high level of precision.

3. 3D model building

3.1. The basic flow chart

This paper introduces a work flow of Agisoft PhotoScan which is shown as figure 1.

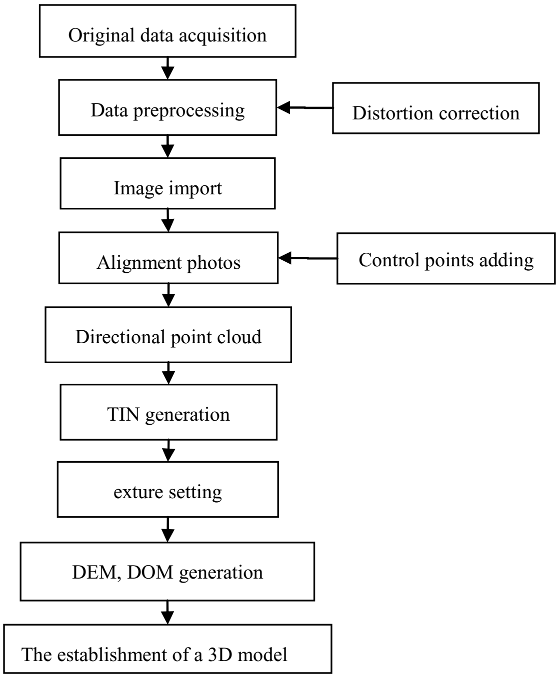

Fig.1: flow chart of 3D model reconstruction

3.2. Raw data processing

The experiment data of this paper are from the Dream Park 3D rock landscape in the Jiangxi province. Influenced by the site and size of the landscape rock, the UAV aerial photography combined with the ground photography are adopted. Two of the images obtained by an Unmanned Aerial Vehicle (UAV) are shown in Figures 2 and 3.

Fig.2: left facade image of the landscape rocks by UAV

Fig.3: right facade image of the landscape by UAV

During data processing, the pictures of the study area should be sufficient; however, blind areas should be minimized. The camera and the holder are carried on an aircraft to take photos which requires continuous shooting without any intervals. Simultaneously, it is necessary to refer to the standards of the aerial photogrammetry which requires 60% lateral overlap and 80% forward overlap. The camera used is a SONY NEX – 7 with 240, 00000 pixels (6000 x 4000), a pixel size of 0.0039 mm and a prime lens with a focal length of 16 mm. There are three times of shooting and eight times of flight. The aerial photography shooting is taken from three sides including the top, the back and the front sides. Orthographic shooting is used for the top side, whilst oblique photography is adopted for the back and front sides. Ground photography is used to supplement the aerial photography. The shooting distances range from 30 to 60 meters. 750 photographs are taken in total. The object space resolution is less than 0.01 meters.

3.3.Orientation and point cloud data extraction

By loading the image into Agisoft PhotoScan after distortion treatment, the software automatically aligns with the camera. At this stage, the software will search for the corresponding points and match the photographs at the same time to identify the location of the camera. The alignment process takes a long time if there are many photographs. If only a subset of the images is selected and requires alignment then the process is accelerated. In this paper, the raw data obtained from the non-metric camera processed using a digital graphic workstation DELL X25 are used to perform the 3D model construction. Low precision is used in the general primary mode setting. In the primary mode of ground control, the overlapping pictures are chosen based on the position of the non-metric camera. A sparse point cloud is generated after the above mentioned adjustment. In this study, nine million points are generated as the cloud data by the Agisoft PhotoScan software in the ASPR S LAS (LAS) file formats.

3.4. TIN production

Traditional surveying and mapping mainly concern precise measurements of single points. Using the data obtained from this technology, there are many problems associated with 3D model construction. To sufficiently describe the properties of the structure of the target features and the geometric information of the online scene, millions of points need to be collected [8]. Agisoft PhotoScan can build an irregular triangle net (TIN) with a dense point cloud. From this, the target area is divided based on finite point sets to produce a triangular surface mesh where arbitrary points in the region are used to locate the vertex at the side or inside of the corresponding triangle. In this paper, there are two million irregular triangle net (TIN) models being generated. The TIN changes the density between sampling points and determines the position of them according to the complicated topographic relief to reduce the data redundancy of flat terrain. This reflects the digital elevation features on the basis of the terrain feature points such as valley lines, the ridge and other terrain change lines. After this, elevation points are interpolated into the obtained TIN to generate an irregular triangle mesh model.

3.5. Texture setting

Texture mapping is carried out according to the TIN. There are five mapping modes in the Agisoft PhotoScan used to generate the textures including a general mode, an orthogonal projection image, an adaptive orthogonal projection image and a sphere and single camera. In accordance with the features of the study area, we chose the adaptive orthogonal projection model in which the target surface is divided into horizontal and vertical parts. Orthographic projection deformation is used where the surfaces are flat and accurate textures are present according to deformation in the vertical part of the map. In this mode, the software shows the texture information in a better way and maintains high quality. The local texture map is shown below Fig. 4.

Fig.4: local texture map

3.6. Results output

Digital Elevation Model (DEM) is a digital expression of the attribute information of the terrain surface morphology, which digitally describe the characteristics of the spatial location and terrain attributes [9]. The DEM represents the height value of the terrain surface and is often used in aerial surveying. The type and view plane of the projection and pixel values are adjusted as the DOM is the output. The export formats are usually GeoTIFF (* tif) and JPG formats. In this paper, the digital elevation mode is generated after a series of processing and the ortho-image is then produced through a unifier of ray and color. Combining the above DEM and DOM, a 3D model is reconstructed for the study which is shown in Fig. 5.

Fig.5: 3D model reconstruction of the landscape rocks

4. Accuracy testing

A 3D model should be ideally consistent with the shape and size of real buildings. However, in practice, there are certain types of errors[10] due to the limits regarding data source, the construction methods and other problems. To inspect the accuracy of the generated 3D model, distance measurements of ten buildings are taken by total stations. The relative mean square error of the traverse length is 0.00003 and the error in the control point measurement is less than 0.1 meters. The relative mean square error of the traverse length for most of the control points is less than 0.05%. Comparing the length of the 3D model generated in the experiment with the actual measured lengths, the resulting error data are shown in table 1. It is shown in the table that the relative error is less than 10%, which is similar to the actual field data, therefore the 3D model reconstruction is of high precision.

Table 1. Relative error calculations.

Serial number	Model distance (unit: M)	Control points calculation or measured distance of object space (unit: M)	Difference value	The relative error
z1-z12	7.283	7.299	-0.016	-0.22%
z22-z23	9.267	8.96	0.307	3.43%
z24-z25	5.255	5.023	0.232	4.62%
rtk12-13	47.956	49.39	-1.434	-2.90%
rtk3-4	49.232	49.194	0.038	0.08%
52-53	11.355	11.681	-0.326	-2.79%
176-188	40.594	40.371	0.223	0.55%
The Windows width	1.80	1.759	0.02	1.13%
Tao yuan ming Statue height	37.2	38.0	-0.8	-2.10%
Rock depth	0.72	0.70	0.02	2.86%

5. Conclusion

Basic data from the images of the 3D landscape rocks for the Dream Park in Jiangxi, China, are taken using non-metric camera and processed using a relevant software package so as to successfully construct a 3D model of the study area. The test results show that the Agisoft PhotoScan software is able to quickly produce the point cloud of the study area from the images taken by the non-metric camera. From these images the DEM and DOM from the 3D model construction and the 3D scene model are built accordingly. This method is a technical platform to quickly process images using a non-metric camera. The software extracts the required texture data from the original images and efficiently constructs a 3D model of the study area. High precision 3D model with low construction time and cost can be built using this method, which can potentially be applied to many relevant 3D modelling applications.

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