Dynamic Risk Prediction in Underground Spaces: A Real-Time Evolutionary Approach Using LSTM and BN

M. Mousavi[1], *B. Li*[2] *and X. Shen*[3]

1. Ph.D. Student, School of Civil and Environmental Engineering, The University of New South Wales (UNSW), Sydney, NSW 2052, Australia. Email: milad.mousavi@unsw.edu.au
2. Associate Professor, School of Mineral and Energy Resources Engineering, University of New South Wales (UNSW), Sydney, NSW 2052, Australia. Email: binghao.li@unsw.edu.au
3. Associate Professor, School of Civil and Environmental Engineering, The University of New South Wales (UNSW), Sydney, NSW 2052, Australia. Email: x.shen@unsw.edu.au

Keywords: Underground Spaces; Dynamic Risk Management; Evolving Long Short-Term Memory (LSTM); Bayesian Network (BN); Real-Time Monitoring

ABSTRACT

The escalating demand for underground spaces, driven by rapid urbanization and resource extraction, presents unprecedented challenges in managing environmental risks and ensuring safety within these intricate domains. The inherent variability and unpredictability of underground environments pose significant challenges for conventional risk assessment methods, necessitating a transition towards continuous and dynamic risk monitoring and management techniques. This research proposes an innovative approach that combines data-driven insights with expert engineering knowledge to dynamically predict and manage environmental risks in underground environments. The methodology features a self-improving Long Short-Term Memory (LSTM) model that utilizes both historical data from previous projects and real-time monitoring data from ongoing projects to forecast environmental variables. These predictions then inform an expert-elicited Bayesian Network (BN) to assess and manage environmental risks, with a particular focus on safety in underground coal mining. Moreover, the research underscores the struggle in handling multivariate and heterogeneous sensor data streams and the inadequacy of conventional statistical and data-driven models in comprehending the complexity of underground spaces. This dilemma emphasizes the critical need to balance data-driven insights with engineering knowledge to develop adaptive and transparent decision support systems. A case study conducted in an underground coal mine in China demonstrates the effectiveness of this approach in understanding the intricate spatial and temporal relationships among environmental variables. By integrating data-driven patterns and engineering expertise, this approach continuously learns and adapts, providing a robust foundation for decision-makers and domain experts. Ultimately, this methodology offers a valuable tool to enhance safety and productivity in complex underground spaces.