Application of UAV Oblique Photogrammetry in Mine Ecological Environment Restoration

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Abstract. At present, total station or gnss-rtk is often used in mine ecological environment restoration survey, which has the disadvantages of high intensity, long cycle and high cost. In particular, the problems of landslide and collapse in abandoned mines bring potential safety hazards to the surveying and mapping personnel. The traditional surveying and mapping results are 2D graphics, and the information of topography and geological disasters is not intuitive, which brings inconvenience to the design of ecological environment restoration scheme. In order to meet the actual needs of mine ecological restoration, UAV incline photogrammetry technology is applied in the survey and mapping, scheme design and construction management stages of mine ecological environment restoration. The research results show that UAV incline photogrammetry technology can realize: ensure the safety of technical personnel, make the survey and mapping more efficient; make the mine environment information more intuitive, vivid and vivid, which is conducive to the formulation of ecological restoration plan, dynamic grasp of construction progress, and make mine ecological restoration more accurate.

Keywords. UAV, oblique photogrammetry, mine, ecological restoration.

1. Introduction
China’s mineral resources development activities have a long history, and its long-term high-intensity, large-scale mining has seriously affected the regional ecosystem. Since the eighteen Party’s Congress, general secretary Xi Jinping has put forward the important guiding ideology of “beautiful scenery and green hills and clear hills”. In recent years, through the integration of mineral resources, the management and closure of small, scattered and disordered mines, the number of abandoned mines has gradually increased, causing serious damage to water, land, atmosphere and other environment.

In view of abandoned mines, the Ministry of natural resources has issued a series of policies, such as “opinions on accelerating the implementation of comprehensive renovation of open-pit mines”, “opinions on exploring the use of market-oriented methods to promote ecological restoration of Mines” and other policies to promote the ecological restoration and management of mines Construction mode to speed up the recovery process and improve the level of governance. EPC mode is the integration mode of exploration, design and construction. The whole process of implementation requires the cooperation of exploration, design, construction, evaluation, surveying and mapping, monitoring and 3D effect production.

The traditional surveying and mapping technology for mine ecological restoration has the characteristics of high intensity, long cycle, high cost, low precision, as well as the potential safety hazards caused by many problems such as landslide and collapse. Moreover, the traditional surveying
and mapping results are two-dimensional results, and the information of topography and geological disasters is not intuitive, which brings inconvenience to the design of ecological restoration scheme. In recent years, with the popularity of UAV and the rapid development of oblique photogrammetry technology, UAV oblique photogrammetry technology is more and more widely used in mine monitoring [1-2], mine geology [3-4], mine modeling [5-6], mine topographic survey [7]. Reference [8] used UAV incline photogrammetry technology to carry out mine environment treatment application. However, the whole process of mine ecological restoration, especially EPC ecological restoration mode, has not been applied in detail. Therefore, the author proposes to use UAV incline photogrammetry technology to carry out survey and mapping, scheme design, construction management in the whole process of mine ecological restoration EPC mode, so as to achieve digital and quantitative management, and apply this technology to ecological restoration of an abandoned open-pit mine in Chongqing.

2. UAV Oblique Photogrammetry Technology

2.1. UAV

Unmanned aerial vehicle (UAV) is an unmanned aircraft operated by radio remote control equipment and self-contained program control device. Compared with manned aircraft, UAV has the advantages of small size, low cost, easy to use, low environmental requirements, strong survival and ability. With the rapid development of technology, unmanned aerial vehicle (UAV) has been widely used in urban management, agricultural geology, meteorology, electric power, disaster relief, video shooting and other industries from the initial military field to the civil field, and continues to maintain a rapid development trend.

2.2. UAV Oblique Photogrammetry

The UAV flight platform is equipped with five camera lenses of digital camera, one of which is vertical lens to obtain the Orthophoto Image of the bottom area, and the other four lenses are used to obtain the oblique images in front, back, left and right directions respectively, which can quickly and efficiently obtain multi angle images, obtain more abundant texture image information, truly reflect the actual situation of ground objects, and overcome the vertical photogrammetry The limitations of Orthophoto make up for the shortcomings of Orthophoto, as shown in figure 1. Through POS (position, POS) positioning and orientation technology and GNSS (global navigation satellite system, GNSS) differential technology, the spatial information is obtained, and the real scene 3D model is generated by data rapid processing system.

![Figure 1. Unmanned aerial vehicle oblique photogrammetry.](image)

2.3. Key Technologies of UAV Oblique Photography

UAV oblique photogrammetry technology usually includes the layout and measurement of image control points, joint adjustment of multi view images, dense matching of multi view images, 3D modeling, information acquisition, etc.

(1) Image control point layout and measurement. The layout and measurement of image control points have great influence on the accuracy of the results. Therefore, when selecting image control points in the field, we should follow the layout principle of control points and choose the appropriate
field control point layout and measurement scheme. Image control point layout scheme: UAV incline photogrammetry image control point layout usually adopts area network layout scheme. According to the accuracy requirements of different mapping scales for plane points and elevation points, the baseline number interval of course and side direction is obtained and the points are arranged. Phase control point measurement scheme: the traditional image control point adopts hierarchical control. Through the control network composed of image control points and existing control points, the adjustment is completed. With the continuous development and maturity of GNSS positioning technology, image control point measurement using GNSS positioning method fully meets the requirements. In particular, GNSS-RTK technology can obtain the coordinates of image control points quickly and accurately.

(2) Combined adjustment of multi view images. Multi view image includes vertical photography image and oblique photography image. The traditional adjustment method mainly deals with the vertical photography image, but it can’t deal with the occlusion and geometric deformation between oblique photography images. Therefore, it is necessary to combine multi view image adjustment. In the joint adjustment of multi view images, feature extraction is a basic work. The accuracy of adjustment is determined by the accuracy of extraction and the distribution of feature points. After the feature points are extracted by feature extraction algorithm, combining with the initial POS exterior orientation elements, the pyramid matching strategy is used to match the same points on each level of photos, and the matching information is obtained. Through the joint adjustment, the error equation of the adjustment of the connection point, control point coordinates and other data with the multi view image self-inspection campus area network is solved to obtain the ground coordinates of the internal and external orientation elements and all encrypted points of each photo.

(3) Multi view image dense matching. Multi view image matching is one of the basic problems in digital photogrammetry. Compared with single stereo image matching, multi view image matching can make full use of redundant information in the image for matching correction and supplement the features of blind area. In the same region, the number of images obtained by oblique photography is large, which will produce a large number of redundant observations, and has the characteristics of high overlap, large coverage and high resolution. Therefore, the key to dense matching of multi view images is how to better use redundant information, and use multi view matching algorithm to accurately obtain the coordinates of the same points, so as to obtain 3D spatial information. After dense image matching, dense point cloud is obtained, and 3D mesh reconstruction and texture mapping of object surface are carried out to generate image model.

3. Technical Process
The technological process of mine ecological restoration includes four stages: preparation, exploration and mapping, scheme design and construction management.

3.1. Preparation
Collect basic mine information, including mine location information and surrounding conditions. Collect geological data and mining data, including mine geological disaster report, land use planning map, land use status map, ecological red line and database. At the same time, airspace application shall be carried out.

3.2. Surveying and Mapping
(1) Route design. Before the oblique photography is carried out, the route design work should be done well, including aerial photography division, route design, route laying, flight height design, and determination of aerial photography overlap.

(2) Layout and measurement of image control points. The active layout method before aerial photography is adopted, and the appropriate position is selected according to a certain grid spacing, and the control is implemented by using the made signs. GNSS-RTK technology is used to measure image control points. Two observation sets are observed, and the time interval between the two sets is
more than 60s. The observation value of each observation set is recorded after the RTK fixed solution is obtained and the convergence is stable. The difference of plane coordinate component is not more than 2cm, and the difference of vertical coordinate component is not more than 3cm. The average value of 2 sets of measurement results is taken as the final result of image control point measurement.

(3) Real scene 3D modeling. The multi view image adjustment is carried out by using contextcapture software. The external orientation elements are initialized by feature points extraction, and the connection points are matched. The aerial triangulation is carried out by bundle area network adjustment. In order to improve the accuracy, the inner orientation elements of each camera in a small area are calculated, and then the elements are imported into the project for relative orientation, which can improve the accuracy of relative orientation. In the measurement of image control points, each image control point is distributed in different angles of view, and there are at least three images in each view angle. The image control point is located in a clear picture, and the image control point position is close to the center of the image. Through the optimization and adjustment of control point measurement link, the mean square error of control point is controlled within 1 pixel, so as to improve the accuracy of aerial triangulation. On the basis of aerial triangulation, a large number of high-density point cloud data are obtained by dense matching of inclined images. Irregular 3D mesh model is constructed, and automatic texture mapping is carried out by optimizing and simplifying mesh model. Finally, the 3D model with clear and vivid texture is generated. In order to improve the efficiency of modeling, cluster processing and 3D model construction are carried out by using multiple servers.

(4) Data acquisition. Based on the real scene 3D model, automatic block output of high-precision orthophoto, in order to save image information to the maximum extent, the resolution is set to the highest resolution. On this basis, remote sensing image processing software is used to inlay the block image, and then resample according to the grid size required by production to generate large-scale DOM (Digital Orthophoto Map). Using EPS 3dsurvey 3D mapping system to call 3D model osgb tile data, using real 3D model and orthophoto linkage mode to carry out digital mapping, collect information of houses, roads, rivers, landforms and other features, and complete DLG (digital line graphic) production. In EPC mode of mine ecological restoration, earthwork excavation is very heavy, and it is also an important part of ecological restoration fund source. The accurate calculation of earthwork must rely on the high-precision DEM (digital elevation model) data of mining area, adopt EPS 3dsurvey 3D mapping system, and collect feature points and lines according to the real 3D model data. All the feature points and lines are used to construct the triangulation network to complete DEM production.

(5) Accuracy test. The accuracy verification of 3D modeling and 4D product is carried out, and the scheme design can be entered if the accuracy requirements are met.

3.3. Scheme Design

(1) Based on the real scene 3D model, combined with DLG, DOM, DEM data, according to different geological disaster information, ecological restoration scheme is designed to form different sub projects.

(2) The sub projects of ecological restoration and treatment include earthwork, greening and irrigation works. The quantities of the project are counted according to the actual 3D model and 4D digital products, and the budget is made according to the quota standard.

(3) According to the ecological restoration scheme, the 3D platform is used to design the effect and generate the effect model. The comparison, decision-making and analysis between the real 3D model and the effect model shall be submitted to the competent department for approval.

3.4. Construction Management

According to the ecological restoration design scheme, the project construction is carried out. During the construction process, the UAV oblique photogrammetry technology is used to generate the three-dimensional model, and the real scene three-dimensional model is compared with the design effect model, and dynamic monitoring is carried out.
4. Application and Analysis

4.1. Introduction to the Study Area
The research area is a mine in a county of Chongqing, with an area of 0.346km², which is currently in the state of shutdown and abandonment. After years of mining, the mine has caused land occupation, mountain damage, rock exposure, vegetation damage, water, soil and air pollution. The terrain fluctuates greatly, the overall terrain is high in the South and low in the north, and the maximum relative height difference is nearly 150m. At the same time, the mine has a steep mining face and exposed rocks, which will cause geological disasters such as collapse at any time. Therefore, there are serious security risks in the traditional surveying and mapping method.

4.2. Application of Survey and Mapping
The multi rotor UAV equipped with five 42.4 megapixel sensor oblique cameras was used for oblique photography. According to the shape and scope of the area, it is divided into one zone, and the route is laid in the north-south direction. Course overlap 80%, side overlap 80%. According to the highest mountain condition in the survey area, the flight height is 230m.

GNSS-RTK technology is used to measure image control points. A total of 10 image control points were completed, the coordinate system was CGCS2000, and the central longitude was 106 degrees. 3010 multi angle images were obtained. The resolution is 3.4m. The maximum re projection error of image control points is 0.72 pixels, the maximum plane position mean square error of control points is 0.012 m, and the maximum elevation mean square error is 0.018 M.

Using 10 nodes cluster calculation, the tile size is 100m, and it takes 0.5d. Based on the real 3D model, 4D products are produced. The color of 3D model product is real and the texture is clear. The accuracy of DLG control points was checked, and the mean square error of plane points was 6cm. The mean square error of elevation is 3cm. The DEM was checked by scattered points, and 20 elevation points were checked, and the error of elevation was 11.4cm. No deformation and offset was found in DOM

4.3. Application of Scheme Design
Through field investigation, the mine has geological disaster information such as working face, mining platform, slag slope, steps, etc., as well as topographical features such as roads and abandoned houses. Combined with the real scene 3D model and field survey information, the mine geological environment map is drawn, as shown in figure 2.

![Figure 2. Geological environment model mine.](image)

According to different geological environment, combined with the real 3D model and 4D digital products, the design effect model and the real 3D model are compared before and after, so as to assist the scientific and reasonable scheme design. The mine ecological restoration effect model is shown in figure 3.
Figure 3. Effect model of mine ecological restoration.

At the same time, the quantities of different schemes are summarized. Earthwork engineering, with the help of three-dimensional model and high-precision DEM to calculate the amount of excavation and filling. Greening engineering, irrigation engineering and masonry engineering were counted with the help of three-dimensional model, DOM product and DLG product respectively. On the basis of engineering quantity, the investment budget is carried out and the total investment amount is calculated. From the perspective of feasibility, construction period and other aspects.

At present, the ecological restoration of the mine is being submitted for approval. After the scheme is submitted for approval, it will enter the construction stage. During the construction process, the UAV oblique photogrammetry technology will be used to dynamically track and monitor the construction progress, quantities and construction effect of sub projects, so as to achieve digital and quantitative supervision.

4.4. Application Analysis

The UAV oblique photogrammetry was used for survey and mapping, camera control points and aerial photography were set up. Three people were involved and the time was 1D. The office data processing and the generation of real scene 3D model, 1 staff, 1 day, 4D product acquisition, 2 personnel input, 1.5D. A total of 7D man hours were invested, that is to say, 3D model and high precision 4D products were obtained. It ensures the high efficiency and visualization of mine ecological restoration.

Combined with the real 3D model and 4D products, the scheme design is carried out for different geological environment information, and the effect model is generated by using the three-dimensional platform. Compared with the real scene model, the effect of ecological restoration is displayed intuitively and vividly, which ensures the rationalization of mine ecological restoration plan design.

5. Conclusion

(1) Exploration and mapping is more efficient. Surveying and mapping work based on UAV oblique photogrammetry technology can ensure the safety of technical personnel, save manpower and financial resources and other cost investment, with high efficiency and short cycle.

(2) The scheme design is more intuitive. The real scene 3D model makes the mine environment information more intuitive, vivid and vivid, which is conducive to the formulation of ecological restoration plan. At the same time, the scheme effect model is in sharp contrast with the real scene three-dimensional model, which makes the ecological restoration scheme more scientific and reasonable.

(3) More comprehensive management and construction. In the construction process, the use of UAV oblique photography technology to obtain the real scene 3D model for dynamic monitoring and comparison with the design effect can play a role in mastering the construction progress, supervising the construction and design compliance, so that the management personnel can fully grasp the information.

(4) Mine ecological restoration is more accurate. From the establishment of two-dimensional and three-dimensional models in exploration and mapping, product manufacturing, project quantity
statistics and budget amount calculation in project design, and construction progress and quantity quantification in construction management, the accuracy of mine ecological restoration is guaranteed.

(5) Keep the historical files of the mine. The two-dimensional and three-dimensional model, data and ecological restoration effect model of abandoned open-pit mine can be used as an important part of mine historical archives, which is of great significance to promote the ecological restoration of mine and play a leading role.

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