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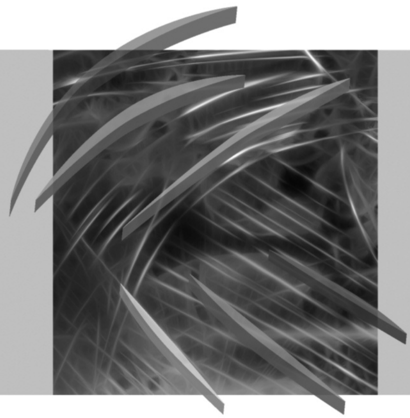

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Intelligent Technologies and Applications

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DESIGNING A KNOWLEDGE BASE FOR AN ADVISORY SYSTEM SUPPORTING MINING WORKS PLANNING IN HARD COAL MINES

Abstract: The paper presents a preliminary design of a knowledge base to support the selection of equipment for the planned mining works in hard coal mines. After introduction into ideas and scope of the mining production planning, the conception of an advisory system supporting planning of openings and exploitation works in coal mines is described. Moreover, the preliminary results of development work on the current version of the knowledge base are presented and further directions of development works are given as well.

Keywords: knowledge base, planning, mining works, hard coal mining.

1. Introduction

Hard coal is the basic, non-renewable energy source in Poland and in the world. National, balanced resources of this product (as estimated on 31 December 2006) equalled 9.96 billion tonnes at the opened levels [Sobczyk 2008]. In Poland, hard coal mining is conducted in 30 mines of which 25 belong to 3 large mining enterprises. In every mine, the output is a derivative of the appropriate distribution in time and the appropriate management of the mining works (in particular the openings and the exploitation works). With such specificity of conducting the mining process, in the difficult geological-mining conditions, it is important that knowledge and experience, derived from the already completed works, were effectively applied in planning future works (e.g., through models describing the mining results achieved in the past in the specific conditions of the excavation, equipped with the specific machinery).

The characteristic feature of information systems currently used in hard coal mining enterprises is a distributed structure storage systems, warehousing the data regarding the manufacturing process. Part of this data is stored in a traditional form (on the projects and schedules), part is stored in an electronic form, with a full access

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to the data, and another part is stored in an electronic form, yet the access to this data is restricted (the distributors' programs). In order to be able to effectively utilise the warehoused knowledge (also the knowledge which can be derived from the data) for planning the mining works, that is for production planning, the sources of the knowledge have to be identified, and by applying the appropriate information solutions, this knowledge shall be shared and utilised. The possibilities for collecting and warehousing this knowledge were given by the expert systems which have been developed for over 40 years. The basic element of those systems, distinguishing them from other information systems, is the knowledge database [Awad 1996; Darlington 2000; Giarratano, Riley 2005; Grzymala-Busse 1991]. In the mining industry, those types of solutions have been applied in various situations, described, among others, in [Basu, Yuejin, Singh 1991; Britton 1987; Grayson et al. 1990; Hart, Duda 1977; Liu et al. 2010; McCammon 1996; Plümer 1992; Samanta, Samaddar 2002; Zhang, Zhao 1999].

In this paper, a certain stage of authors' works on the development of the knowledge database, comprising an element of the advisory system, supporting the planning of the openings and exploitation works in hard coal mines (described, among others in [Brzychczy 2011]) was presented. The purpose of the presented database is to assist the designer in selecting the equipment, appropriate for the planned works and in estimating future production results on the basis of knowledge and experience obtained by the mine (or mining enterprise).

2. Planning the mining works

The basic "sources" of coal in a hard coal mine are the longwall panels (longwalls). The example of the longwall panel structure was presented in Figure 1.

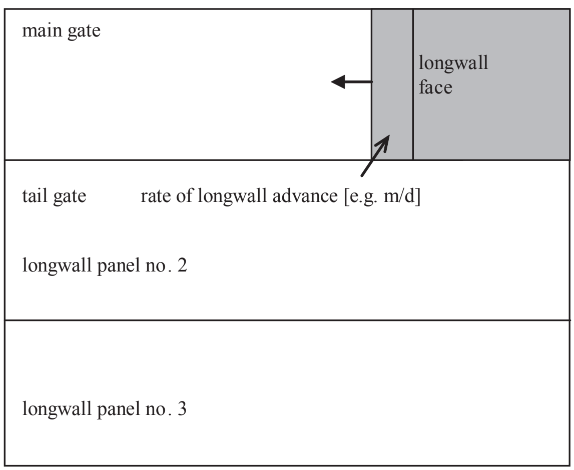

Figure 1. Longwall panels

Longwall panel is a part of the exploitation panel and it comprises the following elements:
– main gate,
– tail gate,
– longwall face.

The basic geometric parameters of the longwall panel are the length of the longwall (distance between the main and tail gates) and the length of the longwall gates. Each longwall panel is characterised by the specific geological-mining conditions (including the specific risks), technical – organisational parameters, etc. Output in the longwall panel depends on the so called rate of longwall advance (meaning a number of meters the longwall face advanced per time unit) and the conditions of the excavation. And the longwall advance rate depends mainly on the equipment installed in the excavation. The basic equipment, comprising the so called longwall complex, which is presented in Figure 2, consists of a longwall shearer, a longwall conveyor and of sections of mechanized supports.

Figure 2. Longwall face in KWK Pniówek

Source: [www.jsw.pl].

The elements, which are subject of the planning works at the hard coal mines, are mining works associated with the preparation and exploitation of longwall panels, conducted as a following sequence:

– openings, involving the drilling of the longwall gates;
– drilling the longwall face, involving the completion of a excavation, connecting the longwall gates;
– installation works, involving transport and assembly of the necessary equipment on the longwall face;
– exploitation works, involving coal mining and its extraction from the longwall panel;
– removal works, involving the disassembly of the equipment installed in the longwall face and liquidation of the excavations.

Taking into consideration the specific conditions for conducting the underground exploitation works and associated with this degree of uncertainty and risk, it is important for the designer to have an access to the knowledge and experience from the previously completed works. The knowledge regarding the equipment used for the specific conditions of the excavation and on the production results achieved on that excavation allows planning the future output with a better precision through reaching to the actual results and not to the estimates. It can significantly influence the quality of the prepared plans. In order to support the production designers with regard to the planning of the future work, a concept of an advisory system supporting the planning of the openings and exploitation works at the hard coal mines was developed. The main principles of this system were presented in further sections of this paper.

3. Advisory system supporting mining works planning in hard coal mines

The designed system aims at supporting the designers in the mining work preparation with regard to [Brzychczy 2011]:

– selection of the appropriate equipment for the particular geological-mining conditions and technical and organisational circumstances of the planned excavations;
– combining the mining machines in longwall complexes;
– determining the characteristics regarding the production results in the planned excavations.

The advisory system, apart from the knowledge database and the concluding module, shall contain also the knowledge gaining module. The system, in its entirety, shall be supported with the appropriate interface. The designed knowledge database shall comprise the following modules:

– database – integrating the data describing the geological-mining conditions and technical and organisational circumstances of the currently conducted excava-

tions and their equipment – in order to appropriately document the excavations completed in the past (historical data – facts);
– rule database – in which all rules for the selection of equipment to the specific conditions of the excavations and the rules for assembling together machinery and devices. Those rules shall be determined on the basis of algorithms of machine learning (Data Mining), as described, among others, in [Brzychczy 2008, 2009] and will be formulated by the experts in particular fields;
– model database – containing models of openings and exploitation works (in form of the appropriate probability distribution of work advance).

It should be noted that the knowledge database shall also take into consideration the uncertainty aspects of the knowledge contained in the database. In the first version of the database, the so called certainty factors – CF – were introduced as one of the forms of describing the real conditions for the expert systems.

The first results of the work on the knowledge database for the described system are presented in further sections. On the basis of those results, several conclusions were formulated, which will play a significant role in further work of the research team.

4. Programming works on the design of the knowledge database and the interference module

The first, test, version of the knowledge database and the interference module was prepared with the use of the Microsoft Visual Studio 2010 application and the C# language and Microsoft SQL Server 2008 [Tajduś 2011]. The planned longwalls and elements of the necessary equipment were described with the appropriate parameters which were contained in the knowledge database tables (as facts in the knowledge database). Each table contains key columns. Those are, consecutively:
– nShearer ID,
– nMechanizedSupportID,
– nConveyor ID,
– nLongwallID.

Those rules are also saved in the appropriate charts of the relation database. The decomposition of rules, which assume either the tree like structure or are a result of the work of the algorithm for searching the association rules, occurs after dividing each rule into three tables, contained in the database [Tajduś 2011]:

1. RULES – this table contains data regarding the rules. It is divided into five columns:
– nRuleID (nchar(10), not null) – it is a unique key, developed on the basis of the formula: RU + rulen umber (e.g., RU00000001 – this is the key of the first rule),

- nConNum (int, not null) – this column contains information, how many conditions apply to this rule,
- nConMatch (int) – this column contains information, how many times, the particular rule was used for drawing conclusions,
- bUsed (bit) – determines, whether the particular rule is used at the given moment,
- nTreeID (nchar(10)) – determines, from the tree, from which the particular rule was taken. If the rule did not come from a binary tree, then, the value of this position equals NULL.

2. CONDITIONS – contains further conditions for the rules. Each rule is matched to one or more records from the conditions table,

- nConditionID (nchar(10), not null) – it is a unique key, developed on the basis of the formula: CO + conditions number (e.g., CO00000001 – this is the key of the first condition),
- sConditionColumn (varchar(50), not null) – contains data informing regarding the column, to which the value of this condition shall be compared,
- sConditionSign(varchar(5), not null) – describes the sign, which is placed next to the condition. The allowable signs include (<,<=,==,>,>=, is),
- sConditionValue (varchar(50), not null) – determines the value, which will be used to compare the fact with,
- bMatchSign (bit) – determines, whether the particular condition is used at the given moment,
- nRuleID (nchar(10), not null) – it is a foreign key, determining the rule, from which the particular condition was derived,
- nPosition (int) – determines the number of condition, taken in the rule by the particular condition. This column is necessary for rules derived from the tree structures. Thanks to this column, the decomposed rules can be formed into a tree again,
- sConditonTableName (varchar(50), not null) – determines the table from which the particular column, to which this condition applies, was taken.

3. STATES – this table contains the conclusions regarding the rules. One or more records from the States table can apply to every rule:

- nStateID (nchar(10), not null) – it is a unique key, developed on the basis of the formula: ST + conclusion number (e.g., ST00000001 – this is the key of the first conclusion),
- sState (varchar(50), not null) – contains the conclusion for the particular rule,
- nRuleID (nchar(10), not null) – it is a foreign key, determining the rule from which the particular conclusion was derived,
- nCNF (real, not null) – contains the value of the certainty factor, of the specific conclusion of the rule. The number of decimals is variable, it can assume values from 0 to 100,

– nN (int) – it is the number of devices, which can be introduced to the excavations,
– sStateColumn (varchar(50), not null) – contains information regarding the column, from which the particular conclusion was taken,
– sStateTable (varchar(50), not null) – stores the information, regarding the name of the table from which the conclusion column was taken.

The structure of the rules database is presented in Figure 3.

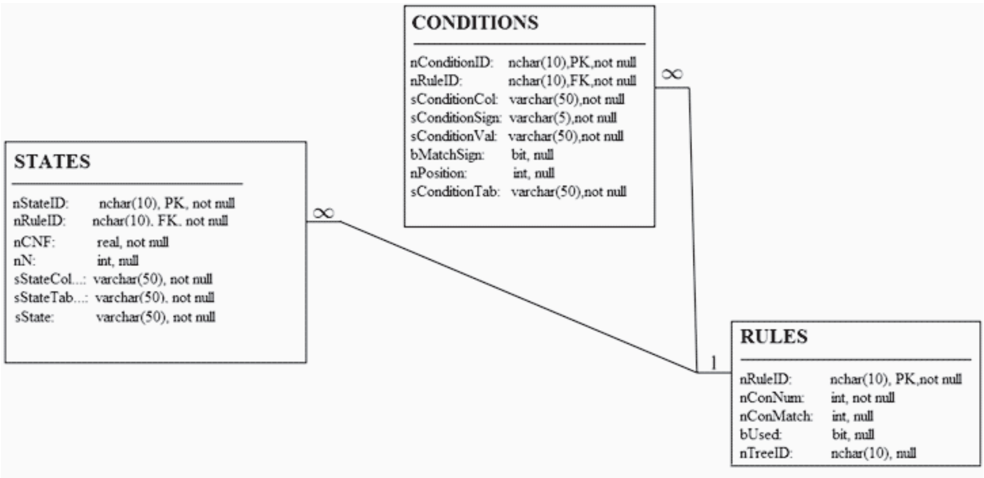

Figure 3. Structure of the rule database

Source: [Tajduś 2011].

The interference module for the developed database structure was prepared with the use of the C# language and Transact-SQL. The file, containing functions, responsible for the conclusions is: InterferingEngine.cs (functions: getRuleID, getConditions, infering, compare, showStates). The conclusion process runs as follows:

1. After starting the CPRG_KB.exe file, the facts, for which the answer in the knowledge database is searched, are entered into the system. In our example the facts refer to the parameters of the planned longwall (Figure 4).

2. Next, the program presents the results of the first stage of conclusion process, that is the type of longwall shearer, which can be used in the excavation of the given parameters (Figure 5). This conclusion was drawn on the basis of rules, determined with the use of the decision tree algorithms.

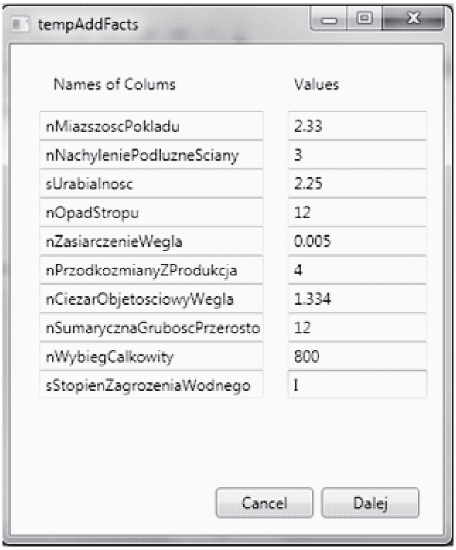

Figure 4. Fact entry

Source: [Tajduś 2011].

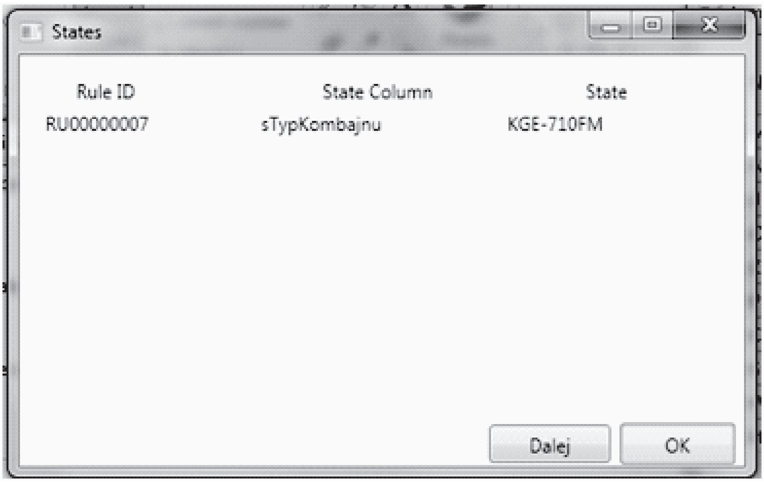

Figure 5. Conclusion drawing – selection of the longwall shearer to the conditions of the excavation

Source: [Tajduś 2011].

3. At the next stage, the system determines additional equipment, which can work together with the selected longwall shearer as a part of the assembly (Figure 6). The equipment is selected on the basis of rules determined with the use of the a priori algorithm (the association rules).

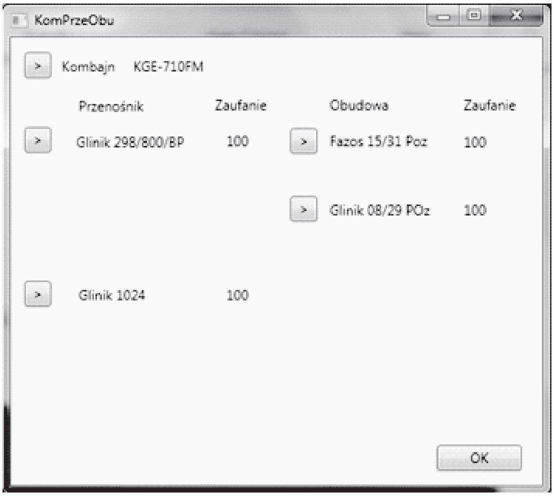

Figure 6. Selection of the additional equipment of the wall assembly

Source: [Tajduś 2011].

At this stage, the designer can either accept the suggested assembly or ask the system to provide an alternative solution. The presented version applies to the selection of the equipment necessary for conducting exploitation works in the particular conditions (ultimately, also for the opening works). After extending the current version, the designer will be able to obtain also the probability distribution parameters for the rate of the work advance in the excavation. This data will be derived from the appropriately designed model database.

5. Summary

In this paper, the results of the so far finished programming works involving the design of the knowledge database, being a part of the advisory system supporting mining work planning in hard coal mines, are presented. Those works were aimed at the development of a simplified model of knowledge database and at drawing certain conclusions, regarding further actions in this field. The scope of the conducted works was limited to this section of the database, which referred to exploitation works, together with the reduction of the number of parameters, analysed for the particular objects (excavations, equipment). The interference module was developed with the use of the object programming language, which limited its abilities to conclusion drawing. Thus, the further work shall concentrate on:

– the development of the conclusion drawing engine based on the Prolog language;

– separation of the rules database from the fact database and checking the functionality of such solution in comparison to the proposed one;
– introduction of the rule classification system, based on the frequency of rule utilisation;
– introduction of other options of describing the uncertainty of the knowledge (probabilistic models, fuzzy models);
– preparing software for the model database and further development of the fact tables.

The conducted works will be aimed at achieving the full functionality of the proposed advisory system. It shall allow, among others, to verify the rate of excavation advance. It can also support the rational management of production means in the single mine and in the multi-mine enterprise.

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PROJEKTOWANIE BAZY WIEDZY NA POTRZEBY SYSTEMU DORADCZEGO WSPOMAGAJĄCEGO PLANOWANIE ROBÓT GÓRNICZYCH W KOPALNIACH WĘGLA KAMIENNEGO

Streszczenie: W pracy przedstawiono wstępny projekt bazy wiedzy wspierającej dobór wyposażenia do planowanych robót górniczych w kopalniach węgla kamiennego. Po wprowadzeniu do istoty i zakresu planowania produkcji górniczej opisano koncepcję systemu doradczego wspomagającego planowanie robót przygotowawczych i eksploatacyjnych w kopalniach węgla kamiennego. Następnie zaprezentowano wstępne wyniki prac programistycznych nad obecną wersją projektu bazy wiedzy wspomnianego systemu oraz podano dalsze kierunki podejmowanych w tym zakresie działań.

Słowa kluczowe: baza wiedzy, planowanie, roboty górnicze, kopalnie węgla kamiennego.