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Sensor Based Sorting in Mineral Exploration and the Advantages of Data Fusion

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Abstract

Sensor-based sorting techniques have the potential to improve ore grades while reducing waste material processing. Previous research has shown that by discarding waste prior to further processing, sensor-based sorting can reduce energy, water, and reagent consumption, as well as fine waste production. Recent studies of sensor-based sorting and the fundamental mechanisms of the main sorting techniques are evaluated in this literature review to inform optimal sensor selection. Furthermore, the fusion of data from multiple sensing techniques is being investigated in order to improve characterization of the sensed material and thus sorting capability. The key to effective sensor-based sorting implementation was discovered to be the selection of a sensing technique capable of sensing a characteristic capable of separating ore from waste with a sampling distribution sufficient for the considered sorting method. Classifications of possible sensor fusion sorting applications in mineral processing are proposed and illustrated with case studies. It was also discovered that the main impediment to implementing sensor fusion is a lack of correlative data on the response of multiple sensing techniques to the same ore sample. To provide data for the evaluation and development of sensor fusion techniques, a combined approach of experimental testing supplemented by simulations is proposed.

Keywords: Selective mining • Sensor based sorting • XRF sensing

Introduction

The mining industry is confronted with numerous challenges, including meeting rising global resource demand, declining ore grades, and minimising environmental impact. The transition to renewable energy, population growth, and global development are all driving up demand for most mineral resources. Concurrently, the richest mineral deposits are being depleted, resulting in the development of low-grade/substandard ores and a continuous decrease in the average grade of mined ore. To meet rising demand, larger volumes of lower grade ore must be mined and processed. Mining and processing increased volumes of lower grade ore risks rapid increases in energy consumption and waste generation at a time when social expectations and legislative requirements to reduce mining's environmental impact are increasing.

Selective mining and processing are methods for mining and processing low-grade ores more efficiently [1-3]. Selective processing control can be implemented using sensor-based algorithms, which also has the advantage of reducing potential human error. Sensing technologies can provide real-time data that can be used to optimise production and reduce waste processing. Sensor-based ore sorting improves processing efficiency and reduces tailings by diverting non-economic material. Early removal of mined material that cannot be economically processed avoids unnecessary grinding and flotation. This can significantly reduce the consumption of electricity, water, and chemical reagents, particularly for low grade heterogeneous ores containing a high amount of gangue.

Literature Review

Sensor-based sorting first appeared in the mid-twentieth century. The majority of the early sorting machines separated the ore based on appearance, effectively automating traditional hand sorting techniques [4-6]. Rising labour costs made hand sorting uneconomical, so this type of automated sorting was implemented. Furthermore, the desire for greater security through fewer people handling the ore resulted in diamond mines being early adopters of sensor-based sorting technology. Scientific advances, particularly in the fields of radiation, nuclear, and fluorescence physics, enabled the development of new sensing techniques that could provide additional information on the material sensed. These sensing techniques allowed for the separation of mined material based on characteristics other than appearance, allowing for the separation of more ore types that could not previously be separated.

Particle sorting and bulk sorting are the two main approaches to sensor-based sorting of mined material. Individual particles of mined material are sensed and classified as valuable or waste in particle sorting [7,8]. The particles are then ejected from the stream selectively based on their classification. It should be noted that depending on the expected proportions, it is possible to eject either the valuable particles or the waste. Instead of individual particles, parcels of bulk material transported on a conveyor belt are sorted in bulk sorting. The parcels are defined as the material transported on the belt for a specified period of time, which is determined by the speed at which the material can be diverted within the system.

Typical parcels consist of the transported material for 30 seconds to a few minutes. In the case of particle sorting, parcels are classified as valuable or waste based on sensor results, and the material is then separated by diverting either the valuable or waste material to a separate conveyer belt or stockpile. The use case dictates whether particle or bulk sorting is used, as each has advantages and disadvantages. Particle-based sorting is more selective and can result in a higher ore quality upgrade. This is especially useful for ores with high particle scale heterogeneity, in which a small number of particles containing the majority of the valuable material are mixed with many barren particles, lowering the total grade.

Discussion

The main limitation of particle sorting is capacity, because the volume of material presented to the sensor must be small enough to separate individual particles. Furthermore, particle sorters can typically only handle a limited range

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of particle sizes; for effective sorting, a maximum size ratio of approximately 3 between the smallest and largest particle is generally recommended [8]. As a result of the wide size distribution produced by blasting and crushing, the processed material must be separated by size into several streams prior to particle sorting. Due to capacity constraints and size range limitations, many particle sorters must operate in parallel to provide sufficient capacity for a high output mine.

When sorting relatively small particles, the surface characteristics of the particles usually provide enough information to sort the particles. Surface sensing techniques can often be used effectively for particle sorting as a result of this. While surface sensors are less expensive than bulk sensing techniques, this is offset by the need for a large number of sensors. While not as selective as particle sorting, bulk ore sorting allows sorting decisions to be made for larger batches of material on a scale appropriate for high output mines. A single bulk sorter can handle a large tonnage per hour, equivalent to the output of a large scale mine. Bulk sorting is particularly well suited to the sorting of ore with a high level of heterogeneity on a medium scale, with changes in mined ore quality occurring over a few minutes to a few seconds.

The investigated ore is irradiated with incident X-ray photons during XRF sensing. The incident X-ray photons interact with the ore's bound electrons, causing excitation and ionization of the bound electrons. This leaves an orbital electron vacancy that can be filled by a higher energy electron. When an electron is transferred from a higher energy state to a lower energy state, it emits a photon with an energy equal to the difference between the electron energy levels. The energy of the emitted photons is characteristic of the energy gaps and thus the material isotope with which the initial photon interacted. Because of this association, the resulting emitted X-rays are known as characteristic X-rays. A photon detector detects the X-ray energy spectrum emitted by the sensed material. The relative contribution of different characteristic X-rays to the elemental composition of the sensed ore can be used to determine its elemental composition. It is worth noting that the energy gaps between orbital electron energy states are typically less than 1 MeV. As a result, the emitted X-rays have a low energy and limited penetration potential. As a result, the observed photon signal is primarily from the sensed material's surface. The energy spectrum of the emitted photons is scored, and the relative contribution of each characteristic energy to the spectrum provides information about the sampled material. The investigated higher energy level transitions are located further away from the nuclei of the excited atom than XRF and are thus affected by the adjacent nuclei within the investigated material. As a result, the sensor response reflects not only the excited elements, but also their interactions with nearby elements, and thus the mineralogy of the investigated material.

Conclusion

This is the key distinction from XRF, in which higher energy photons are used to ionise bound electrons from lower energy levels. These lower energy levels are closer to the nuclei of the excited atoms and are thus unaffected by the chemical state of the material. As a result, XRF provides elemental composition information. Both the photons used to excite the material and the resulting photon emissions in XRL and Optical Fluorescence have relatively low energies and thus have a low potential to penetrate the observed material. As a result, sampling is primarily limited to the surface of the sensed material. Despite the fact that XRL-based sorting is a well-established technique in diamond mining operations no recent publications on the technique were found. However, there is interest in developing optical fluorescence sensors for detecting minerals of interest in order to enable sorting, and a fluorine fluorescence sensor has been developed in this regard. These fluorescence sensors can excite and induce a specific response in a target mineral, allowing its abundance to be measured precisely. It should be noted that one requirement for florescence sensing to be feasible is that the target mineral have a fluorescence response, which limits the minerals for which the sensing technique is appropriate.

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Conflict of Interest

Authors declare no conflict of interest.

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