A Framework for Tailings Pond Drainage Failure Detection System

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Abstract: Tailings dam is a subsidiary facility of mining production. In order to decrease tailings dam accidents caused by the failure of flood drainage system, this paper proposed a framework of potential failure detection system of tailings dam flood drainage facility based on three dimensional panorama technology. A collection device of three dimensional panorama is designed to capture the onsite images of flood drainage system of tailings dam. The spatial information of flood drainage facility of tailings dam is recovered through projecting the image information to spherical surface by using three dimensional panorama technology. Two dimensional images are transformed into three dimensional images in three stages of panorama images process, which are pretreatment, registration and splicing. Combined with the framework of HTML5, panorama images are embedded into webpage. These web pages have the functions of user interface that the images could be displayed, moved and zoomed. With the function of interaction with panoramic display, 3D panorama scenes can be changed and scaled. Browsing the webpage is helpful to find potential risks such as possible holes, fractures and leakages of flood drainage system of tailings dam. The realization of this system can detect the potential safety risks of flood drainage system of tailings dam. The application of this system would improve the safety and provide the ability of accident pre-warning. It is useful to maintain the healthy and sustainable operation of tailings dam.

Keywords: tailings dam, flood drainage system, virtual reality, three dimensional panorama, potential failure detection

1. Introduction

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 \(2012\)](#) 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. It is reported by [Dong \(2011\)](#) that the collapse of the tailings dam causes secondary disasters such as environmental pollution at the same time. It's a serious impact on regional economic development and social stability.

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.

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This paper proposed a framework of potential failure detection system of tailings dam flood drainage facility based on three dimensional panorama technology which focus on the drainage culverts that personnel can enter. This system designed specific equipment to collect image data of drainage culverts and computer panoramic technology to generate a panoramic image. A potential failure detection system of tailings dam flood drainage been proposed in this system. This system can associate professionals to understand the malfunctions or potential failures in tailings dam flood drainage.

2. Three-dimensional Panorama Technology

It is reported by [Ma \(2012\)](#) that the method implemented scenes rendering in virtual reality in three main types: Geometry-Base Rendering referred to as GBR, Image-Base rendering referred to as IBR, Image-Base Modeling and Rendering referred to as IBMR. The realization of virtual reality can be divided into fully immersive virtual and semi-immersive virtual. It is reported by [Guo \(2010\)](#) that three-dimensional panorama technology is a semi-immersive virtual and one of the most representative applications of Image-Base Rendering of virtual reality. It is reported by [Wu \(2012\)](#) that the use of three-dimensional panorama technology of image data processing to generate the panoramic image through three steps: image acquisition, image mosaic and projection transform.

2.1 Image acquisition

The work of image acquisition needs to use special equipment and special approach. The general panorama image acquisition methods include the following several kinds. Firstly, it uses a single special lens to get the panoramic image. For example, using a fisheye lens to capture the image information of the environment around the level of 360°. Fisheye lens has a very short focal length and angle of view close to or equal to the lens. Its perspective to reach or exceed the human eye viewable range. Secondly, it uses a single general lens or camera to take photos. Performance indicators that affect the general camera to obtain panoramic images including the resolution, optical lens, lens focal length, aperture and shutter, white balance, sensitivity, exposure compensation and exposure mode. General camera shooting methods are generally divided into the following: rotate and translate. When the camera rotates, the camera rotates around the vertical main axis in one direction. It takes a picture at every angle of rotation until its closes, the overlapped part of the adjacent two images is greater than 30%. Camera translation is to place the camera on a straight track prepared in advance, keep the camera at the same time to do the translational motion, according to a certain direction to obtain continuous sequence images. Thirdly, a panoramic image is obtained by ray reflection of a plurality of camera lenses combined with a mirror. Wide-angle optical imaging lens obtain panoramic images by the light reflection of mirror. Finally, it develops a device with the spherical surface to obtain a plurality of images by arranging a plurality of camera sensor on the

spherical surface, and then the image mosaic, covering the 360°×180° panoramic image of sight environment.

2.2 Image mosaic

It is reported by [Li \(2016\)](#) that image mosaic is a technology that assembles two or more images into a high-resolution and wide synthesis from the perspective image. Image mosaic is divided into three steps: image preprocessing, image registration and image fusion.

The image preprocessing is to reduce the difficulty in the next step of image registration and improve the registration accuracy.

The quality of image mosaic mainly depends on the precision of image registration. Therefore, image registration is the core content of image mosaics. It is widely used in three-dimensional reconstruction, object detection, feature recognition and image mosaic and other fields. Image registration is defined as two or more images, the process according to a similarity to determine the best matching relationship between them. It is reported by [Duraismy \(2016\)](#) that this process generally consists of four elements: (1) Feature space extracted from the image for the registration of the image information (feature space). (2) Similarity metric between meta-registration images features (similarity metric). (3) The search space of all possible image transformation parameters (searching space). (4) Searching strategy of finding the optimal estimation such as translation, rotation and so on in the searching space.

[Shao \(2010\)](#) regards that image registration algorithms can be divided into two categories. One is region-based algorithm. This method takes advantage of gray relationship between two images to calculate the similarity of images. Firstly, it is to determine the parameters of coordinate changes between images, and then it searches in the parameter space according to a certain algorithm to find the highest similarity transformation parameters. The algorithm includes two categories: spatial pixel registration algorithm and frequency domain based algorithm. The other is feature-based algorithm, calculate the transform among images by using the obvious characteristic of image, rather than using the gray information of image. This method extracted common features from two images, then created the transformation parameter between features. The specific algorithm includes algorithm based on contour feature, the corner detection algorithm and SIFT (scale invariant feature transform algorithm) and so on.

It is reported by [Zahra and Mehdi \(2016\)](#) that scale invariant feature transformation algorithm (SIFT) is one of the best algorithms to extract and match the applicability of the image features of image registration. This algorithm divided the image into two spaces, scale and gray searching for extreme point, to extract the location, scale and rotation invariant and detect the registration. This kind of feature extraction keeps invariance property to image scaling and rotation of image registration. It has a strong adaptability for image morphing, image illumination changes, the change of perspective and noise. The acquisition object of panoramic image is the flood drainage of tailings dam. According to the environmental characteristics of flood drainage of

tailings dam, this paper adopts the algorithm of scale invariant feature transformation (SIFT) image registration.

It is reported by Fu (2011) that the SIFT algorithm consists of four steps:

1) Scale space extreme value detection

For the two-dimensional image $I(x, y)$, $L(x, y, \sigma)$ can be obtained by convolution of the image $I(x, y)$ and the Gaussian $G(x, y, \sigma)$ in the scale space at different scales. Build the DOG (Difference-of-Gaussian) pyramid, and detect the extreme values in 26 fields in the DOG scale space. The $D(x, y, \sigma)$ is the difference between two adjacent scale images.

$$D(x, y, \sigma) = (G(x, y, k, \sigma) - G(x, y, \sigma)) \times I(x, y) = L(x, y, k, \sigma) - L(x, y, \sigma) \quad (1)$$

where $G(x, y, \sigma) = \frac{1}{12\pi\sigma^2} e^{-\frac{(x^2+y^2)}{2\sigma^2}}$ is a two-dimensional Gaussian function; $I(x, y)$ is the original two dimensional image; x, y represent the coordinates of the point; σ represents the variance of the Gaussian normal distribution; $L(x, y, \sigma) = G(x, y, \sigma) \times I(x, y)$ is the definition of scale space.

A point is a feature point of the image at that scale if it is the maximum or minimum value of the 8 adjacent points and 18 adjacent points of upper and lower adjacent scales. So the middle detection point be compared to a total of 26 points to ensure that extreme points are detected in both the scale space and the two-dimensional image space.

2) Using the gradient direction distribution of the neighborhood of the key points, the direction parameters are specified for each key. The operator has a rotation invariance

$$m(x, y) = \sqrt{\frac{(L(x+1, y) - L(x-1, y))^2 + (L(x, y+1) - L(x, y-1))^2}{2}} \quad (2)$$

$$\theta(x, y) = \arctan\left\{\frac{L(x, y+1) - L(x, y-1)}{L(x+1, y) - L(x-1, y)}\right\} \quad (3)$$

where $m(x, y)$ is the mold value of the gradient at (x, y) ; $\theta(x, y)$ is the direction of the gradient at (x, y) , and L is the scale of each key scale.

3) Generate SIFT feature vector

First rotate the axis to the direction of the feature point to ensure that the rotation invariance. In order to enhance the robustness of the matching, we use 4×4 total 16 seed points for each key point, so that 128 data can be generated for a key point, finally form 128-dimensional SIFT feature Vector (descriptor).

4) Feature matching

Feature point matching refers to finding the correspondence between the feature points of the image after finding the feature points of image. Usually the nearest neighbor method is used to find the nearest neighbor of each feature point in another image. Ideally, the feature points of the same part between the two images should have the same feature description vector. The distance between them should be the nearest.

The matching of SIFT feature vectors is to measure the similarity of SIFT eigenvectors of two images to be matched.

Image fusion is the last key steps of image mosaic. After registration two images, it determines the spatial relationship between each other. And then it transforms two images into the same coordinate system to fuse by the image fusion technique to make the effect of the image mosaic become more natural.

2.3 Projection transformation

As the cameras are in different positions, different angles, the registration of the image is not on a projection surface. There is a certain angle between the planes of projection. In order to maintain the perspective effect and visual consistency, the image needs to perform projection conversion after the image mosaic. Commonly used projection conversion has cube, cylinder and spherical projection. The principle is to shoot the scene for the scene center. The scene image polygon projection mapped to a single plane image.

Projection conversion process includes: series of image, projection model, data point matching, the parameters of the model, coordinate system, integration. Choice of the projection model direct impacts the efficiency and quality of panoramic image mosaic, and has a certain impact to the panoramic image storage, display, browse and other issues.

Cubic projection, which is six on the spatial orientation of the plane of projection, up and down around. Each face needs to correspond to the wide-angle width to prevent its edge deformation. It is a relatively simple panoramic projection. Cylindrical projection projects the image on the cylinder, the cylinder does not involve lateral deformation and easy to stitch. Spherical projection is the closest visual effects of the human eye. The images are projected on the spherical surface. Spherical projection achieves the rotation roaming at the shooting point, and give people the strongest sense of 3D immersion. In practical applications, the cube projection has a serious boundary deformation. Cylindrical projection cannot show pole information. And spherical projection applications are the most extensive.

Projection conversion can remove redundant information that exists between images. In the case of a spherical projection, in the panorama image, only reserve all the visible space information within the spherical field of view which point of view.

3. Potential Failure Detection System of Tailings Dam Flood Drainage

3.1 Framework of potential failure detection system of tailings dam flood drainage

Framework of Potential Failure Detection System of Tailings Dam Flood Drainage is mainly composed of three parts: the panoramic image collector, the image data processing terminal and the panoramic information display platform. As shown in Figure 1.

Figure 1. Framework of potential failure detection System.

This paper uses the 4TH method of image acquisition. Panoramic image collector by the cover, under the cover, the wide-angle lens, the top fisheye lens, the 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, and installed on a UFO shaped platform, as displayed in Figure 2.

Figure 2. Panorama image collector.

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.

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.

3.2 Function of potential failure detection system of tailings dam flood drainage

This paper first constructs a panoramic image collector. Panorama image acquisition using a total of 17 cameras, of which 14 cameras in the horizontal direction of the average 360° distribution, the top 1 and the bottom 2 are arranged fisheye lens, the lens unified control by the panoramic image collector. Panorama image collector can be carried into the tailings dam flood drainage culvert by personnel. People use the collector to shoot, the all cameras on the panoramic image collector will shoot at the same time. Compared with the traditional cube layout and rotating shooting stitching way, this panoramic image acquisition device can effectively avoid the image stitching corners issues caused by the cube layout method by using a circular layout of the way. And it can solve problems that generate a panorama image without the effect of three-dimensional effect and rotation shooting cannot be used for sports objects scene. The panorama data collector takes two cameras (equivalent to the left and right eyes) to take the same position to get the depth, using 14 shots for each of the surrounding 360° three-dimensional shots, and all the lenses are synchronized to 30 to 60 frames per second. To ensure images have a more realistic 3D stereo effect after the data collection process.

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 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, as displayed in Figure 3.

Figure 3. Function module of the panoramic information display platform.

(1) The panoramic image display, navigation and interactive function

As the most intuitive function of the three-dimensional panorama technology, the system platform needs to display the panoramic image after image fusion. Platform interaction function is the recognition and the response to user actions, such as click of the mouse, drag and roll rotates. The system platform can realize the corresponding panoramic view of the scene, and the change of scene and scaling back.

(2) The function of user management

This system has user management function of user registration, user login function and user security management. Registered users identified as an administrator, have different levels of access and editing privileges, registered users can see a panoramic view of the exhibition content and the content of labeling and allowed mark and modification of the scene. Non-registration users can watch the content of panorama display.

(3) The menu navigation function

This system generates the menu with function button with the combination of HTML5. Through a menu button can realize the scene, the vision of scale, full-screen playback, audio commentary and other functions.

4. Conclusions

This paper proposed a potential failure detection system of tailings dam flood drainage culvert based on three dimensional panoramic technology. The system is mainly composed of three parts: panoramic image collector, image data processing terminal, panoramic information display platform. The main features of the collector are designed to

quickly capture image data and ensure image quality, accurate perception of depth and breadth, and three-dimensional display that make viewer feels comfortable in image effects. Image data processing terminal process the original image combined with three-dimensional panoramic technology to, generate panoramic images through image preprocessing, image registration and image fusion and projection conversion. Panoramic images are displayed on the platform, allowing users to roam in the tailings dam flood drainage culvert and identify facilities and areas with potential failure or disease. The whole system realizes the complete presentation and safety detection of the potential failure of in the tailings dam flood drainage culvert, which helps to discover the potential failure or diseases of the tailings dam flood drainage culvert, and reduce the percent of the tailings accident. Good for the long-term stability and safety of tailings dam, and promote sustainable production of the mine.

The system presented in this paper has some shortcomings. First of all, the collector device developed in this paper requires staff to enter the tailings dam flood drainage culvert for data collection, although staff have been working inside the culvert under a smaller risk compared to the traditional manual detection, but this collector device is not intelligent enough. The further development trend is the robot equipped with collector into the culvert for data collection, to reduce the accidents of the disease caused by the possible risks when taff into the drainage culvert. Second, the panoramic information platform shows only a simple number of interactive features, failed to combine the actual production safety supervision of the mine to develop more features.

Acknowledgement

This work is also supported by National Natural Science Foundation of China (71373245, 50974109, 2016YFC0801305), the basic research funding of China Academy of Safety Science and Technology (2016JBKY07).

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