Safety Training in Coal Mining based on Cloud Computing with Support Vector Machine Algorithm for Virtual Reality Platform

C Srinivasan
Department of Computer Science and Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India

Abstract
Because of the inherent dangers of the job, virtual reality (VR) is in great demand for use in coal mine safety and rescue drills. VR has made great strides in the last decade toward better hardware and software for miner training. But there are still some downsides, such as pricey and inappropriate technology, an unsatisfactory user experience, no direct browser access, and an intelligent and humanized design that is missing. This research proposes a cloud-based VR system for coal miners' training as a solution to these issues. The eight modules that make up the system show the whole process of an underground coal mine. It has a browser/client architecture. A better experience for users using browsers is achieved using online cloud-rendered video streaming, which provides sufficient computation and rendering capability. To further enhance the system's ability to communicate with users on an emotional level, gaming artificial intelligence (AI) and Support vector machine (SVM) are also included in the systems. To improve the training experience, this system creates two virtual miners, which is different from the usual VR training software. A non-player character (NPC) with a focus on tasks, the first virtual miner educates players about the mine as a whole and shows them the ropes when they go down to do their job. Users may become ready for common calamities with the help of the second virtual miner, who is disaster oriented. Successful implementation and validation of the system's performance have been carried out in a controlled laboratory setting. However, further procedures are required to encourage the development of novel uses for VR in disaster drilling and miner training.

Keywords—Safety Training, Coal mining, Artificial Intelligence, Cloud Computing, Support vector machine and Virtual Reality

1. Introduction

A new trend in the mining business is smart mining, particularly autonomous mining, which might solve the safety problem and increase efficiency all at once. This is in response to the conventional mining sector's aging workforce and the associated safety risks. However, different kinds of equipment and expensive development costs have resulted from the absence of standardized standards for smart mining. So, provide you with information on the work of Chinese mining research groups and businesses on autonomy and automation standards [1]. In addition, shows several real-world uses of autonomous trucks in mining operations, as well as a few important intelligent technologies for autonomous mining transportation. Following these criteria, these critical, intelligent technologies will most certainly be enhanced and made more inexpensive for miners. A system for online vibration monitoring, early fault warnings and diagnosis, and predictive maintenance and health management of equipment were put in place for different kinds of motors in the coal industry's storage and transportation system. This was made possible by utilizing Input/Output (IO) links, intelligent sensors, IO link masters/edges gateways, AI, and data processing technologies [2].
Coal mine mines-used underground monorail cranes (MUMCs) are the subject of a proposed method for non-line-of-sight (NLOS) mitigations using distances geometric constraints (DGC). The precision of a MUMC-

DOI: https://doi.org/10.5281/zenodo.19315574

based localization system using ultrawideband (UWB) mobile tags attached to UWB anchors in highways is the subject of this investigation. The measurement inaccuracy of UWB devices is eliminated using a linear fitting equation. Utilizing the distance measurement data and geometric connection of UWB networks, a correction approach based on the DGC and Cayley-Menger determinants (DGC-CMD) is used to decrease the NLOS errors in order to determine the exact position of the UWB mobile tag—which is attached to the MUMC and stands for its real-time locations—the corrected distance measurements data is fed into a robust extended Kalman filter (REKFs) [3]. Experimental comparisons using the extended Kalman filters (EKF), the multiliterate based on the least square technique (LSM), and the weighted centroid localizations (WCL) approach are used on a MUMC, verifying the proposed methodology. The result demonstrates that the suggested algorithm is more advantageous and feasible than alternatives. The suggested method has a normal deviation of 0.0739 m, an average localization error of 0.2372 m, and a maximum localization error of 0.4098 m. An increasing need for intelligent and autonomous mining systems is being driven by the modernization and development demands of the worldwide coal industry [4].

Based on the integration of intelligent mining theory, Artificials societies, Computational experiments, Parallel executions (ACP) parallel intelligence approach, and new generations of AI technologies, this paper proposes and develops the Intelligent Mining Operating System (IMOS). It is based on the parallel management and control of mining operating infrastructures. By using the principle of digital quadruplets, the IMOS architecture is designed to meet the intelligent and unmanned needs of open-pit mines [5]. The following IMOS subsystems and their functions are described in detail: operating subsystem for a single vehicle, collaboration subsystem for multiple vehicles, vehicles-road collaborations subsystem, intelligent subsystem operated by an unmanned entity, management subsystem for dispatch, control subsystem for parallel management and controls, supervisory subsystem, communication subsystem, and remote takeover subsystems. Over the last several years, ten key open pits in China have adopted the IMOS, the first integrated solution for intelligent and autonomous mines, as described in this study. Its implementation and use will significantly boost open pit mine production efficiency and safety, encourage the building of environmentally friendly mines, and play a pivotal role in the attainment of sustainable mining development goals [6].

Coal mine production safety relies on sophisticated video surveillance, and cloud-edge collaboration is a great way to make that surveillance system even better. Nevertheless, inefficient use of computer and network resources at the edge layers leads to poor real-time performance and resource wastage. This study proposes a mechanism for allocating resources at the edge of a cloud-edge cooperation architecture that is based on deep deterministic policy gradients (DDPG). To begin, various jobs call for diverse architectures, and cloud-edge collaboration is no exception [7]. Second, we simulate the edge computing-related joint-minimizing-latencies and bandwidth-usages issue. Change it to MDP (Markov Decisions Process) so that the joint optimization issue may be solved quickly. To further improve DDPG's feature perceptions and action outputs, an Edge status perception network (ESPN) is also suggested. At last, DDPG-ESPN is suggested as a solution to the joint optimization issue. The simulation result demonstrates that DDPG-ESPN outperforms alternative approaches in terms of real-time performances and bandwidth use by a significant margin of 18.88% and 42.81%, respectively [8].

The mining of coal is among the world's most dangerous occupations. Unanticipated crises often befell them. Improving health management and preventing injuries are two outcomes of mining's use of the Internet of Things (IoT) and AI. The research suggests that a helmet is a kind that may warn the miner of danger by sending signals to a central station. The STM32 module continuously monitors environmental factors like temperature, humidity, and toxic gases. It also tracks the worker's vital signs, like heart rates and vibrations caused by excavations and blasting. All this data is transmitted to the control center through a low-energy Bluetooth module [9]. If the control unit detects any threats to the workers, the system's panic button might be activated. The digital temperature and humidity sensor DHT11 has an accuracy range of ±5% for measuring temperature and humidity levels.

DOI: https://doi.org/10.5281/zenodo.19315574

However, the MQ135 sensor has an accuracy of 85% when it comes to sensing gas concentrations. Miners may experience light-headedness and disorientation due to the high concentrations of gases in coal mines. Miners may solve this problem by pressing a panic button on their helmet; this will notify the control centre's personnel and expedite rescue efforts. Also, the module was enhanced with an integrated heart rate sensor using the inter-integrated circuit (I2C) protocols [10].

An unhealthy situation requiring treatment is indicated if the heart rate value drops below 60 or rises over 100. In addition, the AI model is trained to detect the worker's gestures with the use of a machine learning method that utilizes a convolutional neural network (CNN). In this area, four distinct gestures were established to facilitate communication between the staff. These actions have been classified as EMERGENCY EVACUATION, DOING FINE, GOOD, and NOT GOOD. The data from different sensors may be visually represented with a receiver air position indicator (API), which can then be used to take the necessary precautions to keep miners safe [11]. The problem statement is discussed below. Because of the inherent dangers of the job, coal miners are always at risk of things like cave-ins, explosions, and toxic gas exposure. It is critical to have thorough and efficient safety training programs in place to guarantee the well-being of miners. While there is value in traditional safety training approaches, they aren't always up to snuff when it comes to participation, interaction, and practical application. On top of that, miners could not adequately prepare for the ever-changing and unexpected mining settings using these approaches. Safety training for coal miners may be radically improved with the use of cutting-edge technology like VR and machine learning. VR offers a secure and regulated environment for miners to practice responding to dangerous situations via an immersive and interactive training experience.

By evaluating performance data, SVM algorithms may improve this training by giving individualized feedback and highlighting problem areas. Furthermore, virtual reality training modules may be more easily managed and delivered using cloud computing, which improves accessibility, scalability, and updateability. One solution to the problems with conventional training techniques is a cloud-based safety training system for coal miners that makes use of SVM and VR. The system's goal is to improve miners' safety and readiness for potentially dangerous circumstances in the workplace by giving them a more effective, interesting, and tailored training experience via the use of these cutting-edge technologies.

The following are the work contributions.

- Developed a list of essential safety situations, including cave-ins, gas leaks, equipment failures, and evacuation protocols, in conjunction with mining safety specialists.
- Developed VR simulations to faithfully reproduce these situations, making every effort to achieve a state of complete immersion.
- Developed complete 3D models of coal mining settings using cutting-edge VR software (e.g., Unreal Engine, Unity).
- Included user-controlled features into the VR settings so that students could interact with their environment as they learned safety procedures.
- Tracking and sensor technologies were incorporated into the VR platform to gather comprehensive performance data from participants as they engaged with VR situations.
- Things like response times, decision-making methods, and compliance with safety protocols were recorded. Cleansed and normalized the acquired data as part of the preprocessing step to guarantee correctness and consistency for analysis.
- Extrapolated useful information on the trainee's performance and development as learners from the collected data. Created and trained SVMs to sift through performance data, revealing patterns and classifications that point to varying degrees of competence and development gaps.
- Achieved very accurate performance evaluation by hyperparameter optimizing the SVM models. Personalized trainee feedback is now a reality because of a new feedback system that incorporates SVM analysis findings.
- Presented trainees with comprehensive reports and suggestions outlining their accomplishments, shortcomings, and opportunities for growth. Built a scalable, reliable, and user-friendly cloud architecture to house the VR training modules.

DOI: https://doi.org/10.5281/zenodo.19315574

- Streamlined data storage, processing, and administration by using cloud services like Amazon Web Services (AWS), Azure, or Google Cloud. Tested the cloud platform to make sure it can handle a lot of users at once so it can be used for widespread mining operations.
- Made it easier for administrators and trainees to use by including capabilities for managing users and access. Cloud-based real-time data processing capabilities have been developed; now, users can get instant feedback and analysis while training in VR.
- Designed for optimal performance with minimal latency for a lag-free training session. Developed thorough data management procedures to deal with the mountain of performance data created by VR training.
- Maintained and organized the data so that it could be easily retrieved, analyzed, and reported. Implemented encryption, access restrictions, and secure data transfer protocols to guarantee the security and privacy of all acquired data.
- Kept all student records secure by following all applicable data protection rules. Developed the first method to augment coal mining safety training utilizing VR, SVMs, and the cloud.
- Proven that machine learning and immersive technology may enhance training results and readiness for safety risks.

A review of the relevant literature will follow in Section 2, and the Cloud computing and SVM - Security training in coal mining will be covered in Section 3. Section 4 then discusses the outcomes and feedback on the provided dataset to establish a mechanism in coal mining. Finally, covered the Systems' long-term objectives and the system's overall performance.

2. Literature Survey

Several elements influence the designs of the shaft blasting, one of which is the complicated and dynamic rock geology around the shaft. Using conventional wisdom to arrive at reasonable and scientific blasting settings is challenging. In response to the critical technical issues, this study proposes a knowledge base and AI-integrated vertical shaft blasting scheme design approach. Using the analytic hierarchy processes (AHP) of particle swarm optimizations, first, we will examine the characteristics and weight of factors influencing the blasting designs. Based on expert opinion, we settled on the type of surrounding rocks, rock sturdiness coefficients, section shapes, and gross diameters as the primary indicators to guide our blasting method selection [12]. The second step is to set up the inference engine and expert knowledge base. Establishing an explosive expert knowledge base based on expert experiences, industry standards, and typical situations, this work proposes a research approach that integrates knowledge bases with relational databases. It characterizes and conveys information content using knowledge attributes. Created a hybrid reasoning machine for vertical shaft blasting designs by combining the cyclic search algorithms with the production rule reasoning approach. Next, by using computer development technologies, a visually intelligent design system was put in place for vertical shaft blasting. Until recently, Jinzhuang Coal Mine has put the system into action. The optimized schemes of the system model reduce the total number of holes by 8.39% compared to the standard blasting scheme [13].

It also increases the single-cycle progress by 11.11%, increases the hole utilization rates by 10%, and reduces the unit explosive consumptions by 15.57%. A novel approach to vertical shaft blasting design is presented, and the overall result is positive. It is critical to learn how to establish trustworthy communication and safety monitoring in coal mines. While there are sensing-based monitoring systems and current transmission strategies, many of them fail to address non-line-of-sights (NLOS) issues caused by twisting tunnels or mine collapse since they focus on a single purpose. Specifically, aims to enhance the sensing accuracy by maximizing the energy efficiency of the joint communications and sensing (JCAS) access points and the cumulative sensing rate via the use of a multi-hop reconfigurable intelligent surface (RIS)-aided JCAS strategy [14]. By coordinating the design of the access point's transmit power, the phases-shift matrix, and the condition of the RISs's switches, we derive an optimization problem that minimizes energy consumption. Using the second-order optimizations approach, the Lambert-w function, Newton's method, and the successive convex approximations-based alternating optimization procedure; the issue is

DOI: https://doi.org/10.5281/zenodo.19315574

solved. The Lagrange relaxations and Gradient descent methods are also used to address a rate optimization issue that is dependent on sensing [15].
The suggested approach is more energy efficient and has more resilience, according to the simulation findings. Coal proximate analysis has been extensively used to characterize coal by revealing its moisture, ash, volatile contents, and calorific values. To get a steady weight, the coal is heated under different circumstances. The technique of identifying these properties is time-consuming, but it is not complicated and does not need costly analytical equipment. As an alternate approach to proximal analysis, spectral analysis combined with other machine learning algorithms is considered. However, much of the prior research has focused on individual traits without investigating their interrelationships [16]. A combination of near-infrared spectroscopy and a multioutput attention U-net (MOA-U-net) will provide a proximal analysis technique that can concurrently predict various attributes in this research. To enhance the U-shape network's representational power, an attention-based U-net is created as the shared feature extractions subnetwork. This network consists of an encoder, a decoder, convolutional block attentions modules, and multiscale feature fusions modules. The second step is to use four separate subnetworks, each with four outputs and fully linked layers, to do the regression on those four attributes [17].
To address the issue of training imbalance across tasks, apply the gradient normalization technique to remove the masking impact of gradient magnitude. Using 670 coal samples collected during an on-site test, the proposed MOA-U-net is compared to standard chemometric approaches. With correlation coefficients of 0.9015 for moisture, 0.9538 for ash, 0.8986 for volatile content, and 0.8884 for calorific value, the experimental findings show that the suggested model achieves advanced performance. A significant amount of energy is used during material transportation, which is an integral part of mining operations [18]. Autonomous mining trucks have been used in open-pit mines to save transportation expenses as automation technology has progressed. Because of their superior control, high-precision sensing, and informatization, autonomous mining trucks are a better fit for automated scheduling methods than human trucks. However, current research on truck scheduling is stuck in the past and fails to make use of autonomous vehicles' capabilities to execute more nuanced control. Our research presents a mixed-integer programming approach that can optimize the trips and speeds of autonomous vehicles simultaneously to reduce their energy consumption. The proposed scheduling model can be solved using a new tabu search algorithm [19].
The algorithm is divided into two parts: first, an improved flow allocation model with matching factors is developed to find the optimal truck flow, and second, a tabu search procedure is developed with the optimal flows as its guide. It also suggests a method for scheduling autonomous vehicles in real-time for the unpredictable and ever-changing mining environment, which is based on the mathematical models and solutions approach. Our team tested the suggested truck scheduling models and real-time scheduling method in a coal mine in Inner Mongolia, China, to ensure its efficacy. This shows that the suggested allocation model efficiently speeds up the tabu search process, and for choices with a short time horizon, the suggested solution method meets the computing needs of the real-time scheduling systems [20].

3. Proposed System

This article designs and develops a VR system utilizing the Unreal Engine to teach coal miners to overcome the difficulties. This system employs cloud rendering and game AI technologies in contrast to the typical standalone or client/server VR applications. It adopts a browser/client architecture. Its stated goals include making learning more engaging, enhancing memory retention, and raising users' level of safety consciousness. Rendering, animation, networking, terrain, streaming, scene graphs, AI, and the Blueprint programming language are all components of Epic Games' Unreal Engine, which is used by the system. To accomplish multiuser online operations and enhance the engagement and immersion of VR devices, this article employs three technologies: cloud rendering architectures, 3D modeling, and AI behavior designs.
Everyone uses a web browser to view 3D streaming on the cloud since that's how cloud rendering works. The virtual world's state and all events are handled by the cloud servers,

DOI: https://doi.org/10.5281/zenodo.19315574

which also deliver the VR render streaming to the clients. These servers might take the form of physical ones or even clusters of servers. Utilizing almost limitless processing power, they produce, record, and compress high-resolution rendered streaming, which is then sent to the client using less powerful and less efficient hardware. The key reason cloud rendering is superior to other popular Web3D technologies like HTML5 and WebGL is that it doesn't need any costly or specialized client-side infrastructure.

Mobile phones, tablets, and desktop computers are just a few of the devices that consumers may choose from. In addition, with the advent of Wi-Fi 6 and 5G, there will be more than enough bandwidth for online cloud rendering to meet all your computing and rendering needs. Users may now experience VR with low-response times and high-quality video thanks to improvements in the Internet's architecture that allow for client-side network interactions. It is the job of the portal server to take user login information, determine which server is suitable based on the user's preferences, and then command that server to launch the render server, which is a virtual machine. Once the portal server informs the client of the virtual machine's address, a connection may be established between the client and the render server. The user can access the 3D software on the distant server and engage with it over the network.

Render servers translate and transmit client-sourced input events (such as mouse or keyboard clicks) to the 3D program's interaction module for further processing. We record the scenario in three dimensions, compress it, and then provide the encoded video to the customer. Render server software consists of three main sections: basic, Game AI, and advanced SVM. VR's foundational module offers a variety of essential features, including 3D scene management, audio, particle effects, physical simulation, and more. Making advantage of a programming language, the Game AI module constructs a behavior tree for synthetic miners. VR's sophisticated module models complicated computations and simulates calamities, such as numerical fire simulation and calculating escape routes. The client communicates with the server and displays the 3D scene that has been received via streaming. It is also responsible for delivering events from the user's keyboard and mouse.

To create subterranean and surface-level 3D sceneries, rely on 3ds Max. Continue by bringing the 3D models into the Unreal Engine editors. Several material tools, including a normal map, a diffusion map, a metal map, and a texture map, are used to apply 3D models. Think of these resources as the "paint" that you'd use to decorate your model. Proceed to light up our scenarios by turning on the lights. Automatically construct 3D geological and subterranean laneway models. Blueprint is the scripting language that we use to create the User Interface (UI), AI behavior tree, and character animations.

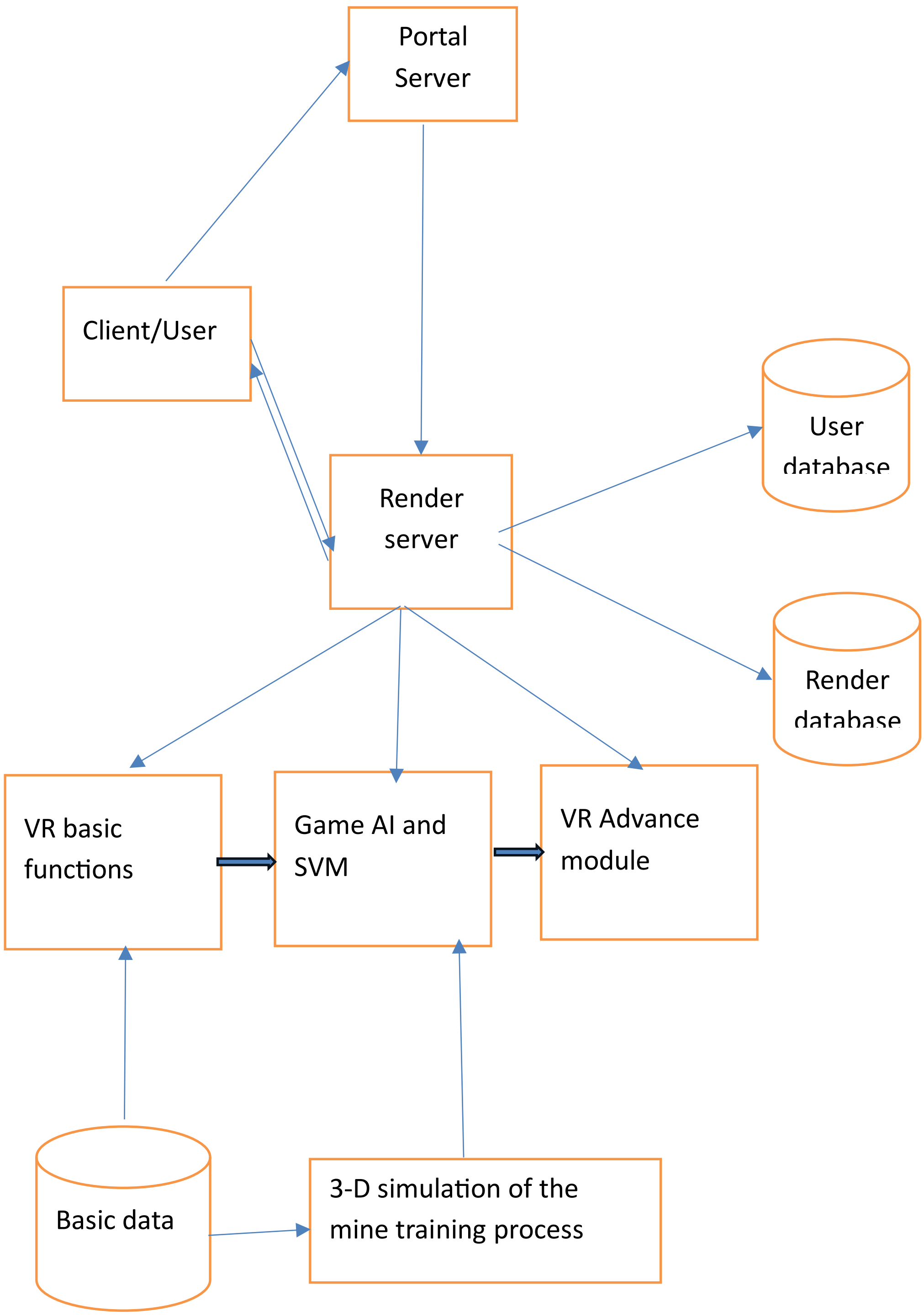
A 3D engine module known as "Game AI" operates in the gaming industry. Planning, learning, reasoning, problem-solving, knowledge representations, visions, movement, and manipulations are some of the traits shared by humans and traditionally represented by AI. Game AI is developing into its own specialty within artificial intelligence. AI in video games is the computer-controlled virtual person that mimics the smart actions of real people or animals to provide players with a fair challenge. These non-player characters (NPCs) may act as miners, helping students and aspiring miners learn the ropes, immerse themselves in the subterranean environment, and strengthen the bond between users and computer programs in general and during training in particular. On top of that, these AI characters can figure out the local navigation grid way on their own.

One of the non-playable characters is task oriented. Meeting it on the ground will teach the user the basics of coal mining and lead them down a well to see the longwalls and heading faces that are part of the underground work sites. The NPC will release the next job after the user completes the one that corresponds to it and gives feedback. The miners must complete these steps before venturing into the mine since they will be better prepared to find the entrances, enter the cages, and see the working faces below ground. The second non-playable character is a disaster educator who leads players through realistic scenarios like gas explosions, roof collapses, and fire incidents.

Using the blueprint, construct a behavior tree graph by adding and connecting nodes; this will allow the NPC's behavior to be realized. In a basic acyclic graph, a behavior tree consists of a composite node and a leaf node. Build selection, sequence, parallel, and decorator nodes using composite jobs. A branch job that

DOI: https://doi.org/10.5281/zenodo.19315574

controls the actions of its offspring is called a selector. If any of its offspring execute successfully, it will promptly provide a success status code. Nodes in the chain are not performed until the first one returns to the selector. Instead, the node job is executed progressively by a sequence. Until every child has reported that they have executed successfully, a sequence node will attempt to execute them one by one. If a job doesn't succeed, the process will loop back up to the top node. Figure 1 shows the system architecture of the proposed system.



DOI: https://doi.org/10.5281/zenodo.19315574

Figure.1. System architecture of the proposed system

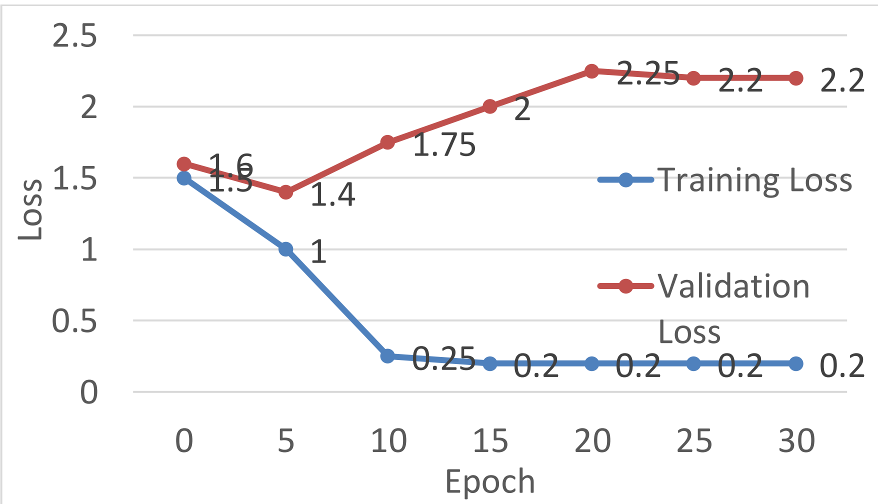
Consequently, nothing happens to the other jobs. Composite tasks that manage concurrent activities are known as parallels. All children run on this branch job when it is executed. Node task, which might be a state machine, can run in parallel in the behavior tree. Parallel execution of many state machines is possible. For instance, the second NPC will run the user and provide notifications after determining whether the situation is unsafe. After this, it provides on-site emergency solutions via a sequence of animation steps. The sequences check the user's response by executing the catastrophe animation.

4. Results and Discussion

Two virtual rendering servers, each with an 8G M60 Central Processing Unit (CPU), 32 GB of Random Access Memory (RAM), and 40 Mbps bandwidths, make up the cloud rendering cluster. The technology can handle up to seven players simultaneously, according to the trials. A minimum requirement for a client's Personal Computer (PC) is an Intel i7 processor and 16 GB of RAM. Undergraduates from Beijing's China University of Mining and Technology have tried out the system at the VR Teaching and Experiments Laboratory. An infrared laser tracking device and 120-degree 2-channel VR projectors are also available in the lab. The option of using the PC headset or the immersive VR gear to operate the system. Visit the longwall mining face or the blasting area, go past buildings, and enter the mining via a cage with the NPC's virtual roaming capability. Additionally, the power supply, water supply, drainage, transportation, and ventilation systems will be introduced. New miners or students may get a feel for the mine using this feature.

To identify the user's actions and offer details on unlawful activities, the accident guidance functions of the NPC would initiate a conversation with them while they are aimlessly roaming the roads. Based on the location, the system will activate the catastrophe animation, and the NPC will show the ways out so the player may save himself. Have a mechanism in place that only allows gas explosions, roof collapses, and fire events to occur in mining catastrophes. The disaster simulation module incorporates the 3D engine's physical-mechanical models, music, particle effects, and 3D animation. The purpose of the 3D model is to provide the groundwork for the NPC, mine, landscape, and tunnel models.

Footsteps on grass and road, gasping as a runner, and the mechanical sound of a cage opening are all examples of noises that the audio function aims to produce as realistically as possible, given the source's dimensions. A catastrophe simulation knowledge library is built by examining the causes, characteristics, and situations of disasters and accidents. Find a concise overview of disaster preparedness, site disposal programs, emergency procedures, mitigation, and post-disaster assessment in this library. When used in conjunction with system guidance, it may illustrate the possible outcomes of catastrophes. Gas and coal dust explosion boundary conditions are shown in this simulation. Figure 2 shows the mining loss of the proposed system, and Figure 3 shows the mining accuracy of the proposed system.



DOI: https://doi.org/10.5281/zenodo.19315574

Figure.2. Mining loss of the proposed system

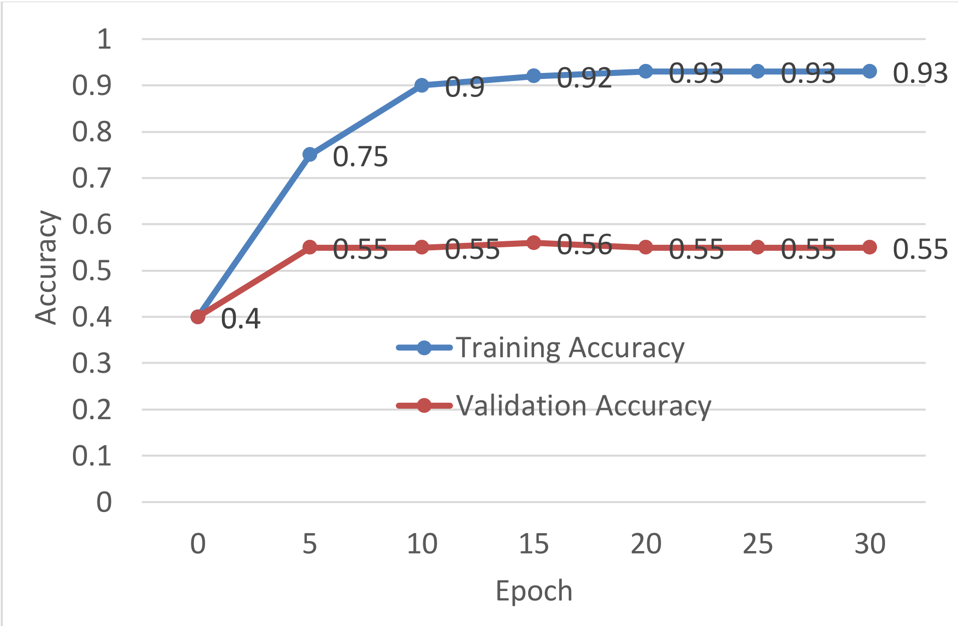


Figure.3. Mining accuracy of the proposed system

Users can comprehend the devastation caused by the wind and dust by using their eyesight, hearing, and other senses. Furthermore, some emergency procedures, including collaborative gas extraction, are shown in full. The user will get an understanding of the primary components of a roof fall and a wall collapse via these simulations. It may introduce the kind of catastrophe, its causes, and possible ways to avoid or control it by simulating different rock explosion and ground pressure disasters. Here, the user may see the most common types of fires, including those that start outside the building and spread by blasting, short circuits, and open flames and those that start within the building and spread through the combustion of coal or other combustible materials because of oxidation or burning.

VR can show the severity of different flames by simulating their circumstances, which may help with disaster preventive decisions. Methods of therapy, such as nitrogen injection and closed grouting, are also shown by the device. Cloud rendering and artificial intelligence behavior trees are used by the VR system to improve training performance. It has login, roaming, virtual simulation, and operation evaluation functions, and it can effectively recreate the complicated underground coal mine environment. However, only a subset of the features is available to the public on the website because of intellectual property restrictions.

The training system has received a perfect score of 5.0 out of 5 from users on the National Virtual Simulations Experiments Teaching Project Sharing Platforms, and there have been 20,853 visits to the system. The data from the experiment shows that 1355 participants have completed it, with a 46.0% percentage of great scores. Without going to the coal mines themselves, the students felt the technology might help them better grasp the subterranean environment and its hazards.

Need to replace our present cloud render hardware with a bigger cluster to give a faster response and a better experience, even though it's working well, and we're getting great feedback. A performance test is also required to get a better idea of concurrency and runtime efficiency. To further enhance the user experience, further study is needed into the system functionalities. A behavior tree design with greater information may be implemented. The systems may be transformed into a testbed

DOI: https://doi.org/10.5281/zenodo.19315574

to assist with ventilation designs, emergency drilling, and other related sectors when combined with numerical computing. VR has the potential to revolutionize disaster drilling and miner training in the coming years.

5. Conclusion

Intelligence mining using VR includes a new tool for managing work procedures, simulating workplace health and safety hazards, and visualizing the consequences of disasters. Information such as the location of staff, safety monitoring, and equipment management may be seen in the virtual reality system's macroscopic and microscopic subterranean 3D settings for the coal mine. It may provide more lifelike and intricate 3D visual effects when used in conjunction with cloud rendering. This study develops a VR system that uses cloud rendering and AI to educate mine safety personnel. Subterranean exploration with artificial intelligence supervision allows for the simulation of disasters, including gas bursts, roof collapses, and fires. Predicting that the findings will be a valuable resource for coal mine safety training, helping individuals mitigate the risks associated with working in such a hostile subterranean setting. The SVM algorithm gives the best accuracy performance and minimizes the loss of the proposed system.

References

1. S. Ge, F.Y. Wang, J. Yang, Z. Ding, X. Wang, Y. Li, and L. Chen, "Making Standards for Smart Mining Operations: Intelligent Vehicles for Autonomous Mining Transportation," in IEEE Transactions on Intelligent Vehicles, vol. 7, no. 3, pp. 413-416, 2022.
2. Y. Xiao, H. Wu, Y. Zhang, and S. Yao, "Health management of coal storage, transportation and loading equipment based on predictive maintenance with vibration perception," 2nd International Conference on Computer Science, Electronic Information Engineering and Intelligent Control Technology, pp. 381-384, 2022
3. S. R. Thumala and B. S. Pillai, "Cloud cost optimization methodologies for cloud migrations," International Journal of Intelligent Systems and Applications in Engineering, vol. 12, no. 2, pp. 4797–4809, 2024.
4. L. Chen, X. Hu, G. Wang, D. Cao, L. Li and F. Y. Wang, "Parallel Mining Operating Systems: From Digital Twins to Mining Intelligence," IEEE 1st International Conference on Digital Twins and Parallel Intelligence, pp. 469-473, 2021.
5. Z. Xu, and J. Li, "DDPG-Based Edge Resource Management for Coal Mine Surveillance Video Analysis in Cloud-Edge Cooperation Framework," in IEEE Access, vol. 9, pp. 155457-155471, 2021.
6. S. R. Thumala, H. Madathala and S. Sharma, "Towards Sustainable Cloud Computing: Innovations in Energy-Efficient Resource Allocation," International Conference on Machine Learning and Autonomous Systems (ICMLAS), pp. 1528-1533, 2025.
7. X. Ma, Y. Wang, T. Lin, and L. Yang, "Intelligent Decision System for Vertical Shaft Blasting Scheme Based on Knowledge Base and Its Application," in IEEE Access, vol. 9, pp. 163831-163842, 2021.
8. T. Guo, Y. Wang, L. Xu, M. Mei, J. Shi, L. Dong, and C. Huang, "Joint Communication and Sensing Design for Multihop RIS-Aided Communication Systems in Underground Coal Mines," in IEEE Internet of Things Journal, vol. 10, no. 22, pp. 19533-19544, 2023.
9. S. R. Thumala, H. Madathala and V. M. Mane, "Azure Versus AWS: A Deep Dive into Cloud Innovation and Strategy," International Conference on Electronics and Renewable Systems (ICEARS), pp. 1047-1054, 2025.
10. V. Ramesh, "Evaluating Apache Kafka performance and operational efficiency: A comparative study of ZooKeeper and KRaft architectures," International Journal of Computer Applications, vol. 187, no. 46, pp. 12–18, 2025.
11. Y. Yin, and M. Zhao, "Application of AI, Big Data and Cloud Computing Technology in Smart Factories," 6th International Conference on Artificial Intelligence and Big Data , pp. 192-196, 2023.
12. H. Madathala, S. R. Thumala, and G. Yeturi, "Optimizing cloud migration: Designing robust architectures for seamless transition from on-premises to Azure for SAP and database systems," International Journal of Engineering Technology Research & Management, vol. 9, no. 1, 2025.
13. X. Zhang, L. Chen, Y. Ai, B. Tian, D. Cao, and L. Li, "Scheduling of Autonomous Mining Trucks: Allocation Model Based Tabu Search Algorithm Development,"

DOI: https://doi.org/10.5281/zenodo.19315574

IEEE International Intelligent Transportation Systems Conference, pp. 982-989, 2021.
14. V. Ramesh, "Performance benefits of reactive frameworks," International Journal of Computer Applications, vol. 975, pp. 8887, 2025.
15. M. Szelążek, D. Hudson, S. Bobek, G. J. Nalepa and M. Atzmueller, "Enhanced Explanations for Knowledge-Augmented Clustering using Subgroup Discovery," IEEE 10th International Conference on Data Science and Advanced Analytics, pp. 1-11, 2023.
16. S. R. Thumala, V. Mane, T. Patil, P. Tambe and C. Inamdar, "Full Stack Video Conferencing App using TypeScript and NextJS," 3rd International Conference on Self Sustainable Artificial Intelligence Systems (ICSSAS), pp. 1285-1291, 2025.
17. Z. Qin, S. Chen, X. Xu, and M. Zhao, "Research on Key Technologies and System Construction of Smart Mine," 5th Asia-Pacific Conference on Intelligent Robot Systems, pp. 116-121, 2020.
18. H. Liu, F. Wang, and Y. Ai, "Fast node localization algorithm for underground coal mine based on RSSI," 9th International Conference on Modelling, Identification and Control, pp. 892-896, 2017.
19. N. Ganesh, A. Sriram, S. N. Krishnan, and T. S. Rao, "Simultaneous enhancement and detection of brain tumors using GAN," in Intelligent Computing—Proceedings of the Computing Conference. Cham, Switzerland: Springer Nature Switzerland, pp. 206–220, 2025.
20. J. Tang, Y. Gao, H. Yu, Y. Wang, Y. Ai, and D. Cao, "Real-time Display Method for Mining Vehicle Simulation based on Virtual reality," IEEE 28th International Symposium on Industrial Electronics, pp. 1530-1535, 2019.

DOI: https://doi.org/10.5281/zenodo.19315574