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An intelligent hybrid system for surface coal mine safety analysis

N. Lilić*, I. Obradović, A. Cvjetić

Faculty of Mining and Geology, University of Belgrade, Djusina 7, 11000 Belgrade, Serbia

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ABSTRACT

Analysis of safety in surface coal mines represents a very complex process. Published studies on mine safety analysis are usually based on research related to accidents statistics and hazard identification with risk assessment within the mining industry. Discussion in this paper is focused on the application of AI methods in the analysis of safety in mining environment. Complexity of the subject matter requires a high level of expert knowledge and great experience. The solution was found in the creation of a hybrid system PROTECTOR, whose knowledge base represents a formalization of the expert knowledge in the mine safety field. The main goal of the system is the estimation of mining environment as one of the significant components of general safety state in a mine. This global goal is subdivided into a hierarchical structure of subgoals where each subgoal can be viewed as the estimation of a set of parameters (gas, dust, climate, noise, vibration, illumination, geotechnical hazard) which determine the general mine safety state and category of hazard in mining environment. Both the hybrid nature of the system and the possibilities it offers are illustrated through a case study using field data related to an existing Serbian surface coal mine.

1. Introduction

One of the most important and also most complex problems encountered in surface coal mines is safety analysis. An appropriate and reliable solution for this problem is vital for the working process in mines with surface exploitation.

Published studies on mine safety analysis are usually based on research related to accidents statistics (Kecojevic and Radomsky, 2004; Karra, 2005; Bennett and Passmore, 1986; Marovelli, 1981). Several studies have been conducted on hazard identification and risk assessment (South African Mining Industry, 2003; Joy and Griffiths, 2005) which aims to provide advice on hazard identification and risk assessment within the mining industry.

Systems safety analysis methods provide a proactive approach to analyze systems for potential hazards that may threaten the health and safety of miners. The systems approach to the safety problem focuses on the system taken as a whole. It involves the interaction of people, machines, and environment within procedural constraints (Hammer, 1972). It uses a number of techniques: the technique of operations review, the failure mode and effects analysis technique, the fault tree analysis technique. Contemporary mining theory operates with a number of methods and techniques which can be used to solve mine safety problems. These methods are used in current engineering practice with the help of appropriate software products.

Software products in mine safety need expert knowledge and experience to be fully exploited. This knowledge consists of rules and heuristics experts use when they apply numerical methods, and Artificial Intelligence offers formalisms and mechanisms for its incorporation in software systems (Russell and Norvig, 2002). Formalization of knowledge representation and development of mechanisms for using this knowledge are among methods and tools developed by AI for solving complex problems (Giarratano and Riley, 2004). However, the complexity of some problems outgrows the potentials of single methods. A possible solution is to combine two or more AI methods into a hybrid intelligent system (Goonatilake and Khebbal, 1995). This approach has been adopted in the case of PROTECTOR, a hybrid system for the analysis and estimation of safety in mining environment, developed at the Faculty of Mining and Geology of the University of Belgrade. PROTECTOR was developed by combining neural networks and expert system technology. While the mining environment estimation methodology is implemented through an expert system, some of the related estimation parameters are determined by neural networks.

Discussion in this paper is focused on the application of combined AI methods in the analysis of safety in mining environment. A full understanding of the process and use of all collected data require the involvement of an experienced specialist in the mine safety field. The solution was found in the creation of PROTECTOR, whose knowledge base represents a formalization of the expert knowledge in the mine safety field.

Section 2 of this paper outlines the global problem-solving strategy through a hierarchical decomposition of the main goal,

* Corresponding author: Tel.: +381 11 3219 101; fax: +381 11 3235 539.
E-mail address: lilic@rgf.bg.ac.rs (N. Lilić).

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the evaluation of the mining environment, and the formalization of this strategy by means of a modified object-oriented analysis (OOA) model. The system structure and the main architectural components of the PROTECTOR system are described in Section 3. The implementation of the system in the KAPPA-PC expert systems shell is discussed in Section 4. Section 5 presents a case study, followed by a conclusion in the last section.

2. A formalization of mining environment evaluation problem-solving

Analysis of safety in coal mines represents a very complex process based on estimation of numerous and interdependent parameters that are classified into several basic criteria for estimation of mining environment. These criteria are related to the following conditions: gas, dust, climate, noise, vibration, illumination and geotechnical hazard (highwall stability and waste stability).

In discussing occupational risks in the mining industry, it is common practice to identify health and safety hazards separately. Some of these environmental stresses may interact to produce a greater overall effect. In combination or alone, if environmental stresses exceed human tolerance levels for prolonged periods of time, feelings of discomfort will arise, alertness will decrease, accidents will occur, and performance and productivity will drop.

Mining is among the more traditional and conservative engineering disciplines. Although various assessment techniques and numerical methods are available, the analysis of safety in surface coal mines relies mostly on heuristics formulated by mine safety experts. This was precisely the motivation for developing of PROTECTOR as a hybrid system, with its expert system component in its core. The system architecture draws upon the experience gained by successful implementation of hybrid systems in different fields, but represents a novel approach when mining is concerned. The novelty of the approach to mine safety was further reinforced by the development of an evaluation strategy. The main goal of the system is the estimation of mining environment as one of the significant components of general safety state in mine. This global goal can be subdivided into a hierarchical structure of subgoals where each of these subgoals can be viewed as the estimation of a set of parameters (gas, dust, climate, noise, vibration, illumination and geotechnical hazard) which determine the general mine safety state and category of hazard in mining environment. During this process, the importance, i.e. significance of each particular parameter must be taken into account. The hierarchical decomposition of the main goal into subgoals, representing the problem-solving strategy, makes it easier to cope with the complexities and to coordinate the use of the knowledge incorporated in the system.

The strategy for evaluation of the safety in mining environment is formally represented using a modification of the Coad-Yourdon object-oriented analysis (OOA) model (Coad and Yourdon, 1991). In the standard model every real world entity is represented by a class (object) consisting of its name, attributes and methods pertaining to the procedures related to the object. However, in order to incorporate declarative knowledge, we have resorted to a modification of this model by including a new (fourth) element, featuring the production (IF-THEN) rules related to an object in the model. Thus both the procedural and declarative knowledge related to a class object could be represented. Such a modified OOA model was then used for the representation of the mining environment evaluation strategy as well as other objects in the system and their mutual relationships (Fig. 1).

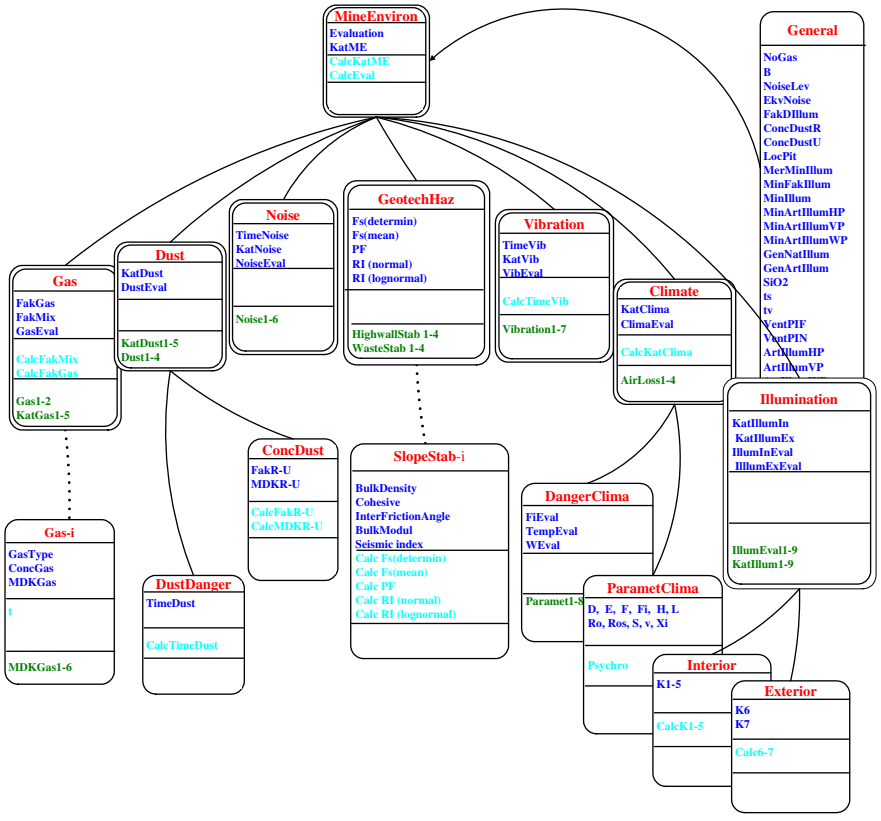

Fig. 1. Modified OOA model of the mining environment evaluation.