AI-Based Geotechnical Hazard Detection for Autonomous Underground Mining

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ABSTRACT

The transition to fully autonomous mining requires an interoperable system that is autonomous at all stages of a mining operation including geotechnical hazard management. AI algorithms using deep learning is a viable option to develop autonomous technologies. However, the success of deep learning depends on having a large and diverse training set. Geotechnical hazard management requires on-site data collection. The restrictions on on-site data collection cause small and unbalanced datasets that limit the performance of deep learning and thereby prevent the increased use of autonomous technologies. We present a methodology that includes transfer learning, synthetic data generation, and a data sampling technique to train a deep learning model using convolutional neural network (CNN). The methodology is implemented in a large-opening limestone underground mine to develop an autonomous roof fall hazard detection system. Images depicting hazardous and non-hazardous roof conditions are collected. Using the transfer learning approach, a pre-trained network provided the suitable low-level features to train the final fully connected layer of a CNN. The network classification accuracy was improved by expanding the training set with synthetic images rendered from a 3-D model of the mine roof. Then, a deep learning interpretation technique is implemented to identify the important features in each image for prediction. The analysis shows that the system uses the same visual features as the expert on roof fall hazard detection. The interpretability of the developed AI algorithm provides more insight to improve the quality of the training set. A data sampling technique that uses Gabor magnitude responses was introduced. This allowed enhancement of user confidence on the autonomous systems as the features being used by the network are understood and similar to the expert judgement. The final network performance is verified with an independent test set. The results provide a foundation for the increased use of autonomous hazard detection technologies for the future of underground mining