Mine Automation and Data Analytics

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Virtual Reality Application in Mining

Welcome to my course. In this lecture, we will discuss the VR in the perspective of the mining industry, and specifically, we will try to focus on a few case studies that have already been done in different countries. So, in this lesson, we will cover the following. The challenges for the VR in the mining industry and we are going to discuss three case studies. One is a virtual reality collaboration planning simulator and its method for three machines in a fully mechanized coal mine phase. Second is a virtual reality for mine safety training in South Africa and third head mounted display based intuitive virtual reality training system for the mining industry.

Challenges for VR in the mining industry. Lack of strategic and collaborative development in VR for mining till now and the project often lack a roadmap or strategic plan leading to ad hoc development. Significant time and resources are required for the development of the VR system and for that it often involve several years and a team of developers is required for the same. Support is required to prevent the VR simulation for becoming obsolete and due to technological advancement is going on in all the sector in the technology.

The VR development requires skilled personnel with a detailed understanding of simulation principle because VR required simulation of different scene in different environment to virtually reproduce the real scene in the virtual world. The VR applications in mining have been limited mainly to training and, with untapped potential in other areas like education, risk assessment, product development and emerging technologies. So, let us go to our case study, a virtual reality collaborative planning simulator and its method for three machines in a fully mechanized coal mining phase. So this case study is basically tried to deal with an underground mines operating with shear, weld conveyor and the, power support and hydraulic system. Basically, it is a long wall phase.

So we know from the background of longwall mining that these machines are very, very complex, and these machines have some connection and interrelationship and dependency. So this particular mathematical model tried to focus on developing a simulator based on an agent theory, multi-agent theory, how these machines are interacting with each other and where the interaction is poor, how it is resulted, where the interaction is better, how it resulted. So it basically focus on tandem applications that every machines are operating in tandem with relation to each other and finally deliberating what is the need, that is production and producing safely with supporting appropriately the room. So this is basically the exercise been done, and it is basically published in an international journal. So, we try to explain what is basically done in this particular paper, and this particular paper is based on the VR system and the simulator they have used.

So this is one module of this particular framework, FM unity sim. This FM unity sim is based on the collaborative mathematical model of three machines in a dynamic environment and the multi-agent system theory, mass theory. The FM unity sim defines the virtual behaviours of three machines and their interaction with virtual environment using C programming in the unity 3D, another module, another basically the portal where we basically do the virtual simulation. The purpose is to enable the visualization of the entire planning process. So this particular work is also tried to focus and given an understanding how these machines are interacting and what is the final result so that user, those who are using, they can get a real view what is happening in the long-world phase.

FM unity sim allow the acquisition and analysis of all relevant process data. So this FM unity basically collect all the data and simulate based on that and basically developed a perception. So this is basically the FM unity sim. So this is module have basically three layers if you see. Here the collaborative mathematical model is working between the CRR, scrapper conveyor, hydraulic support and there are other component like environment and the hydraulic system.

So these are basically agents, basically taking action, taking a role in the system. So these are basically interacting with each other and finally cutting the coal, transporting the coal safely and supporting the rope adequately. So here, based on this collaborative model, this is basically the inherent model, and here they are basically developing the perception. They are analyzing it and they are trying to control the process. So, they are trying to establish control over the process.

So, this is virtually done. So perception, analyze and control, this is basically the mass theory, multi-agent theory, how these machines should interact, how they are interacting and what is the final outcome. So, what level of change is required? So, these basically adjust mutually among themselves. And then here is the unity 3D, this is the visualization.

Agent theory, virtual sensor, virtual sensor is basically just like a real sensor that collect the data here, virtual sensor collect the virtual data about the virtual scene and the information sensing. Here is XML data, XML data about the geology, about the rock, about the coal and everything. So, these are basically the virtual motion. So, from time to time, the scene will change. So that has to be displayed on a 3D screen.

That is basically the work of the unity 3D. So here, basically, the total module is the FM unity simulator. So, this simulator basically simulates these conditions in running conditions. You can see in the inherent model then running data. So it collect data when scraper come back doing something, shear cutting coal.

So, all this data is basically updated. So these are all updated on the FM unity sim. Collaborative mathematical model to three machines. Coordination process of three machines in accordance with shear that is very important. So here synchronization of this operation is very, very essential, and that is to be understood by the training people that yes it is required and when they will be basically given the responsibility to look after this phase, they will keep informed and they will keep track of these particular things.

Different actions of hydraulic supports. Those in front of the shear are flap out and, while those at the rear side in front of the front to support the suspended roof and coal wall after coal cutting. After sliding advance, then hydraulic support push the scraper conveyor close to the coal wall side and load falling coal for the cement means for the transportation. So, this is basically the interaction. So here, the CRR is the central theme.

So, all these machines work in close coordination with the CRR. So CRR is basically connected with the hydraulic support system and the hydraulic system. So, the hydraulic system is basically responsible for giving the required amount of hydraulic pressure. So pressure and amount and here another is the amount. So amount is fine tuned depending upon the necessity, and these hydraulic systems support the hydraulic support system. and based on the working condition, this hydraulic support system pressure is fixed and based on their condition perception after hydraulic support, perception other hydraulic supports based on the data and these basically is in close coordination with the CRR during the advancing support mode as well as during the reaction.

So, this is basically close cooperation with the hydraulic support system with the CRR. And the CRR is also closely connected with the scraper conveyor for the running track as well as for the transporting coal, coal from the full coal phase. So this way, it is connected. All these basically are connected two way. Based on the response of that particular machine, this machine will do this next.

So based on these tasks, again this particular information sent back to the another machine that you do it. So this communication is two way communication. And here CRR is basically is also connected with the environment in particular here environment is considering all environment, the rock quality, the rock behavior and then the environment surrounding environment in the coal phase. So, this CRR is basically an interface between coal and rock, and the identification is based on that. So based on that identification environment reaction, so reaction is basically directly impact the hydraulic support system.

So based on that hydraulic support, again, it will react, and based on the necessity, it will raise the pressure. And here the scraper conveyor is connected with the environment because scraper conveyor need to be straight. And this basically shape the accidental collapsing. So this basically have to mention the straightness of the bell conveyor, scraper conveyor with the situation. So this is hydraulic support system is also connected with that scraper conveyor response to making and continuing a straight shape.

And these basically finally all these interaction basically deals the multi-agent theory, how these machines and different agent are interacting with each other, what kind of information exchange is going on. So, this is basically the principle proposal of the multi-agent theory. Overall goal of coordinating three machines. Automatically moving coal mining equipment, then avoiding interference between CRR and hydraulic support and maintaining suitable running posture and straightness of scraper conveyor. So we have to keep these coordination in close loop so that these are basically maintained.

So, the straightness of the scraper conveyor is one must thing, and we should not interfere between the CRR and the hydraulic support, and all these machines should run automatically. Effectively managing coal wall and roof, amount of support, amount of low pressure to be exerted in the hydraulic system. Ensuring hydraulic support strength meets the specified value. What is the required support required that is basically supplied by the hydraulic system. So, this is basically the core of this particular simulator.

So these, basically as better and better understanding will develop, we can build a better and better interactive simulator and model. Influencing factors in three machines for different agents. Influencing factors in three machines for different geological conditions at the coal mining phase. Comprehensive organization ability to synthesize, optimize and control information from the underground environment, equipment conditions, supplier devices, CRR running speed, and scraper conveyor loads. So these are basically the factors that basically changes depending upon different geological conditions in the mining phase.

Adaptation and optimization capabilities to automatically adjust CRR haulage speed, advancing mode numbers and parameters according to various production scenarios and roof conditions. Collaborative planning model based on a multi-agent system. Coordination and cooperation are the core aspect of multi-agent analysis. So coordination involves enabling knowledge, expectation, intentions, planning and action of agent to collaborate towards a common goal. Coordination in a multi-agent system is a process where all agents interact to achieve a common goal in a compatible and harmonious manner while avoiding deadlock or mutual locks.

So here we see that these machines, here we can see that there are virtual sensors, there are virtual sensors. So based on these operations and actions, here different informations are collected, data is collected. Here is the scraper conveyor agent, CRR agent, and hydraulic system agent. This is the hydraulic support agent. So now you see the CRR, so information processing is done, different information is collected, how much pressure was operated, what was the speed, what was the cutting height and so on and so forth.

So these information processing done based on that a perception developed, how these machines function. So once that is developed, then we can establish control about the system. So this is equally applicable for all these machines, information processing, perception and control. So information processing is the core, that is of the core of the multi-agent system as well. So that basically collect information and based on that developed a perception model and finally establish control over the system.

So this is equally applicable for all these machines. So here you can see the underground mine environment where all these machines working in tandem and all are connected. You see, the virtual CRR agent is connected to the hydraulic system agent, and it is basically connected to the hydraulic support system that is also connected with the scraper conveyor agent and the scraper conveyor system. So all these are basically interacting among themselves towards the common goal of continuously operating the machines and producing the highest amount of core. So, in this study, the CRR, scraper conveyor, grouped hydraulic support, hydraulic system and underground environment are treated as agents.

So, these agents exchange and sense information with each other, influencing and controlling their behaviors. Interaction among all agents and the environment are crucial for effectively cutting and transporting coal in the context of the three machines. VR planning method. In a unity 3D VR environment, virtual equipment can be controlled using program C script based on collaborative mathematical and planning model control functions of different agents. Agent 1 controls the virtual CRR enabling coordinated motion between the rocker arm and the vertical steering cylinder and simulating CRR hallways speed and direction.

Agent 2 controls the virtual scraper conveyor, allowing adaptive placement of the virtual floor, pushing itself to the coal wall side and simulating coal transport and capacity detection. Agent 3 controls the hydraulic supports, facilitating movement such as setting and reacting legs, advancing supports and pushing the conveyor. Agent 4 controls the hydraulic system, providing hydraulic oil for hydraulic support based on different conditions. This is a vital one because these hydraulic system supports the hydraulic support and maintain the straightness of the conveyor belt and also this basically helps to maintain the amount of support required in the hydraulic support system. Agent 5 controls the virtual environment constructing a virtual roof and floor from the XML data assigned by the user to simulate mine pressure and broken roof.

This is the model repair result. So, a different response has been received based on that model has been repaired in real condition. It is here. Here it is the real condition and this is the virtual simulated conditions. 3D model of 3 machines obtaining and repairing 3D models in UG that is unigraphs Nx process. Scene mapping and referencing full set of drawing, scope, external dimension are precisely model.

Limitations, internal transmission structure are disregarded due to software and hardware constant and that is also not required for this particular training. Conversion to Unity 3D compatible format. Initial format was a 3D model obtained in UG is, exported in STL format, and then conversion converted to FBX format using 3D max. Integrating with Unity 3D, importing the FBX format is imported into Unity 3D. Then outcome is established virtual model consistent with physical and counterparts.

Model for the underground environment. The underground environment involves various types of variable including roof height, mine pressure and degree of breakage. To facilitate planning, the floor is assumed to be ideally flat and the roof height is describing using 100 points of the cutting height of the front drum collected from the actual underground cold wall. Mine pressure and breakage conditions are generated in virtual scene based on settings input by users into GUI module. GUI interface. GUI interface can set up different initial conditions by entering different planning parameters.

It is mainly divided into six modules. First module is the module of geological terrain parameter is a general overview of underground geological environment which includes the deep angle of the cold scene, the degree of broken roof and mine pressure regulation. The second module, the module of the roof and floor parameters, is responsible for the roof and floor parameters, which determine the generation of the virtual roof and floor in the FM unity simulator. Third module, the module of cold cutting method and process parameters includes the selection of cold cutting methods and three rules between the shearer and hydraulic supports. Fourth module, the module of the shearer parameters contain the movement and performance parameters such as scope and acceleration of the shear or hollow speed, the scope of the permitted follower distance and the virtual current of the motor. Fifth module, the module of the scrapper conveyor parameters include the movement and performance parameters such as the scope of the chain speed, power of the motor, detection of straightness and collapse probability of the cold wall.

Sixth module, the module of the hydraulic support parameter and hydraulic system include the movement and performance parameters such as total amount, pressure and the form of hydraulic system. So, this is basically the mutual perception between the shearer and hydraulic support. Here is the flap out, then the virtual roof, scrapper conveyor here, this is the shearer, then hydraulic support, this is basically cross grouping advancing mode. This is an S-shape bending selection, and it is the face, it is the shearer, and this is the support. So another case study, this is virtual relative for mine safety training in South Africa.

So once introduced to the virtual simulator, the trainee retains the knowledge and skills which can be further developed with subsequent exposure, enhancing the overall technological competence of the workforce, and that is basically the need why the VR module of the training program is required. So without sending the operator miners into the actual mining conditions, we can basically train them in a virtual simulator so that they can get a good amount of knowledge about the perspective where the operator role is crucial. It increase familiarity with technology benefits, the mining industry as a whole, particularly the technology adoption is increasing. And VR shows promise for meaningful application in South African mine training especially for hazard awareness training. The training simulator, the development of a pre-prototype VR mine model and an industry survey helped identify the requirement and feature necessary for a VR simulator suitable for mine hazard awareness training.

The factors considered included the purpose of the application, the target users, trainee interaction, trainee evaluation and trainer instructor interaction. Basic system components for the VR simulator were assembled, and the software programming was undertaken to create the necessary virtual environment. The PC window-based simulator represent a portion of a stove, medium to deep level gold mine, specifically Elan's Rand gold mine. So here it is, the trainee. Trainee has a joystick interacting with the touch screen or in the computer.

Here there are some sound system and that basically connect with the VGA splitter box, PC with the WTK, then keyword, standard computer monitor, mouse and here is the instructor. So instructor is giving some amount of training to the trainee and trainee is interacting in the environment and based on this interaction trainee is learned about the specific conditions in the mine. So the virtual stove include typical object and major hazards such as loose rock that can fall as the trainee navigate the environment. Trainee movement through the VR stove is achieved using a standard computer joystick with interaction and selection of corrective action done by a touch screen monitor. Additional functions and control sequences for training instructor are accessible via the keyboard including loading, resetting hazard, activating scoring and evaluation module, making adjustment to the model.

So these are the scenes. Here is the general view of the inside the VR stove main travelling way and general viewer inside VR stove working face. This is the loose rock you can see. Loose rock waiting to fall on the unsuspecting trainee. So trainee has to identify where is the loose rock is so that he can instruct or he can specify, he can inform to the mine that here is the support record now.

Loose rock is safely supported now the support is erected. So these, basically the miner is the joystick interacting with the wall, understanding the condition of the wall and the roof and based on that, this support direction is done. So how these are basically done, how the users that are trainee basically identified based on that there is a score and based on that score the instructor will basically inform that how much amount of training is done and how much these miners are competent to be sent in a real mining condition. Training must identify hazards and select appropriate corrective actions using on screen button icon. Successful correction allows the trainee to proceed safely, while failure results in visual and audio cues indicating potential injury. A scoring feature record and evaluate the trainee session saving data to hard disk for analysis.

From the analysis VR group rating 77% for the good level of realism in the VR material was comparable to the video group rating 94% for the conventional video material. So this suggests that here can represent content that is similarly understandable and realistic as video and potentially replacing or supplementing traditional video training. Head mounted display based intuitive virtual reality training system for the mining industry. This is another example here in this particular case study we are going to elaborate you how HMD head mounted display based training system is very very effective in imparting the training to the miners. VR system training technology in the mining industry represents a new and critical area of research and utilization.

Successful implementation of a VR training system is crucial for improving mine safety and production efficiency. Current research and application of VR training system in the mining industry have been categorized based on the input output device used. Three main types have been identified screen based general type, projector based customized type and head mounted display HMD based intuitive type. An HMD based intuitive type VR training system prototyping for drilling operation in underground mines has been developed utilizing a VR headset, smartphone and leap motion devices. A comparison between the HMD based intuitive system and the screen based general control system was conducted with 10 training focusing on user experience and training effects.

Five classical component of VR system VR engine software, database, input output device, user and task. A VR training system for the mining industry should incorporate these same five component I will discuss that in the next slide. Among these components input output device are deemed the most crucial as they provide the exclusive means through which user can interact with and perceive the virtual environment. Here, it is the virtual engine.

This is basically different components here is a task of the user. User is doing some operation then sensing. Operation is done in the input device data, then there is a software database that is basically simulated in a virtual engine that is supported by the hardware, and then based on that, some data is to be displayed as an output device, and based on that, it is really sensed by the user. So these virtual reality system comprises of VR engine, head mounted, HMD based intuitive here hardware and software and database. This is closely interacting with the user and user basically doing some task or performing some task and getting experience about the system.

So screen based general VR training system. The screen based general training system uses general physical devices such as a key board, joystick as input device and a desktop monitor as output device. The whole system has little to none immersion and is mainly used to develop the basic VR mind training system. Projector based customized VR training system. The projector based customized VR training system is currently the most popular choice for VR training in the mining industry.

This system utilize projector as output device for visual perception. Paired with various screen fabric such as flat, multiple curved and zoomed screens. Additionally, customized operational platforms based on real equipment are often integrated in this into the system to enhance realism and effectiveness. By employing projectors and large screen fabric system offer a degree of immersion to user enhancing their training experience. HMD-based intuitive VR training system. The HMD based intuitive system utilize the high immersion or high immersive visual output devices specially head mounted display along with intuitive input device such as automatic tracking devices.

In this VR system training experience full immersion allowing them to interact with the virtual environment and equipment in a natural and intuitive manner. Currently, immersion immersive natural system like these are not widely developed or utilized but they are considered to be most advanced and represent the future of VR training system for the mining industry. Drilling training program. Blender and Unity 3D. These are the two softwares were utilized for software and database and VR engine component of the VR training system.

Blender was used to create the virtual miner model while Unity 3D was employed to develop the underground coal mine scene and establish interaction rules between the user and virtual environment. In the screen based general system, user control drilling objects such as joystick and the screen depicts a person in the drilling scenario limiting immersion. So here the two scene, the user is basically with the mouse is, seen the drilling operations. So here user miss the immersion. HMD based intuitive system provides a first person view through HMD allowing user to experience the environment more realistically.

Additionally, the gyroscope built into smartphone enables real time head movement tracking and adjusting the view accordingly. So here, immersion is higher and higher. So user can see the different intricacies of the operations and user be within that virtual environment. So a better amount of training or better amount of understanding will be important through this training. And this is because these are the different hardwares used for this particular training.

So in HMD based system user can directly manipulate the virtual miner hands rather than controlling the entire virtual character. Furthermore, the leap motion device allows user to control individual finger enabling more complex interaction and gesture with the virtual drill in the environment. The result is 10 student training evaluated both on HMD based intuitive and screen based general training system and filled out questionnaires about the level of immersions, intuitiveness, interactivity, ease of use and easy of learning and, with each aspect rated from a scale of 0 to 5. HMD based intuitive training system receives significantly higher score in immersion 4.

8 out of 5 compared to the screen based general system. Additionally, it scored 1.5 to 2 times higher in intuitiveness, interactivity, and ease of use, indicating a better overall user experience. Both systems demonstrated good training result with screen based system only slightly lower than the HMD based system in terms of ease of learning. After experiencing both systems, 9 out of 10 students preferred the training experience with the HMD system and expressed a preference for its future uses.

These are the references.

Let me summarize in a few sentences what we have covered. So we have explored the specific hurdles and obstacles that VR system to be adopted in the mining industry. And we have discussed three case studies, one with the interaction of three machines in an underground longwall mines. Then we have discussed the training of miners in an hazard awareness situation for gold mines in South Africa. Then finally, we are landed with the drilling operations to be done in the screen based projection system and the HMD based systems. And we have seen that these VR training are very much effective in imparting good amount of knowledge and experience to the user and future is there in this particular direction. Training would have an alternative to the miners in the futures.

Thank you.