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Hazards Detection System Based on 3D Panorama for Tailings Dam in Mining

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Abstract: Tailings dam is a key facility for the mining process, which is also the major hazards for the surrounding environments. It could cause catastrophic accidents and severe personal injuries if the tailings dam failed. The occurrence of tailings dam accidents will greatly damage the life and property of the people in the surrounding areas and damage the ecological environment around the region. In recent years, Chinese government has introduced policies to step up investigation and management of mine tailings potential hazards and results in great achievements. However, a large part of the tailings dam still has prominent safety problems due to long-term site selection, design, system construction and management. Flood drainage system plays an important role both in the mining process and in the tailings dam safety. Through the analysis of the causes of tailings dam accidents, this paper discoveries that a number of accidents caused by the failure or damage of flood drainage facilities, and the risk in flood season is especially prominent. The safety hazards detection of the flood drainage is vital to secure the tailings dam safety. A safety hazards detection system based on 3D panorama technology has been achieved in this paper. It provided a new way to detect the safety hazards remotely on portable devices. Firstly, the 3D panorama data acquisition device was designed and developed. The functions and requirements of 3D panorama data acquisition device were investigated according to the actual environment of flood culvert. The structure and hardware of the device were calculated according to the target functions. Three-dimensional environment image data for rapid acquisition, and the use of feature matching and optical flow principle of the collected images were spliced to generate a 3D panoramic image of flood drainage of tailings dam in mining. The safety hazards detection system includes 3D panorama client and panorama images cloud database. It has five layers which are basic configuration layer, interface presentation layer, data management layer, function module layer and background management layer. The functional module layer has five functional modules, including mine personnel management module, tailings pond panoramic scene module, culvert potential danger detection module, interface menu navigation module and material information management module. It can help safety inspectors to detect and investigate potential safety hazards in flood drainage culverts, which would strengthen the safe operation of tailings dam and maintain the safe and sustainable production of mines. This system has been applied to the tailings dam of a mine to collect 3D environmental image data of the flood drainage culvert. The panoramic image is spliced to generate a panoramic view through the cloud platform. The results show that this system can be used in mine drainage culvert safety hazards detection.

Keywords: tailings dam, flood drainage system, virtual reality, 3D panorama, safety hazards detection

1 Introduction

Tailings dam is a key facility for the mining process, which is also the major hazards for the surrounding environments. It could cause catastrophic accidents and severe personal injuries if the tailings dam failed. It is reported by Xie et al (2009) that tailings dam are necessary facilities for mine production and places which constructed by damming troughs or encirclement used to store tailings that eliminated after ore selection in Metal and non-metallic mines. It is reported by Mei and Wu (2012) that tailings dam is a dangerous source of high-energy man-made debris flow, the collapse of the tailings dam takes devastating damage, which seriously threatens the safety of life and property of the enterprises and the downstream residents. The occurrence of tailings dam accidents will greatly damage the life and property of the people in the surrounding areas and damage the ecological environment around the region. The collapse of the tailings dam can also cause secondary disasters such as environmental pollution at the same time. It's a serious impact on regional economic development and social stability.

In recent years, Chinese government has introduced policies to step up investigation and management of mine tailings potential hazards and results in great achievements. However, a large part of the tailings dam still has prominent safety problems due to long-term site selection, design, system construction and management. Flood drainage system plays an important role both in the mining process and in the tailings dam safety. Through the analysis of the

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causes of tailings dam accidents, this paper discoveries that a number of accidents caused by the failure or damage of flood drainage facilities, and the risk in flood season is especially prominent.

The phenomenon of collapse of destruction is general excessively of tailings dams in China. It is reported by Zhang et al (2011) that most of these phenomena are caused by flood over the top of dams. The main reason is the lack of capacity or the failure of the drainage system. There are also accidents caused by the failure of drainage system in foreign countries in recent years. For example, November 5th 2015, the tailing dams collapsed because of the insufficient drainage capacity of the Germano mining area in Germano Mariana area in central Minas Gerais state in Brazil. After a small post-earthquake, the liquefied tailings fill sand submerge downstream cities and towns. It finally destroyed 158 houses, killed at least 17 people, polluted 663km river and destroyed 15 square kilometres of land along the river. It is reported by Rico et al (2008) that it's necessary to continuous monitor and control the tailings drainage system in order to reduce the occurrence of tailings accidents and guarantee the sustainable production of the mine. The traditional artificial detection methods of flood drainage system of tailings dam exist many problems such as heavy workload, low efficiency, and susceptible to meteorological conditions. And it is reported by Luo (2013) that the tailings dam wastewater is corrosive which result a certain disease in flood discharge facilities such as tailings drainage culvert, etc. In order to realize the effective monitoring, management and maintenance of flood drainage system of tailings dam, advanced technologies need to be used to acquire the information of collection and management of flood drainage facilities of tailings dam.

With the development of Virtual Reality (VR) technology, VR has been studied and applied in more and more fields. It is reported by Wang et al (2010) that virtual reality technology has been included in one of the 3 cutting-edge technology which needs to focus on the development in the field of information technology in Medium and Long Term Plan Compendium of Development of Science and Technology of China (2006-2020). It is reported by Zhou and Hu (2012) that three-dimensional panorama technique of virtual reality technology based on the digital real scene by panoramic image. This technology uses cameras to take pictures of 360 degrees real scene and generates panoramic images with 3D experience.

A safety hazards detection system based on 3D panorama technology has been achieved in this paper. It provided a new way to detect the safety hazards remotely on portable devices. Firstly, the 3D panorama data acquisition device was designed and developed. The functions and requirements of 3D panorama data acquisition device were investigated according to the actual environment of flood culvert. The structure and hardware of the device were calculated according to the target functions. Three-dimensional environment image data for rapid acquisition, and the use of feature matching and optical flow principle of the collected images were spliced to generate a 3D panoramic image of flood drainage of tailings dam in mining. The safety hazards detection system includes 3D panorama client and panorama images cloud database. It has five layers which are basic configuration layer, interface presentation layer, data management layer, function module layer and background management layer. The functional module layer has five functional modules, including mine personnel management module, tailings pond panoramic scene module, culvert potential danger detection module, interface menu navigation module and material information management module.

2 The Framework of Hazards Detection System

A safety hazards detection system based on 3D panorama technology is mainly composed of three parts: the panoramic image collector, the image data processing terminal and the panoramic information display platform.

2.1 3D panorama data acquisition collector

3D panorama data acquisition collector

The collector configuration uses 17 camera lenses (a total of 14 camera lenses with wide-angle angles arranged on the side of the device in a circle of 360°, a fisheye lens on the upper layer, and 2 fisheye lenses on the lower layer). The assembly is complete. Mounted on a disk-shaped platform, each camera lens is an HDTV lens with more than 16 million pixels. The camera lens arrangement is shown in Figure 1.

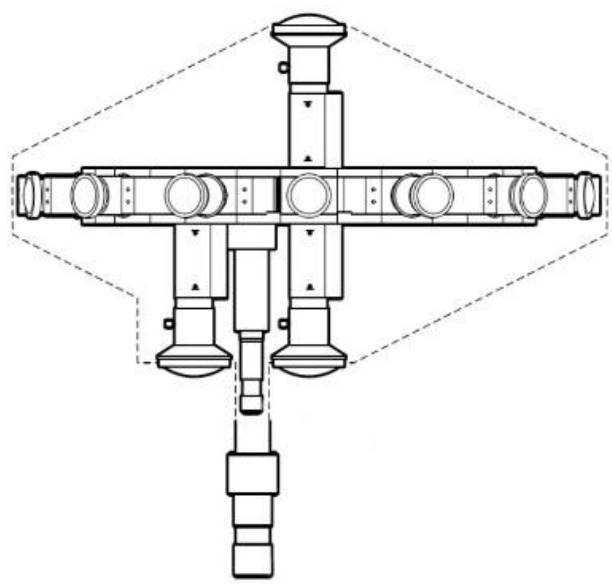

Figure 1 3D Panorama image collector camera lens arrangement

When collecting image data in the tailings reservoir flood culvert, the entire equipment rack works on the tripod, and the three-dimensional spatial image data of each location in the flood drainage culvert can be captured by the personnel's movement of the tripod. The main feature of the collector is the rapid completion of image acquisition. While maintaining the high resolution of the image, it can accurately describe the three-dimensional space environment and bring a good sense of space. The 14 cameras in the ring layout of the collector can shoot angles of up to 77 degrees. With one shot, the image data of 360°×180° environment can be acquired. Each camera can acquire images up to 4k and can achieve 60 frames per second. 3D Panorama image collector is combined by the upper cover, under the cover, the wide-angle lens, top fisheye lens, bottom of the fisheye lens, lens sleeve, support rod and other components. Among them, the side wide-angle lens total of 14, the top fisheye lens 1, the bottom of the fisheye lens 2. 3D Panorama image collector as displayed in Figure 2.

(a) Composition

(b) Photo

Figure 2 3D Panorama data acquisition collector

2.2 Data processing terminal

The image data processing terminal uses the three-dimensional panoramic technique to process the original image data acquired by the panoramic image collector. The original image data is first subjected to image preprocessing, mainly to complete the initial positioning of the image and smooth sharpening work. After the completion of preprocessing, the image registration is performed. Image registration is the core process of image stitching. In this paper, SIFT algorithm is used to perform image registration. After the registration is completed, the image fusion work will turn a number of images into a panoramic image, and through the projection conversion to produce three-dimensional and spatial integrity in panoramic images. This paper selects the projection transformation method for the spherical projection, more in line with the visual effects of the human eye, and the 3D feel of the panoramic image will be stronger after projection.

2.3 Information display platform

The panoramic information display platform can display the panoramic image generated by the image data processing terminal. At the same time, the user can annotate and describe the facilities and areas of interest on the panoramic image. These annotations and descriptions will form additional layers by rendering on the panorama image so that these can be edited and edited by interactive application. Data management is the administrator to manage the input, storage and output of the data such as text data, multimedia data and so on. System data including panoramic image data, navigation data, map data and attribute data. Logical service is the process of processing the input data, and mainly divided in two parts mathematical processing and rendering services. Mathematical processing includes projection transformation, coordinate transformation, rotation, etc. Rendering services includes scene rendering, animation rendering, layer rendering and so on. Interactive application services to meet user roaming, mobile scale, scene changes, demand of virtual operation and so on.

3 The Achievements of HDS-3DP

3.1 The functional modules of HDS-3DP

The functional module layer has five functional modules, including mine personnel management module, tailings pond panoramic scene module, culvert potential danger detection module, interface menu navigation module and material information management module. It can help safety inspectors to detect and investigate potential safety hazards in flood drainage culverts, which would strengthen the safe operation of tailings dam and maintain the safe and sustainable production of mines.

The image data are input to the image data processing terminal for processing which are collected by the panoramic image collector in the tailings dam flood drainage culvert. Image data processing terminal turn the original image into a broad perspective and high-definition panoramic image by using three-dimensional panoramic technology, through image preprocessing, image registration, image fusion and other processes. The 3D panoramic information display platform combines the image data processing terminal to display the panorama image on the web page. The monitoring staff can use the panoramic information display platform to discover the present situation of the tailings and the potential failure. Through the platform the monitoring staff can label the areas or facilities which have potential failure or disease, so that technical staff can solve timely. The panorama information platform includes the following features (Figure 3).

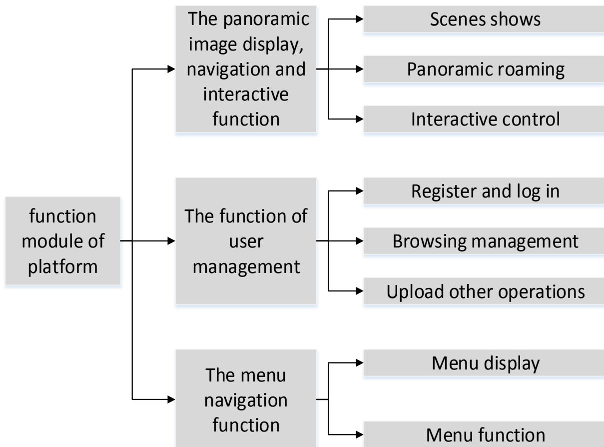

Figure 3 Function module of the panoramic information display platform

3.2 The application of HDS-3DP

The tailings dam has been redesigned for drainage facilities with a height above 435m above sea level, as well as for accumulation dams. The final design elevation reached 492.0m, the effective storage capacity of the tailings reservoir reached 7900104 m^3, and the total storage capacity reached 8700.104 m^3, to meet the tailings storage requirement of 22.66 years for the mine concentrator. After the design is finalized, the tailings dam belongs to the valley type. The outer slope ratio of the tailing dam is 1:4.0, and the drainage system is a well-hole combination.

The geographical climate of the area where the tailings reservoir is located is in a marine monsoon climate. The average annual temperature in the area is 5.34 °C, of which the minimum temperature in winter can be as low as -32 °C, and the maximum temperature in summer can rise to 36.3 °C. The average annual rainfall in the area is generally within the range of 600-800mm. The maximum annual rainfall is 855.2mm, and the minimum annual rainfall is 365.4mm. July and August each year is the main rainfall season, with frequent heavy rains. There is a freezing period in the winter in the region, and the time is generally from November of the year to March of the second year. The maximum amount of snow that can be reached in winter is 800mm, and the maximum depth of frozen soil is 1.55m.

The tunnel surrounding rocks are mainly Paleozoic sedimentary metamorphic rock series. Because of the influence of tectonic and weathering, the rock masses at the two ends of the tunnel are strongly weathered, the average value of the rock integrity coefficient is 0.20, and the integrity of rock mass is broken. Strongly weathered rock mass; with the exception of veins and fracture zones in the middle, the weathering of rocks is relatively weak and moderate weathering. The tailings dam location and basic information is displayed in Figure 4.

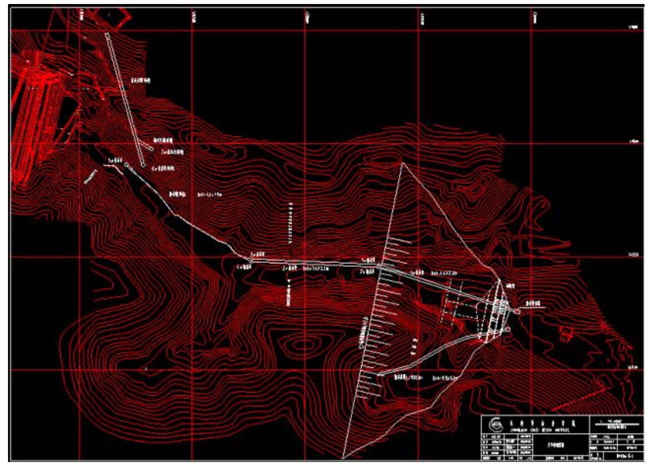

Figure 4 The tailings dam location and basic information

First, use the data collection device for flood culvert to collect the initial image data from the main hole of the tailings dump. The collection work was conducted at a fixed point, and a point was determined every 20 meters. The image collection of the main drainage environment in the point drainage hole was performed at the point, and a total of 3 sets of acquisition were performed. The raw images data is shown in Figure 5.

The raw image data collected by the collector is the RAW Bayer format. The Gamma correction is used to adjust the color, and the raw image data of the RAW format is converted into RGB format data. Gamma is also known as gamma. The reason Gamma correction is because the perception of brightness in human eye imaging changes exponentially and the camera changes linearly. Therefore, the purpose of gamma correction is to change the gamma value so that the output image gray value and the input image gray value exponential relationship, reduce color error, significantly enhance the image contrast when the low gray value, so that the camera imaging is more suitable for human eye identification habits. After gamma correction, projection processing is performed on each RGB image data. Taking the tailing gallery image data as an example, the projected images are further spliced in sequence, and each image is one of the components of the entire three-dimensional space panoramic image.

For the raw image captured by each camera of the collector, due to the image distortion generated by the camera lens, a distortion correction problem is involved and the flood culvert data collector is calibrated to preliminarily capture the image of the calibration plate, as shown in Figure 6 below. Then, the image is calibrated according to the obtained image, and related parameters such as camera parameters and distortion coefficients are obtained to perform image distortion correction. The calibration plate has black and white squares, multiple pictures are taken from the calibration plate from different angles, the corner information of the squares is extracted, and the homography matrix is solved (the projection mapping of one plane to another plane is represented by a matrix). Each perspective corresponds to a

Figure 5 The raw images data of tailings dam drainage tunnel

homography matrix, and the camera internal parameter matrix and external parameter matrix are obtained through homography matrices of multiple perspectives. Finally, according to the camera's internal parameters and external parameters to correct the distortion. Image matching feature points of tailings dam drainage tunnel is shown in Figure 6.

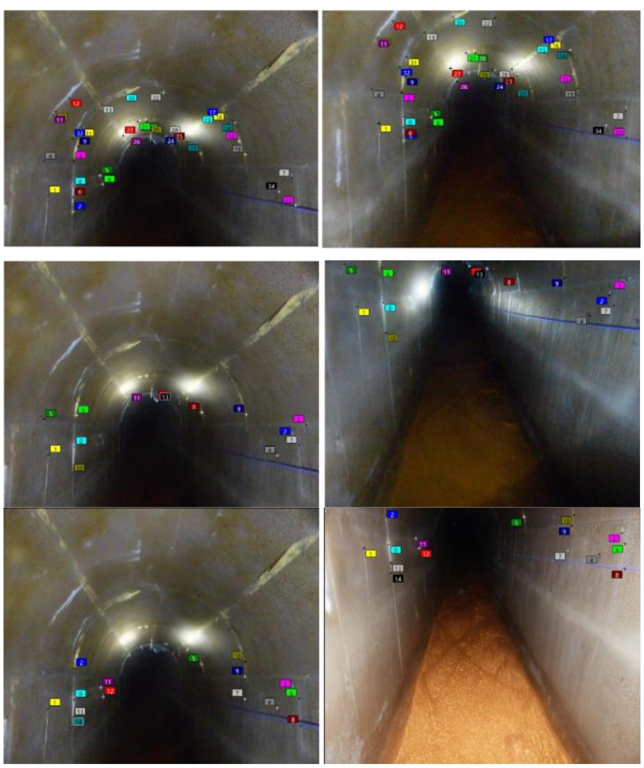

Figure 6 Image matching feature points of tailings dam drainage tunnel

The flood culvert data collector also corrects for camera instability, bracket support rotation, lens shift, etc. This kind of situation will mainly cause the image to appear parallax within a certain range, produce the shadow effect, and influence the picture mosaic. For this type of situation, the flood culvert data collector solves the above problems by adopting feature point matching on adjacent images. For 14 side wide-angle camera lenses, feature matching is performed between the images captured by each group of adjacent cameras. For feature matching between two adjacent images, the corresponding feature points need to be found first. As shown in Figures 4 and 5, taking the image of the top of the tailings gallery as an example, there is a similar area between two adjacent images. In the similar area, the image is based on the pixel features, shape features, and texture features. Edges, corners, pixel areas, etc. are used as feature points.

Select a group of data with better performance among the three groups of point data, and stitch the images of this group of images to generate a panoramic image of the flood culvert. Through the feature matching method, the image of the collected flood culvert image is searched. The correlation between adjacent images, in the form of feature points, the images are stitched together to generate corresponding flood discharge culvert panoramic images as shown in Figure 7.

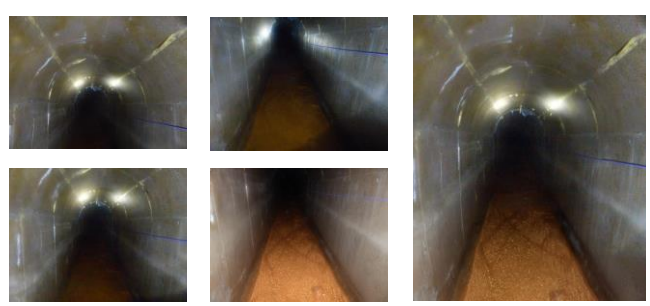

Figure 7 Flood culvert 3D panoramic image of tailings dam drainage tunnel

The panorama display platform is used to publish the panoramic image of the drainage main tunnel. After the release of the panoramic image of the flood culvert, a panoramic view of the webpage can be made through the platform. At the same time, users of the platform can remotely log in to the panoramic display platform through the cloud to experience the experience of the drainage main tunnel panoramic scene, and use the powerful panoramic editing function of the platform to customize the panorama of the main drainage tunnel as shown in Figure 8.

Figure 8 3D panoramic image of tailings dam drainage tunnel

When the mine staff uses the platform to view the panoramic view of the flood culvert, the related image of the flood culvert image that has been uploaded can be detected based on the panorama. Through the platform's own potential danger detection function module, relevant information such as adding text interactive hotspots is added after discovering potential points, and the potential content can be noted. This can be viewed through interaction with text hotspots, making it easier for other mine workers to understand the type of potential danger and specific the situation is conducive to the next step in the investigation of potential hazards in flood culverts. At the same time, a scene switching hot spot is added to the panoramic view of the flood discharge culvert, and the worker switches the hot spot by clicking on the scene to realize the movement of the scene, that is, the panoramic scene becomes the other panoramic scene. , After clicking the “Drainage Culvert” entrance scene to switch hot spots, the panoramic scene screen will be switched to show the panoramic image of the flood discharge culvert entrance as shown in Figure 9.

For the specific content of potential hazards points in flood culverts, edit them when adding text hotspots. After the mine staff clicks on potential hazards points in the panoramic view of the flood culvert, the exposure of the panoramic screen is reduced, a new layer appears on the interface, and the text information stored in the text hot spot is displayed on the layer. Corresponding to the text information in the potential points of the flood culvert, the potential content related information is added in the text hotspot.

4 Conclusions

Mainly aiming at the safety risks existing in the potential

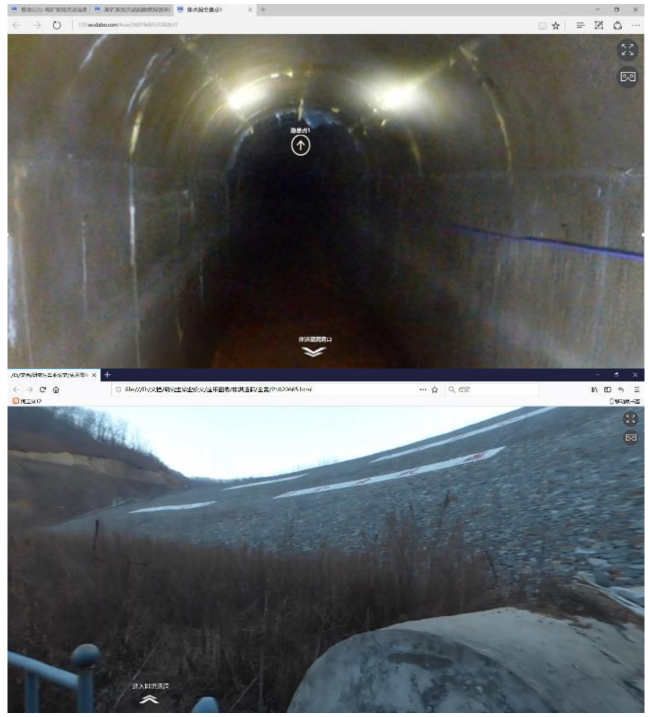

Figure 9 3D panoramic image of flood culvert entrance

troubles of the mine tailings reservoir flood culverts, using virtual reality technology to reduce the time for personnel to carry out potential investigations in the flood culverts, and through the flood culvert data collector to the tailings dump culvert Three-dimensional space environment for rapid image data acquisition, combined with three-dimensional panoramic technology to achieve the true environment of the flood culvert in the remote computer port to restore accurate, easy for personnel to carry out potential investigations, reduce flood culvert in the corrosion, landslide, oxygen concentration is insufficient Occurrence probability of damage caused by mine workers and other diseases and potential dangers, better detection of potential dangers in mine tailings reservoir flood culverts, strengthening of safe operation of tailings ponds, maintenance of safe and continuous production of mines, and harmonious social and regional stability Has positive significance.

3D panorama data acquisition collector for flood culverts was developed. The structure of the collector consists of an upper cover, a lower cover, 14 wide-angle lenses on the side, a fisheye lens on the top, 2 fisheye lenses on the bottom, a lens sleeve, and a support rod. The collector can be carried by the personnel into the tailings dump flood culvert to achieve rapid collection of image data of the flood culvert. For the collected image data of flood culvert, the collector can work on the image splicing through the principle of feature matching and optical flow method to generate a high-quality, high-resolution panoramic image. During the process of using the platform, the mine staff will display a panoramic view of the tailings dump flood culvert through the panoramic display platform, which is convenient for the staff to find possible diseases and potential troubles. For potential risks discovered, editing and remarking using the potential danger detection function module is conducive to the investigation of the potential dangers of flood culverts.

This system can help safety inspectors to detect and investigate potential safety hazards in flood drainage culverts, which would strengthen the safe operation of tailings dam and maintain the safe and sustainable production of mines. This system has been applied to the tailings dam of a mine to collect 3D environmental image data of the flood drainage culvert. The panoramic image is spliced to generate a panoramic view through the cloud platform. The results show that this system can be used in mine drainage culvert safety hazards detection.

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