Binocular Stereo Matching For 3d Image Synthesizing Of Coal Workface

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***Abstract*— 3D Video synthesis with multi camera is a safety production foundation technique for realization remote control mining in coalface. The combination of the virtual and real, real-time interaction and 3D registration function are used for coalface 3D dynamic image. Scaling the 3D view of the coalface production scene and observing coalface from any angle enhance sense reality to ground user feeling for underground coalface. The study of two-camera visual platforms includes cameras calibration, image processing, stereo matching, 3D reconstruction and movement analysis. Stereo matching techniques are used to solve optical distortion and noise imbalance.**

Keywords-coalface; augmented reality; 3D image; binocular stereo matching

I. INTRODUCTION

After an unmanned mining technology is used in coal mining working face, coal mine safety problems can be thoroughly solved. Feasible technical method is to build a visual 3D (three Dimensions image, 3D image) coal mining working face production model, the mining face in the user's virtual reality, the observation and operation, the control of mining face equipment and production. On the ground, the user can freely control the coal mining machine, full-mechanized coal-face powered support and other mining equipment. The user has sensory entering real scene roaming in the coal mining face, has immersion sense, and can rotate the 3D graphics to get from different angles, and scaling to meet the mining face of observation of the whole or part of the system requirements [1]. Coal mining working face visualization will lead to underground miners out of dangerous area, and in a safe position. The mining face in building a dynamic and open after the overall layout, production to control the coal mining face with interactive way.

For coal mining working face mining, it is necessary to study the enhanced virtual reality theory, implementation method and characteristics in coal mining face, mining face to allow virtual "miners" free to walk on the mining face, make the production control decisions, users will result immediate feedback to the ground at the same time [2].

II. FROM VIRTUAL REALITY TO AUGMENTED REALITY

Virtual Reality VR (Virtual Reality) is made by the user on the computer Virtual environment, applied to the coal mine has some disadvantages, because the natural complexity of the coal mine environment to simulate, this also limits the popularization and application of Virtual Reality technology in coal mine safety. Figure 1 is a virtual coal mining working face.

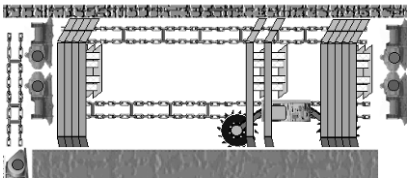

Figure 1. Virtual long wall equipment layout.

On the other hand, a new technology called for Augmented Reality AR (Augmented Reality) is applied to underground mining, it bases on the real image of the map to create a virtual environment [3]. Compared with the method of computer graphics, it requires no special hardware support or complex 3D modeling, moreover it can high fidelity simulation of live and reproduce the real world. But this method reduces the characteristics of the "virtual", for example, in some applications, users often need to add some actual does not exist in a virtual environment of virtual objects, with rich content, improve the performance of the system, but at present most of the virtual reality system of real image can't do that. Figure 2 is a schematic diagram of augmented reality.

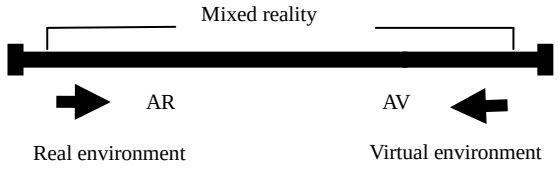

Figure 2. Movement of the virtual environment.

With augmented reality AR technology, the user complete immersion environment, visual sense by the control system, as shown in figure 3. System to enhance the real world scenario, the user feel like in the real world, requires a mechanism combination of virtual and real world. Mixed Reality MR (Mixed Reality) is a kind of virtual reality than AR. AR is a broader concept; enhance the comprehensive real world and electronic data. Instead, there is a term to enhance AV (Augmented Virtuality), to enhance VE (Virtual Environment) and integrated from real world data [4]. Covers the AR to AV mixed reality;

this article will focus on the AR in the 3D synthetic technology, real-time synthesis experiment of coal mining working face.

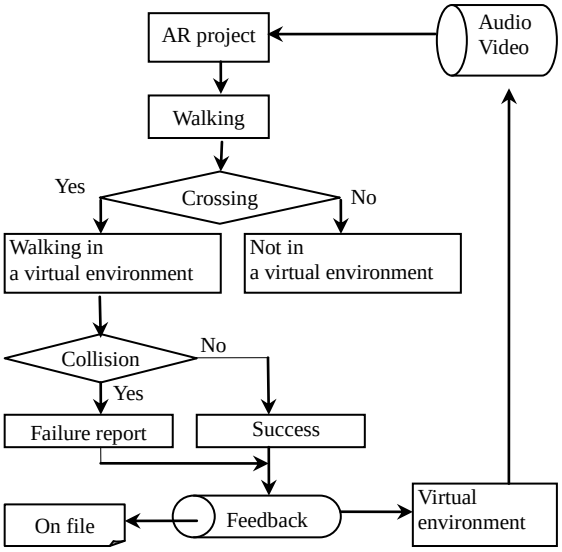

Figure 3. Move processes in virtual environment

A. *Coal Mining Working Face in 3D Visualization*

AR allows virtual object or other information synthesis by computer to the user to see the real world, to improve the visual perception of users. Research of virtual reality implement unmanned mining in coal mining face, mainly based on the augmented reality technology, the design of the main idea is: first, use a separate which based on the data, pictures and video continuously get panoramic post-processing; Then put these panorama through appropriate space model in virtual reality space; Finally using the synthetic virtual objects produced by the computer virtual reality space, realize an augmented reality environment, make the interactive roaming, virtual reality.

3D model of the mining face can enlarge, shrink, and from all angles, mining face can automatically display parameters and 3D coordinate points; By modifying the coordinates, the layout of the 3D graphics can be changed. Users can roam coal mining working face, the mining face and observe internal three-dimensional structure and equipment configuration. In augmented reality system, into the 3D graphics program, the video will automatically play, easy to understand the actual situation of coal mining work face, the mining face and to discuss the production control technology solutions. In 3D view of the mining face, the geographic location information can be updated automatically, based on input data can be automatically calculated reserves, the current position, height and Angle, etc. As shown in figure 4.

Safety monitoring marking directly on the 3D mining work face, the mining face due to the 3D view and the actual scene, along with coal mining working face advancing, 3D graphics will be automatically updated [5]. Security monitoring function and the working face production conditions can be showed at the same time, suitable for coal mining working face production scheduling and mining safety monitoring. Monitoring alarm when the coal mining face, click on the emergency alarm, display monitor information (such as gas concentration, air quantity and equipment running state).

Through the 3D view to switch to emergency alarm location, in order to stand out, alarm location set to shine. According to the comprehensive monitoring information of alarm point and mining safety monitoring, the control of the coal mining working face production decisions is made by ground staff.

B. *Coal Winning Machine Location and Tracking*

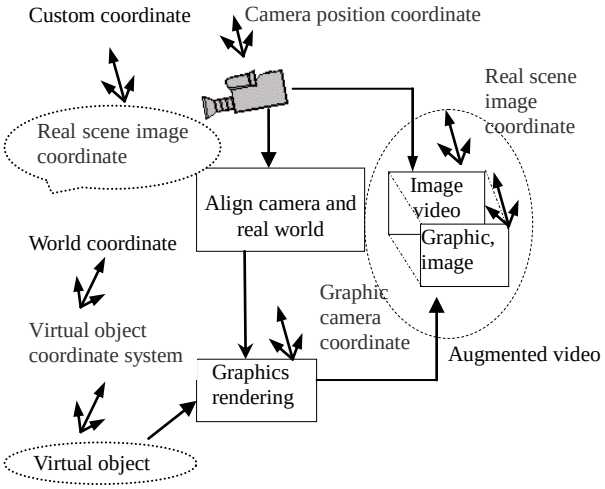

Figure 4. Location coordinates.

Mining face in order to realize the virtual users on the ground and coal winning machine equipment such as the perfect combination of physical and virtual user object must accurately integration to the corresponding position of coal mining working face in the real world, this process is commonly referred to as registration [6]. Tracking for the position of the system must be able to check the audience in the scene, Angle, and even the audience moving direction of the head, to help decide which virtual object, according to the reconstruction of coordinate system and according to the audience's view, as shown in figure 4. Also need to through the following technical cooperation realize shearer, hydraulic support equipment such as locating and tracking.

C. *Video Measurement*

Pattern recognition technology to identify the predefined tags, object or reference point of the video image, and then according to the displacement and Angle

of rotation transformation matrix is calculated.

D. Optical System

By measuring the installation on the objects of the LED light and the CCD/CMOS camera line, can measure the Angle between the two, and then the movement of the moving objects can be calculated according to the Angle and direction of movement.

III. BUILD 3D MODEL OF COAL MINING WORKING FACE FOR VIDEO

By using two explosion-proofs camera can build interactive 3D model of coal mining work face, and real-time generation knowledge management system. Maintenance system for knowledge, and interactive electronic manual, on the one hand, using the virtual reality model to simplify database access; On the other hand, the existing knowledge stored in the interactive 3D applications, and can be used in underground working places. Through virtual reality screen in a comfortable office environment of manipulating hundreds or even thousands of meters depth of coal winning machine cutting coal and more accurately. Augmented reality technology research also should include mining of underground geological surrounding environment influence each other, study of coal mining machinery control, such as coal mining working face of the hydraulic support electro-hydraulic control. The dynamic changes of the mining face tracking in time can send out warning signals to the problems [7]. At the beginning of the study, the goal is realized less people mining in coal working face, through the further research of the key technologies, eventually realize unmanned mining technique in coal mining working face.

A. Hardware Configure

Computers may be used in the synthesis of 3D augmented reality processing configuration pressure plate, on the pressure plate can join a stereo system, and program in a number of 3D perspective displays provides a wide AR view the desktop version. In addition to the 3D augmented reality, users also can use lossless audio system on-site voice, to feel the coal mining face USES various sensors to collect working site environmental conditions.

B. Synthesis of 2D Image Acquisition to 3D

Of course, 3D video image real-time processing and high performance computer, especially image processing and display capabilities, when necessary and use FPGA to implement parallel hardware acceleration, to meet the real-time enhanced virtual reality technology. Design and methods such as scene roaming, scene control, location query, collision detection and so on. It can be used on high configuration PC VC++ DirectX and OpenGL (Open Graphics Library) programming technique such as mining face reappearance production scenarios, the FPGA (Field Programmable Gate Array) platforms recommended using OpenCL development tools. Figure 12 is using the VC2008 with VTK library (Visualization ToolKit) processing of the video screenshots.

C. Binocular Matching and Parallax Computation

Stereo matching is mainly through and find out the corresponding relationship between each pair of images, according to the principle of triangulation, obtain parallax graphs. After get the parallax information, according to the projection model can easily get the depth information of the original image and 3D information. Stereo matching techniques are generally recognized is the most difficult in the stereoscopic vision is the most critical problems, mainly of the following factors: optical distortion and noise imbalance (brightness, hue, saturation, etc.).

Figure 5. Specular reflection of smooth

Figure 6. Synthesis of 3D video capture.

Figure 7. Foreshortening of work surface.

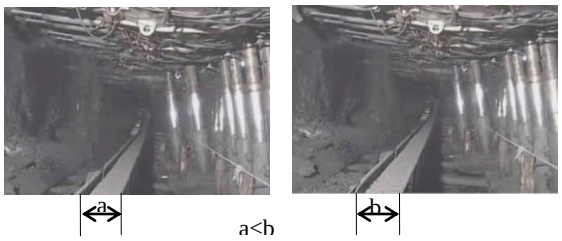

Figure 8. Perspective distortions of work surface.

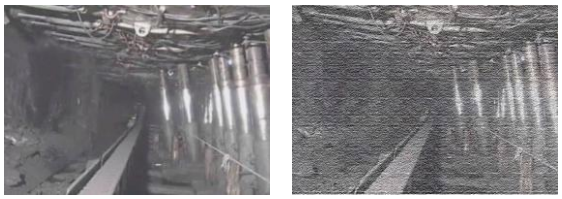

Figure 9. Low texture of work surface.

The stereo matching algorithm is a difficulty and hotspot in computer vision. Constructing the 3D virtual scene of a coal mine is the objective requirement for modernizing and processing information on coal mining production. To implement many algorithms the general steps are as follow.

D. Matching Cost Compute

Matching cost calculation is the basis of the three-dimensional matching algorithm, is actually to the gray similarity measurement under different parallax. Common method is the square of gray level difference SD (Squared intensity Differences), the absolute value of gray difference AD (Absolute intensity Differences), etc. In addition, in the original match cost can set an upper limit, to weaken the influence of mismatch in the process of superposition. AD method to match the cost, for example, can be used under calculated, including T for the set threshold [8].

$$C(x_i, y_i) = \begin{cases} |I_L(x_i) - I_R(y_i)|, & |I_L(x_i) - I_R(y_i)| < T \\ T, & |I_L(x_i) - I_R(y_i)| > T \end{cases} \quad (1)$$

1) Matching cost imposing

In general, the global matching algorithm is based on the original cost for subsequent algorithm calculation. Regional algorithm requires through window overlay matching to enhance the reliability of the cost, according to the original matching the cost is different, can be divided into: SSD (Sum of Squared Difference).

$$C(x,y,d) = \sum_{i=-n}^{n}\sum_{j=-n}^{n}\left[L(x+i,y+j) - R(x+d+i,y+j)\right]^2 \quad (2)$$

SAD (Sum of Absolute Difference):

$$C(x,y,d) = \sum_{i=-n}^{n}\sum_{j=-n}^{n}\left|L(x+i,y+j) - R(x+d+i,y+j)\right| \quad (3)$$

NCC (Normalized Cross-Correlation):

$$C(x,y,d) = \frac{L(x+i,y+j) - \overline{L(x+i,y+j)}}{\left|L(x+i,y+j) - \overline{L(x+i,y+j)}\right|} \cdot \frac{R(x+d+i,y+j) - \overline{R(x+d+i,y+j)}}{\left|R(x+d+i,y+j) - \overline{R(x+d+i,y+j)}\right|} \quad (4)$$

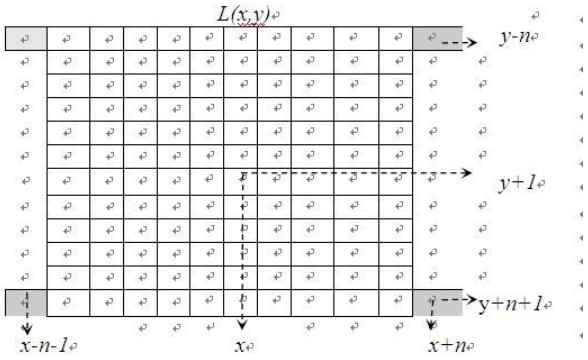

Figure 10. Left view coordinates calculation.

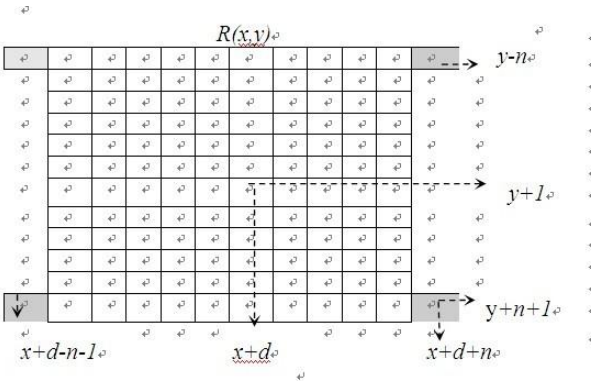

Figure 11. Right view coordinates calculation.

1)Parallax access

For regional algorithm, after the completion of matching the cost stack, it's very easy to get, parallax, only within a certain range to select optimal superposition matching costs points (take minimum SAD and SSD, NCC maximize) as the corresponding matching points, such as the king of the WTA (Winner Take All) algorithm. And

global algorithm is directly processed to the original matching cost, typically an energy evaluation function is given first, and then through the different optimization algorithm to obtain the minimum value of energy, at the same time, the parallax value of each point is calculated.

*2)Parallax refinement (subpixel level***)**

Most stereo matching algorithms calculated the parallaxes of the specific integer value are discrete, can meet the accuracy requirement of general application. Precision but in some occasions with higher requirements, such as the accurate 3D reconstruction, it needs to adopt some measures after initial parallax access to refine the parallax, such as matching the cost curve fitting, image filtering, image segmentation, etc.

IV. CONCLUSION

After studying the characteristics of augmented reality and its application to the coal mining face, the coal mine safety production is realized by 3D visualization technology. Discussed from the basic principle of 2D to 3D synthetic technique, the mining face, the virtual human and real scenes are combined together organically. The acquisition and processing of experimental system is established, and the high performance computer is applied to the real-time processing. If we want to get a higher processing speed, but also need to use the FPGA parallel technology to realize the image processing hardware acceleration.

(a) Left perspective video. (b) Right perspective video.

(c) 3D screen capture with 2 cameras video synthesis.

Figure 12. Synthesis of 3D video capture.

ACKNOWLEDGMENT

Foundation item: Project (ZR2011FL015) supported by Shandong provincial Natural Science Foundation of China.

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