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Review article

A review of soft computing technology applications in several mining problems

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ABSTRACT

Soft computing (SC) is a field of computer science that resembles the processes of the human brain. While conventional hard computing is run based on crisp values and binary numbers, SC uses soft values and fuzzy sets. In fact, SC technology is capable of address imprecision and uncertainty. The application of SC techniques in the mining industry is fairly extensive and covers a considerable number of applications. This paper provides a comprehensive overview of the published work on SC applications in different mining areas. A brief introduction to mining and the general field of SC applications are presented in the first section of the paper. The second section comprises four review chapters. Mining method selection, equipment selection problems and their applications in SC technologies are presented in chapters one and two. Chapter three discusses rock mechanics-related subjects and some of representative SC applications in this field. The last chapter presents rock blasting related SC applications that include blast design and hazards. The final section of the paper comments on the use of SC applications in several mining problems and possible future applications of advanced SC technologies.

Contents

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1. Introduction

Mining[1] is one of the earliest primary industries of human civilisation [1]. It is considered a key industry for many countries, and it has huge ripping effects on other industries. In comparison to past centuries, the efficiency of modern mining has been dramatically improved through the development of associated technologies. Many innovative mining methods and theories have been developed by a multitude of scholars and engineers. Advanced high-tech computing technologies with improved machineries have significantly contributed to the development of the mining industry. In fact, modern mining is an advanced amalgamation of all the fundamental sciences.

In the case of actual mining activities, the mining manager frequently encounters many complex decision-making problems without sufficient data or precise information available to overcome them. An inappropriate decision could endanger people's lives and cause irreversible damage to the mining economy, considering the huge size of the capital of mining. The main causes of difficulties in the decision-making processes in mining can be categorised as follows:

- Uncertainties in commodity markets
- Geological and geotechnical uncertainties of rock mass
- Lack of clarity of qualitative and linguistic expressions of mining-associated factors
- Subjectivity of individual decision makers
- Uncertain effect of weights of single, multiple, and mutual relationships of mining-related factors
- Possibility of undefined mechanisms of rock mass behaviours under particular conditions

To overcome these difficulties, many researchers have employed soft computing (SC) technologies in mining-related subjects. The definition of soft computing is '*a collection of methodologies that aim to exploit tolerance for imprecision and uncertainty to achieve tractability, robustness, and low solution cost*' [2]. The principal SC technologies can be categorised as fuzzy algorithms, neural networks, supporting vector machines, evolutionary communication, machine learning, and probabilistic reasoning. McCulloch and Pitts [3] introduced an initial model of an artificial neural network (ANN), which was recognised as the first study of artificial intelligence. Since then, a significant amount of ANN-related research has been conducted. In 1994, SC became a formal area of computer science [4] and many new and hybrid algorithms, e.g., ANFIS [5], DENFIS [6], swarm intelligence and bio-inspired computations [7], computational intelligence aided design (CIAD) [8], were introduced with the help of advanced computer technology. SC's advantages in treating imprecision and uncertainty have fascinated engineers and scientists, and it has propagated rapidly to other industries. So far, SC has achieved meaningful progresses in many industries. However, its history of use in mining industry is rather short. The purpose of this review is to generate constructive discussion of employing SC technology in the mining industry by reviewing previous applications of SC technologies in several mining problems.

2. Mining process and applications of soft computing technologies

Normally, there are five stages of a mining application: prospecting, exploration, development, production, and reclamation. The location, geometry, extent and worth of the mineral deposit can be estimated with in the prospecting and exploration stage. If the deposit has minable value, then appropriate mining methods can be selected for development and exploitation. Based on the method selected, the mining process used for the removal of valuable minerals can be executed. Such process includes drilling, blasting, loading, and hauling of the materials in the production phase. At the end of a mine's life, the mine will be closed through reclamation processes. During the process of mining, several problems can be addressed using SC techniques. The issues that can be addressed using SC technologies are reviewed in this section, which is comprised of four review chapters. Mining method selection, equipment selection problems and previous applications of SC technologies are presented in chapters one and two, respectively. Rock mechanics-related subjects and some SC applications are discussed in chapter three. The final chapter presents rock blasting-related SC applications, including blast design and blast hazards.

2.1. Mining method selection

Mining method selection (MMS) is a crucial issue in the planning process of mining, and choosing the most appropriate mining method for a given mineral deposit among available alternatives is the goal of MMS. In fact, MMS significantly influences the economics, safety, and productivity of mine. Furthermore, MMS is recognised as a multiple-attribute decision-making (MADM) problem that requires concerning numerous factors, such as technical and industrial problems, financial concerns, and mining related policies, environmental and social issues. Fig. 1 demonstrates a conceptual frame work of MMS.

As shown in Fig. 1, not only numerous main criteria but also their sub-criteria need to be in the consideration of MMS processes. For instance, Nicholas [9] categorised the factors considered in MMS process, i.e., the 3D features of the deposit, geological and geotechnical surroundings, environmental and economic considerations, and other industrial factors. In addition, political and social limitations, machinery, and workforce supply conditions are also important factors. Besides, it is rather difficult to delimit the ranges of criteria which have a huge influence on the selection process. In addition, there are a few mines that can be mined by a single mining method, but the majority of them require the use combinations of two or more feasible methods.

2.1.1. Conventional MMS methods

A few researchers have worked to develop an effective MMS model. In 1973, a mining method classification system had demonstrated by Boshkov and Wright [10] which recognised as the one of first quantitative approaches. The first quantitative ranking system for MMS analysis presented by Nicholas [11], but the proposed system had a critical defect in that all criteria were considered equally important. Nicholas [9] modified the initial MMS method by adopting weighting factors for the criteria, but this modification received negative reviews because of the narrow ranges of score disturbs the optimum selection. Later, Miller-Tait et al. [12] reformed the Nicholas method by extending the maximum and minimum scoring domain.

2.1.2. MMS using soft computing technologies

Although conventional mining method classifications and quantitative and qualitative ranking systems are very convenient for MMS processes, the possibility of subjective effects by decision makers remains. Thus, with the intention of solving this complex problem, different SC approaches have been designed by various researchers.

[1] In this review paper, 'mining' is associated with all activities that extract mineral resources both above and below ground, not including petroleum and natural gas.