The Development and application of 3-D visual display platform for safety monitoring information of hydropower project

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Abstract. In the long-term project operation and safety management, the safety monitoring is used to monitor the project safety change and to identify and avoid project risk. As the eyes, ears and technical means of administration department, it can ensure the safety and can improve the efficiency of the project. How to display the monitoring information and results intuitively has been a constant pursuit of monitoring technicians. This paper introduces a kind of the monitoring data display platform based on the virtual reality technology and the interactive simulation technology. The platform will have a unified expression of the hydropower project applying the TST-VR virtual reality tools and 3-D modelling technology. It will set up the integrated visible virtual environment and realize the 3-D scene roaming, monitoring information query and other interactive control. The platform integrates the existing data resources of information system and displays all the information in an intuitive way, which is convenient for managers to query and manage, and can also meet the macro-control of superior management departments.

1. Overview

The monitoring of hydraulic structure uses sensors as tools. The measuring sites, lines and sections are constructed. The arrangement of measuring sites and measuring results are spatial distribution. The analysis of the monitoring results is generally a text description, form recording or process line graph (distribution graph). As for the size and position of the monitoring results, the technical personnel usually build the space distribution graph of the monitoring project and its magnitude and changes according to the location information of sensors, using the brain thinking. Such utilizing and display way of monitoring data, both the analyst and the report user need to be familiar with buildings arrangement and equipments installation enough. The utilization efficiency of monitoring information is very low [1].

By modern high technology such as virtual reality and interactive simulation technology [2-3], measuring site positions are expressed by the 3-d coordinate and the monitoring results information can also be easily displayed in the way of 3-d visualization through the computer. Denghua Zhong et al. [4] showed that integration and the interactive query analysis of the multi-source construction information and the 4-d visualization analysis of construction process of rockfill dam can be realized based on 3DGIS platform. It can provide important theory and technology support for rockfill dam construction control and management. Weiya Xu et al. [5] established a 3-d geological information model of high rock slope and realized the coupling visualization of slope excavation progress and
geological information. Yongdong Meng et al. [6] realized the virtual reality visualization of safety monitoring system and geological conditions of rock-mass high slope of hydropower station. Wenqi Sa et al. [7] realized the coupling of real-time simulation of the structure safety and progress of underground cavities during the construction period through the establishment of the real-time dynamic mapping relationship between the actual construction status set of underground cavities and 3-d full scale numerical simulation model. Yi Xiao et al. [8] realized the data management, analysis, virtual interactive display, 3-d dynamic data change and other functions of the safety monitoring information of the waterfall channel hydropower station by using the virtual reality technology.

Based on virtual reality and interactive simulation technology, we research and develop the display platform of monitoring data. Combining with underground cavities of a certain hydropower project in southwest of China, we realize the virtual environment, scene roaming, construction progress query and monitoring information interactive control. It can meet both the field engineering requirements and the macro scheduling of management department. The research results of the platform explored actively in the aspects of construction progress, monitoring information management and display.

2. The key technology of 3-d visualization of project
The traditional display platform is in the way of two-dimensional graphics, without the feeling of stereo and intuition. And 3-d visual display platform based on virtual reality technology will model all the objects in the engineering construction digitally. In the virtual scene, it can roam the whole project area in any height and any direction, so it can understand the 3-d image of project. So that the management department can monitor and manage the engineering more efficiently and timely.

The VR technology can generate a three-dimensional virtual world by computer simulation, provide users simulation about senses such as vision, hearing and touch, and let users observe things in three dimensions timely and freely. When the user moves, the computer can immediately perform complex calculations to transmit accurate 3-d images back to the scene. This technology integrates the latest achievement of computer graphics (CG) technology, computer simulation technology, artificial intelligence, sensing technology, display technology, network parallel processing and other technologies.

From a technical point of view, the virtual reality system has the following three basic characteristics: three "I" - immersion - interaction-imagination, which emphasizes the leading role of people in the virtual system. In the past people can only observe the results outside the computer system, and now the person can immerse into the environment created by the computer system. In the past people can only interact with the 1-dimensional digital information in the computing environment through the keyboard and mouse, and now the person can make interaction in multi-dimensional information environment through a variety of sensors. In the past people can only deepen the understanding of things through the quantitative calculation results, and now the person can possibly get perceptual and rational knowledge from qualitative and quantitative integrated environment and so as to deepen the concept and new idea [9].

3. The structural framework of 3-d informatization platform of project
A large-scale scene is often made up of lots of different complex objects. A hydropower project is generally consisted of several hydraulic constructions, and each construction includes all kinds of building and monitoring sensors in it. So they are hierarchical and inclusive. Objects such as monitoring sites can be regarded as special ‘parts’, and the whole project is a ‘product’ composed of these parts. We bring in the product data management and virtual reality technology and develop a display platform system which can manage and maintain the large-scale virtual scene. It can realize the effective management of the data such as the 3-d model, 2-d CAD drawings and monitoring results and configure the virtual environment flexibly according to the data to implement the 3-d visual display platform system based on VR and product data management technology. The system mainly involves the organization, management and display of the data information, and the corresponding system frameworks are the back-end data service module, the geographical information management
module and the front-end information representation module.

3.1 The back-end database module
The module is the basis of the whole system and stores the spatial information and attribute information data required by the system. The spatial data include 2-d line graph data, 3-d scene model data, image data and 3-d model data of each component. The attribute data mainly includes the information data and the texture data of components.

3.2 The geographic information management module
The module combines the geographical position and attribute data of the scene and constitute parts, can orient and query fast and accurately and can provide other services required by information representation, such as scheduling of terrain data when 3-d roaming, coordinates conversion in multi-dimensional information represented, etc.

3.3 The front-end information representation module
This module provides users with various information representation forms and operations users can do. A 3-d scene graph interface gives the user a feeling of being there, in which the user can move in a natural way, viewing the attribute data of the scene, various structure equipments and the location of positioning query. The 2-d map reflects the location and geographical relationship of the structures on the terrain, and is mainly used for the navigation of three-dimensional roaming, the rapid orienting of roaming location and the query of component information. The logic framework of platform is shown in figure 1, and the physical framework of platform is shown in figure 2.

![Figure 1. The logic framework of platform.](image1)

![Figure 2. The physical framework of platform.](image2)
The 3-d information management platform of project is an integrated platform of data, models, pictures and video based on a ‘virtual reality’ technology. The platform is intuitive, real-time and interactive, so it will be understood and applied by the user more easily than the traditional management platform. The 3-d information management platform of project uses the model as the independent object, so through the link to monitoring data of independent object, the user can operate the model object directly, which can make the data more directly and convenient for management. The functional framework is shown in figure 3.

![Figure 3. The functional framework of platform.](image)

4. Development and application of 3-d visual display platform for safety monitoring information

A hydropower project in the southwest of China arranges the main machine building, the main transformer room, surge-chamber, water diversion tunnel and the tailrace tunnel under the ground, and each single tunnel and big cavities form an interchange of underground cavern group structure. The safety monitoring data and results are important for the stability evaluation of surrounding rocks during the cavern construction. The 3-d visual display platform of the safety monitoring information can simulate vividly and query interactively the monitoring results in the process of construction, so it can display the safety status of the surrounding rocks real-time.

The platform system models the underground information unified. It expresses the underground space unified through TST - VR virtual reality tools and 3-d modeling technology, builds the integrated visible virtual environment and realizes 3-d scene roaming, information query and other interactive control.TST - VR simulation platform is the development software which integrates the polygonal modeling, the vector modeling and real-time rendering. It provides interface functions to manipulate database files and can add custom database entities, extension capabilities, extension/generation tools and algorithms, allowing for more in-depth development of application tools. The construction process of the platform system is shown in figure 4.
4.1 The development of 3-d roaming module of platform

The 3-d roaming module of 3-d visual display platform for safety monitoring information includes the following contents and functions:

(1) The geometric modeling: The system platform reconstructs the whole underground cavern group geometrically. It establishes geometric models of the underground water diversion power generation system through mathematical methods and inputs them into the computer. The geometric model is completely constructed in accordance with the CAD drawings provided by the first party so as to ensure the accuracy of the geometric model.

(2) The physical modeling: The system platform processes the color, the lighting, the material and the texture of the geometric model and will eventually convert the geometric figure element and its visual characteristics to graphics or image available for display. So the verisimilitude can be ensured.

(3) The scene setting: Before we render the 3-d scenes, the system platform sets relevant scene parameter values. These parameters include the properties of light sources (mirrors and diffuse light and environment light), light source azimuth (distance and direction), light and shade processing way (smooth or plat treatment) and the way of texture mapping.

(4) The model rendering: The 3-d space scene is transformed to the 2-d images on computer screen by projection. The system platform adopts the perspective projection technology so as to simulate the real world better.

(5) The realization of virtual roaming function: In the 3-d scene roaming, users can control the position, visual direction and reference direction of the view point by mouse or keyboard. When the position, direction and reference direction of the view point change, the object’s orientation in the scene relative to the user also changes.

The platform roaming effect is shown in figure 5.
4.2 The 3-d visual module of the construction progress simulation of underground caverns

The three-dimensional visual model is divided into blocks according to the construction plan and displays the 3-d visual model of the current construction progress of each cave real-time through changes in elevation and pile number data.

(1) The geometric modeling: According to CAD drawings, geometric models of each cavity are established. These models are accurate. According to the construction plan, the geometric models of each cavity are divided into layers and blocks. Independent layers and blocks have independent address numbers. The effect of stratification and fragmentation is shown in figure 6.

(2) The physical modeling: We set different colors, lighting, materials and textures for the independent layer and block of the geometric model of the cavity, so we can distinguish between finished and unfinished layers and blocks in the construction process.

(3) The parameter setting: We development the parameter setting interface of cavity construction progress simulation. Through the parameter setting of the construction way of the main machine building and the main transformer cavity layer and block, elevation, and the pile number, we can simulate the 3-d visual model real-time of the current construction progress of the main machine building, the main transformer cavity. The setting of construction progress is shown in figure 7.

(4) The background data: The background database is established to save the construction parameters entered in each period of time so as to provide reliable construction data and experience parameters for subsequent construction.

(5) The progress playback: The progress playback function is developed to browse the 3-d visual simulation models of the construction process of each cavy chamber real-time.
4.3 The module of sensors layout, display and query

By data of elevation, pile number and so on, the monitoring sensor model is added to the 3-d visual scene, which is classified according to the different function and has independent ID number.

(1) The establishment of sensors model: We establish 3-d visual models of different monitoring sensors, such as multi-point displacement meter, bolt stress meter and anchor rope dynamometer. The sensors model is shown in figure 8.

(2) The differentiation of sensors model: We set different colors, lighting, materials and textures for different sensors, so users can distinguish different sensors more quickly and accurately.

(3) The installation of sensors model: We development the module of sensors installation. Through the module users can add 3-d visual model of sensors at any position in the scene, and can operate the 3-d visual model of sensors such as rotation, translation, scaling and so on. At the same time users can set independent ID number for sensors.

(4) The identification of sensors model: Through the identification function of sensors model,
obvious identifications can be added to the sensors, so users can distinguish and query easily. The sensors identification is shown in figure 9.

Figure 8. The sensors model.

Figure 9. The sensors identification.

Sensors are set and geological sections are arranged for underground caverns. When we select different geological sections, sensors on different sections can be displayed.

(1) The indoor scene roaming of underground caverns: The 3-d visual model of indoor scenes of underground caverns is established. Users can know the indoor scenes of the caverns after construction through the roaming of the indoor scenes. The effect of the roaming of the indoor scenes is shown in figure 10.

(2) The geological section: According to the installation location of sensors, the geological section of sensor installation location is established. By choosing different geological sections, the 3-d scene of the section can be opened and the 3-d scene of sensor installation of the section can be known
intuitively. The identification of the geological section is set at the same time. The 3-d display effect of sensors layout for section monitoring is shown in figure 11.

Figure 10. The effect of the roaming of the indoor scenes.

Figure 11. The 3-d display effect of sensors layout for section monitoring.

4.4 The display module of monitoring results

(1) The display module of line graph of time series processes
We can choose any sensor of measuring sites by clicking mouse in the system platform. Through the function module of process graph query, we can open the process line graph of the measuring site, with measuring values changing over time. According to the need, the process graph interface displays the name, number, buried depth of measuring sites, measuring original values, physical valid values quantities, and date and so on. The process line of measuring sites is showed in figure 12.

(2) The display module of measurement distribution diagram
The system platform can set a certain type or group of measuring sites of the same or different monitoring sections as a distribution unit, and can set a fixed ID for it. By clicking the mouse at the distribution unit, the measuring value distribution at the set time can be viewed. The distribution of
measuring values is shown in figure 13.

Figure 12. The process line of measuring sites.

Figure 13. The distribution of measuring values.

5. Conclusions
The 3-d information management platform of hydropower project is a combination of modern information technology, construction technology and management technology. It plays an important role in realizing the goal of project construction and is used widely. In the future it will be used more and more widely. The 3-d information management platform system developed in this project uses 3-d models to realize dynamic safety visualization analysis of construction process. It can not only simulate the real geological form of the project, making the dynamic graph more accurate, vivid and realistic, but also can know the geological conditions and deformation stress of underground cavern groups more. So the 3-d information management platform system can provide more information for project decision-making and can help the analysis and confirmation of construction plans.

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