Application of Visual Technology in Fully Mechanized Coal Face

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**Abstract.** With the gradual improvement of coal mining automation, visual technology is more and more widely used in coal mine production line. Especially in fully mechanized coal face, visual technology provides a guarantee for reducing the working face personnel and remote control. Aiming at the application scene of fully mechanized coal face, the key technologies such as visual imaging algorithm, visual data compression algorithm, panoramic reconstruction technology of fully mechanized coal face and reliable video data storage technology are combed. The distortion correction, image registration, image fusion and video data compression methods based on depth learning technology in panoramic video surveillance system of fully mechanized coal face are mainly expounded. It effectively solves the problems of large bandwidth, incomplete video storage, non-intuitive working picture of shearer and uneven video splicing picture. At the same time, the development direction of video surveillance system in fully mechanized coal face is discussed.

1. Introduction

Fully mechanized coal face is the first production site of coal mine, which has the characteristics of narrow working space, many mechanical equipment and poor visual environment. Its safety accidents occur frequently, which seriously affects the safety production of the whole coal mine and is the most important part in the safety management of coal mine[1]. There were 274 coal roof accidents and 325 deaths nationwide in 2013, accounting for 45.4% of total accidents and 30.5% of deaths. Eight major roof accidents, among them, 4 coal working face; the national coal mine gas accident killed 348 people, 32.6% of total deaths from coal mine accidents; 10 major gas accidents, among them, 7 coal face[2].

Domestic fully mechanized coal face basically realized three machine equipment "one key" start and stop, hydraulic support automatic moving frame, shearer automatic heel machine, scraper conveyor automatic straightening and so on. With the development of network communication technology, fully mechanized coal face has the condition of full video coverage and uploading to the ground. Some mines have even begun to try to construct a three-dimensional mining reality environment with the help of virtual reality technology to simulate the operation process and equipment operation of the three machines in fully mechanized coal face. The operator can grasp the operation of the working face remotely and in real time and control the operation of the equipment[3-6].
As an auxiliary system of coal mine safety production, underground video system has been paid more attention by coal mine managers[7]. With the gradual improvement of coal mining automation, it is of great significance to reduce the number of workers in dangerous operations by replacing manual work with the application of visual technology to improve the level of underground safety production. By using the remote video surveillance system, the ground operator can directly monitor the underground situation in real time, find the hidden trouble of the accident in time, guide the ground personnel to control the start and stop of the equipment remotely, and avoid the accident. It can record and reproduce the whole production process and scene, and provide first-hand image data for post-analysis of accident causes.

2. Application of Visual Technology in Fully Mechanized coal face

The structure diagram of video surveillance system in fully mechanized coal face is shown in figure 1. It mainly realizes the remote monitoring of coal mining, support and transportation in fully mechanized coal face, as well as the remote monitoring of the working state of the equipment, and the visual signal is required to cover every corner of the working face.

The concrete implementation is to establish the network connection of well and underground and the collection and transmission of face vision. A large number of camera instruments are installed on the coal wall in the working face hydraulic support group, which are connected with the nearest working face switch through the hard disk video recorder, and the working face switch is connected by optical fiber to form the working face ring network. Then through optical fiber access underground ring network switch. The ground host is connected to the underground ring network through the switch, and the video picture of any camera can be obtained. In order to show the situation of the whole fully mechanized coal face intuitively, the ground controller splices the video picture of all the cameras in real time. The video data of the camera is also stored in the network video storage server.

The main purpose of introducing hard disk video recorder in this system is: to reduce network bandwidth and avoid network congestion. The hard disk video recorder with high compression ratio video coding and decoding technology, when the video data of the camera enters the hard disk video recorder, it is compressed and stored and then forwarded, which greatly reduces the amount of transmission data and reduces the bandwidth occupancy rate of the network. To reduce data loss and ensure data integrity. When the video data are uploaded, they are stored in the network hard disk recorder. Each input channel of the network hard disk recorder corresponds to a camera, which is not affected by the network bandwidth and ensures that the video data of each camera can be completely stored in the network hard disk recorder. This distributed networking and storage structure improves the network transmission efficiency and reliability.
3. Key Technologies for Visual Technology Applications

3.1. Visual Imaging Algorithm

The space of fully mechanized coal face is narrow and the camera is close to the coal wall. In order to improve the visual coverage and reduce the number of cameras, a wide angle camera is needed to increase the coverage of a single camera. The larger the field of view angle of the camera, the greater the distortion of the video picture, which increases the difficulty of video splicing. In the process of panoramic video splicing, the most critical techniques are distortion correction, image registration and image fusion. The flow of image stitching is shown in figure 2.

![Figure 2. Flow chart of image mosaic algorithm](image)

Image distortion is divided into linear distortion and nonlinear distortion. Linear distortion can be effectively corrected by single response matrix. Nonlinear distortion is an inevitable bending deformation introduced by the inherent characteristics of lens. Even if the lens is modified, the nonlinear distortion phenomenon cannot be completely eliminated, and nonlinear distortion will lead to dislocation and double shadow in boundary region fusion. By using the NAM (nonlinear anti-distortion model) correction algorithm, the mapping point pairs between the ideal image and the actual image are found by inverse transformation, and the transformation relationship is established to restore the image without distortion.

After the image is corrected, the control frame image is extracted and matched. In order to improve the accuracy of image transformation monosyllabic array, the control board can be added to the scene to increase the matching points and accuracy. A SURF feature detection algorithm is used to establish scale space, feature point detection, feature point main direction confirmation and feature descriptor. SURF feature detection algorithm maintains good scale invariance and rotation invariance, and
reduces the computational complexity of the algorithm through some approximate calculation and reduction of feature description vectors. It not only has strong robustness and accuracy, but also improves the computational speed and meets the real-time performance of video mosaic.

The image is projected to the reference plane by bilinear interpolation, and the coincidence region is calculated. The image pyramid with multi-resolution information is established first. The matching image to be fused is downsampled into the band-pass layer image at different scales, and then the band-pass layer image is obtained by linear weighted fusion of each band-pass layer image. Finally, the band-pass layer image after splicing fusion is added to obtain the final fusion image. As shown in figure 3, it can be seen from the diagram that the image distortion is small, the feature matching is accurate, the image fusion effect is better, the wide angle image distortion is large and the distortion correction is not ideal.

![Figure 3. Schematic diagram of image splicing](image)

(a) telephoto original image 1  (b) telephoto original image 2  (c) telephoto original image 3  (d) telephoto original image 4  
(e) Panoramic images after telephoto splicing

(f) wide angle original image 1  (g) wide angle original image 2  (h) wide angle original image 3  (i) wide angle original image 4  
(j) Panoramic image after wide angle splicing

3.2. Visual Data Compression Algorithm

Fully mechanized coal face strike length of 200~400 meters. The realization of panoramic video requires the installation of a large number of cameras perpendicular to the direction of the working
face to collect images in real time and splice them. The traditional video image compression method of compressing video data itself is not enough to realize the high compression ratio and real-time transmission required in this scene, this paper presents a video data compression method based on deep learning technology, it not only compresses the image itself, but also compresses the data between frames. As shown in Figure 4, a completed video is divided into video fragments composed of multiple image frame sequences, each video segment consists of a sequence of 16 frames in length to improve the accuracy of video segment classification. So that two adjacent video clips overlap eight frames, based on the convoluted neural network model of two-channel three-dimensional CNN, input the output of the network model to the SVM classifier, classify video clips into variations, gradients, and generic types, meanwhile, connect the same type of adjacent video clip into a video clip, and the total length of the connected video segment is not more than 32 frames. To classify video clips accurately, a large number of data sets are necessary to train CNN models. This article uses synthetic and incremental data sets, generating sufficient samples of dramatic and gradual changes from normal video frame sequences through image mixing models. Using this sample to train to form a preliminary classifier model, and use this classifier model to predict unlabeled data, then select the correct data set as the incremental data set. Repeat this process, until the convolution neural network model error is small enough, then the high performance classifier is obtained by training the final data set. After the video clip is classified, the color histogram of the first frame and the last frame is calculated. If the Bhatta-charyya distance between the color histograms of the two frames is small enough, the video clip is considered as a common type. Since both dramatic change and gradual change indicate that the frame order of the video clip is in change, we do not process these two kinds of video clips. For ordinary video clip types, only the first frame and the tail frame are retained. During video decoding, frames should be inserted between the frames.

To verify the effectiveness of the algorithm, the algorithm is implemented on H.264/AVC reference software JM16.0 and HEVC reference software HM13.0, and experiments on 8 general test sequences. Table 1 shows the experimental results under the whole I frame coding structure. As a result: for flat video content (e.g. FourPeople sequences), compared to classical H.264/AVC coding standards, this algorithm saves 79.43% bit rate; for HEVC coding standards, the bit rate of the algorithm is saved by 13.65. As video content changes dramatically (e.g. BasketballDrill sequences), compared to H.264/AVC coding standards, this algorithm saves 37.82% bit rate, Compared to HEVC coding standards, the bit rate of the algorithm saves 1.97%. Than H.264/AVC and HEVC coding standards, the average bit rate of the algorithm saves 53.87% and 7.44%, respectively.

| Test sequence     | H.264/AVC  | HEVC  |
|-------------------|------------|-------|
| Akiyo             | -65.38%    | -8.95%|
| BasketballDrill   | -37.82%    | -1.97 |
| Claire            | -67.89%    | -20.14%|
| Drawing           | -39.15%    | -2.23%|
| Foreman           | -45.76%    | -2.98%|
| FourPeople        | -79.43%    | -13.65%|
| Pairs             | -38.21%    | -2.03%|
| Silent            | -57.32%    | -7.53%|
3.3. Panoramic reconstruction technology of fully mechanized coal face

Shearer is the main production equipment of fully mechanized coal face, which is of great significance to safe production. If presented according to the 1:1 ratio, the shearer occupies a small proportion in the panoramic video picture after splicing, so it is impossible to see clearly the running state of the shearer. As shown in figure 5, this is a small part of the whole panorama, which is almost invisible to the shearer. In addition, the premise of video splicing is that the center point of all camera images is located on the same horizontal axis, while the position and angle of the camera on the hydraulic support are different, so it is impossible to be completely on the same horizontal axis. This leads to the phenomenon that the picture after video splicing will inevitably appear uneven, not only aesthetically affected, but also the fluency of the whole picture is greatly affected by the single camera picture. As shown in figure 6, the edges of the video splicing are uneven.

![Figure 5. Shearer position in panoramic picture](image1)

![Figure 6. Partial screenshot of video splicing screen](image2)

In order to restore the real scene of the working face as far as possible and realize the goal of remote guiding the production operation, the video picture and the equipment state parameters of the fully mechanized coal face are reflected on the display screen by combining real-time video with animation simulation to highlight the key points and the principle of partial magnification. As shown in figure 7, the shearer cutting window is specially used to display the shearer cutting screen. The system has intelligent recognition function. Automatic switching is a splicing picture of the video taken by three cameras of the shearer, local display can clearly show the running state of shearer cutting. A wide angle camera is used in the system, and the AI intelligent video splicing algorithm is used to cut the upper and lower edges of the panoramic picture after splicing, so that the panoramic picture is neat and intuitive. After selecting the shearer panoramic window, you can view any part of the panoramic picture by moving the progress bar. According to the running state parameters of the conveyer, the animation shows the working state and state parameters of the conveyer. The hydraulic support moving frame window displays the field support moving frame by animation, and can slide the progress bar to view the position of any hydraulic support. Each number in the camera window corresponds to a camera, and click on any number can view the video picture of the corresponding camera. The camera number is green, which represents the normal work, the red represents the fault state, and the blue is the location of the shearer.
3.4. Reliable video data storage technology

The existing video surveillance system uses the ground network video storage server to store the video data of each camera in the underground. The underground camera and the ground network video storage server are connected by multi-level network, and the number of cameras is large.

In order to reduce data loss and ensure the integrity of the data, the video data are uploaded and stored in the network hard disk recorder, and each input channel of the network hard disk recorder corresponds to a camera, which is not affected by the network bandwidth. It ensures that the video data of each camera can be completely stored in the network hard disk recorder. At the same time, it changes from centralized storage to decentralized storage, which avoids the collective loss of the video data of the camera caused by the connection failure of the upper line of the network hard disk recorder. It ensures that the video data of each camera can be reliably stored under the normal condition of the camera. Even if there is a communication failure, it can also achieve the reproduction of the working condition by calling the video after the system recovery.

4. Development of Visual Technology in Fully Mechanized coal face

4.1. Camera self-cleaning technology

As the core part of the underground video surveillance system, the performance of the camera directly affects the overall effect of the video surveillance system. In the special environment of high dust and water mist in coal mine, the camera lens will inevitably adsorb a large amount of dust, solidify and condense for a long time, and cause the picture collected by the camera to be unclear and so on. At present, there are three main methods of dust removal: (1) coating nano-coating on the lens surface to prevent dust adsorption; (2) installing wiper cleaning device to the camera to keep the lens transparent through regular flushing and scraping lens; (3) installing air shield in front of camera lens, forming wind curtain in front of lens through constant blowing, preventing dust from adsorbing on lens[7-8]. This method has its own advantages and disadvantages, and the actual use effect is not ideal. It is necessary to find a new method of dust removal. It is small in size, light in weight and convenient to install and use in the narrow space of fully mechanized coal face.
4.2. **Intelligent Identification Technology of Video Surveillance System**

With the development of artificial intelligence, the intelligence of video surveillance system has become a trend, which is also the inevitable requirement of fully mechanized coal face in coal mine in the future, especially in thin coal seam, replacing manual work by intelligent video surveillance system to create an unmanned working face. Intelligent video surveillance system mainly includes target identification, target tracking, target ranging, target positioning, danger alarm and so on. For example: (1) early warning of coal piling in belt conveyor, when there is a small amount of coal piling at the belt conveyor lap, the video monitoring system sends a prompt warning signal, and when there is a large amount of coal piling at the belt conveyor lap, the danger warning signal is sent; (2) early warning of dangerous area intrusion, when the shearer is running, the video monitoring system detects the personnel activities in the dangerous area set up, sends out the dangerous alarm signal and stops the machine; (3) personnel management, establishment of face database, completion of attendance through face recognition at underground handover; (4) early warning of dangerous movement, working face personnel without a safety hat, personnel in the same position for a long time still, personnel lying, sitting and other dangerous movements when the alarm signal[9].

4.3. **High bandwidth and low delay wireless network communication technology**

The video surveillance system with wired transmission needs a lot of wiring, which will bring great trouble in the narrow space of fully mechanized coal face, and will cause cable pulling and increase the failure rate of the system during the movement of hydraulic support. The existing wireless communication methods are mainly WIFI, 4G and 5G, WIFI and 4G bandwidth is insufficient, which can not support a large number of video data transmission and 5 communication equipment is expensive, which is not conducive to large area use. Intelligent video surveillance system needs to rely on high bandwidth and low delay communication network to realize[7,8]It is necessary to keep an eye on the development of communication technology and track, research and develop the communication network suitable for the video surveillance system of fully mechanized coal face.

4.4. **Working face virtual reality technology**

Virtual reality technology is a collection of computer graphics, man-machine interface technology, multimedia technology, sensing technology, network technology and other technologies in one. At present, it is widely used at home and abroad to arrange all kinds of camera instruments on the working face to obtain real-time video information, install all kinds of sensors on the equipment to collect data such as temperature, current, voltage and displacement, transmit video information and data information to the centralized control center for remote operators to analyze and make decisions. Although this method has been widely used and achieved good results, but as a remote operator received only one-sided and local information, and has never felt immersive. Using virtual reality technology to combine real-time video images, production data, sensor data, production data, sensor data, GIS data to construct the real-time production scene of the working face, so as to truly realize the unmanned and intelligent fully mechanized working face[3,4,10].

4.5. **Coal-rock boundary identification technology**

The condition of coal seam and surrounding rock is very complicated. It is one of the key technologies of fully mechanized coal face to identify the dividing line of coal and rock accurately and reliably and to improve the effective cutting level of shearer[3,11]. Many technical routes have been tried in the industry, such as vibration spectrum sensor system, memory cutting control system, force cutting, noise sensor, infrared ray, ultraviolet ray, ultrasonic wave and radar detection. The multi-technology fusion method should be considered, and the infrared thermal imaging technology should be used to make a beneficial attempt[12].
5. Conclusion
There are many cameras needed for full visual coverage of fully mechanized coal face. The network transmission efficiency and reliability are improved by using distributed network structure and storage network structure, and visual data compression algorithm based on depth learning technology. Aiming at the bad imaging conditions such as short depth and wide angle in fully mechanized coal face, the techniques of distortion correction, image registration and image fusion are used synthetically, which greatly improves the imaging quality and the adaptability of remote video surveillance system, that makes the vision extend to the production line and provides theoretical guidance for the design of video surveillance system in fully mechanized coal face and lays a technical foundation for intelligent and unmanned fully mechanized coal face.

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