Next generation of geotechnical risk management: Unlocking the power of Virtual and Augmented reality in mining operations

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# ABSTRACT

The mining industry is recognizing the necessity of adopting advanced technologies to address complex geotechnical challenges and improve risk management practices. Among the most promising innovations, Virtual Reality (VR) and Augmented Reality (AR) offer transformative capabilities for enhancing decision-making and safety in mine operations. However, the widespread application of these immersive technologies remains limited due to the absence of standardized implementation methodologies.

In geotechnical contexts, VR and AR enable immersive visualization of digital terrain models, slope stability simulations, and real-time monitoring data. These tools allow engineers and operators to better interpret complex surface conditions, identify early warning signs of failure, and communicate hazard scenarios more effectively.

Integrating VR/AR into geotechnical workflows reduce the time and cost of site inspections, support predictive analysis, and optimize mine design, all while contributing to reduced environmental impacts through data-driven and low-carbon planning strategies.

This paper presents a practical methodology for implementing VR/AR technologies in geotechnical risk management. The framework focuses on aligning immersive tools with data acquisition systems to support decision-making. The goal is to demonstrate how immersive technologies can transform geotechnical workflows, improve risk mitigation, and drive safer, more efficient mine operations.