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Editorial

Applications of Unmanned Aerial Vehicle and Artificial Intelligence Technologies in Mining from Exploration to Reclamation

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Mining has been an essential aspect of human civilization, providing the raw materials necessary for the development of industries and infrastructure. However, mining can be a hazardous and challenging task, requiring significant resources and specialized expertise. Advances in technology have made mining safer, more efficient, and more environmentally sustainable. Unmanned aerial vehicles (UAVs) and artificial intelligence (AI) are two technologies that have revolutionized the mining industry in recent years.

This Special Issue of *Minerals*, entitled "Applications of Unmanned Aerial Vehicle and Artificial Intelligence Technologies in Mining from Exploration to Reclamation", showcases the latest research on the use of UAVs and AI in mining operations, covering a wide range of topics, including remote sensing, geospatial analysis, mineral identification, and predictive maintenance.

Two review articles were published in this Special Issue. Park and Choi [1] reviewed 65 academic papers published between June 2010 and May 2020 to classify the applications of unmanned aerial vehicles (UAVs) in the mining industry into three phases: exploration, exploitation, and reclamation. The study found that UAVs are utilized for various applications, such as geological and structural analysis, working environment analysis, underground surveying, and monitoring of soil, water, ecological restoration, and ground subsidence. This review contributes to the identification of prevalent UAV types, data acquired by sensors, scales of targeted areas, and styles of flying control for the applications of UAVs in mining. Jung and Choi [2] reviewed 109 research papers published in the past decade that employ machine learning (ML) techniques for mineral exploration, exploitation, and mine reclamation. The results showed that ML studies have been actively conducted in the mining industry since 2018, primarily for mineral exploration, using support vector machine and deep learning models. The ML models were mostly evaluated in terms of their root mean square error and coefficient of determination.

One of the key benefits of using UAVs in mining is the ability to collect data from hard-to-reach areas. UAVs can be equipped with various sensors, such as LiDAR and hyperspectral cameras, that can collect high-resolution data on topography, geology, and mineralogy. This data can then be analyzed using AI algorithms to identify potential mineral deposits and optimize mining operations. Martelet et al. [3] discussed the use of a multi-sensor drone survey for geological mapping and modeling of mineralization in a complex polyphased magmatic-metamorphic environment. The combination of multispectral imagery with field geological observations enhances detailed geological mapping, while the combination of field magnetic susceptibility measurements and their use in detailed regional magnetic modeling allows for a consistent model of the mineralization across scales. A case study in French Brittany demonstrates the effectiveness of this approach, resulting in a realistic conceptual and geometrical model of the magnetic mineralization in its geological environment, tightly constrained by field observations and measurements. Honarmand and Shahriari [4] used drone-based photogrammetry for mapping the geology

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of the Shahzadeh Abbas Cu deposit in Iran for mineral exploration. A low-cost drone was used to collect geological data with a spatial resolution of 3.26 cm achieved at a flight altitude of 70 m. Orthophoto and hill-shade images were used to prepare a draft geology map, which was later finalized based on fieldwork data and petrology studies. The study showed that drone-based photogrammetry is a time- and cost-effective method for preparing base geology maps for vein-type mineralization exploration in areas with rough topography.

Another advantage of UAVs and AI is their ability to improve safety in mining. UAVs can be used for inspecting mining sites and identifying potential hazards, such as unstable rocks or areas with high methane concentrations, or for mining operations that are dangerous to access, such as in the deep sea. AI can be used to analyze real-time data from sensors to detect anomalies that could indicate an imminent safety hazard. Stachowiak et al. [5] discussed algorithms for detecting potential damage to conveyor belts, which are critical components of underground mines. The algorithms analyze video recordings of the conveyor belt and detect edge damage, belt deviation, and conveyor load estimation. The research aims to find potential applications for image recognition to improve monitoring and prevent unexpected stoppages of production. Raja et al. [6] presented the design and construction of an unmanned amphibious vehicle (UAmV) inspired by fish that efficiently travel underwater to detect and collect deep-sea minerals for investigations and usage purposes. The UAmV is designed to operate at a 300 m depth and has a unique mechanism for extracting and storing minerals. Standard analytical approaches and computational analyses were used to design and optimize the UAmV's components, leading to the selection of the best material for the UAmV's construction. Overall, this work provides a promising path for the development of a UAmV suitable for targeted real-time applications.

The articles in this Special Issue also highlight the potential for UAVs and AI to reduce environmental impacts associated with mining. By using UAVs and AI to optimize mineral extraction, mining companies can reduce waste and minimize the use of chemicals that can harm the environment. Daud et al. [7] presents a mechatronic system that uses thermal analysis to detect potential saturation zones in heap leaching piles. A hexacopter equipped with a thermal infrared camera is used to obtain temperature information, which is useful in tracing the level of saturated zones. The system allows for proper control of the irrigation system in potentially saturated zones, reducing the potential danger of liquefaction and achieving full stability in the pile.

The use of UAVs and AI in mining is a rapidly evolving field, and the articles in this issue demonstrate the potential for these technologies to improve safety, efficiency, and environmental sustainability in mining operations. As such, this Special Issue is a valuable resource for researchers, practitioners, and policymakers who are interested in the future of mining.

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