Application of UAV Photogrammetry and 3D Modelling in Mine Geological Environment Monitoring

Jiwen Liu[1,a,*], Linfu Xue[1] and Zhongtan Li[1]

[1]School of Earth Sciences, Jilin University, Changchun, China
a. jiwen17@mails.jlu.edu.cn
**corresponding author: Jiwen Liu*

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Abstract: UAV low-altitude remote sensing technology enables fast and accurate real-time monitoring of mines within a specific range. The mining area and volume can be accurately calculated on the basis of orthophoto and DEM image. The generated high-precision real-scene 3D image can accurately reflect the environmental problems of the surface. Geological hazards and hidden dangers such as collapse, landslides, mudslides and unstable slopes can be identified on the image, which can guide humans to repair the mine environment in a targeted manner.

1. Introduction

Mine development not only invades a large amount of land resources, destroys forest land, pollutes the ecological environment, but also induces geological disasters and secondary geological disasters, which seriously hinder the sustainable development of the national economy. Since the 1990s, UAV remote sensing technology has been developed rapidly and widely used in various fields such as geographic country monitoring, land use change monitoring, new rural construction, and large-scale topographic mapping. With its small size, low cost, fast response and high imaging resolution, UAV has great application potential in mine geological environment monitoring.

In this study, the mine of Yangjiazhangzi Village in Xingcheng City, Liaoning Province, China, was selected as the research area to carry out mine geological environment monitoring. The high-resolution orthophoto of the mine was obtained by low-altitude photography of the UAV and the 3D model of the mine real scene was established in order to monitor the mine land occupation, geological disasters and hinder disasters. The monitoring of mine environmental pollution is carried out aiming at putting forward countermeasures and suggestions for prevention of mine geological disasters and restoration of ecological environment.

2. Key Technology

2.1. UAV Photogrammetry

The UAV low-altitude remote sensing system mainly includes the UAV flight platform and the ground control platform. It is equipped with digital remote sensing devices such as digital cameras and digital camcorders for shooting and recording. The remote sensing data processing technology is used for image analysis and processing to achieve real-time investigation and detection of ground information.

In this research, we used DJI Phantom 4 Pro multi-axis UAV for low-altitude photography. It carries internal GPS/GLONASS dual-mode satellite positioning module and the camera resolution is 20 million pixels. The flight height, waypoints and track of the aircraft were taken under the command of the ground control personnel after take-off. A total of 661 mine images were acquired, and the lateral overlap was over 57%. The acquired mine images were under the same lighting conditions to eliminate the influence of different exposure conditions while ensuring the accuracy of data information in the image.

2.2. Data Processing

We import high-resolution UAV remote sensing image data into the computer and perform data preprocessing. After the automatic aerial triangulation, the digital surface model (DSM) is extracted to obtain high-precision DSM data of the entire mining area, and the high-precision digital elevation model (DEM) of the mining area is obtained by DSM filtering or manual editing. Finally, DEM image processor is used for rapid monolithic correction, radiation processing, and orthophoto stitching to generate an orthophoto of the entire mine area. (Figure 1)

Figure 1: Orthophoto of the mine.

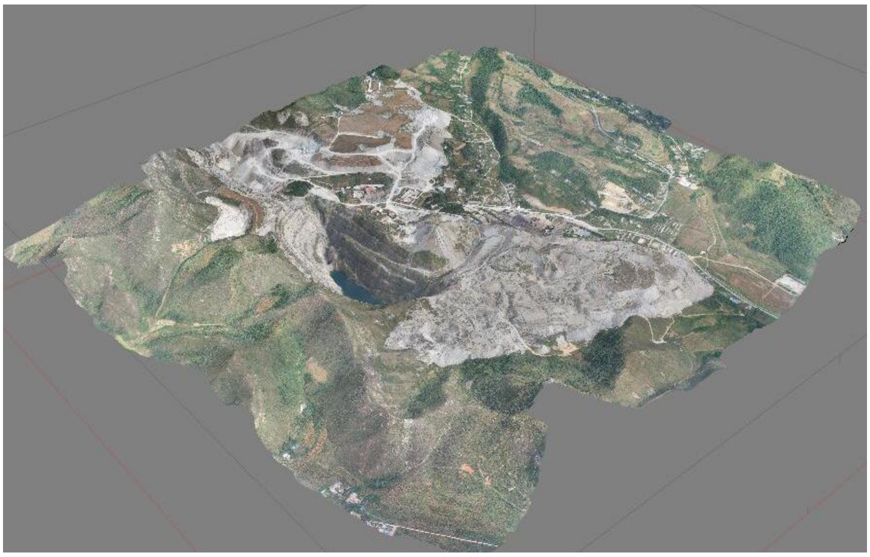


Figure 2: Real-scene 3D model of the mine.

2.3. Data Processing

Photo-based 3D reconstruction, also known as 3D photo-reconstruction (3D-PR), refers to the use of photo images to recover a three-dimensional geometric model of an object. This technology mainly includes steps such as feature point detection and matching, point cloud sparse reconstruction, camera self-calibration, and point cloud dense reconstruction. Two core technology of 3D geological modeling are Structure from Motion (SfM) and Multi-View Stereo (MVS). (Figure 2)

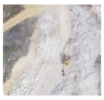
Structure from motion is a technique for obtaining camera parameters and performing three-dimensional reconstruction by analyzing an image sequence. A typical Structure from Motion algorithm involves several steps: image feature extraction, estimate the initial knot and camera motion of the scene, optimize the estimated results, calibrate the camera, get a dense description of the scene, derive the geometry, texture, and reflection properties of the scene.

3. Application of 3D Modei in Mine Area

3.1. Esteblishment of Interpretation Mark

After preliminary reviewing of the data in the early stage, we establish the remote sensing interpretation mark according to the basic conditions of the study area, including geological conditions and hydrological conditions, combined with field investigation. (Table 1)

Table 1: UAV Orthophoto Interpretations.

Land type	Image	Image interpretation feature
Mining site		There are obvious traces of mining. Rough texture is presented on the image with roads.
Mine construction		The houses that appear as geometric shapes on the image are mostly blue and white.
Transfer site		Transfer site is displayed as a separate cone on the image, surrounded by geometrically shaped walls or fences
Dumping site		The dumping site is mostly adjacent to the active mining face, and the pattern is thinner, and the upper and lower sides are scattered and broom-like.
Tailings pond		Take tailings dam as the boundary, the outside is the bare tailings area or the reclamation area, and the inside is the alkaline wastewater area.

3.2. Main Geological Enveronment Problems in the Mine Area

3.2.1. Surface Damage

The exploitation and utilization of mineral resources will inevitably occupy and destroy the land, including the destruction of land by the mining site, the destruction of land by slag dumping, the destruction of land by land subsidence, the repair of roads in mining areas and the destruction of land by construction plants. The destruction of land by mines exists in all aspects of mineral resources development. Before the mining, the exploration and the three-way and one-level work were mainly carried out on the mining area. At this stage, the landform was mainly destroyed and the scale was relatively small. In mining, when open-pit mining, the cover layer on the ore layer is to be stripped, a large amount of land is excavated, and the surface vegetation will be completely destroyed. This process is devastating to the destruction of land resources.

According to the remote sensing image interpretation statistics, the mining area of the pit is 267,600 m2, and the mining volume is 18.55 million m3, occupying cultivated land and forest land. The mining industry has a great destructive effect on land resources and forest vegetation, and has obvious impact on the ecological environment. Unreasonable development and utilization of mineral resources has long-term negative effects on land quality and vegetation cover.

3.2.2. Land Occupation and Destruction

Waste slag discharge, vegetation removal, soil pollution and degradation all seriously affect the survival of animals and plants in the mining area, and the damage caused to biodiversity is often irreversible. After the loss of biodiversity, although some resistant species can achieve natural plant settlement in the mine, the quality of the vegetation formed is usually relatively inferior, because the abandoned land of the mine is thin, the biological activity is poor, and the damaged ecosystem will be restored slowly.

The accumulation area of waste slag around the mining area is 1,147,600 m2, and the slag volume is 1670.08 million m3. A large amount of tailings slag in the tailings pond buries the original surface vegetation. The accumulated slag body has poor stability and is prone to gravity erosion such as landslides and diarrhea. At the same time, the surface of the slag body is exposed to a large area, and the rain erosion and wind erosion. Under the circumstances, the quality of the ecological environment in the surrounding areas has declined. Under the circumstances, the quality of the ecological environment in the surrounding areas has declined.

3.2.3. Dust Pollution and Water and Soil Pollution

Water pollution caused by mining includes surface water pollution and groundwater resource pollution. The pollution of surface water resources mainly refers to the pollution caused by the discharge of ore dressing water and ore dressing wastewater into surface water bodies. In the mining production process, open-pit mining or underground mining and drainage and waste rock leaching water contain high suspended solids and heavy metals. After being discharged into water bodies, it often causes organic pollution and heavy metal pollution of surface water bodies, and increases water turbidity, which affects the ability of water bodies to get dirty.

In the field investigation, it was found that the waste generated by the unreasonable stacking of the mine during the mining process is likely to form a certain range of dust pollution and water and soil pollution. Some of the excess or harmful elements contained in the waste rock and waste residue piled up in the mining area are replenished to the groundwater under the leaching of rainwater, which has a certain influence on the chemical composition of the groundwater.

3.2.4. Dust Pollution and Water and Soil Pollution

Loose deposits in the study area are developed and there are a certain number of landslide hazards. The landslide has a fan-shaped or arc-like structure on the image, and the texture is rough. The new landslide is mostly light gray while the old landslide is mostly khaki and its back wall is covered with plants. According to the interpretation, three landslides were identified in the study area. Some areas in the study area have steep slopes and almost no vegetation cover. When the rainy season comes, it is very likely that geological disasters such as collapse, landslides and mudslides will be formed under the action of rain. Combined with the slope map, six unstable slopes with slopes greater than 40° and less vegetation coverage are interpreted. Most of these slopes are close to the roadside and residential areas, which is a potential hazard. (Figure 3)

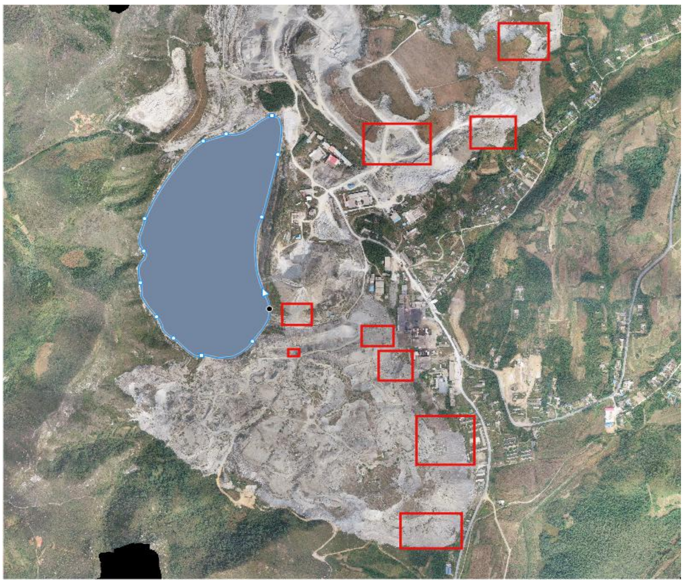


Figure 3: Interpretation of the mine.

4. Conclusion

UAV technology can be used to acquire high-precision low-altitude remote sensing images of mines. Researchers can conduct mine environment monitoring based on orthophotos, digital elevation models and real-world 3D models. According to this study, we can draw the following conclusions: Firstly, UAV low-altitude remote sensing technology enables fast and accurate real-time monitoring of mines within a specific range, with less terrain and climate constraints. Secondly, the data processing operation of the drone is simple, and the generated high-precision real-time 3D image can accurately reflect the environmental problems of the surface and geological disasters. Third, the mining area and volume can be accurately calculated on the basis of orthophoto and DEM image.

In addition, geological hazards and hidden dangers such as collapse, landslides, mudslides and unstable slopes can be identified on the image, which can guide humans to repair the mine environment in a targeted manner. In summary, the low-altitude remote sensing technology of UAV is highly feasible in the actual project and the data accuracy is reliable. As a new type of remote sensing means, it can be widely applied to the monitoring of mine geological environment.

Acknowledgments

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