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Research on virtual and real collaboration method for multi-dimensional visual inspection in mines

Jinchuan Chen

Beijing Longruan Technology Co., Ltd., Beijing, China

Abstract: *Underground inspection is a key constituent of mine work and an important step in ensuring safety. And under the impetus of information technology development, intelligent mine underground virtual inspection has become possible. The paper proposes the virtual and real collaboration method for multi-dimensional visual inspection in mines, so that real video, monitoring and surveillance data and virtual scenes can achieve automatic virtual and real synergy and real-time correspondence in the inspection process, through providing an automatic inspection method based on mine spatial objects, spatial relationships and inspection logic.*

Keywords: *underground inspection; intelligent mine; multi-dimensional visual inspection; virtual-real collaboration*

1. Introduction

At present, underground inspection is an important part of the daily safety management of the mine. With the construction of intelligent mine, the underground virtual production environment can be built with the help of virtual reality, augmented reality, digital twin and other technologies, and underground remote dynamic inspection can be carried out in the virtual environment.

2. Current limitations of underground remote inspection

Nowadays, there are two main ways of underground remote inspection based on the virtual environment. One is building a virtual scene of key places in mine such as mining working face, so immersive inspection can be carried out with the help of VR, AR and other software and hardware, and information, like the videos, monitoring and automation, can be viewed manually and interactively in the scene in the inspection process; And the other is building a virtual scene of the whole mine. Inspection can be carried out according to the planned inspection route, and the corresponding information can be popped up when you approach the inspection equipment, cameras and monitoring points. The above two ways have the same problem, that is, there is no spatial relationship construction for the roadway, equipment, real-time data and inspection virtual observers in the system. And during the inspection process, you can only manually and interactively click to view or can only view the video, environmental monitoring data, automation and intelligent equipment monitoring and control data within a certain distance in front of you, and you cannot automatically call up information that meets the observer's requirements according to the position, observation direction and spatial relationship of the virtual observer of the inspection.Also you cannot realize the real-time synergies and automatic correspondence inspection process between the monitoring and control data and the virtual scene.

3. Virtual and real collaboration method for multi-dimensional visual inspection in mines

3.1. Building the multi-dimensional visual system of the whole mine on the basis of the graphics processing platforms GIS or CAD

The multi-dimensional visual system is a visual system of two-dimensional graphics, three-dimensional scenes, four-dimensional temporal scenes and digital twins of the whole mine which is constructed on the basis of geographic coordinate data; The geographic coordinate data include geographic coordinate-based mining engineering diagrams, roadway cross-section design diagrams, roadway sketch diagrams, ventilation system diagrams, underground equipment layout diagrams,

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equipment design diagrams, underground pipeline layout diagrams, underground monitoring point layout diagrams, and laser point cloud data; Based on the geographic information system or the computer-aided design graphics processing platform, the graphics, models, and scenes in the multi-dimensional visual system are integrated into a unified geodetic coordinate system, so that the spatial correlation relationships is achieved.

3.2. Constructing geometric and attribute models of roadways, equipment and pipelines in the multi-dimensional visual system

The construction of geometric and attribute models of roadways, equipment and pipelines in the mine-wide multi-dimensional visual system includes that, on the basis of geographic coordinate data, geometric models of roadways, equipment and pipelines are constructed and different attribute models are constructed for describing the attributes of the geometric models of the roadways, equipment and pipelines. And the attribute descriptions include unique ID, center position of the geometric model, wrapping rectangle, and orientation of the model. Among them, the values of the geometric model center position and the spatial coordinates in the wrapped rectangle are based on the values of the geographic coordinate system; the model orientation is the positive direction of the model according to the model structure or specific rules; the equipment model includes: the equipment model of the underground coal mining, tunneling, mechatronics, transportation, ventilation and drainage systems, as well as the equipment model of the monitoring and control, personnel positioning, emergency avoidance, self-rescue by compressed air, and water supply and salvage, communication and liaison system; pipelines includes underground water supply, drainage, slurry drainage, ventilation and other pipelines, as well as underground electric wires, network lines.

3.3. Constructing the relationship between virtual observer and tunnel, equipment and pipeline in the multi-dimensional visualization system

3.3.1. Constructing the static topological relationship between the roadway, equipment and pipelines

Constructing a static topological relationship between a roadway and equipment and pipelines includes constructing a network topological map of the roadway and a topological map of equipment and pipeline monitoring points in the roadway, which is intended to be used to dynamically and quickly retrieve the IDs of equipment, video cameras, and pipeline monitoring points associated with the roadway. Wherein the topological map of the roadway is a topological network map with the roadway's start point, midpoint, end point, or intersection point as a node, and the roadway as an arc segment. In the network topology diagram of the roadway, the arc segment contains the attribute description of the corresponding roadway construction, including unique ID and outsourced rectangle. The topological map of device and pipeline monitoring point, based on the roadway topology, stores the ID related to the roadway like the device, video camera and pipeline monitoring point in the corresponding arc. Pipeline monitoring points refer to monitoring devices placed at intervals in underground pipelines, including water pressure monitoring, water flow monitoring, and wind pressure monitoring. The main index for judging whether the equipment, video camera and pipeline monitoring point have relationship with the roadway is whether the roadway is included in the relationship with the roadway, and the judgment basis of the equipment that has a contained relationship with the roadway is the contained relationship between the roadway outsourcing rectangle and the equipment outsourcing rectangle; and the judgement basis of the pipeline monitoring point that has a contained relationship with the roadway is the contained relationship of the volume and the point between the roadway outsourcing rectangle and the pipeline monitoring point.

3.3.2. Constructing the dynamic topological relationship between the virtual observer and the roadway based on the static topological relationship

The construction of a dynamic topological relationship between a virtual observer and a roadway includes calculating a dynamic topological inclusion relationship between the virtual observer and the roadway. Whether the virtual observer is in the roadway is determined by calculating a relationship between the dynamic position coordinates of the virtual observer's inspection and an outer rectangle of the roadway.

3.3.3. Constructing a sequential space and metric space relationship of the virtual observer with equipment and pipeline monitoring points

The virtual observer uses the camera to simulate the human’s observation in the inspection process,

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including raising the head, lowering the head, turning the head, turning around. With the change of the action, the observation direction of the virtual observer changes accordingly. When constructing a sequential spatial relationship and a metric spatial relationship between the virtual observer and the equipment and pipeline monitoring point, we should firstly calculate the observation direction of the virtual observer and the angle with the equipment, the camera, and the pipeline monitoring point facing direction, and calculate the angle between the four vertical directions(up, down, left, and right) that the virtual observer observes and the direction of the device, camera, and pipeline monitoring point, so the sequential spatial relationship between the equipment, the camera, the pipeline monitoring point and the front, back, up, down, left and right of the observation direction of the virtual observer is obtained; and then, we calculate the distance and angle between the position of the virtual observer and the position of the equipment, camera, and pipeline monitoring point to obtain the metric spatial relationship of the distance and angle between the position of the equipment, camera, pipeline monitoring point and the position of the virtual observer. The construction of the sequential spatial relationship and the metric spatial relationship between the virtual observer and the equipment and pipeline monitoring point is to prepare for the subsequent setting of display rules.

3.4. Setting display rules based on the spatial position and observation direction of the virtual observer

The display rules of real-time data in the virtual inspection process are based on the spatial position of the virtual observer and the observation direction of the virtual observer in the current inspection, and the conditions set for the display of multiple types of real-time data to be met include: (1)meeting the set types of display by multiple types of real-time data, including the setting of video, environmental monitoring, automation, and intelligent equipment monitoring data of one or more types to be displayed at the same time (2) meeting the set display distance and display angle between multiple types of real-time data and the position of the virtual observer, including setting the maximum and minimum distance and the maximum and minimum angle of display for each type of video, environmental monitoring, automation and intelligent equipment monitoring data; (3) meeting the display direction and display position between multiple types of real-time data and the viewing direction of the virtual observer, including that environmental monitoring, automation and intelligent equipment monitoring data display direction is set to be opposite to the observation direction, and the video display direction is set to be the same or opposite to the observation direction or to be displayed at the same time; (4) meeting the set display relationship between the outsourcing rectangle of multiple types of equipment and the observation direction of the virtual observer, including setting the electromechanical equipment to be displayed intersecting with the observation direction of the virtual observer, that is, the real-time data of the equipment is displayed only when it intersects with the observation direction of the virtual observer.

3.5. Automatically calling real-time data based on the position and attitude of the virtual observer in real time

Based on the mine-wide multi-dimensional visual system, remote dynamic virtual inspection is carried out according to the configuration route and the requirements of the inspection logic. At the same time, on the basis of the spatial inspection position and the observation direction of the virtual observer, spatial relationship, and inspection logic, the real-time invocation is automatic, and the two-dimensional graphic, the three-dimensional scene, the four-dimensional temporal state scene and the digital twin are displayed on the same screen in the form of a single sub-window or a plurality of sub-windows. Wherein, the spatial relationship includes a static topological relationship between a roadway and equipment and pipelines constructed, and a dynamic topological relationship between the virtual observer and the roadway constructed on the basis of the static topological relationship, as well as a sequential spatial relationship and a metric spatial relationship between the virtual observer and the monitoring points of equipment and pipelines constructed; the inspection logic includes setting a display mode of the mine-wide multi-dimensional visual system and setting rules for displaying multiple types of real-time data in the inspection process; the display mode of the multi-dimensional visual system of the whole mine shaft is to display the number of the multi-dimensional visual system and the display contents of the main window and the sub-window at the same time in the inspection process.

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4. The specific implementation of multi-dimensional visual inspection virtual real synergy in mine

4.1. Constructing the multidimensional visual system of the whole mine based on the graphics processing platforms GIS or CAD

The multidimensional visual system of the whole mine is based on geographic coordinates data to build the whole mine two-dimensional graphics, three-dimensional scenes, four-dimensional temporal scenes and digital twins of the visual system. The geographic coordinate data include: geographic coordinate-based mining engineering map, roadway section design map, roadway sketch map, ventilation system map, underground equipment layout map, equipment design map, underground pipeline layout map, underground monitoring point layout map, and laser point cloud data. Two-dimensional graphics refers to visual graphics that express spatial objects in the form of (x, y). Three-dimensional scene is visual graphics that expresses spatial objects in the form of (x, y, z). A four-dimensional temporal scene is a visualization graph that expresses a spatial object in the form (x, y, z, t), where t is time. A digital twin is a visual graphic that maps physical spatial objects into digital space in the form of (x, y, z) or (x, y, z, t) and it can display physical spatial objects in two-way interaction. Based on graphic processing platforms such as GIS or CAD, the graphics, models, and scenes in the multidimensional visual system are integrated into a unified geodetic coordinate system, so that they have spatial correlation relationships.

4.2. Constructing geometric and attribute models of roadways, equipment and pipelines in the multi-dimensional visual system of the whole mine

Firstly, we need collect the equipment models involved in the underground coal mining, tunneling, mechatronics, transportation, ventilation and drainage systems, the equipment models of the monitoring and control, personnel positioning, emergency avoidance, forced-air self-rescue, water supply and rescue, and communication and liaison systems, as well as the responsive geographic coordinate data. And we need collect the data of underground water supply, drainage, slurry removal, ventilation and other pipelines based on geographic coordinates, as well as underground electric wires, network wires and other lines[1]. Secondly, the geometric models of the roadway, equipment and pipelines are constructed based on the geographic coordinate data; and then different attribute models are constructed to describe the attributes of the geometric models of the roadway, equipment and pipelines, which include: unique ID, center position of the geometric model, outer wrapping rectangle, and model orientation.

4.3. Constructing the relationship between virtual observer and roadway, equipment and pipeline in the multi-dimensional visual system

Firstly, the static topological relationship between the roadway, equipment and pipelines is constructed, including the network topological map of the roadway and the topological map of the monitoring points of equipment and pipelines in the roadway.

The topological map of the roadway is a topological network map formed by taking the starting point, midpoint, end point or intersection point of the roadway as the node, and the roadway as an arc segment, and the arc segment in the network topological map of the roadway contains attribute descriptions corresponding to the construction of the roadway.

The topology map of equipment and pipeline monitoring points is based on the topology map of the alleyway to store the IDs of equipment, video cameras, and pipeline monitoring points that have an inclusion relationship with the alleyway in the corresponding arc segments.

Based on the static topological relationship, the dynamic topological relationship between the virtual observer and the roadway is constructed. Specifically, the dynamic topological containment relationship between the virtual observer and the roadway is calculated, and whether the virtual observer is inside the roadway is determined by calculating the relationship between the dynamic position coordinates of the virtual observer's inspection and the outer rectangle of the roadway.

The specific construction of the sequential spatial relationship and metric spatial relationship between the virtual observer and the equipment and pipeline monitoring points is calculating the angle between the observation direction of the virtual observer and the facing direction of the equipment, camera, and pipeline monitoring points, as well as calculating the angle between the four vertical directions(up, down, left and right) that the virtual observer observes and the facing direction of the

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equipment, camera, and pipeline monitoring points. The directions are the same as those of the calculation if the angle is less than 90°, and if the angle is more than 90°, it is the opposite of the calculated direction, and the sequential spatial relationship between the equipment, camera, pipeline monitoring point and the observation direction of the virtual observer is obtained in the front, back, up, down, left and right directions.

The distance and angle between the position of the virtual observer and the position of the equipment, camera and pipeline monitoring point is calculated to obtain the metric spatial relationship of the distance and angle between the equipment, camera and pipeline monitoring point and the position of the virtual observer; The construction of the sequential spatial relationship and the metric spatial relationship between the virtual observer and the equipment and the pipeline monitoring point is to prepare for the subsequent setting of the display rules[2].

4.4. Collecting and transferring monitoring and control information in real time to the multi-dimensional visualization system of the whole mine

Real-time collection of monitoring and control information of environmental monitoring, comprehensive automation and smart equipment includes collecting real-time operation information, real-time spatial information and constructing the correspondence between real-time operation data and corresponding equipment. It includes the followings: (1) Spatial information of environmental monitoring, comprehensive automation and smart equipment is collected, including the position information and orientation information of the equipment, with the position information being the coordinates of the precise geodetic coordinate system where the equipment is located, and the orientation information being the positive orientation of the equipment. (2) Real-time operation information of environmental monitoring, integrated automation and smart equipment is collected. (3) The correspondence between real-time operation data and equipment is constructed, which mainly means that the equipment utilizes ID to bind real-time operation data with equipment, so that the real-time operation data has spatial location and orientation.

4.5. Inspecting dynamically and virtually in a distance according to the configured route on the basis of the multi-dimensional visual system of the whole mine

The rules are set for virtual inspection, and the set display distance and angle are met between various types of real-time data and the virtual observer's position, including setting the display maximum and minimum distance and display maximum and minimum angle for each type of video, environmental monitoring, automation and intelligent equipment monitoring data.

On the basis of the whole mine multi-dimensional visual system, inspection is dynamic and virtual in a distance according to the configuration route and the requirements of inspection logic. And at the same time, the two-dimensional graphic, three-dimensional scenes, four-dimensional temporal scenes and digital twins are transferred automatically in real time and displayed on the same screen in the form of a single window or multiple windows according to the inspection space position of the virtual observer, the observation direction, spatial relationship and inspection logic[3].

In the process of inspection, according to the inspection virtual observer position and virtual observer observation direction, the video, environmental monitoring, automation and intelligent equipment monitoring data which meet the inspection logic are automatically display; In addition, with the change of virtual observer action, the video, environmental monitoring, automation and intelligent equipment monitoring data which meet the conditions of the display are automatically called and displayed according to the virtual observer observation direction; Similarly, the video, environment monitoring, automation and smart equipment monitoring data that satisfy the display rules can be automatically switched while the inspection is carried out.

5. Conclusion

The virtual and real collaboration method of the multi-dimensional visual inspection in mine constructs the spatial relationship of topology, order and association between the roadway, equipment, pipeline, real-time data and the virtual observer of inspection in the multi-dimensional graphic system, and solves the problems that only manual interactive clicking can be viewed in the inspection process, or that only the video, environmental monitoring data, automation and intelligent equipment monitoring and control data within a certain distance right ahead can be viewed. The demand for

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real-time dynamic and automatic invocation of multimedia data that meets the observer's needs is realized according to the position, observation direction and spatial relationship of the virtual observer of the inspection, and the real-time collaboration between monitoring and surveillance data and virtual scenes is realized, as well as automatic correspondence to the inspection process.

References

[1] Chu Wenkai, Li Nan and Cao Rui (2022). 3D visualization technology for ultimate pit limit optimization in open pit mines. Journal of Geology (03), 278-284.

[2] Wang Xiaomin. (2021). Visualization research based on multidimensional geological hazard data. Computer Park, (03),378-380.

[3] Liu, Hongda. (2020). Research on the application of 3D visualization geophysical exploration technology in mine geological exploration. World Nonferrous Metals (03),125-126.