Risk Behavior Simulation in Virtual Environment

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Abstract—Because of the complexity of risk behaviors in stressful environment, the diagnosis and prevention of human risk behaviors is often elusive and difficult. Combined with virtual reality and Multi-agent technology, a Multi-agent virtual environment for risk behaviors simulation was proposed to assist risk analysis and prevention in underground coalmine. Emphasis was put on simulating individual miner behaviors during coalmine risk accidents. Incorporated miners’ cognitive processes and internal state characteristics, the behaviors of virtual miner are constructed by a set of parameterized basic actions and are controlled by personalized action selection mechanism. Through hierarchical pathfinding model, virtual miner can autonomously explore virtual mine to simulate human risk behaviors during risk accidents in underground mine. The simulating results of risk accidents show the effectiveness of proposed approaches to explore human risk behaviors in underground coalmine virtual environment.

Keywords- virtual agent, risk behavior, virtual environment, virtual human

I. INTRODUCTION

Human behaviors in stressful environment are complex phenomena, involving a broad range of physical, environmental, psychological and social factors, many of which have not been well understood. For example, in underground mine, some normally safe behaving and experienced persons may spontaneously engage in unsafe acts that have high risks of serious injury. Therefore, the diagnosis and prevention of risk behaviors in underground mine environment is often elusive and difficult.

Virtual Reality (VR) or Virtual Environment (VE) technology brings forward an effective approach to analyze human risk behaviors. In mining industry, VR is increasingly being used in risk accident simulation, miner training, equipment simulation, and risk evaluation [1-2]. Reference [3] has introduced a generic safety training tool, SAFE-VR, which can be used for accident reconstruction, space planning, risk assessment, hazard spotting, equipment operation training, etc. However, SAFE-VR is not suitable for modeling human risk behaviors. Reference [4] has developed PC-based VR hazard awareness training simulator. The trainee’s movement is achieved via a standard computer joystick and interaction with the hazards and the selection of corrective actions are via a touch-screen monitor. After identifying one of the hazards, the trainee is required to select the appropriate corrective action from on-screen button icons. When successfully correcting the situation, the trainee is able to proceed safely. If, however, the hazard is not identified or correctly made safe and the trainee ‘walks’ underneath, then a series of visual and audio effects indicate the disastrous outcome and likely injury. But they don’t pay much attention on modeling the virtual miner’s risk behaviors, especially miner’s cognition and personalities. Reference [5] has successfully developed a 3D computer model as the primary means to aid in studying boom arm vertical speed for roof bolting machines to determine the impact that appendage speed had on an operator’s risk of experiencing a contact. They simulate the operator's risk behaviors only by random motions, and the behaviors of their virtual miner also are greatly limited.

In this paper, we combined with VR and multi-agent technology to describe a Multi-agent virtual environment for risk behaviors simulation in underground mine. The purpose is to yield better understandings of human factors in stress situation and to assist risk analysis and prevention in coalmine. This paper puts emphasis on the simulation of individual behaviors during underground risk accidents. The behaviors of our virtual miner are constructed by a set of parameterized basic actions and are controlled by personalized action selection mechanism, which incorporates miners’ cognitive processes and personalities’ characteristics. Reference [5] has successfully developed a 3D computer model as the primary means to aid in studying boom arm vertical speed for roof bolting machines to determine the impact that appendage speed had on an operator’s risk of experiencing a contact. They simulate the operator's risk behaviors only by random motions, and the behaviors of their virtual miner also are greatly limited.

Through hierarchical pathfinding model, our virtual miner can autonomously explore virtual mine environment to simulate risk behaviors mechanism under stress situation in underground mine environment. Although many behavioral models of virtual human are now available, due to the scarcity of human and social behavioral data in underground coalmine, many of these models can’t be used in coalmine virtual environment. Our work is significative in the context of modeling human risk behaviors in underground coalmine and of realizing virtual miner model for taking into consideration of miners’ cognitive processes and personalities.

This paper is organized as follows: Section 2 discusses the proposed risk behavior simulation environment. In section 3, we introduce the modeling approaches of human
risk behaviors. Section 4 introduces the path planning algorithm. Section 5 presents a simulating case of underground risk accident. Finally, we make some conclusions in section 6.

II. RISK BEHAVIORS SIMULATION ENVIRONMENT

Based on Multi-agent technology, risk behavior simulation environment was modeled as a three-tiered architecture, as shown in Fig.1. The bottom is simulation platform layer, the middle is Multi-agent environment layer, and the upper is intelligent man-machine interface layer.

III. HUMAN RISK BEHAVIOR MODELING

In order to effectively simulate the human risk behaviors in stress situation of underground mine, behaviors of autonomous virtual miner are constructed by a set of basic actions and are controlled by personalized action selection mechanism, which correspond to the internal states of virtual miner. Basic actions are parameterized and serve as
behavioral building blocks. Thus, these actions can be largely reused and combined to the complex actions to represent specific risk behavior.

As an implementation of the low-level motor levels, we employ a human animation software package DI-Guy [6], which provides textured human characters with basic motor skills. Furthermore, our virtual miner is equipped with a visual sensor using the ray tracing method [7]. By casting laser rays from the eye position of an agent within a visual angle, virtual miner can compute the intersection of a ray and the near object, which allows it to determine the geometrical distance from the sensor to the intersecting object and the type of the object that the ray intersects.

A. Parameterized basic action

Parameterized action representations specification for virtual human was introduced in [8], which provides a structure for action representation but the actual lists of actions and the parameters for each specific action were not defined. Different from maintenance simulation, virtual miner’s basic actions are oriented to the typical application of risk behavior simulation in mine virtual environment, which reflects the cognitive process and personalities of underground miners more by virtual human’s movement, posture and expression.

We currently attempted to define a set of basic actions including three types of motion, gesture and operation. These basic actions are described by Finite-State Machines (FSM) and/or Hierarchical Finite-State Machines (HFSM). The basic actions of motion class include Go_ahead, Stand, Sit_down, Run_away, Stride_over, Side_Walk, Crawl_Walk, Reach_for_Position, Look_at_Position, etc; The basic gesture actions include Storlling, Power_Walk, Stagger_walk, Pronning, Shaking, Fall_to_Ground, Tired, Choking, etc; The basic actions of operation class include Turn_on_Device, Open_Door, Close_Door, Sweep_Tunnel, Kicking, Throwing, Hammer_at, etc. These basic actions are independent semantically and can be enriched gradually. Some typical actions are shown as Fig.3.

B. Personalized action selection

Virtual human action selection mechanism determines its decision-making process and controls its behavioral hierarchy at a high level. When a certain combination of internal state variable value and proper external situation is perceived, the action selection mechanism will initiate an appropriate behavior to fulfill the desire indicated by the internal state. For example, if a tired miner sees a safety seat, he will probably go and sit down to take a rest. In case more than one desire awaits fulfillment, the most important desire ranked by the action selection mechanism receives the highest priority. Finally, once a desire is fulfilled, the value of the associated internal state variable begins to change back asymptotically to its nominal value.

In virtual coalmine environment, we classify miners by their job. Each type of miner has an associated action selection mechanism with behavior-triggering combinations of internal state thresholds and situation patterns set accordingly. For safety inspector, When the current site must conduct safety checking (such as measuring environmental parameters, inspecting equipment running status, etc.), virtual miners will first complete the safety checking task; when the task is not very urgent, but safety checker’s fear variable value exceeds a predetermined value, he would choose to flee the site; when he is hurried in going to next site, virtual miner will pass away quickly; and when the miners tired, he will likely choose the appropriate place to rest until the value of its internal state variable back to normal levels.

IV. Hierarchical Path Planning

Path planning is one of the most important capabilities for autonomous agent. Coalmine is a large-scale environment. In order to cut down the CPU overhead of pathfinding, we represent virtual mine by a hierarchical model for path planning of different granularities—one coarse, one fine, which includes a topological map and a Grid map, shown in Fig.4.

At the upper level, a topological graph represents the relations of between different parts of virtual mine. In this graph, nodes correspond to region of intersections or stopes in underground mine, and edges between nodes denote the drifts, which is horizontal underground opening and represents accessibility between nodes. At the bottom level, we represent the regions of nodes in topological graph by Grid map to generate configuration space.
During pathfinding, the planner firstly searches for a shortest path between nodes by Dijkstra algorithm [9] to generate a set of navigated nodes, then agent takes use of the coarsely grained navigated nodes to go ahead. When a navigated nodes region requires a more fine path, the planner searches for the local space of navigated nodes by A* [9]. In this way searches of the finely grained path are kept shallow, and therefore quick. Fig.5 shows a local pathfinding of an intersection in mine shaft station by A*.

![Figure 5. Path planning for virtual mine](image)

**VI. ACCIDENTS SIMULATION**

In underground coal mine, all rules and regulations must be strictly abided to maintain a high degree of vigilance to all risk sources. Based on VR and Multi-agent technology, we developed a risk behaviors simulation environment to achieve risk analysis and prevention in underground mine. A typical case is to assess the procedural knowledge of operation rules and regulations for underground miner.

At begin of simulation, user can configure virtual mine environment model and virtual miner’s attributes by interactive interface. During simulation, virtual miner agent will make a path plan first according to received commands, and then go ahead along with the navigated path. In the course of moving, the virtual miner agent may encounter some obstacles or hazards such as moving tramcar, unsupported roof, uncovered holes, uneven surfaces or electrical cables. Normally, virtual agent can autonomously avoid these obstacles by its basic reactive behaviors. However, in simulated accidents, a miner is passing through a roadway tiredly and cannot take notice of a moving mine car faraway in the drift. Subsequently, virtual miner was hit badly by the mine car when he is close to the track. Fig.6 is some screenshots of the simulated accident.

![Figure 6. Case simulation](image)

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**ACKNOWLEDGMENT**

This work is supported by Nature Science Found of China (50804061, 60905066), Natural Science Foundation Project of CQ CSTC (CSTC, 2009BB2281), and Chongqing Education Administration Program Foundation Project (KJ080514, KJ080509).


