Artificial Intelligence in the Mining Industry: An Overview

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ABSTRACT

Keeping the Digitalization and Upgraded Technology in mind, the effort to rapidly transform the way we use energy, it is required to advance new technologies and accelerate the lowering of carbon emissions. However, their extraction often comes with high societal and environmental costs. Therefore, developing ways to extract various minerals in a way that benefits global as well as an individual country's sustainability goals and mitigates direct and indirect negative impacts of extraction, is a worthwhile endeavor. Artificial intelligence (AI) enabled applications provide one avenue by which to potentially speed up this process. The question remains, how do we ensure AI is used in an ethical way that benefits communities, societal development, and environmental sustainability in the mining industry? In this article we give an overview of current and potential uses of AI in the mining sector and present some ethical considerations for the use of AI in the industry. We then outline a way forward to a more ethical and sustainable approach to using AI in the mining sector.

***Keywords**:* Artificial intelligence; Mining industry; AI Ethics; Sustainability.

1.Introduction

To realize the plans for electrification of transport, power, and heat sectors, and for deployment of fossil-fuel-based alternatives, the expansion of mining operations is needed. However, the metal and mineral resources should help to address the climate change and environmental problems brought by the utilization of fossil fuels, their extraction is often associated with water, land, and air pollution, health problems, and other issues (Adler et al., 2007; Ayuk et al., 2020; Bolger et al., 2021). Although the total land footprint estimates vary depending on the methodology applied, the most recent global mining assessments suggest that close to 100,000 km^2, or an area larger than Portugal or South Korea, has been used for mining or mining associated activities, such as waste dumps, across 135 countries (Tang and Werner, 2023). Moreover, over 50 % of current mining sites and deposits are located in politically unstable and economically poor countries of South America, Africa, and Asia, or the 'Global South' group.

In many locations, counterintuitively, the growth in production correlates with acute social and economic challenges, threatening the ability of poor and underdeveloped countries to follow the sustainable development path (L`ebre et al., 2020; Sengupta, 2021; UNEP, 2019). Besides the climate-related considerations, there is an important economic development and value argument that urges mining growth. Resource extraction is a strong contributor to the economic sustainability of 81 countries (United Nations, 2021), of which 63 % are low and middle-income countries, whose national budgets increasingly depend on resource production revenues (Roe, 2016). For example, mining provides almost 50 % of the government's revenues and generates over 99 % of the exports revenues in the Democratic Republic of Congo (DRC).But how much we rely on the technology and AI for sustainability is the main concern.

Such a large-scope and multifaceted question calls for an approach powerful enough to perform a complex system analysis and to run simulations of future developments, capturing nonlinear time-varying behavior of the involved parties. Recent advances in methods for optimization and simulations highlight artificial intelligence (AI) capabilities and AI-enabled applications as a promising tool for identifying a development venue leading to the desired outcome (Barmer et al., 2021; Mirjalili and Dong, 2020; Xu et al., 2021). Improvements in computational abilities and data availability empower AI algorithms and lead to a new era of AI-based research. The fast-growing body of research shows that machine-learning (ML) and AI-driven approaches may enhance mining economics. Superior in data mining and analytics, AI algorithms used for projections and simulations help people choose the best patterns of behavior and management practices, boosting productivity, optimizing operations, and increasing profitability (Jung and Choi, 2021; Kumar and Dimitrakopoulos, 2021; Noriega and Pourrahimian, 2022; Sircar et al., 2021).

The benefits of using the same models and approaches for achieving environmental sustainability and/or social justice, however, are obscure and questionable (Dauvergne, 2021, 2022; Francisco, 2023; Halpern, 2021). Along with the worries regarding the narrow focus and, thereby, impact of AI solutions, scientists and the general public, it has been raised concerns about the ethics of AI solutions (Boddington, 2017; Hickok, 2021; Jobin et al., 2019; Srikumar et al., 2022). Debates on the subject, namely on the guidelines and principles for conducting research and using AI applications, signal that consensus has not yet been reached and that the developed recommendations have not spread far (Chatila and Havens 2019; Hagendorff, 2020). It is important to also note that while much of the increase in mining activities, and therefore related AI use, occurs in "developing" countries of the Global South, a prevailing body of the frameworks mentioned above have been established by the "developed" members of the Global North region, appealing to its ethics, community values, and political and institutional capabilities (Amugongo et al., 2023; Corrigan et al., 2023; Eke et al., 2023). The differences in cultural perspectives, immediate needs, technical capabilities, and institutional capacities of the two regions have given rise to the debate over the use and design of AI-enabled tools and associated data. Along with the necessity to recognize those distinctions comes the need for review of where, with which tools, and how AI can be employed. In this context, driven by the question of how AI approaches can help communities in societal development, environmental sustainability, and economic growth when it comes to the mining industry, we discuss the use and applicability of AI in the mining sector, what ethical considerations need to be discussed alongside the use, and how multi-objective optimization, as an approach, has the potential to use AI to provide a more sustainable, in terms of the UN's definition, pathway forward in this important industry.

2. Overview of AI in mining

Formulated at the United Nations summit in Rio de Janeiro in 2012, the seventeen UN Sustainable Development Goals (SDGs) set the objectives for the balanced economic, societal, and environmental development needed for achieving equity and prosperity on a global or planetary level. The comprehensive system of SDG indicators helps track an individual country's, but not industries, progress. The industry sustainability taxonomy substituted by the environmental, social, and governance (ESG) reporting lacks clarity, transparency, and international consistency. Therefore, in this section, we outline the need for innovative solutions for making mining sustainable in the 'global' UN SDGs sense.

We review the current state of the mining industry, that are falling far behind on their SDGs, and we point out the scope of changes needed and the associated complexity that calls for the use of powerful AI algorithms. Next, we take a general view on mining processes and discuss how AI-based approaches may help with particular operations and decisions. We purposely focus on the opportunities for AI applications, leaving the discussion of the associated ethical challenges for usage of AI.

2.1. Background

To mitigate climate change, which is threatening human populations around the world, countries should cooperate in reducing greenhouse gas (GHG) emissions and switching to clean energy technologies (IPCC, 2023). The solutions, such as adopting battery-based electric vehicles or increasing large-scale offshore and onshore wind power generation, however, requires a manifold increase in metals and minerals supply. This raises a critical question of whether such developments will bring low-income and resource-rents-dependent economies more prosperity and improvements along multiple axes of sustainability or instead will deepen the often-cited "resource curse". To understand why AI algorithms, applications, and their design are of great value and importance in the mining industry, consider the SDGs' multidimensionality and complex interdependencies. Although we are heading towards the AI era, but many of the Mining industries with low profit margins are not showing interest towards AI because of high cost.

2.2. Current and upcoming uses of AI applications in mining

Several areas have been identified, where AI applications have already proven to be useful in the mining industry. Loosely speaking, resource extraction may be divided into the exploration, exploitation, and reclamation phases. Mining activities and upstream operations may differ dramatically depending on resource, production method, location, equipment used, and more. Taking a general look at the data types and decisions made, we distinguish a few more stages and position the review of AI use around them . We start the discussion with the models focused on exploration. Next, we review AI methods supporting mining and production approach and design decisions. We discuss the use of AI in mine operation and management practices separately, highlighting the aspects overlapping with SDGs. Additionally, with the goal of analyzing the effect of mining on sustainability, we consider activities associated with mining, namely extracted ore processing. Finally, we highlight the critical but often neglected stage of mineclosure and abandonment. Note, our objective is to provide an overview of AI's capabilities assisting decision-making related to resource extraction and enhancing mining industry operations. Therefore, technical details on AI models and algorithms are beyond the scope of this paper. The provided list of references and discussions, however, should inspire interested readers to critically review and revisit the setups and frameworks of AI applications, following the suggestions provided in the next two sections.

2.2.1. Exploration

The AI applications focuses on prospecting and exploration, representing the initial stage of resource development. It includes the potential mining site or deposit location and an analysis of its grade or characteristics critical for productivity and profitability. Existing AI-enabled approaches use data obtained from geologic and geophysical resource properties mapping, remote and other sensing surveys, and chemical and mineralogical analyses, among others. Such data are compiled during exploration sampling and borehole logging, during laboratory work, and upon further investigation of prospects' operations .ML methods such as support vector machines (SVMs) and deep learning models are commonly used to clean and process data, perform imputations, and conducting data mining, addressing missing and erroneous data issues. Those functions are especially useful when it comes to information collected from drilling, sensors, or measurements made in real time (Jung and Choi, 2021). Results generated with the help of AI aid in understanding and predicting future resource production characteristics and supply potential, examples of use having come already from Goldspot Discoveries Incorporated and IBM Watson (Murphy, 2019). Thereby, AI-based analyses underpin and facilitate economic evaluations, enable measuring the financial potential of mining operations under various market conditions, and support investment and fiscal decisions (Lane, 1988).

2.2.2. Mining setup

After the location of the deposits is known from the exploration and survey, Mining owners and industrialists have to make a decision about mining method. The two commonly distinguished mining approaches are open-case / surface mining and underground mining. The primary characteristics influencing the decision on mining approach are geologic and mineralogy properties of the deposit, i.e. its depth and size, which affect productivity and extracted resource quality. The next most influential factors are economic. Open pit and underground production methods are compared on the basis of expected profitability, accounting for the equipment needed, its costs and operational expenses, costs to comply with corresponding regulations, mining site abandonment costs, and more. Advances in experimental geomechanics, combined with the growing collections of geologic rock data and insights from rock engineering, led to applications of AI in mining site design, e.g. tunneling and underground excavations, for improved productivity and profitability (Morgenroth et al., 2019). Along with that, the understanding of rock physical properties allows providing recommendations on safer and resilient mining. Thanks to continuous operational data collection, AI models can also now be applied to the analysis of surface vibrations (and microearthquakes) and slides predicting blasts and various failures (Montiel et al., 2016; Ali and Frimpong 2020; Bui et al., 2020; Ali, 2022). Thus, AI not only helps improve mining efficiency and economics, but also can reduce life-risks, suggesting the optimal mining approach.

2.2.3. Operations

Mining setup and operations management studies intertwine with AI-enabled tools by incorporating workplace safety considerations along with productivity and environmental impact analyses. Mining activities may be associated with a variety of risks, for instance, when resource extraction environment is represented by small workspace with inadequate lighting and contact with toxic materials, waste, and gasses. Inhalation of harmful particles not only damages the health of involved workers, but also leads to respiratory infections, which have become the top cause of death in Africa (Madhi and Klugman, 2006; Reiner et al., 2019). Drilling and blasting, heavy machinery, and specialized equipment operations may result in critical injuries, thus raising questions of mine safety and calling for monitoring and mine hazard assessments. For this reason, AI tools have been created to limit workers' exposure to these conditions through machines that 'autonomously monitor the atmosphere, send signals and warnings, locate problematic areas, and work continuously even in dangerous situations' (Hyder et al., 2019). Furthermore, AI-enabled tools have a potential role for government use in monitoring mining site and worker safety violations. For instance, some of the same technologies being already used to monitor biodiversity (Arteta et al., 2016; Kesari, 2019; Microsoft, n.d.) or detect air or water pollution violations (Carbon Tracker Initiative, n.d; Han et al., 2022), could help governments in mining communities also monitor violations. Earth observation techniques that employ machine learning can also potentially aid in identifying illegal mining, speeding up verifications or administration for land management, or identifying and planning for effective reclamation of land. On the company side, facial recognition and image detection systems are already being used in public spaces (Tucker, 2020) and could aid in monitoring.

Fig.1: Role of AI in various activities of Mining Industry.

3.Conclusions

The use of AI-enabled tools in the mining industry is already underway. Given the key role of this sector in the energy transition and the speed with which that transition needs to occur, AI has the potential, if used correctly, to increase the efficiency of this process. If AI is employed while factoring in sustainability and community development needs, the potentially negative ethical implication of AI use could be significantly reduced. However, if considerations for the ethical use of these tools, and the tradeoffs that accompany their use, are not taken into account. We thus losing the opportunity to transition away from fossil fuels in a sustainable and planet/human-centric way. Thus, it is a pressing and worthwhile endeavor for both industry players and policymakers to take an ethical and holistic perspective on the use of AI in the mining sector. Moving beyond economic and efficiency gains, AI-enabled tools have the potential to help improve the comprehensiveness or sustainability of decision-making in mining operations.

By incorporating not only large amounts of economic data, but also significant amounts of data on environmental, land use, communities, and governance factors, multiobjective optimization of operations through machine learning processes is potentially useful. Generally, AI applications aimed at decision-making for economic outcomes are prone to accept utilitarianism, originated from consequentialism moral theory, focusing on the maximization of the overall consequences. Although this concept allows for redistribution of benefits to compensate for suboptimal individual outcomes, the inclusion of transparency and moral principles often remains neglected. Without scrutiny and transparency in the trade-offs, the use of such tools may accelerate already unjust or suboptimal results. Acknowledging that this is just a starting point, we conclude our review of the path forward, noting that whereas data and AI algorithms may empower the scientists and decision-makers, without transparency and continuous verification of ethical principles, the society may not be able to use its powerful tools for a greater good, stepping out of the way toward SDGs.

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This research is completely based on the Secondary data and there is no relevance and connection with any mining Industry.

References

1. Acemoglu, D., Johnson, S., Robinson, J.A., 2002. An African success story: botswana. Avail. SSRN, 304100. https://ssrn.com/abstract=304100.
2. Acheampong, A.O., Boateng, E.B., 2019. Modelling carbon emission intensity: application of artificial neural network. J. Clean. Prod. 225, 833–856. https://doi. org/10.1016/j.jclepro.2019.03.352.
3. Addison, T., Roe, A., 2018. Extractive industries: The management of resources as a driver of sustainable development: WIDER studies in development economics. Oxford University Press, p. 2018. https://doi.org/10.1093/oso/ 9780198817369.001.0001.
4. Adhikari, B., King, J., Vadlamannati, K.C., Chachu, D.O., 2023. Why do some natural resource-rich countries adopt prudent fiscal rules? An empirical analysis. Extr. Ind. Soc. 14 (10123), 4. https://doi.org/10.1016/j.exis.2023.101234.
5. Adler, R.A., Claassen, M., Godfrey, L., Turton, A.R., 2007. Water, mining, and waste: an historical and economic perspective on conflict management in South Africa. Econ. Peace Sec. J. 2, 2. https://doi.org/10.15355/epsj.2.2.33.
6. Ali, D., 2022. Advanced analytics for surface mining. in advanced analytics in mining engineering: leverage advanced analytics in mining industry to make better business decisions. In Advanced Analytics for Surface Mining. Springer, Cham. https://doi. org/10.1007/978-3-030-91589-6.
7. Angelov, P.P., Soares, E.A., Jiang, R., Arnold, N.I., Atkinson, P.M., 2021. Explainable artificial intelligence: an analytical review. Interdisciplin. Rev. 11 (5), e1424. https://doi.org/10.1002/widm.1424.
8. Australian Resources and Investment. Ethical considerations of artificial intelligence in mining. https://www.australianresourcesandinvestment.com.au/2021/06/07/ethical-considerations-of-artificial-intelligence-in-mining/, 2021.
9. Ayuk, E., Pedro, A., Ekins, P., Gatune, J., Milligan, B., Oberle, B., Christmann, P., Ali, S., Kumar, S.V., Bringezu, S., Acquatella, J., Bernaudat, L., Bodouroglou, C., Brooks, S., Bonanomi, B., E, C., J, C., N, D., K, D, 2020. Mineral Resource Governance in the 21st Century: gearing extractive

industries towards sustainable development. Internat. Res. Panel, United Nations Environ. Programme. https://doi.org/10.1007/s13563- 021-00265-4.

10. Barmer, H., Dzombak, R., Gaston, M., Palat, V., Redner, F., Smith, T., Wohlbier, J., 2021. Scalable AI, White paper prepared by the national AI engineering initiative. the National AI Engineering Initiative. https://insights.sei.cmu.edu/library/scalable-ai/.
11. Bashir, R.N., Bajwa, I.S., Shahid, M.M.A., 2019. Internet of Things and machine-learningbased leaching requirements estimation for saline soils. IEEe Internet. Things. J. 7 (5), 4464–4472. https://doi.org/10.1109/JIOT.2019.2954738.
12. Bedue, P., Fritzsche, A., 2022. Can we trust AI? An empirical investigation of trust requirements and guide to successful AI adoption. J. Enterprise Info. Manage. (JEIM) 35 (2), 530–549. https://doi.org/10.1108/JEIM-06-2020-0233.
13. Boddington, P., 2017. Towards a Code of Ethics For Artificial Intelligence. Springer.https://link.springer.com/book/10.1007/978-3-319-60648-4.
14. Boehmer, M., Kucera, M., 2013. Prospecting and exploration of mineral deposits (ISSN), 2nd ed. Elsevier Science https://shop.elsevier.com/books/prospecting-and-exploration-of-mineral-deposits/bohmer/978-0-444-99515-5.
15. Boffo, R., Marshall, C., Patalano, R., 2020. ESG Investing: Environmental pillar scoring and reporting. OECD, Paris. https://www.oecd.org/finance/esg-investing-environmental-pillar-scoring-and-reporting.pdf