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Artificial Intelligence Applications in Mineral Processing

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ÖZET

Bu çalışma kapsamında, öncelikle yapay zekâ konusu genel hatlarıyla ele alınmış ve içinde bulunduğumuz çağı temsil eden Endüstri 4.0 ile ilişkisi irdelenmiştir. Ayrıca cevher hazırlamada kullanılan yapay zekâ teknikleri literatür çalışmalarına dayalı olarak açıklanmıştır. 2017-2021 yılları arasında yapay zekâ teknikleri ile ilgili literatür incelenmiş ve Cevher Ayıklama/Tane Boyutlandırma, Konsantrasyon, Öğütme, Hidrometalurji ve Flotasyon & Flokülasyon olmak üzere 5 kategoriye ayrılmıştır.

ABSTRACT

In this paper, first of all, the subject of artificial intelligence was discussed in general terms, and its relationship with Industry 4.0 was examined. Moreover, artificial intelligence techniques used in mineral processing are explained based on literature studies. Between 2017-2021, the literature about artificial intelligence techniques was reviewed and separated into 5 processing categories: Ore Sorting/Particle Sizing, Concentration, Milling, Hydrometallurgy, and Flotation & Flocculation.

INTRODUCTION

The Mineral Processing Sector is one of the most significant and necessary components of the industry today. So much so that practically all products and goods used in daily life are produced from industrial raw materials, metals, and other minerals that have been processed. One of the most important causes for this increase in production is advancements in artificial intelligence. Today, there are numerous applications of artificial intelligence, whose name is frequently mentioned. These breakthroughs in artificial intelligence, combined with the rapid growth of the Internet of Things, Big Data, and the fourth industrial revolution, have enhanced interest in data science in a variety of fields, including mineral processing engineering.

ARTIFICIAL INTELLIGENCE

Artificial intelligence is a branch of computer science and an area of research designed to analyze intelligence functions using computer models and to apply them after they are formalized to artificial systems.

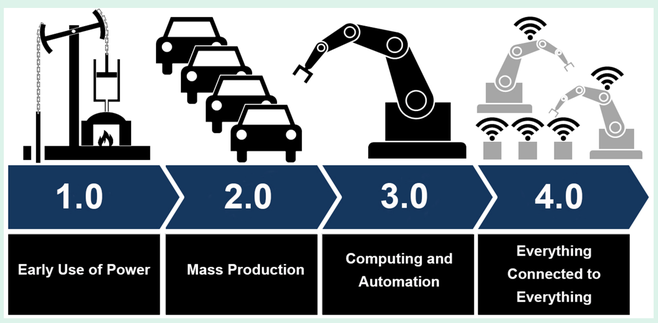

Figure 1. Change in Industry 1.0 to Industry 4.0.

INDUSTRY 4.0

Industry 4.0 is the transformation of Industry 3.0, which began with automation and contains digitalization concepts like data collection and monitoring, sensors, inter-machine connections, artificial intelligence, cybersecurity, and industrial robots. The most significant contribution of the Industry 4.0 revolution to manufacturing is the efficient production of intelligent robots. In this way, it is hoped that machines and devices made smart by artificial intelligence will be able to do everything that humans can and struggle to do.

AI & Industry 4.0

The most significant contribution of the Industry 4.0 revolution to manufacturing is the efficient production of intelligent robots. In this way, it is hoped that machines and devices made smart by artificial intelligence will be able to do everything that humans can and struggle to do. It is not, however, limited to this. For example, machines that can produce even in dark environments, i.e., the concept of production in a dark factory, are beginning to be discussed for the first time in conjunction with Industry 4.0 and Artificial Intelligence. Intelligent machines that communicate information, paper, and data using Industry 4.0 and Artificial Intelligence technologies can also produce the most efficiently in low-light environments.

AI APPLICATIONS IN MINERAL PROCESSING

Modeling, design, and optimization are the main methods in the utilizing of AI in Mineral Processing. Soft computing, which has been used in the modeling of mineral processing applications, is highlighted. Soft computing is a collection of computational techniques that are based on artificial intelligence, including neural network fundamentals, fuzzy logic, and genetic algorithm that in turn provide superiority of humanlike problem-solving capabilities in an environment of uncertainty and precision.

Figure 2. Modeling mineral processing techniques divided in three groups.

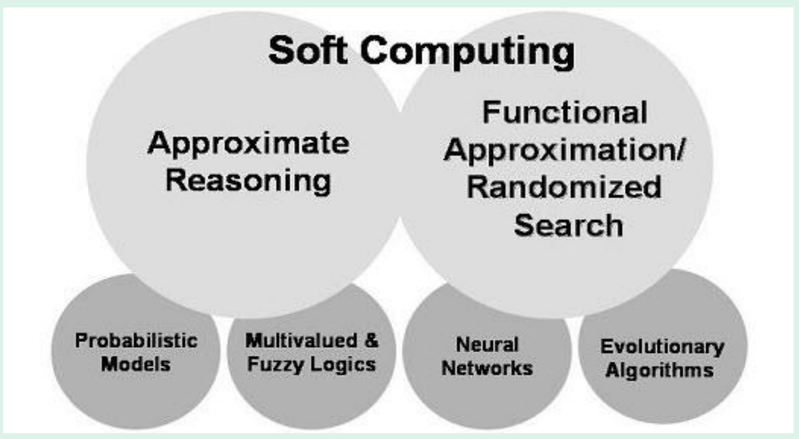

Figure 3. Soft computing includes certain computational techniques.

Used Techniques

There are several AI algorithms, such as CNN (Convolutional Neural Networks), the SVM (Support Vector Machine), the LSTM (Long-Short Term Memory), that can vary in mineral processing depending on the application.

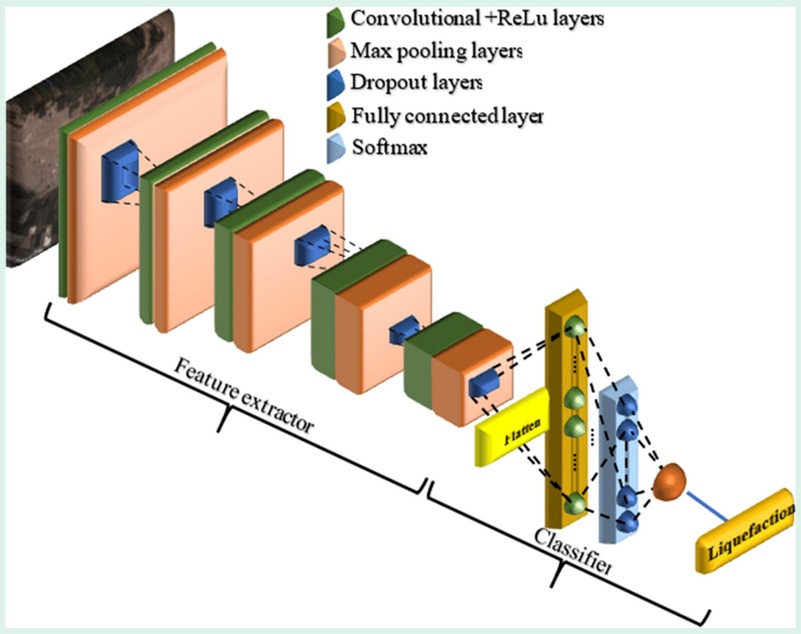

Figure 4. Layers of the typical CNN model which is widely used in mineral processing

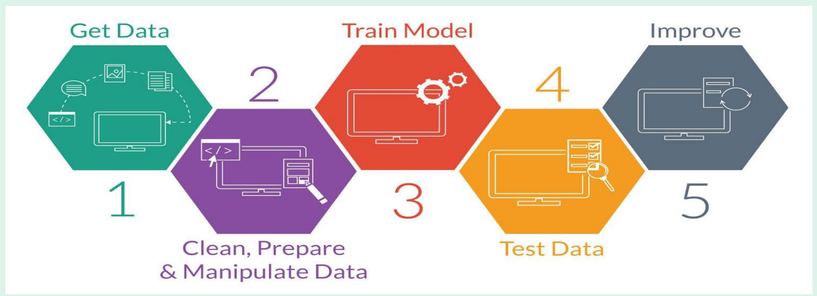

Figure 5. Developing an Artificial Intelligence Model

LITERATURE REVIEWS

Ore Sorting : Coal and Gangue Separating Robot System Based on Computer Vision (Sun et al., 2021),

Concentration : Spiral Concentrator Interface Monitoring Through Image Processing (Nienaber et al., 2017)

Milling : Recurrent neural networks-based modelling of industrial grinding operation (Inapakurthi et al., 2020)

Hydrometallurgy : Fault Diagnosis for an Industrial High Pressure Leaching Process with a Monitoring Dashboard (Haasbroek et al., 2018)

Flotation : Long short-term memory-based grade monitoring in froth flotation using a froth video sequence (Zhang et al., 2021)

Table 1. Certain AI applications in 2021 from Literature

Reference	Techniques & Algorithms	Application	Ore Type	Description	Analyses & Conclusions
Sun Z. Et al., 2021	Machine Vision, CNN, CG-YOLO network	Ore Sorting	Coal	Coal and Gangue Separating is proposed with a Robot system based on computer vision	Robot grasping experiment is done & average grasping rate of 75% is achieved, improving the accuracy and efficiency of coal and gangue separating.
Diaz et al., 2021	Random Forest, Model Predictive Control	Concentration	-	Random forest model predictive control for paste thickening	MPC benchmark strategy results showed that RF-MPC performs better both qualitatively and quantitatively approaches.
Mir et al., 2021	Fuzzy Sets, MCDM methods	Hydrometallurgy	Lithium (Extraction)	A new framework is proposed that integrates two fuzzy group decision making approaches	The results of the analysis indicate the rationality and enforceability of the proposed method.
Diaz et al., 2021	Random Forest, Model Predictive Control	Milling	-	Two Machine Learning methods used for control of abnormal feeding conditions in thickening-dewatering process	The proposed self-healing control scheme provides a new method for self-healing control of complex industrial processes under abnormal conditions.
Zhang et al., 2021	Machine Vision, LSTM	Flotation	Lead-Zinc	LSTM-based grade mon-itoring in froth flotation is utilized.	The proposed grade moni-toring model could capture more valuable temporal information between the froth videos.
Yan et al., 2021	Bayesian Network, Case-Based Reasoning Hybrid Approach	Flotation	-	A two-step operational adjust-ment approach for the flotation process combining CBR and BN is proposed in this article.	The results show that intelligent operational adjustment can significantly improve the copper concentrate grade index.

DISCUSSION

The advancement of artificial intelligence applications in mineral processing will benefit from :

- **Lower costs such as used reagents,**
- **Electricity consumed,**
- **Concentration,**
- **Optimized and efficient facility operation.**

CONCLUSIONS

As a result, artificial intelligence techniques should be implemented in mineral processing plants. While there are some examples in specific mineral processing plants, this type of novel application has arrived relatively late in heavy industry sectors such as mineral processing. A probable reason for this could be that companies plan their feasibility and projects for 10-15 years or more since they are hesitant to revise and make changes to previously established mineral processing facilities for financial reasons. This impediment will be overcome as the number of different industrial applications mentioned in the article continues to expand.

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