Surface Mine System Simulation and Safety Risk Management

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Abstract: Modern surface mines, either mono-system or multi-systems, need a large fleet of equipment consisting of excavators, loaders, haulers and auxiliary machines. Presently, the complexity of the system, the interference between sub-systems and the lag in management skills has been a bottle neck for improving productivity of the system. Based on the fact that the traditional tools for safety analysis have been insufficient to evaluate systematically and dynamically the safety risks, this paper tries to create a virtual reality tool consisting of human, machine and mines, using Pro/E and the 3D MAX software in order to evaluate visually the operations of typical mining equipment, such as the bucket wheel excavator (BWE), the shovel, the truck and the dragline. Within this virtual world, the behavior of the system, such as interaction, interference and potential risk can be replayed and reviewed visually. The objective of the study is to identify the critical safety issues of the system and to provide a convenient and powerful tool for safety training and safety management.

Key words: surface mine; virtual reality; mining system; risk identification

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1 Background

As a consequence of the expansion of existing pits such as Zhungeer and Pingshuo and the development of greenfield projects such as Shengli and Baiyinhua, the total production of surface mines in China keeps increasing yearly and is expected to increase by up to 200 000 000 t/a by the year 2010. The system of surface mining has been developing towards larger equipment, continuous systems and fewer segments[1]. Advances in technology increase productivity and reduce unit costs for mines. But at the same time it also raises more challenges, such as more complexity in production organization, subsystem collaboration, equipment operation, etc. Owing to the number of large pieces of equipment, the complexity of the organization and the interference between sub-systems, management skills have lagged behind this development and are insufficient to fulfill the expectations from the new surface mining system in terms of elemental risk analysis and identification of critical issues.

Virtual reality (VR) is a technology which allows users to interact with a computer-simulated environment, be it a real or imagined one. It has gradually become an important tool for various scenarios. VR technology incorporates a three dimensional virtual environment, digital simulation experimentation and human interaction.

This paper tried to create a VR world consisting of human, machine and mines, using Pro-E and the 3D MAX software, to evaluate visually the operations of typical mining equipment, such as BWEs, shovels, trucks and draglines. Within this visual world, the behavior of the system, such as interaction, interference and potential risk can be replayed and reviewed visually. The objective of the study is to identify the critical safety issues of the system and to provide a convenient and powerful tool for safety training and safety management.

2 Objectives

2.1 Simulation of surface mining systems

Different methods are adopted by surface mines depending on rock properties, geology and infrastructures. For example, a BWE and belt-conveyor system is suitable for top soil or soft overburden stripping. A shovel-truck system is versatile and suitable for moving most coal and overburden. At the start, the study created three dimensional solid models for the BWE, the shovel, the truck, the dragline, the belt conveyor and the spoil spreader. The pit topography and bench slope dimension were also digitized in three dimensions. All of these were prepared for the mining system simulation for further study.

2.2 Risks identification of equipment and operation

The degree of the risk is defined based on safety

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regulations and previous research. Within the virtual world, the safety zone and the degree of the risk are spatially represented by different colors. For example, red refers to a high level of danger, yellow refers to medium danger and green refers to a low danger level. Because the mining system includes a number of mobile machines and miners, the risk zone and its degree vary when the equipment or the miner moves. This virtual system can also illustrate variations at different stages.

2.3 Safety technique training on personnel

In China, the BWE technology has not been fully recognized and experienced and the first dragline is, so far, still at the assembly stage. The practice is extremely inadequate. Therefore, the probability of an accident is very high and safety issues are critical. The VR tool provides a virtual environment that can be viewed from multiple angles and points; the operators immersed in the scene can quickly understand the operational procedures, operating regulations, safety risks and potential accidents. As a result, operators can be trained in a timely and cost-effective manner.

3 Technique Realization

The organization of the study is shown in Fig. 1[5-7].

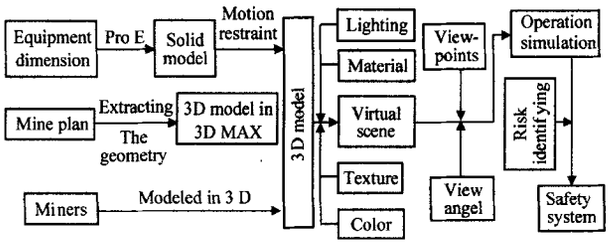

Fig. 1 Organization of the study

3.1 Object modeling

Modeling of objects is the core of virtual reality. The complex mining system, including the human-machine-mines, is represented through a number of models created in the computer. The objects can be divided into two categories depending on their characteristics.

One is a regular shape represented by a few parameters. These objects can be batch generated and reused. An example is generic mining equipment. The other category is irregularly shaped, such as mine topography and the human body. Two different types of software were used in this study for these two categories of objects.

1) Mining equipment

Around the world, typical surface mining equipment includes the shovel, the BWE, the dragline, the belt conveyer, the truck and the dozer. The modeling of equipment is of critical importance in system modeling. First, the technical specification and parameters of the equipment, such as bucket capacity and boom length are collected by field investigation. Secondly, the constraints between components, the connections and the degree of freedom, the equipment operation and the material flow are analyzed in detail.

Pro/Engineering (Pro/E) software was utilized to create the three dimensional computer models. Pro/E is a 3D CAD/CAM software. It has powerful functions, such as component modeling and product assembly. As well, the Pro/E file has been a well-accepted format that can be imported by many other 3D systems. The equipment models created by Pro/E were exported to 3D MAX, after which the motion mechanism was defined in accordance with real functions, the degree of freedom and logical relationships.

2) Mine environment

The surface mine has unique characteristics which are better than those in underground mines; for example, benches, faces and haul roads are relatively regular in shape; bench heights and widths are usually unified in mines. In order to reduce the work of the model while properly representing the actual environment of the open pit, the system utilized 3D MAX software to create a virtual environment. Three-dimensional coordinates of the topography points were obtained and imported into the virtual environment. In addition, the texture, color of the soil, the rock and the coal were submitted for better visual effects.

3.2 Scenic synthesis

The open pit, equipment and personnel are located at respective spatial positions, synthesizing scenes, producing a virtual environment.

3.3 Cruising and driving

Given the cruising path and the respective view points, a virtual tour can be experienced in the virtual environment. The safety range of people and machines can be observed and evaluated. The safety risk can be identified and indicated with highly visible light color.

4 Application Example

As an example, we present in VR one open-pit mine with a coal production of 20 000 000 t/a and an overburden of 89 000 000 m^3. The working area is approximately 2 000 m wide 4 000 m long. More than 220 large pieces of equipment, including 2 BWE, 10 shovels and 82 trucks are in operation at present.

A few methods are utilized in the mine: top soil is stripped by a BWE-belt conveyor system, about 50 m overburden above the coal seam is removed by a dragline, the rest of the overburden and the coal is loaded and hauled by fleet of shovels and trucks. The BWE in the mine was the first one introduced to