Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 11, No. 3, 2024

Uav Photogrammetry and Digital 3D Product Production Technology Design

Qinshu Pang

University of Science and Technology Liaoning, Anshan 114000, China

Abstract: The use of drone photogrammetry to produce 3D digital products is a rapidly developing technical field in recent years. The technology can use the high-definition camera carried by the UAV for aerial photography, and process the aerial images through image processing software to generate high-precision digital elevation model, digital ortho map and digital line map, which provides strong support for urban planning, land resource management, environmental monitoring, cultural heritage protection and other fields.

Keywords: Drone Photogrammetry; 3D Digital Products; Zoning Measurement; Smart City.

1. Introduction

1.1. Background of Topic Selection

When it comes to smart cities, 3D digital products are inextricably linked to them. In fact, 3D digital products help realize the planning and design, resource allocation and decision management of smart cities. With the advancement of informatization, the idea of changing the blueprint of future urban development based on information technologies such as the Internet and big data has been put forward internationally. Smart city is based on a series of data and technologies such as big data and cloud computing. The city building smart city can have a comprehensive perception on the basis of network and digital modeling. Whether it is medical care, education or the most common water and electricity in life, it can form a clear expression in smart city. So that people have a deeper understanding of the city they live in, but also a three-dimensional understanding of the city's future infrastructure and urban planning.

1.2. Physical Geographical Condition of Measuring Area

Anshan City is located in northeast China, located in the geometric center of Liaodong Peninsula, is an important fulcrum of Shenzhen-Dalian Golden Economic Belt, is an important connection belt between Shenyang modern metropolitan area and Liaoning coastal economic belt, Liaodong Peninsula north-south and east-west traffic channel intersection here. It is 270 kilometers away from Dalian Port, 90 kilometers away from Taoxian International Airport, and 100 kilometers away from Yingkou Port. Its geographical coordinates are located at 40°27 '~41°34' north latitude and 122°10 '~123°41' east longitude.

2. Measurement Basis

2.1. The Length of the Measuring Area is Deformed

The 2000 national geodetic coordinate system is used in the design of the measured plane control network. Its reference ellipsoid parameters are major semi-axis a=6378137m, minor semi-axis b=6356752.314m oblate f=1/298.257222101. The plane control selected the whole Anshan city as the survey area, with an average elevation of 79m. The central meridian of the measuring area is 123° according to the 6-degree zone. Next, we need to calculate the length deformation per kilometer due to elevation and the length deformation per kilometer due to projection according to the formula shown below

$$\Delta S_{投} = \frac{1}{2}\left(\frac{y_M}{R_M}\right)^2 \times S_0 \qquad \Delta S_H = -S_0 \times \frac{H_M}{R}$$

As this design plan adopts the four-level plane control measurement, the specification stipulates that the length deformation value should be less than or equal to 2.5cm/km, and according to the calculation, the combined impact of each kilometer of the two is greater than the specified 0.025m, so it is necessary to establish an engineering coordinate system. According to the above calculation process, it is known that the length deformation caused by the elevation of the measuring area in the design meets the accuracy requirements, but the length deformation caused by the projection is beyond the limit, so we use the method of moving the central meridian of the measuring area, that is, the method of compensating the elevation plane, to reduce the projection error. First, we should keep the mean elevation of the measuring area unchanged and ensure that the sum of length deformation and projection deformation is zero, that is, $\Delta S_H + \Delta S_{投} = 0$. According to the formula of ΔS_H and $\Delta S_{投}$, the following formula can be obtained $\left(\frac{y^2{}_M}{2R^2{}_M} - \frac{H_M}{R_M}\right) \times S_0 = 0$ .In order to meet the projection deformation requirements, we recalculated yM according to the formula as follows $y_M = \sqrt{2H_M R_M}$ Final inspection is required to match the length deformation.

2.2. Height Datum

The 1985 national elevation datum was selected according to the elevation requirement of mapping. Three third-order level points under the national 1985 elevation system were collected within the measuring area.

3. Image Control Point Layout

3.1. Image Control Point Layout Requirements

The regional network pattern formed by the layout of image control points should be slightly rectangular, covering the whole range of the test area and evenly distributed in the test area to form a certain geometric strength, and the number of control points should be appropriately increased in difficult and complex areas. The selection of image control points should be clear and obvious, which is conducive to the identification and puncture points, and the color difference between it and the surrounding ground objects should be large. Sharp features can be used as image control points. The image control point should be arranged at a flat high point and located near the side overlapping center line, away from the edge of the photo.

3.2. Site Selection and Sign Layout

Field inspection and selection point is to implement the image control point on the map to the field, not only need to meet all the requirements of the above image control point layout, but also need to consider the following circumstances: when selecting the field layout point, if it is a large Angle intersection photography, the sign is made into a three-dimensional shape, if it is a special case, you can use luminous spray materials.

4. Image Control Point Measurement

4.1. Image Control Point Plane Measurement

4.1.1. Method and Grade of Plane Measurement

According to the requirements of "1:5001:1001:2000 topographic map aerial Photogrammetry Field Specification", the basic control point is 5 "(corresponding to GPS first-level accuracy), so the image control point plane can be measured with GPS second-level accuracy.

4.1.2. Accuracy Requirements of Image Control Points

According to the requirements of 1:5001:1001:2000 Field Specification for Aerial Photogrammetry for Topographic Maps, the median error of the plane position of the image control point relative to the adjacent base control point should not exceed 1/5 of the median error of the plane position of the ground object point. The elevation accuracy relative to the adjacent foundation control point should not exceed 1/10 of the basic contour distance. The maximum error of the control point of the photo is 2 times the median error.

4.1.3. Data Processing and Coordinate Conversion

The field industry data is processed according to the secondary observation data, the coordinates in the 2000 coordinate system are obtained, and the coordinates in the 2000 coordinate system are converted to the coordinates in the engineering coordinate system of the survey area.

4.2. Image Control Point Elevation Measurement

4.2.1. Methods and Requirements

The elevation fitting method also has relatively strict requirements on the point position, because the elevation fitting method is generally calculated on the basis of leveling, so it also has certain requirements on the point position. The control point should cover the entire measurement area as far as possible and the distribution in the measurement area should be relatively uniform, and the number of known points should also be required. If the elevation fitting calculation adopts zero-degree polynomial, Only one parameter needs to be determined, so only more than one known point is needed; If the first order polynomial is used for elevation fitting, it is necessary to determine 3 parameters, and more than 3 known points are needed. If a quadratic polynomial is used for elevation fitting, more than 6 known points are needed to determine 6 parameters [4].

4.2.2. Height Fitting and Accuracy Requirements

First of all, the principle of elevation fitting method needs to be clear. Since RTK measurement can only measure the geodetic height of the corresponding point, we need to carry out elevation fitting processing on the measured data in order to obtain the normal height. According to the formula, we can know the relationship between the geodetic height H, normal height H_γ, elevation outlier ζ, normal height Hg and the geoid gap hg $H = H_g + h_g = \zeta + H_\gamma$ .According to the above formula, if we want to find the normal height of the calculation point, we only need to know the earth height and the elevation anomaly. The earth height is the data we measured in the field, and the elevation anomaly is calculated by the elevation fitting. The corresponding mathematical model is established by the following formula $\zeta = f(x, y) + \varepsilon$ .f (x, y) in the formula is the fitting surface, is the fitting error, according to the mathematical model can finally establish the error equation V=-BX+L, substituting the corresponding value and the elevation of the known point can calculate the normal height of the point we want. The fitted elevation results of GPS points should be tested [5]. The number of detection points is not less than 10% of all elevation points and not less than 3 points [6]: height difference test can be carried out by the leveling method of the corresponding level or the triangular elevation measurement method of electromagnetic wave ranging, and the height difference should not be greater than 30√Dmm (D is the length of the inspection route, in km) [7].

5. Field Photogrammetry

5.1. Airspace Application

In general, the process and requirements for airspace applications may vary by region, country or specific circumstances. First of all, before applying for airspace, you need to understand the relevant laws and regulations. The flight area is then determined and the application is submitted to the appropriate civil aviation authority or professional drone service company. Wait for the civil aviation management agency or professional drone service company to review the application, and make a decision to approve or reject according to the actual situation. If approved, the corresponding flight activity can be carried out.

5.2. Instrument Selection

The selection of field photogrammetric instruments usually takes into account several factors：

1.Select the right UAV: When selecting a UAV, it is necessary to consider factors such as the size of the aerial shooting area, flight height, and load capacity to ensure that the aerial shooting effect meets the requirements.

2.Choose the right camera and lens: Different types of cameras and lenses have different upper limits of accuracy and need to be selected according to topographic map accuracy requirements. It is also necessary to ensure that the camera Settings are correct (such as exposure time, ISO value, etc.)

5.3. Strip Selection and Field Photogrammetry

5.3.1. The Choice of Navigation Belt

In the selection of navigation belt, the following factors need to be considered when 1:2000 topographic map aerial navigation belt：

1. Terrain complexity: If the terrain is relatively flat, and there are not too many details and features, you can choose a wider navigation strip; If the terrain is complex, such as mountains or river valleys, you need to choose a narrow navigation strip

2.Accuracy requirements: If a high-precision topographic map is required, a narrow navigation strip needs to be selected to improve the measurement accuracy.

3.Wind speed and direction: When carrying out aerial photogrammetry, wind speed and direction are crucial to affecting the quality of photography. If the wind speed is too large or the direction is unstable, it is necessary to choose a narrower navigation band to reduce the error.

5.3.2. Field Photogrammetry

According to the above requirements, after the completion of the ribbon layout, the field photogrammetry needs to go through the following steps：

1. Pre-flight preparation: The aircraft needs to be inspected and tested before flight to ensure that it works properly. At the same time, it is also necessary to determine key positions such as the starting point, end point and turning point of the route according to the layout plan of the navigation belt, and mark these positions on the map.

2. Route flight: to fly according to the predetermined route plan and collect aerial image data. In the course of flight, attention should be paid to the control of flight altitude, speed, attitude and other parameters to ensure the accuracy and integrity of data acquisition.

3. Data processing: Import the acquired image data into the computer, and perform pre-processing, correction and splicing operations. Normally, this step requires the use of professional photogrammetric software to complete.

4. Data quality assessment: Quality assessment of the processed data, including data accuracy, integrity, overlap and other indicators. If the data is found to be problematic, it needs to be re-collected or re-processed.

5. Data application: Finally, the processed data is applied to related fields, such as map production, 3D modeling, resource survey, etc. In the application process, it is also necessary to pay attention to issues such as data security and privacy protection.

6. Space Triangulation

6.1. The Process of Space Triangulation

1. Forward intersection： Forward intersection is a method of calculating the space coordinates of unknown points in aerial photogrammetry by using the image control coordinates of known points on the photo and the internal and external orientation elements of the camera.

2. Rear intersection: After the completion of the photogrammetry, by processing the known control points and photogrammetric data, the internal and external orientation elements of the camera and the position of the point to be sought in space are determined.

3. Accuracy check: Accuracy check refers to the inspection and verification of the measurement results to ensure that their accuracy meets the requirements. The specific methods include error analysis, accuracy evaluation, accuracy optimization, etc. Among them, error analysis is the most commonly used method, which determines the source and size of various errors through statistical analysis of measurement data, and carries out error transmission and synthesis to predict the accuracy range of measurement results.

6.2. Internal Work Calculation

6.2.1. Choice of Software

The selection of empty three computing software needs to consider the following requirements：

1. Functional requirements: Different empty three computing software has different functions and needs to be selected according to actual needs.

2. Accuracy requirements: Empty three calculation is a high-precision technology, and it is necessary to select software with high-precision calculation capabilities.

3.Data formats and coordinate systems: Different types of mapping projects may use different data formats and coordinate systems, and you need to choose software that supports multiple formats and coordinate systems.

4. User interface and operation guide: A good user interface and operation guide can help users quickly master related skills and improve work efficiency.

5. Technical support and update frequency: Because empty three computation involves a large number of complex calculations and data processing, there may be some technical problems. Therefore, when selecting software, it is necessary to consider the technical support and update frequency provided by the software to ensure the stability and reliability of the software.

6.2.2. Calculation Process

The space triangulation software calculation process for aerial surveying consists of the following steps:

1.Pretreatment of observation data: This step is to screen, remove weight, and correct errors of the original data collected. The main purpose is to ensure the accuracy and reliability of the observation data, to avoid error transmission and calculation bias.

2.Data preparation: Import the acquired aerial image data and control point data into the internal software for calibration and registration.

3.Feature extraction: Automatically or manually extract the feature points of the object to be measured in the image, such as corner points, edges, etc.

4.Matching point pair generation: By matching the feature points between different images, a group of matching point pairs is generated for the subsequent triangulation calculation.

5.Net adjustment calculation: using the known control points and matching point pairs to calculate the net adjustment, to obtain the projected coordinates of the object to be measured on the image.

6.External orientation element calculation: based on the known control point and the projected coordinates of the object to be measured on the image, the external orientation element of the camera is reversely derived.

7. Triangulation calculation: Using the known control points, the external azimuth elements of the camera and the projected coordinates of the object to be measured on the

image, triangulation calculation is carried out to obtain the three-dimensional coordinates of the object to be measured in space.

8. Accuracy assessment: Through the accuracy assessment of three-dimensional coordinates, determine whether the calculation results meet the requirements.

7. Digital Product Production

7.1. DEM

According to the requirements of Digital Aerial Photogrammetric Mapping Specification Part 1 1:50, 1:1000, 1:2000 Digital Elevation model DEM digital Positive image DOM Digital Line Mapping DLG, the accuracy requirements of one-way model should follow the relevant provisions:

7.2. DOM

DOM image making process:

1 Correction: Using the digital elevation model data whose accuracy meets the requirements, the digital differential correction of image data is carried out to generate the digital orthophoto of the photo. [8]. Check the image quality of the digital orthophoto image, and find and analyze the causes of the problems and phenomena such as blur, dislocation, distortion, deformation, and loopholes, and deal with them. Image stretching and distortion caused by viaducts, overpasses and DAMS should be dealt with as necessary [9].

2 Color leveling and image processing: Adjust the color, brightness and contrast of the image. There should be no trace of color smoothing on the processed image. For problems and phenomena such as dirty spots and scratches in the image, the causes should be found and analyzed, and the corresponding image processing should be carried out [10].

3 Mosaic: The digital orthophoto of the adjacent photo should check whether the edge accuracy of the Mosaic meets the requirements, and rework when the error exceeds the limit. After Mosaic, the image should ensure that there are no obvious splicing marks, the transition is natural, and the texture is clear [11].

4 Map cropping: Crop data to a specified range to generate a map digital orthophoto. Color, brightness and contrast between adjacent sheets should be consistent [12].

5 Finish: Finish the outline according to the requirements of regulations and technical design [13].

7.3. DLG

In the process of mapping, according to the requirements of Digital Aerial Photogrammetric Mapping Specification Part 1 1:50, 1:1000, 1:2000 Digital elevation model DEM digital positive image DOM Digital Line mapping DLG, the expression and selection of elements are based on the principle of the importance of elements, the load of the map, as well as the maintenance of field characteristics and taking into account regional characteristics.

7.4. Field Drawing

In the process of digital line drawing editing, if the ground object information of the internal staff is not clear, field personnel should be on-site adjustment, and the ground object that needs to be remeasured should be remeasured during field adjustment. In addition, the work of field mapping also includes the inspection of elements that the internal staff is uncertain about, the correction of elements that are misinterpreted, and the supplement of ground elements that are newly added or lost during aerial survey.

8. Sum Up

This design takes the development of Anshan city as a prospect, and uses UAV aerial survey technology to produce 3D digital products of Anshan City. In the whole design encountered many problems, such as: in view of the problem of the projection deformation of the measurement area, the design made the processing of the central meridian to the west according to the calculation accuracy, and successfully solved the problem of deformation per kilometer. In order to solve the problem of large measuring area in the design, the method of partition measurement is adopted. The advantages of this method are to reduce the measuring error, improve the working efficiency, facilitate the data management, have better space coverage and adapt to the needs of different scenes. At the same time, the precision is also strictly required in the whole design, and each design process refers to the corresponding national measurement specifications.

References

[1] Đuka Andreja,Tomljanović Kristijan,Franjević Milivoj,Janeš David, Žarković Ivan, Papa Ivica. Application and Accuracy of Unmanned Aerial Survey Imagery after Salvage Logging in Different Terrain Conditions[J]. Forests,2022,13(12).

[2] Du Qingsong, Li Guoyu, Zhou Yu,Chen Dun,Chai Mingtang, Qi Shunshun,Cao Yapeng,Tang Liyun,Jia Hailiang. Route Plans for UAV Aerial Surveys according to Different DEMs in Complex Mountainous Surroundings: A Case Study in the Zheduoshan Mountains, China[J]. Remote Sensing, 2022, 14 (20).

[3] McDonald Kristian K., Fletcher Charles H., Anderson Tiffany R., Habel Shellie. Weekly Small Uncrewed Aerial System Surveys, Structure from Motion, and Empirical Orthogonal Function Analyses Reveal Unique Modes of Sediment Exchange Generated by Seasonal and Episodic Phenomena: Waikīkī, Hawaiʻi[J]. Remote Sensing,2022,14(20).