

Keynote speech

From Rocks to Intelligence: AI and Data-Driven Technologies for Sustainable Mining

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ABSTRACT

Mining is fundamental to modern society and is becoming increasingly important as the global transition towards renewable energy, electrification and advanced technologies drives demand for minerals and critical resources. At the same time, the industry faces increasing pressure to improve safety, productivity, resource efficiency and environmental performance. Artificial intelligence (AI), machine learning (ML), automation and data-driven technologies offer significant opportunities to address these challenges.

This keynote explores the emerging role of AI and ML in transforming conventional mining into a smarter and more sustainable industry. Modern mining operations generate large volumes of geological, geotechnical, operational and environmental data. When combined with engineering knowledge, these data can support improved prediction, optimisation and decision-making throughout the mining value chain.

Particular attention is given to applications in rock mechanics, drilling and blasting, rock fragmentation, blast-induced vibration and geotechnical risk assessment. Machine-learning models can identify complex relationships between geological conditions, rock properties, blast-design parameters and operational outcomes. Such approaches can assist in optimising fragmentation, reducing unwanted vibration and overbreak, improving explosive utilisation and enhancing overall mining efficiency.

However, predictive accuracy alone is not sufficient for engineering applications. AI models used in mining must also be reliable, interpretable and physically meaningful. Explainable AI, physics-informed machine learning and hybrid models that combine engineering principles with data-driven approaches provide promising pathways towards trustworthy decision-support systems.

AI can also make an important contribution to sustainable mining. Improved blast fragmentation can reduce downstream crushing and grinding requirements and associated energy consumption. Intelligent monitoring can assist in managing vibration, dust, emissions and geotechnical hazards, while predictive systems can improve equipment utilisation and resource efficiency.

The future mine will therefore be characterised by the integration of AI, advanced sensing, automation, digital technologies and engineering expertise. Nevertheless, challenges related to data quality, geological uncertainty, model transferability, workforce capability and responsible implementation must be addressed.

AI should not replace engineering judgement; rather, it should enhance it. By combining computational intelligence with physical understanding and human expertise, the mining industry can progress towards operations that are safer, smarter, more productive and environmentally responsible.

Index Terms— Artificial Intelligence, Machine Learning, Mining Engineering, Smart Mining, Sustainable Mining, Rock Mechanics, Drilling and Blasting, Geotechnical Engineering.

Speaker's short biography:



Dr Manoj Khandelwal is an Associate Professor and Program Coordinator (UG and PG) of Mining Engineering at Federation University Australia and an Australian Endeavour Fellow. He has more than 20 years of research and teaching experience in Australia and India and is recognised for his expertise in mining geomechanics, rock blasting, slope stability, sustainable mining, and soft computing applications in geo-engineering. Dr Khandelwal has published more than 280 research papers in reputed journals and conference proceedings. According to Scopus, his publications have *received* over 8,500 citations, with an h-index of 53. He has also successfully completed several research and consultancy projects in his areas of expertise. He has received several prestigious honours, including the Young Scientist Award from the President of India, Young Engineers Award from the Institution of Engineers India, Young Mining Engineer of the Year Award and SRG Information Technology Award from the Mining Engineers' Association of India, as well as the Endeavour Research Fellowship and Endeavour Executive Fellowship from the Australian Government. Dr Khandelwal serves on the editorial boards of several international journals and has reviewed manuscripts for more than 150 international journals. His current research interests include intelligent and sustainable mining, rock mechanics and blasting, geotechnical engineering, and artificial intelligence and machine learning applications in mining and geo-engineering.