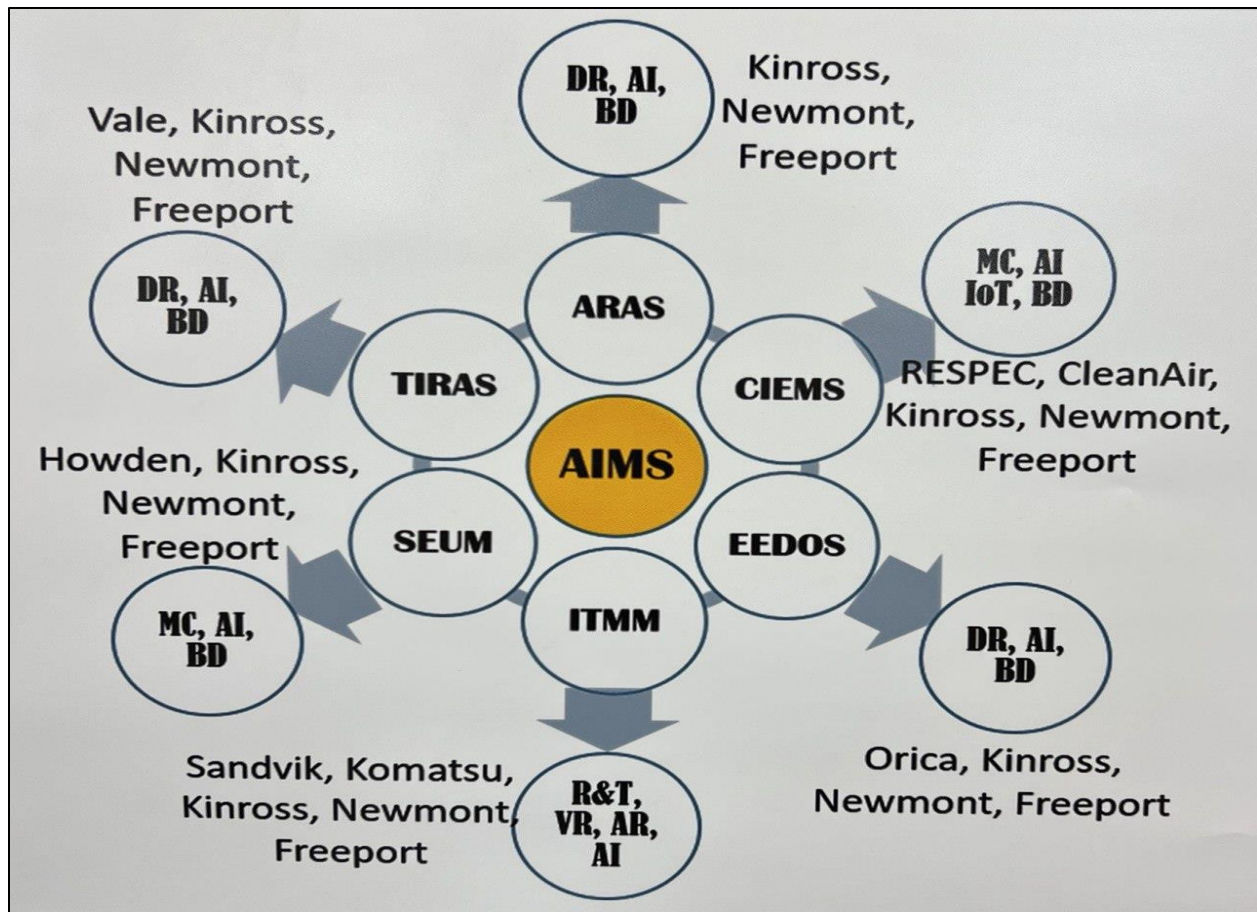


Synopsis

A recent study by Ernst & Young [1] on Digital Mining reveals that the industry will be highly influenced by (i) Robotics and automation through drones, autonomous vehicles, and remote-controlled operational systems, and evolving human-machine interface, (ii) Increasing need for Data and Digital literacy across all phases of the mining value chain, and (iii) Integrated operating centers using cloud computing, information sharing, and big data to take employees away from hazardous sites to enhanced workplace conditions. Accordingly, there is a consensus that the skills requiring a greater degree of task creative intelligence will gain more attraction by the impact of technology enhancement and automation. The current project team and industrial partners believe that the path to safer and healthier mining operations crosses only through the development of academic/industrial human resource capacity with a greater understanding of emerging technological infrastructures such as Artificial Intelligence, Internet of Things, Big Data, Cloud Computing, Robotics, Teleoperation, Immersive Technologies (Virtual/Augmented Reality), Drones, and Mobile Crowdsourcing.

With a strong team of multidisciplinary professionals and teaming up with the world's largest mining companies, we are conducting collaborative research on several challenging and safety topics, such as ground failure, exposure to hazardous emissions, and collision avoidance, by developing artificially intelligent tools. In this regard, with the help of our industrial partners, six major missions have been carefully chosen for the project, and each individual mission aims at developing capacities in multiple emerging technological fields.

Acronym	Sub-Project Title	Related Technological Capacities*	Industrial Partners
ARAS	Automated Rockfall Risk Alert System for Open-Pit Mines	DR, AI, BD	Kinross, Newmont, Freeport
TIRAS	Tailings Instability Risk Alert System	DR, AI, BD	Vale, Kinross, Newmont, Freeport
CIEMS	Comprehensive Intelligent Exposure Monitoring System	MC, AI, IoT	RESPEC, CleanAir, Kinross, Newmont
EEDOS	Explosive Energy Distribution Optimization System	DR, AI, BD	Orica, Kinross, Newmont, Freeport
ITMM	Immersive Teleoperation of Mining Machines	VR/AR, R&T, AI	Sandvik, Komatsu, Kinross, Newmont
SEUM	Simulation-based Smart Evacuation of Underground Mines	MC, AI, BD	Howden, Kinross, Newmont



Dissertation

Subproject V: ITMM

Dangerous working environments, inadequate safety training, low teleoperation, and autonomous systems productivity are major growing problems as surface, and underground mines are becoming wider and deeper. Work efficiency in unmanned operations is less than in boarding operations due to a lack of visual information. The first problem is the difficulties of depth estimation in 2D monitors, reducing the operation's speed. Many researchers and companies have tried enriching visual information by adding multiple views. However, providing excessive visual information can cause "cognitive tunneling" in operators, making them subconsciously more focused on a limited point of view and ignoring others. Hence, the mining industry could significantly benefit from virtual reality (VR) platforms to switch 2D monitors teleoperation systems to an immersive 3D environment to make the teleoperation systems efficient.

The project proposes an approach to solving the challenges of teleoperation. It is an enhanced visualization of the remote equipment by using respective 3D models, whose individual parts move in relation to each other as they would in real life. Spatial data of the machinery's components will be sampled and transmitted in real-time and represented by a corresponding 3D model. The equipment's

surroundings are visualized by modeling the inputs from several cameras on the machinery. A high illumination is usually needed on all sides of the machine since underground mines are usually too dark for good-quality video capturing. The offered approach has four major upgrades compared to the similar technologies available in passenger cars. (i) Passenger cars usually have a single integrated body, which needs only a single virtual model to be inserted into the VR environment. In contrast, most mining machines have moving components, such as a bucket, boom, etc., that move in relation to the main part of the body. We have planned to sense the machine's configuration at each instance and project a corresponding 3D model into VR space. The sensing will be implemented using location actuators in the lab scale and Electronic Control Unit output in real machines. (ii) We have planned to add a series of 3D guidelines illustrating the prospecting trajectory of the machine's moving components. This will assist the operator in performing a safer operation. (iii) The operational environment of mining machines can be extensively dusty, smoky, or foggy, with reduced visibility for both on-site and remote operators. We have planned to virtually reduce invisibility using visual effects to improve the technology's effectiveness. (iv) It is planned to build a dual application for the proposed technology as another layer of proximity detection. In this module, human objects will be detected on the videos using a deep learning neural network and warned to the operators.



The final platform will allow operators to work in fully 3D environments remotely. By switching from 2D display teleoperation systems to fully 3D ones and enhancing the speed of teleoperation systems, the operational cost of exploitation will decrease, and the operator will not have to attend to the dangerous working environment.

Industrial Partners

The project is supported by an exceptional list of ten industrial partners. These collaborators are the world's mining leaders. The project has Kinross, Newmont, and Freeport as general collaborators for all subprojects. In addition, we have specialized industries helping each subproject individually. For example, Orca will be involved in EEDOS, Vale in TIRAS, CleanAir in CIEMS, Howden in SEUM, and Sandvik and Komatsu in ITMM. RESPEC is another collaborator that will not only be involved in CIEMS but will also provide extra funding for a graduate student to work on this topic. Moreover, the Big Data team of Freeport and the Artificial Intelligence Center of Vale are priceless partnerships for this project.




Deadline:

The project was a five years contract funded by NIOSH that started in 2018 and was supposed to be finished by 2023, but the Covid 19 changed the deadline. My advisor can provide more information about the project.

References

- [1] EY. (2019). The Future of Work: the Changing Skills Landscape for Miners. Minerals Council of Australia, 35 p.
- [2] Read, J., Stacey, P. (2009). Guidelines for Open Pit Slope Design. CRC Press, 510 p.
- [3] Rauhala, A., Tuomela, A., Davids, C., Rossi, P.M. (2017). UAV Remote Sensing Surveillance of a Mine Tailings Impoundment in Sub-Arctic Conditions. Remote Sensing, 9: 1318.
- [4] Chen, J., Zhang, Y., & Xue, W. (2018). Unsupervised Indoor Localization Based on Smartphone Sensors, Beacon, and Wi-Fi. Sensors, 18(5): 1378.



Artificially Intelligent Mining Systems (AIMS) for Safer and Healthier Automated Operations

A NIOSH-Funded Capacity Building Project

Dr. Javad Sattarvand (PI), Prof. B. Parvin, Prof. G. Danko, Dr. B. Abbasi, Dr. A. Talei, Prof. S. Düzgün (Co-PIs)

Synopsis

A recent study by Emer 4 Young [1] on Digital Mining reveals that the industry will be highly influenced by (i) Robotics and automation through drones, autonomous vehicles and remote-controlled operational systems, and evolving human-machine interface, (ii) increasing need for Data and Digital literacy across all phases of the mining value chain, and (iii) integrated operating centers using cloud computing, information sharing, and big data to take employees away from hazardous sites in order to enhanced workplace conditions.

Accordingly there is a consensus that the skills requiring a greater degree of task creative intelligence will gain more attraction by the impact of technology enhancement and automation.

The current project team and industrial partners believe that the path to safer and healthier mining operations crosses only through development of academi/industrial human resource capacity with greater understanding of emerging technological infrastructures such as Artificial Intelligence, Internet of Things, Big Data, Cloud Computing, Robotics, Teleoperation, Immersive Technologies (Virtual/Augmented Reality), Drones, and Mobile Crowdsourcing, as illustrated in Figure 1.




Figure 1 Skills needed for future mining engineers and university professors

With a strong team of multidisciplinary professionals and teaming up with world's largest mining companies, we are conducting a collaborative research on several challenging health and safety topics such as ground failure, exposure to hazardous emissions, and collision avoidance by developing artificially intelligent tools. In this regard, with the help of our industrial partners, six major missions have been carefully chosen for the project and each individual mission aims at developing capacities in multiple emerging technological fields (Table 1 & Figure 2).

Acronym	Sub-Project Title	Industrial Partners
ARAS	Automated Rockfall Risk Alert System	Kinross, Newmont, Freeport
TRIAS	Tailings Instability Risk Alert System	Val, Kinross, Newmont, Freeport
CIEMS	Comprehensive Intelligent Exposure Monitoring System	RESPEC, CleanAir, Newmont, Freeport
EEDOS	Enhanced Energy Distribution Optimization System	Orica, Kinross, Newmont, Freeport
ITMM	Intelligent Transportation of Mining Machines	SANDVIK, Komatsu, Newmont
SEUM	Simulation based Smart Evacuation of Underground Mines	MC, AL, BO, Howden, Kinross, Newmont

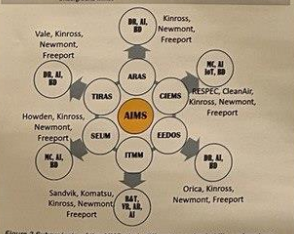


Figure 2 Sub-projects of the AIMS, their different required skills and partners

Subject I: ARAS

The goal is to make a significant improvement in open-pit mine highwall safety by development of a new automated rockfall risk alert system (ARAS) through integrating an unmanned aerial vehicle (UAV) imaging platform with the advanced artificial intelligence (AI)-based technology. The proposed ARAS technology will compute the overall risk of rockfall hazard in open-pit highwalls taking into account two distinct elements of the risk including the possibility of rockfall and the impact area of the falling rock blocks. In this calculation, the risk of rockfall will be assessed according to three major elements, (i) what is the probability of rock fall on a slope, (ii) how far is a potential fallen rock may travel, and (iii) how much would be the methodology for high-definition 3D modeling of rock faces in open pit mines by a new drone control software which will be the main substitute for data acquisition and 3D geometry modeling. At the end, a dynamic rockfall risk map of the whole pit will be produced and updated based on the periodic changes in mine benches and overall slopes (Figure 3).




Figure 3 An example of rockfall hazard plan [2]

Subject II: TRIAS

The project offers to create a high-resolution 3D model of the tailings dams using UAV imaging and photogrammetry. A new ground station software programmed at UNR is a tool that can produce required pictures. Generated 3D models (see Figure 4 as an instance) will be analyzed using automated artificial intelligence algorithms in order to check for the existence of any dam instability signs such as: (i) Seepage signs on the walls of the dam like water stains, vegetation, etc.; (ii) Excessive overtopping; (iii) Sulfur fumes and temperature through hyperspectral and infrared imaging; (iv) Signs of deformations in dam structure in millimeter scale. Our offered technology will be integrated into existing site monitoring programs. The warning signs are to be monitored in an automated and personal manner in order to enable taking actions in advance for the mitigation of the risks.




Figure 4 An example of 3D model of tailings dam analysis around a tailings dam [2]

Subject III: CIEMS

Effective measurement of the exposure of mine workers to harmful emissions such as dust, noise and vibration is a challenging procedure. Although, there are a considerable number of instruments that can measure these exposures, they are usually too heavy for carrying and quite expensive to equip each mine worker. The project offers to combine the data coming from designated stationary units and a special personal tracking system in order to predict the real-time exposures. CIEMS is the practice of obtaining information from workers' installed on specific locations in the site. iBeacon is a new kind of Bluetooth transmitter for Apple's implementation of Bluetooth Low Energy (BLE) wireless technology to provide location-based information to smartphones and other mobile devices. The BLE has risen to prominence in the last two years for its low energy consumption and low cost. Real-time location of the smartphones and other mobile devices. The BLE has the iBeacon signals by smartphones while passing through their vicinity. Figure 5 depicts the essential concept of CIEMS project.




Figure 5 Conceptual presentation of the proposed CIEMS technology

Subject IV: EEDOS

Blasting has a significant impact on the quality of the remaining high walls in open pit mines and an enhanced blasting can considerably reduce the number of loosely hanging rock pieces on bench faces. Usually, the location of the drilled blasting holes deviates from the designed locations and blasting enhancement can be reached by the optimized distribution of the explosive inside rock mass based on the desired area of imaging on an updatable map of the mine. Thus, the location of adjusting blast hole charges according to the real drilling locations because of being time-consuming and costly for mining operations. We are to develop a fast and automated technology for enhancing the distribution of explosive energy in open pits mines using drones and machine learning in order to increase the stability of the remaining highwalls and consequently reduce the risk of rock falls. In the offered technology, high-resolution images will be taken automatically from the blasting hole programmed in UNR. Then, image processing is used to find the deviation of drill hole locations and an energy distribution optimizer will be used to adjust the charge of each shot hole individually in order to reach the best explosive energy distribution (See Figures 6 and 7).

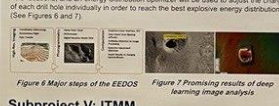


Figure 6 Major steps of the EEDOS

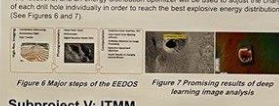


Figure 7 Promising results of deep learning image analysis

Existing Technology at UNR

Drone imaging can be very challenging in open-pit mines. The terrain of open-pit mines is usually very rough and dynamic. These make the conventional constant altitude imaging not to be effective enough for high-resolution imaging. We have developed a unique drone control software (ground station) for open-pit imaging, through a NIOSH BAA contract. It is a mobile application where the user can define the desired area of imaging on an updatable map of the mine. Thus, the location of the camera to provide required image overlay, are computed and exposed to the camera. Implementation of the flight trajectory will be autonomous after this point and battery exchange and resumes the mission after replacing the battery. A unique feature of this software is to import the most updated terrain model of the mine and to use it as a reference for lowering the drone to a closer distance above the ground and keep that distance during the flight. This ensures that the drone will take high-resolution images (about 5 m spacing) that are required for observing small objects such as blastholes. Figure 10 shows the graphical user interface of the software.

In addition, the project team has experience in programming web-based photogrammetry computations in mining applications. These calculations are usually performed on a powerful computer server (8 NVIDIA 2080Ti graphic cards, 256 DDR memory and 10TB of SSD storage) in P3 lab to handle the computational loads of the offered projects. The lab is also equipped with multiple drones from Phantom4 Pro to Mavic 600 Pro with a complete set of sensors and cameras.

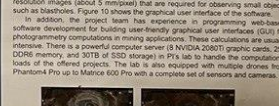


Figure 10 UNR's Ground Station mobile application for drone control in open-pit mines

Subject V: ITMM

The project proposes an approach for solving the challenges of site-operations. It is an enhanced reevaluation of the remote equipment by using respective 3D models, whose individual parts move in relation to each other as they would in real life. Spatial data of the machine's components will be scanned and transmitted in real-time and represented by a corresponding 3D model. The surrounding of the machine (Figure 8). A high illumination is usually needed in all spots of the capturing. The offered approach has four major upgrades compared to the similar technologies available in passenger cars: (i) Passenger cars usually have a single segregated body, which needs only a single virtual model to be inserted into VR environment. In contrast, most of the mining machines have moving components such as a bucket, boom, etc. that move in relation to the main part of the body. We have planned to scan the configuration of the machine at each instance and project a corresponding 3D model step by step. The setting will be implemented using location indicators in the lab scale and Electronic Control Unit output in real time. (ii) We have planned to add a series of 3D guidelines that illustrate the prospective trajectory of the machine in mining operations. This will assist the operator to perform a safer operation. (iii) Operational environment of mining machines can be extremely dusty, smoky, or foggy with reduced visibility for both operator or remote operators. We have planned to virtually reduce the invisibility using visual effects in order to improve the effectiveness of the technology. (iv) It is planned to build a dual application for the proposed technology as another layer of proximity detection. In this module, human objects will be detected on the videos using a deep learning neural network and a will be warned to the operators.

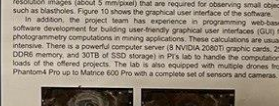


Figure 8 Combining VR and deep-learning in ITMM

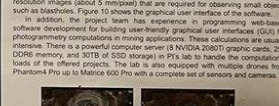


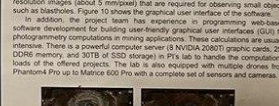
Figure 9 Components of SEUM including smartphones, iBeacons, Wi-Fi

Subject VI: SEUM

A series of smartwatches will navigate miners to safe locations. SEUM consists of wearable personal smartwatches and a series of iBeacon transmitters installed in optimized distances in the mine. The smartwatches will be transmitted to the smartwatches during navigation. Mine catastrophes are modeled and escape routes of the people in different locations of the mine are generated. Mine map is stored in the watch and evacuation orders, destinations, and the safe routes are transmitted to the watches through Wi-Fi network of the mine (Figure 9).

Industrial Partners

The project is supported by an exceptional list of ten industrial partners. These collaborators are the world's mining leaders. The project has Kinross, Newmont, and Freeport as general collaborators for all sub-projects. In addition, we have specialized industries helping each subproject individually. For example, Orica will be involved in EEDOS, Vale in TRIAS, CleanAir in CIEMS, Howden in SEUM, and Respec and Komatsu in ITMM. RESPEC is another collaborator that not only will be involved in CIEMS, but also will provide an extra funding for a graduate student to work on this topic. Moreover, the Big Data team of Freeport and the Artificial Intelligence Center of Vale are process participants for this project.



References

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[4] Chen, J., Zhang, Y., & Xue, W. (2018). Unsupervised Indoor Localization Based on Smartphone Sensors, Beacon and Wi-Fi. Sensors, 18(5): 1378.