

Bridging Planning and Operations: A Dynamic Terrain-Evolution Simulation Framework for Strip Mining Integrating Dozer and Dragline Operations: Application to Selective Mining, Byproduct Extraction, and Operational

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Abstract

Surface strip mining requires coordinated excavation, waste redistribution, and ore recovery under strong geometric and operational constraints. Existing planning models quantify volumes and schedules but do not update terrain explicitly, while most simulation approaches represent equipment flow without reconstructing excavation and spoil geometry. This study proposes a spatially explicit terrain-evolution simulation framework for strip mining that integrates geological surfaces, strip and bench sequencing, equipment-dependent material handling, and dynamic terrain updating within a unified grid-based model. The framework distinguishes between two excavation paradigms: draglines are modeled as surface-following systems with casting-based spoil placement, whereas dozers are represented as elevation-controlled systems with directional push-based placement. Geological surfaces are discretized on a structured grid to compute interval thickness, bench-level bank volumes, and loose volumes. Material is then routed according to bench-specific destination rules, including internal dumping into the corresponding strip of the previously mined trench, external waste routing, and ore extraction outside the terrain-reconstruction domain. The simulator updates terrain after each excavation and placement event and tracks lithology distribution within reconstructed spoil. The case study is designed as a scenario-analysis platform for selective mining, byproduct extraction, and operational efficiency assessment. In addition to reproducing sequential terrain change and spoil geometry, the framework enables comparison of alternative recovery strategies under common geological and operational conditions. The proposed approach provides a computationally efficient bridge between strategic mine planning and operational simulation and supports future scenario testing for recovery improvement, waste management, and mine planning optimization.

Keywords

Strip mining, Terrain-evolution simulation, Internal dumping, Spoil reconstruction, Selective mining.

Acknowledgments

The authors gratefully acknowledge the OCP Group for providing access to the data and for their support of this research.

Biographies

Noaman BOUHLALI is a Ph.D. student at the Geology & Sustainable Mining Institute (GSMI), Mohammed VI Polytechnic University (UM6P), specializing in "Towards New Integrated Mine Waste Management Techniques." His academic journey reflects a strong multidisciplinary foundation in mining and geology. He holds a State Mining Engineer Diploma from the National School of Mines in Rabat, a Master's Degree in Mineral Resource Prospecting

and Valorization, a Bachelor's Degree in Mineral Resources and Quarries from the Faculty of Science and Technology in Settat, and a Specialized Mining Technician Diploma from the Marrakech Institute of Mines. His research explores the intersection of geosciences, mining engineering, and sustainability, with particular emphasis on resource and reserve estimation, mine planning, mining technologies, bulk material handling, mine waste management, scenario planning and simulation, progressive reclamation, and environmental impact assessment. By integrating advanced simulation-based approaches, his work aims to develop optimized mining strategies that balance operational efficiency with environmental responsibility, contributing to the global transition toward sustainable resource management.

Abdellatif Elghali is an assistant professor at UM6P since 2021. He is managing Mines and Mineralurgy axis at GSMI. He is a mining engineer and obtained his PhD degree in Minerals Engineering in 2018 from the University of Quebec. His research interest focuses on geometallurgy, applied mineralogy, environmental geochemistry and natural resources valorization.

Yassine Taha is an Associate Professor at UM6P since September 2017. He is currently leading the Sustainability division within GSMI. He obtained in 2016 his doctorate in Environmental Sciences at the University of Quebec (Canada) with Cadi Ayyad University (Morocco). His research interests turn around sustainability, circular economy, mine-waste repurposing, reuse-recycling-and-recovery, life-cycle assessment and construction materials.

Mostafa Benzaazoua is a researcher in the fields of geosciences and environmental studies. He earned his Ph.D. from the University of Lorraine in 1996, followed by his Habilitation to Direct Research in 2005, both from the same institution. His academic journey led him to join the Université du Québec en Abitibi-Témiscamingue (UQAT) in 1996, where he rose to the position of professor in June 1997. During his time at UQAT, Professor Benzaazoua held a Canada Research Chair in "Integrated Management of Mining Waste" from 2003 to 2011, showcasing his expertise in the field. He also co-chaired an international research chair funded by the International Development Research Centre (IDRC) in 2009, in collaboration with the University of Marrakech in Morocco. Currently, Professor Benzaazoua serves as a Full Professor at Mohammed VI Polytechnic University in Morocco, where he leads the Geology and Sustainable Mining Institute. His research focuses on sustainable management of mining sites, aiming to minimize the environmental impact of the mining industry while promoting the well-being of ecosystems and communities. His dedication to responsible and environmentally conscious practices positions him as a visionary leader in his field.