Augmented Reality on Long-wall Face for Unmanned Mining

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Abstract—**An unmanned mining technology for the fully mechanized longwall face automation production is proposed and studied. The essential technology will bring the longwall face production into visualization through the VR (Virtual Reality) and AR (Augmented Reality) combination. Based on the visual theoretical model of the longwall face, the combination of virtual and reality, the real-time interactive and the 3D registration function were realized. The 3D image of the longwall face may be scaled and viewed from free angles. Using the overall affine coordinate system, the stereoscopic impression for the longwall face was enhanced; the video image is matched to 3D characteristics; the occlusion issue is resolved with the depth information solution; and the simplification visualization interactive method is proposed. The Key technology and Alpha channel are used to the combination of the real longwall face and the virtual user.**

Index Terms — **virtual reality, AR, VR, augmented reality, unmanned mining, long-wall face**

I. INTRODUCTION

Coal mining is a complex time-varying system, in which various factors such as man, machine, and environment interact with each other, the tough underground work environments, complicated geological conditions and the mixture of different environmental factors give rise to the limitation of many traditional technology, especially in fully-mechanized face and roof. In China, the coal mining production safety is more urgent. However, conventional method had not only to guarantee the experimental environment, but also to demand a large cost while the process is dangerous and the result is hard to verify. Therefore, in the information age, the combination of VR (Virtual Reality) technology and coal industry in researching the scientific cognition of coal mining environment is becoming a new method to solve the safety problem in coal mine production particularly longwall faces.

An unmanned fully mechanized longwall face will be the major issue which the coal mine safety in production technology will need to solve from now on. The visualization of a fully mechanized longwall face

production uses the computer science technology based on three dimensions (3D) image modeling. In the coal mine longwall face realistic environment combined with the virtual user's observation and operation, systematically prepare the fully mechanized longwall face equipment and the production, and clearly produce the fully mechanized longwall face production network chart; Moreover the ground user may freely control the parameters of the fully mechanized longwall face to effectively emulate the production network chart of the fully mechanized longwall face. The ground user may roam in the real scene with the feeling to be personally on the scene, and may rotate the 3D graph to get the view in different angles as well as scaling the graph to meet the system's overall or partial requests. Based on this foundation, inspires the user's ideation and decision, so as to strengthen the longwall face automation production and the safety monitoring. The longwall face visualization will make the miners into a safety location in the dangerous region by an interactive way, and establish the overall layout, the dynamic work and the opening environment simulation.
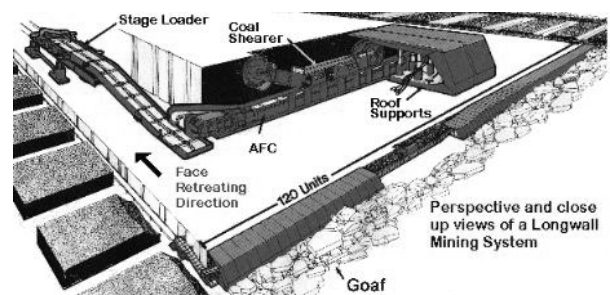

Figure 1. Current longwall face on a mine

To figure a current longwall face on a mine in China, the fully mechanized longwall face visualization is established based on the enhanced virtual reality theory. The virtual fully mechanized longwall face allows "the mining coal staff" to walk in it freely, and makes the decision in the key location. At the same time, no matter whether the decision is correct or not, its result can feed back immediately to the ground user. All of these manifested three particular characteristics of VR: Immersion, Interaction, Imagination and three characteristics of AR: Combining virtual and real objects; Real time interactions; 3D registration.

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II. FROM VR TO AR

The VR technology places the user in the virtual environment (VE) produced by the computer, but this technology has some shortcomings, e.g. difficult to model (an underground coal mine), high performance requirement for the computer, which also limited the application promotion of the virtual reality technology in a certain degree. On the other hand, the international starts to use the popular technology based on IBR (Image-Based Rendering) to produce virtual environment, compared with the computer graphics method, it does not need the special hardware support or the complex 3D modeling, and moreover it can simulate the scene with high fidelity and reappear the real world very well. But this method attenuated the "virtual" characteristic of the virtual reality in a certain degree. E.g. in some applications, the user often needs to join the virtual object in the virtual environment which in some realities does not exist so as to enrich the content of the system's performance, but most of the present virtual reality system based on the real-life scenery picture is unable to achieve this point.
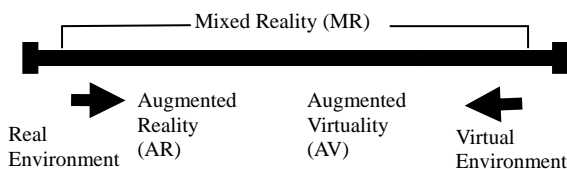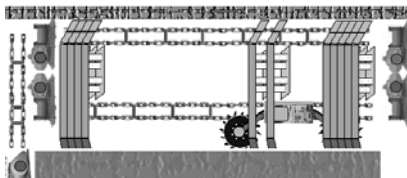

Figure 2. Move in virtual environment

Figure 3.   Virtual long-wall face

A. Virtual Reality

Totally immersive environment;

Visual senses are under control of system (sometimes aural and proprieties senses too).

B. Augmented Reality

System augments the real world scene;

User maintains a sense of presence in real world;

Need a mechanism to combine virtual and real worlds.

The AR technology provided the theory basis to solve the above questions. AR allows the virtual object or other information produced by the computer to be synthesized into the real world the user sees, which may enhance the user's vision feeling. Organically unify the AR and the IBR technology, research and realize the virtual reality space systems - coal mine unmanned mining coal longwall face based on augmented reality technology. The main designing idea is: Firstly use the separate pictures and the continuous videos as the basic data, and get the panorama after processing; Then organize these

panoramas into a virtual reality space through appropriate space model; Finally utilize the AR technology, synthesize the virtual object produced by the computer into the virtual reality space, and achieve an augmented reality environment which allows interactive roam and virtual reality union.
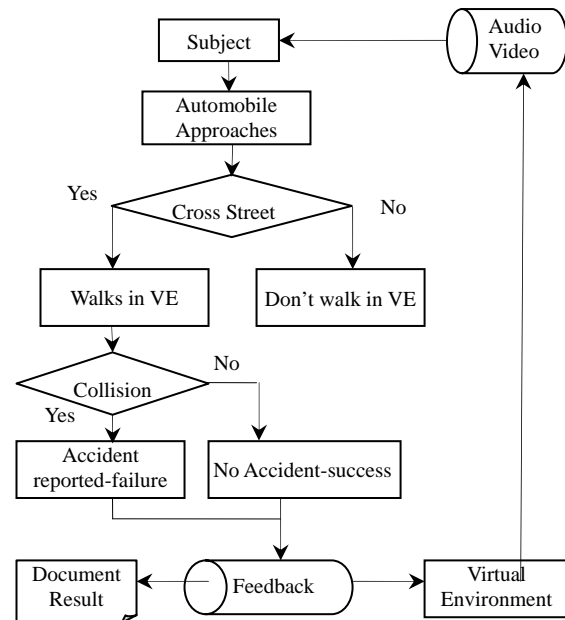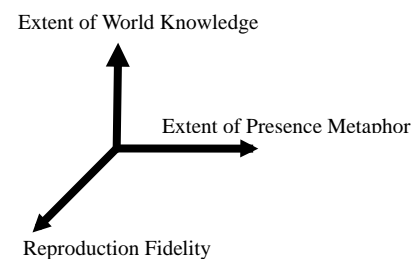

Figure 4.   Move in Virtual Environment

Figure 5. Move in Virtual Environment

Figure 5 shows a moving object in a virtual world and a real world. There is a three-axis coordinate system in a world. These are listed as follow:

Reproduction Fidelity – quality of computer generated imagery;

Extent of Presence Metaphor – level of immersion of the user within the displayed scene;

Extent of World Knowledge – knowledge of relationship between frames of reference for the real world, the camera viewing it, and the user.
Mixed reality (MR) is a kind of virtual reality, but a broader concept than augmented reality (AR), which augments the real world with synthetic electronic data. On the opposite side, there is a term, augmented virtuality (AV), which enhances or augments the virtual environment (VE) with data from the real world. Mixed reality covers a continuum from AR to AV. Focus of this thesis is to AR.

III. 3D VISUALIZATION ON A LONGWALL FACE

The 3D model of the fully mechanized longwall face can be enlarged, reduced and viewed from all angles, and can automatically demonstrate the parameters of the fully mechanized longwall face and the 3D coordinates of any point; by revising the coordinate values, the 3D graphical layout can be changed. The user may roam along the lead of the longwall face, and examine the interior 3D structure of the fully mechanized longwall face and the arrangement of equipments. Click on the 3D graph project, the live video will be played automatically, which is convenient to understand the actual situation of the fully mechanized longwall face and discuss the technical plan. In the 3D view of the longwall face, the geographical position information can be updated automatically according to the input data; information about the longwall face can be computed automatically such as the picked reserves, the surplus reserves, returning pick rate, the current position, the longwall face pick height and inclination angle.
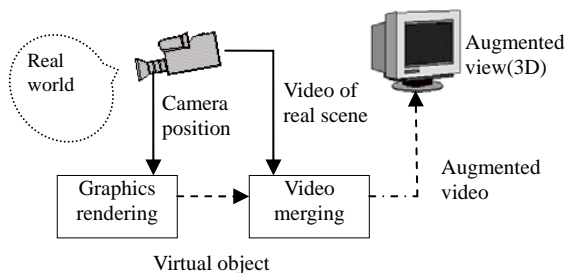

Figure 6. Real and virtual combiner for AR

The safe monitoring point is labeled directly in the 3D longwall face view, because the 3D fully mechanized longwall face view is consistent with the longwall face actual scene, the 3D graph will be updated automatically with the advancement of longwall face production. The safe monitor function and the production condition may be demonstrated at the same time, which is suited to the longwall face production scheduling and the addition of the regional survey station. When the monitor point in the longwall face gives an alarm, click it, and the synthesized monitoring information (e.g. methane gas, amount of wind, equipment running status) of the location where it is installed may be demonstrated immediately. Simultaneously the 3D longwall face view switches to the area map of the alarm point, and the alarm position is blinked. According to the synthesized monitoring information of the alarm point and the information of the region production, the geology and the project, the decision can be made.
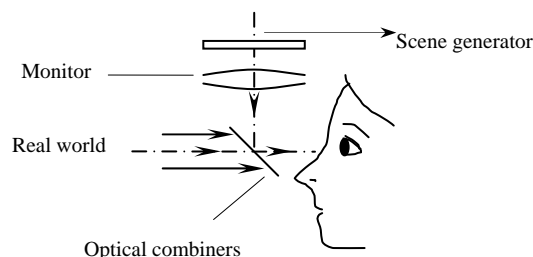

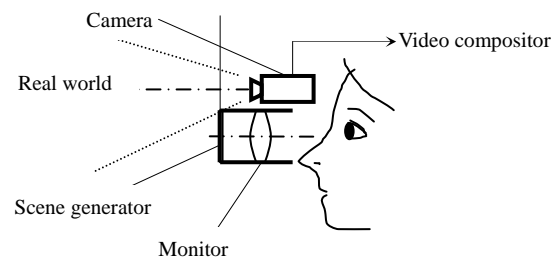Figure 7. Optical see-through HMD

Figure 8. Video see-through HMD

IV. LOCATING AND TRACKING

To realize the perfect union of the virtual and real object, the virtual object must be integrated into accurate position of the real world, and this process is often called registration, therefore the AR track positioning system must be able to examine viewer's position in the scene, the angle of the viewer's head and even the moving direction in real-time, so as to help the system to decide which virtual object to demonstrate, and reconstruct the coordinate system according to the viewer's field of view. In the longwall face AR application, some tracking and locating technology may be used.
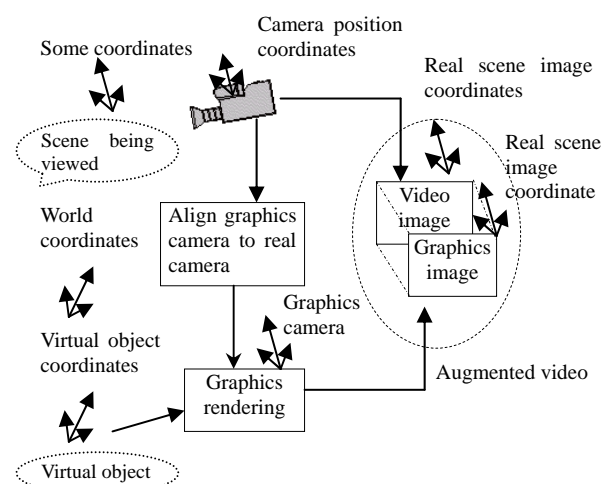

Figure 9. Coordinates location

A. Video Test

The pattern recognition technology distinguishes the predefined marks, objects or reference points in the video picture, then work out the coordinating transformation matrix according to its displacement and rotation angle.

B. Optical System

By measuring the light emitted from LED installed on the objects and the benchmarks with the CCD/CMOS sensor, the angle between the object and benchmark can be measured, and then by this angle, the moving direction and distance of the mobile object can be worked out.

C. Inertial Navigator

User's movement acceleration is determined through the law of inertia. The inertial navigator is used more and more in the longwall face.

D. Gyroscope

It is used to measure the rotation angle of user's head, so as to determine how to transform the coordinates and contents of the virtual scenery in the field of view.

E. Mechanism

Locate each node by the distance between each node and the angle between the lines of each node in the mechanism, which is suitable for the longwall face hydraulic support.

Because of the locating complexity in the long-wall face AR application, there isn't any kind of technology may achieve the perfect effect alone, therefore when using mark track localization, you must observe the object in short distance to distinguish it accurately. Moreover, when the environmental light and shade changes or the marks are occluded or leave the field of view, the system will eliminate the virtual object. Therefore, in the practical application, users often synthetically use the mixed system made by many kinds of track localization technologies. E.g. the shearer localization and the hydraulic support localization need to use different technologies to realize.

V. Combining VR and AR Objects Registration

Traditionally, when solving the virtual-real registration in AR, people always concentrated on the solution of the transformation equations between the various coordinate systems, but neglected other possible solutions, and a very important aspect is to take advantage of the computer graphics and the computer vision technology. In recent years, with the rapid development of the computer graphics and the computer vision technology, many mature technologies may be used to solve the virtual-real registration problem in AR on an unmanned mining longwall face. The key of the correct registration of virtual-real image is to precisely determine the projection coordinates in the scene image of each point on the virtual object. Under the uneven inferior coordinates expression, in the three dimensions space, the transformation relation between the point $[x_0, y_0, z_0, w_0]^T$ on virtual object and the projection point $[u, v, h]^T$ in the enhanced scene plane may be expressed as in (1).

$$\begin{bmatrix} u \\ v \\ h \end{bmatrix} = P_{3 \times 4} C_{4 \times 4} O_{4 \times 4} \begin{bmatrix} x_0 \\ y_0 \\ z_0 \\ w_0 \end{bmatrix} \qquad (1)$$

As in (1), $P_{3 \times 4}$, $C_{4 \times 4}$ and $O_{4 \times 4}$ separately corresponds to the transformation of the 3D scene to the two-dimensional imagery plane, the real scene to the camera and the virtual object to the real scene. Because the virtual object, the real scene and camera are defined under different coordinate systems, therefore the virtual-real registration solution relies on the solution of the transformational relation between the above coordinate systems. This has been proved to be troublesome and extremely easy to produce errors. After

research the conclusion is if at least 4 non coplanar points in the 3D space were given, then for any projection transformation, the transformation result of any point in a 3D space set may be expressed by the linear combination of these 4 points' transformation result. Based on this conclusion, the object coordinate system, the camera coordinate system and the scene coordinate system may be combined to establish an overall affine coordinate system so that the real scene, the camera and the virtual object can be defined under the identical coordinate system, and then to avoid solving the transformational relation problem between the different coordinate systems, thus the virtual-real registration solution doesn't rely on the camera's interior and exterior parameter calibration. Under the new coordinate system, projection transformation expression in (1) becomes (2).

$$\begin{bmatrix} u \\ v \\ h \end{bmatrix} = \prod_{3 \times 4} \begin{bmatrix} x_f \\ y_f \\ z_f \\ w_f \end{bmatrix} \qquad (2)$$

Equation (2), $[x_f, y_f, z_f, w_f]^T$ (subscript f represents affine coordinate) is the point coordinate expression of the virtual object under the new coordinate system. Thus, after defining the origin and 3 coordinate axes, the overall affine coordinate system is determined, now in the enhanced scene, each point on the virtual-real object has a fixed affine coordinate expression. Although the origin and the axis points used to define the overall affine coordinate system may be any 4 non-coplanar points in the 3D space, but in the practical application, people usually select the artificial feature points because it is easy to withdraw the computer image characteristics. Now the points may be expressed by (3).

$$p_0 = \begin{bmatrix} u_0 \\ v_0 \end{bmatrix}$$

$$p_1 = \begin{bmatrix} u_1 - u_0 \\ v_1 - v_0 \end{bmatrix}$$

$$p_2 = \begin{bmatrix} u_2 - u_0 \\ v_2 - v_0 \end{bmatrix} \qquad (3)$$

$$p_3 = \begin{bmatrix} u_3 - u_0 \\ v_3 - v_0 \end{bmatrix}$$

$$p_x = \begin{bmatrix} p_0 & p_1 & p_2 & p_3 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

Equation (3), P_i (i=0~3) is the 4 reference points' corresponding projection point in the 2D projection plane after some transformation $O_{3 \times 4}$ under the affine coordinate system, P_x is the projection point of any point in the affine coordinate system after some transformation $O_{3 \times 4}$ in the two-dimensional plane, $[x, y, z, 1]^T$ is the

affine coordinate of P_x. Equation (3) shows that for one transformation $O3\times4$ under the affine coordinate system, after the image analysis, the coordinates of the 4 reference points in the two-dimensional projection plane were ($[u_{pi}, v_{pi}]^T$, $i=0\sim3$), then in 3D space the two-dimensional projection coordinates $[u_p, v_p]^T$ of any point $P[x_f, y_f, z_f, 1]$ may be calculated through equation (4).

$$\begin{bmatrix} u_p \\ v_p \\ 1 \end{bmatrix} = \begin{bmatrix} u_{p_1}-u_{p_0} & u_{p_2}-u_{p_0} & u_{p_3}-u_{p_0} & u_{p_2} \\ v_{p_1}-v_{p_0} & v_{p_2}-v_{p_0} & v_{p_3}-v_{p_0} & v_{p_2} \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_f \\ y_f \\ z_f \\ 1 \end{bmatrix} \quad (4)$$

Equation (4), as long as the 4 reference points (in the affine coordinate system) projection coordinates in the two-dimensional projection plane has been determined, the transformation matrix $O_{3\times4}$ can then be determined. For any points in the three-dimension space, its corresponding plane coordinates in the 2D projection plane can be calculated according to its affine coordinates. So in the overall affine coordinate system, the AR virtual-real registration solution changes from the troublesome calibration process to the reference points' localization process in the 2D projection plane, which simplifies the computation process. Because the reference points are often marked by the feature points which is easy for the computer to recognize, therefore the latter's realization difficulty is greatly reduced. In order to obtain the 2D projection coordinates of any point in the 3D space, a very important premise is to get its affine coordinates.

In order to get the affine coordinates of any point P in the 3D space may use the binocular stereo vision method. Without the optical axis parallel limitation, camera focal distance and stereo base length, only need to get two 2D projection planes of the scene from any different angles, then determine the 4 reference points' coordinates in the two projection planes, ($([u^j_{pi}, v^j_{pi}]^T$, $i=0\sim3$, $j=1\sim2$)) as well as the corresponding coordinates ($[u^j_p, v^j_p]^T$, $j=1\sim2$) of point P in two projections planes. Now the uneven affine coordinates $P[x_f, y_f, z_f, 1]^T$ of point P may be calculated through (5), the subscript f in the equation represents the affine coordinate system.

$$\begin{bmatrix} u_p^{(1)} \\ v_p^{(1)} \\ u_p^{(2)} \\ v_p^{(2)} \end{bmatrix} = \begin{bmatrix} u_{P_1}^{(1)}-u_{P_0}^{(1)} & u_{P_2}^{(1)}-u_{P_0}^{(1)} & u_{P_3}^{(1)}-u_{P_0}^{(1)} & u_{P_0}^{(1)} \\ v_{P_1}^{(1)}-v_{P_0}^{(1)} & v_{P_2}^{(1)}-v_{P_0}^{(1)} & v_{P_3}^{(1)}-v_{P_0}^{(1)} & v_{P_0}^{(1)} \\ u_{P_1}^{(2)}-u_{P_0}^{(2)} & u_{P_2}^{(2)}-u_{P_0}^{(2)} & u_{P_3}^{(2)}-u_{P_0}^{(2)} & u_{P_0}^{(2)} \\ v_{P_1}^{(2)}-v_{P_0}^{(2)} & v_{P_2}^{(2)}-v_{P_0}^{(2)} & v_{P_3}^{(2)}-v_{P_0}^{(2)} & v_{P_0}^{(2)} \end{bmatrix} \begin{bmatrix} x_f \\ y_f \\ z_f \\ 1 \end{bmatrix} \quad (5)$$

Under the overall affine coordinate systecm, depth computation of projection point is to give the user enough third dimension; the correct occlusion relations among the virtual-real objects in the enhanced scene must be maintained. This not only needs to determine the 2D coordinates in the projection plane of any point in the 3D space, but also needs to know the depth information of each projection point, i.e. the relative distance from the 3D space point to the view point, then by the support of the computer graph system hardware, the object's hiding side may automatically disappear so as to enhance the third dimension. Under overall affine coordinate system, because the camera calibration process is not carried on, it is impossible to know the concrete view point position or to restore projection point's depth data in the absolute sense. To solve the problem, first define a 3D plane L through the coordinates of 4 reference points in the projection plane, and then compute the relative distance from each point under the affine coordinate system to the plane L, and take it as the approximation of the point's depth data in the projection plane. The experiment proved that, the relative distance value approximately obtained can correctly reflect the depth relations between the virtual-real objects in the enhanced scene. The plane L is defined as in (6) (φ expresses the plane vector).

$$\varphi = \begin{bmatrix} u_{P_1}-u_{P_0} \\ u_{P_2}-u_{P_0} \\ u_{P_3}-u_{P_0} \end{bmatrix} \times \begin{bmatrix} v_{P_1}-v_{P_0} \\ v_{P_2}-v_{P_0} \\ v_{P_3}-v_{P_0} \end{bmatrix} \quad (6)$$

Under the affine coordinate system, any spatial point's depth data in projection plane can be approximately calculated as in (7).

$$\begin{bmatrix} u \\ v \\ h \\ 1 \end{bmatrix} = \begin{bmatrix} u_{P_1}-u_{P_0} & u_{P_2}-u_{P_0} & u_{P_3}-u_{P_0} & u_{P_0} \\ v_{P_1}-v_{P_0} & v_{P_2}-v_{P_0} & v_{P_3}-v_{P_0} & v_{P_0} \\ & & \varphi^T & \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_f \\ y_f \\ z_f \\ 1 \end{bmatrix} \quad (7)$$

VI. INTERACTIVE 3D SUPPORTS UNDERGROUND MINING

Increasing the output of mining machines for road heading machines and shearer loaders is difficult to reach. Due to the advanced technical development of the machines, increased use of automation is here the objective. The analysis of daily work schedules of large machines, like the road headers and shearer loaders in German and Polish hard coal mines, show, that start-up, maintenance and repair times are of high potential for further improvement in the sense of increasing the daily period of operation. One possibility of reducing of downtime caused by underground assembly and disassembly work was seen in supplying of the necessary know-how right at the workplace. Technical complex machines require frequently expert knowledge and sometimes also the direct support by the manufacturer. Interactive 3D for support of underground repairs in the mining industry is one of the aims of current unmanned mining research work. During the project ARUM (Augmented Reality Unmanned Mining) several ideas and solutions were converted into demonstration projects. Some of them were successfully integrated into the

mining industry. Together the coal mine partners developed a new Knowledge management system based on interactive 3D models generated in real time. Both the Knowledge Based Maintenance System (KBMS) and the Interactive Electronic Manual (IETM) on the one hand clearly simplify data base access by using Virtual Reality machine models. On the other hand existing knowledge is stored in interactive 3D applications and given to the underground mechanics on suitable terminals right at the workplace.

There are already some elements of these systems in place in applications such as highwall mining, where inertial guidance systems such as HORTA have proven their adequacy for survey positioning at distances in the 350 to 500 meters range from the operator's console, and natural gamma sensors give an indication of the proximity of the cutting head to roof or floor strata. However these capabilities will need to be made much more reliable before we achieve our own version of continuous miner 'top gun' operators, working away at their virtual reality screens in air conditioned comfort at the mine office while their mechanical charges gnaw away at the coalface several hundred meters below and maybe at a distance of a kilometer or two.

Research will also be required to extend the promising starts made on detecting the impact of mining on the surrounding environment through micro seismic arrays, hydraulic support loadings, and arrays of simple and expendable monitoring instruments to comprehend the dynamic changes occurring and to give early warning of the onset of problem situations. We can expect the progress towards the unmanned mining long wall face will be achieved mainly by incremental improvements of technological developments which are already in progress. Safety will be the key driver to promote this research in the short term, but the main impetus to drive the technology through to full implementation will arise as the new systems approach (and eventually surpass) the productivity of manned operations.

A. Hardware configuration

Computer's configuration is as follows: 3.2GHz processor, 2GB RAM, NVIDIA GeForce 6600 GT graphics card, 80GB hard drive. In the pressure-sensing pad also defines the frequency stereo system, however in the course of the study the necessary changes to hardware and device settings. Had not provided to users 180° view of the five objects will change a reducing system design complexity. . Instead, the program is to use a large angle to display. This will provide a view of the desktop version of the AR system. Moreover, the designers also proposed to use mouse clicks to replace the pressure sensor pad. Ordinary users without lossy compression audio system types.

B. Structural arrangements

Figure 10 shows the schematic of the final cost-based, facilitating factors, complexity and availability. A group of three large flat-panel displays, B is a computer mouse, C is the sound system, D is the user / theme, E is the computer with the required configuration. This step is

simple, but the relevance, efficiency, effectiveness, learn ability and usability. Arranged three-dimensional position of the surround sound system is critical to provide users with real audio D from the user to see the screen in a virtual world, based in the visual and sound effects, so people use the mouse model b trigger walk. Rights also set the minimum number of obstacles and distractions to the user audio-visual system. In addition, the use of a wireless mouse can help to eliminate the user's view and allows any wires more flexible in terms of user to user location.
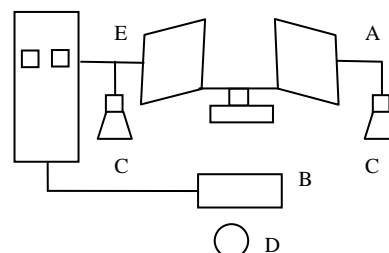

Figure 10. Interactive 3D Structural arrangements

VII.   AR APPLY ON MINING

ARUM modeling characteristics and methods of virtual scene were analysis in the paper and OpenGL was chosed as modeling tool. Mine stope equipment model was set up through three steps: geometric modeling, image modeling and behavior modeling. Dynamic characteristic of fully mechanized mining equipments was analysised by using kinematics and dynamics. The behavior modeling of powered supports was set up with the method of constrained inverse kinematics, and shearer was established with the method of father-son hierarchical model. Powered supports and shearer can be controlled with the application of selection mechanism provided by OpenGL and virtual controller operated by mouse. By setting system timing device, using clock to control the operation of mining equipment and the applying of 3D animation double buffer technology, the dynamic simulation of the production process can be achieved at last.

Figure 11 shows part of virtual reality ARUM geometric topology, Table 1 shows the location ID of the key points. Figure 12and 13 show the video capture the real scene on longwall face. Figure 14 shows the actual scene with the combination of virtual scene and real scene.
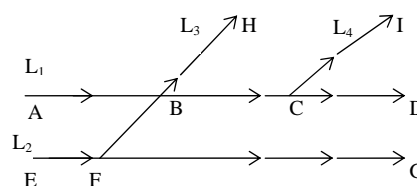

Figure 11.   Topological relation of laneway network

Table 1. Topology node of laneway

Lane	ID	Begin ID	End ID
1	0001	A	B
2	0002	B	C
3	0003	C	D
4	0004	E	F
5	0005	F	G
6	0006	F	B
7	0007	B	H
8	0008	C	I

Figure 12. Video of at a angle

Figure 13. Video of at another angle

Figure 14. Combination of video

VIII. Future Directions in AR Interaction

AR interaction is constantly evolving new hardware, software, interaction techniques, and AR systems; the topics covered here are by no means a comprehensive list.

New products, such as the Immersion Haptic Workstation, provide high quality tracking of the participant's hands coupled with force feedback that will allow the participant to "feel" the virtual objects. The improved interaction could enable AR to be applied to hands-on tasks that were previously hampered by poor haptic feedback.

VEs populated with multiple participants (often physically distributed over great distances) have unique interaction issues. In a University College London study, two participants, one at UCL (England), and the other at UNC at Chapel Hill, (United States of America), are tasked with navigating a virtual maze while carrying a stretcher. How do the participants interact with a shared virtual space, simulation, and each other? Researchers

are interested in how important audio, gestures, and facial expressions are for cooperative interaction.

Combining several interaction methods might develop into solutions which are greater than a sum of its parts. For example, the ARUM system seeks to train emergency response underground environment. The system interprets hand gestures and voice commands in conjunction with traditional interaction methods to interact with the simulation. Researchers are also investigating passive techniques that use image processing and computer vision to aide in tracking and interpreting the participant's actions and gestures.

There is also research into new types of AR systems. Mining environments – VEs that combine real and virtual objects – focus on providing natural physical interfaces to virtual systems as well as intuitive virtual interfaces. There exists a spectrum of environments, from augmented reality – supplementing display of the real world with virtual objects – to mixed and augmented virtual reality – supplementing display of the virtual world with real objects.
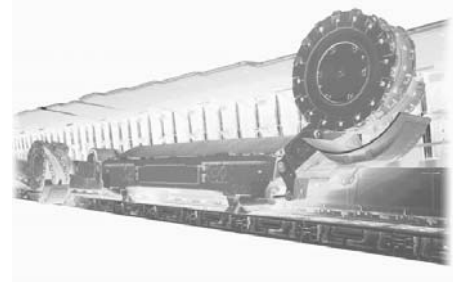

Figure 15. Shearer for ARUM on a longwall face

The ARUM systems look to improve performance and participant sense of presence by having real objects registered with virtual objects. Studies into passive haptics had major virtual objects, such as the lanes and unmovable device, registered with stationary physical objects. It was found that passive haptics did improve sense of presence.

New methods to navigate and interact with virtual objects are constantly being developed, and there are movements to formalize the description and evaluation of interaction technologies. This allows AR system engineers to make interface design decisions confidently and reduce the ad hoc nature of IT creation. Formal evaluation also promotes a critical review of how and why people interact with VEs.

As the types of interactions grow more complex, higher order interactions with simulation objects are becoming a major research focus. Interpreting the participant's facial expressions, voice, gestures, and pose as inputs could provide a new level of natural interaction. Also, participants will interact with more complex objects, such as deformable objects and virtual characters.

As the hardware, interactions technologies, and software progress, AR system designers develop a more natural and effective means for participants to interact with the VE. We believe improved ARUM will allow AR to fulfill its promises in providing a new paradigm for humans to interact with digital information.

The AR representation of the complex underground scene result in the declination to computer operation speed, this paper used the simplified models, examples, partition and fog technology to improve the image rendering speed, met the requirement of VR about real-time. It had also designed methods such as scene roaming, spot controlling, and position querying and collision detection. By using Visual C++, Direct X and OpenGL, the ARUM system based on the PC was developed, reappear the operation in fully-mechanized scene.

IX. CONCLUSION

After shooting videos from two different angles, combine the two videos into a dynamic 3D video through the projection transformation. Based on it, the essential technology - augmented reality is studied for unmanned fully mechanized longwall face automation production, through the virtual-real combination, the fully mechanized longwall face production is visualized. The later work will study the combination of more than 8 cameras' dynamic images, and the effect will become more stereoscopic.

REFERENCES

[1] Progress Towards Longwall Automation M.Kelly, D. Hainsworth, D.Reid, C. Caris CSIRO Exploration & Mining, 2004,5.

[2] Hongbing Li, BoMeng, ShifuChen . An agent based approach for constructing software systems of virtual simulation [J]. International Journal of Virtual Reality, 2005, 5(4).

[3] Johnson W L, Richel, Stiles R . Integrating pedagogical agent VE [J]. Presence: Teleoperators and Virtual Environments,2004.

[4] Reignier P, Harrouet F .Morvan S, AreV :A Virtual Reality Multiplatform[A], Heudin J-C(Ed) : Virtual Worlds 98,LNAI 1434[C], 2005.

[5] Fisher S S, Fraser G .Intelligent Virtual worlds continue To develop Computer Graphics, 2004, 33(2).

[6] [4]Arndt Kraft,Stefan Pitsch,Michael Vetter. "Agent - Driven Online Business in Virtual Communities," The 33rd Hawaii International Conference on System Sciences,04–07,2000.

[7] VRSHOP Homepage,http: //www.vrshop.swt.iao.fhg.de, 1999- 09- 30.

[8] Guttman,R.H.;Moukas,A.G.and Maes,P.;Agent mediated Elec-tronic Commerce: A Survey,1999.

[9] Alan Watt. 3D Computer Graphics, 2nd Edition. Addison-Wesley, 1993.

[10] Bui-Tuong Phong. Illumination for Computer Generated Pictures. ACAM, 1975, 18(6): 311-317.

[11] Gouraud H. Continuous Shading of Curved Surfaces. IEEE Trans. On Computers, 1971, C-20(6):623-629.

[12] James D. Foley, et al. Computer Graphics: Principles and Practice. 2nd ed., Addison-Wesley, 1990.

[13] Paul E. Debevec, et al. Modeling and Rendering Architecture from Photographs: A hybrid geometry- and image-based approach. SIGGRAPH'96, Computer Graphics, 1996, 11-20.

[14] R. Barzel and A. H. Barr. A Modeling System Based on Dynamic Constrains. ACM SIGGRAPH'88 Conference Procceddings, 1988, 22(4): 179-188.

[15] Ronen Barzel. Physically-Based Modeling for Computer Graphics. Academic Press, 1992.12.8.

[16] Pilar Herrero etc.Intelligence Virtual Agents keeping Watch in t Battlefield(J), Virtual Reality, 2005, 8(3): 185-193.

[17] Antonio Riganelli etc.A Multi-scale Virtual Reality Approach Chemic Experiments(J), Computer Science. 2003(2658): 324-330.

[18] Richard A.Klein.Virtual Reality Exposure Therapy in the Treatme of Fear of Flying(J).Journal of Contemporary Psychotherapy,20030(2):195-207.

[19] Akihiko Shiral etc,Entertainment Application of Human-Scale Virtul Reality System(J).Computer Science, 2004(3333): 31-38.

[20] W.Akl etal,Effience Virtual Reality Design of Quict Underwat Shell(J).Virtual Reality.2005,9(1):57-69.

[21] Anton Jezermik etc, A solution to integrate computer-aided design (C and virtual reality) (J) database in design and manufacturiprocesses. 2003, 22(11-12): 768-774.

[22] Bise,C.J.Emerging technology for training of miners(J).Mining Engineering, 1997, 49(1):37-41.

[23] Chakraborty,Pallab R.Bise,Christopher J.Virtual reality base model for task-training of equipment operators in the mining industry(J).Mineral Resources Engineering. 2000,9(4):437-449.

[24] Denby B,Schofield D,Walsha T.Virtual reality for the real timvisualization of environmental date(C). 27th APCOM. London.UK.199.

[25] Schofield D,Denby B,Willams M,etc.New applications of computgraphics and virtual reality in the minerals industries(C).Mine I1st international conference on information technologies in the minerals industry,National Technical University of Athens,Greec 1997.

[26] Crawshaw SAM,Denby B,McClarnon D.The use of virtual reality tsimulate room and pillar operations(J).Coal international,1997 , 245(1):20-22.

[27] Denby B.Schofield D.Role of virtual reality in safety training mine personnel(J).Mining Engineering, 1999,28(10):59-64.

[28] Kizil,M.S.;Hancock,M.G.;Edmunds,O.T.Virtual reality as a trainitool(C).Proceedings AusIMM Youth Congress 2001.2001(2):9-12.

[29] Stothard,P.The Feasibility of Applying Virtual Reality Simulatito the Coal Mining Operations(C).Effective Risk Management for Mini Project Optimisation Conference article,2003,n5:175-183.

[30] Biswas, Debabrata, Nil. An integrated virtual reality system for design of underground roadway support(D). University of New SouWales(Australia). 2001.

[31] Schmid,Martin,Rossmann.Virtual reality teaching and trainisystems in mining-Applications and operational experiences, Deutsche Montan Technologie GmbH,Essen, Germany. Verlag GlueckaGmbH, Essen, Germany. 2004(2):39-44.

[32] Rossmann,Martin.Planning,simulation and real-time depiction coal-mining processes using a "virtual reality" system(J). Gluecka Mining Reporter, 2003,n1:27-31.

[33] Unver B,Yasitli NE.Simulation of sublevel caving method used in thicoal seam by computer(R). Hacettepe University Scientific Researc Unit, Project no:00 02 602 008,2002:148.

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