# INFERENCE PROBLEMS IN THE EXPERT SYSTEM SUPPORTING PLANNING AND DESIGNING THE DEVELOPMENT AND EXPLOITATION WORKINGS IN THE HARD COAL MINE

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**Abstract:** The aim of the paper is to elucidate certain problems extremely important for the inference process in the expert system, supporting planning and designing the development and exploitation workings in the hard coal mine. At first, general rules of the knowledge transformation in the expert system are given and then problems related to creating the expert system for the needs of planning and designing the development and exploitation workings in the coal mine, with the special attention to inference problems, are discussed. Finally, the most essential observations resulting from the performed studies and analyses concerning these problems are presented.

**Key words:** Hard coal mining, mine planning and design, development and exploitation workings, expert systems, inference problems

## 1. Introduction

Rate of operation and computer memory capacity create huge possibilities of data collection, their processing and performing large amounts of operations in a relatively short time. An actual stage of the computer technique already creates the possibility of changing computers into units functioning as living rational beings and opens broad perspectives of expert methods and artificial intelligence systems development [2,6]. The natural process of learning of a human being can be transformed into the training process of computer systems. After the proper refining of the way of putting two and two together and rules of conduct, the computer system can effectively support the man in the decision making process, imitating his way of reasoning. At building such systems the expertise and information data on project solutions realised in the past and effects of their practical implementation can be utilized. This is specially important in case of a mining works planning and designing, since the available knowledge for planning objects and mining processes is either incomplete or only approximate. Therefore the information and data on applied in the past project solutions and their practical realisations, under comparable geological-mining conditions, became essential. On the bases of the knowledge obtained from the practical cases the team responsible for planning and designing can learn and widen its current knowledge. At obtaining new information and data from the practical realisation of the accepted project solutions this knowledge is widened. Due to the computer technique application, it is possible to create the knowledge base which would include the data base recording the existing facts and the base of rules containing the notation of the way of searching for proper solutions, from which it would be possible to choose the best solutions – from the point of view of the determined selection criteria. The way of knowledge transformation for the needs of mining works planning and designing, especially the proper reasoning, becomes specially important. Some inference problems in the expert system supporting planning and designing the development and exploitation workings in the hard coal mine are presented below.

## 2. Knowledge transformation in the expert system supporting planning and designing the development and exploitation workings in the coal mine

A knowledge can be defined as a collection of information from the determined field, formed as a result of gathering experience and learning. A knowledge can be treated as a procedural one, representing strategies of obtaining purposes – "to know how", as a declarative knowledge concerning objects, situations and connections – "to know what" and as a controlled knowledge – "how to transform the declarative knowledge by means of the procedural knowledge" [2].

The knowledge acquiring can be realised from two basic sources:

- from an expert,
- from information and data collected in data bases.

The transformation of the acquired knowledge constitutes an essential element of the expert system, which in general perspective consists of the knowledge base, inference engine and dialogue with the user.

The expert system can be a point of departure for the implementation of artificial intelligence methods based on solving problems by ways patterned on the natural operations and mental processes of a man, by means of computer programs simulating these processes.

In the expert system there is a processing module responsible for the knowledge processing. From this module the inference track - containing automatically generated conclusions - can be separated.

The method based on the rules belongs to the oldest and simultaneously the most popular methods of knowledge representation [2]. The knowledge base contains, in this case, the set of rules and the set of facts. The set of initial facts is being transformed into the set of final facts by means of the set of rules.

The fundamental aim of the expert system creation is preparing the correct knowledge base, which enables drawing the correct inferences.

Building of the universal expert system, which could be utilised in several real domains is practically impossible on account of a diversity of the surrounding us reality. Even for the separated field of research such task is difficult due to the problems arising from inaccurate, not complete or uncertain knowledge of attributes shaping the reality. In relation to the research field determined as "the mining and engineering geology" it is specially difficult and responsible task, especially from the point of view of the mining crew safety and economic consequences.

During the stage of a new mine planning as well as planning of existing mine elements, such as the development and exploitation workings, it is necessary to know the structure of mine production process. Since the mine production process takes place in the space it has a spatial structure. The mine production process includes the means, methods and operations related to winning coal so it also has an engineering structure. The process is conducted in a certain time thus he has a time structure. The time structure of the mine production process results from its spatial and engineering structures because the completion time of any operation originates from the relationship between its spatial dimensions and rate of construction. During the stage of planning and designing the development and exploitation workings a concept of the future mine production structures must be developed.

In the Polish hard coal mines, which exploit bedded type deposits the walling system of coal winning dominates. The mine production process can be interpreted as displacing, in space and time, the basic elements of this system spatial structure which are longwall faces. The main element of the production process engineering structure, the mining process (direct taking, in an intentional and organized way, a useful mineral accumulated in a rock mass) is realised in longwall faces. The mining process can be treated as the basic production process, while the remaining processes can be treated as auxiliary ones in relation to the mining, since they have to be realised in order to have the mining process appropriately realised. These processes, apart from providing the proper safety conditions and work comfort for miners, are aimed at: joining longwall faces with the surface by the roadway system, providing a proper inflow of fresh air and outflow of used air, transporting people, materials and technical elements to ensure a rhythmical exploitation in longwall faces, providing an output haulage and its drawing to the surface, draining of water inflow, processing of raw output into commercial products, etc.

Longwall faces are localised in longwall panels, being in a sense of a space, a part of a bed cut by the development openings in order to be put into operation and continue the mining realised in longwall faces. Development operations must be performed with a proper time advance to be able to realise the production process according to the plan.

A production process in underground hard coal mines is characterised by high financial outlays for mining works, by high remuneration costs and by application of expensive technical equipment. Thus, at planning and designing the development and exploitation workings the maximum possible utilisation degree of the production capacity of the technical means of production, under the given mining-geological conditions, should be taken into account. Also the appropriate usage of the qualified manpower potential as well as the assessment of risk at fulfilling the assumed production tasks, which should be adapted to the hard coal market situation, must be taken into consideration.

Planning and designing of the mining production, including development and exploitation works is the most often realised by special sections assigned for the production preparation in individual mines. For the proper realisation of the planning and designing process the appropriate knowledge of the members of the planning and designing team is required. Their knowledge can be supplemented by the base supplied with the information and data obtained as the realisation of the designed development and exploitation works progressed and supported by the expertise from other organisational units of the mine [5]. Information and data collected for the needs of designing can be gathered in the data base, which supplemented with the base of rules for individual planning operations can constitute the knowledge base. Formulation of rules can be supported by the experts' knowledge and at a certain development stage the artificial intelligence methods can be applied. A special attention should be devoted to uncertainty and risk problems, which inherently accompany a mining production.

A mining works designing is a stage of the mine economic operation referred to the previous planning process. The mine production planning, followed by its designing, should be adopted to the market demand for the product of a mining exploitation. The business plan of the mining enterprise assumes a certain strategy of its functioning in the economic system. The technical-economic plan, prepared for the given fiscal year, assumes a tactical realisation of the business plan strategy. A practical transfer of general rules contained in both documents finds its solutions in the operation plan of the mine, which is being worked out by teams employed in the production development sections. The mining production is a specific one, since it is based on the excavation of useful minerals collected in the rock mass stabilized for millions of years by the natural forces and being managed by its own rules. Uncertainties and risks are immanently accompanying a mine production process. They result from several aspects, among others, of the geological-mining, technical-technological and economic-finance nature. In the mining exploitation design process, apart from the technique and production technology knowledge, the design team members are required to be conversant with several aspects (not always reproducible) accompanying the underground exploitation. Geological-mining conditions of the mine production process are diversified and this constitutes the fundamental argument and even requirement of a systematic learning of the team preparing the mining production. To facilitate the learning process the proper tools and instruments allowing recording of facts and supporting analyses and estimations necessary for drawing reflections, which constitute the departure point for the feedback in the learning cycle, are needed [3]. When one is observing the realisation of the previously assumed solution, it is possible - any time - to notice certain effects which were unpredictable ahead of time, impediments which require adaptive operations and natural conditions, which influence corrections of the primary assumptions. Thus, the monitoring system and collecting information on the realised production process, worked out with the aim of being used by the production preparing team in correcting the applied solution or at working out the new one during continuation of works on operation plans of the mine, becomes more and more important.

All data and information on the realised solution can be collected in the proper data base, gathered up to date from a certain moment of time, as mine works are progressing, containing data of the natural and geological-mining character as well as of technical-organisational and economical-financial features. This data base can be supplemented with the natural and geological-mining data concerning a part of the deposit intended for future exploitations, which can be also actualised as the recognizable works are progressing.

A concept of development and exploitation works realisation comes into existence during the designing process, achieves its real shape in a form of the project documentation, and then is verified during the realisation of these works. In order to facilitate the designing process an attempt of the expert system preparation for the needs of designing the development and exploitation works – using the rules of artificial intelligence - can be made. An application of the artificial intelligence methods, using simulations of the recognition and thinking processes of human beings by means of the properly developed computer programs - is in this case especially recommended. The main condition of the artificial intelligence methods application in solving problems of designing mining works is the knowledge from the field of "mining and engineering geology" as well as the ability of its proper coding. However, it requires the appropriate knowledge base built in such a way as to contain essential information and data with the possibility of their fast access without unnecessary "information noises", which could distort inferences. This can be the practical knowledge based on experience related mainly to the past facts as well as the theoretical knowledge related to general designing rules.

In relation to designing the future mining works we are dealing with an incomplete knowledge of the geological-mining conditions since it is impossible to recognize fully the deposits. There are also implications of the technical and technological nature and economical-financial conditions connected with the market situation. Thus, in this case we can talk of the approximate knowledge, which in a practical perspective can be represented by certainty factors or fuzzy sets.

### 3. Inference dilemma in the expert system supporting planning and designing the development and exploitation workings in the hard coal mine

In the expert system a processing module is responsible for the knowledge processing. From this module an inference track - containing automatically generated inferences - can be separated. Inferences in the expert system can be realised by the so-called inference engine, which imitates various forms of the man reasoning, including: formulating conclusions, proving, verifying and explaining. The principle of operation of the inference engine can be based on the classical propositional calculus and drawing conclusions on proceedings leading to acknowledge the new proposition as the true one on the grounds of propositions acknowledged previously as being true [2].

Reasoning is an intellectual activity attributed to a man-expert, while drawing conclusions can be determined as the inference equivalent in case of a computer-expert. Drawing conclusions means acquiring the inference based on finding the new truth from several known or given truths. Proving is an activity based on demonstrating the truth of the proposition on the grounds of other propositions acknowledged previously as being true. Verifying is an activity leading to demonstrating the truth of the discussed proposition on the grounds of testing whether all next logical propositions are true. Explaining (justifying) is an activity similar to proving, but concerns propositions acknowledged to be true [2].

Drawing conclusions can occur as:

- deductive (logical conclusion results from premises),
- reductive (premise results from conclusions),
- by analogy (based on selecting a new thesis at the assumption that all theses are consequences of a certain theorem).

Drawing conclusions in the deductive method is done by means of inference rules. The interpreter or controlling program – in the expert systems understanding – is the program applied to manipulate the knowledge base in order to analyse and solve the given problems. The aim of the interpreter is drawing conclusions, creating new knowledge elements and adding them to the ones being already in the base.

References concerning these problems supply several procedures of searching for solutions, strategies of selecting the rules and principles of controlling the inference process in the expert system.

In case of the inference process in the expert system, which supplements planning and designing the development and exploitation workings in the hard coal mine, several rules and principles should be taken into account. They are resulting from:

- standards,
- catalogues,
- instructions,
- regulations,
- typical projects,
- legal provisions,
- patents,
- specialist literature from the scope of planning and designing mining works (books, textbooks, papers, etc.).

Thus, in this case several rules are taken a priori, which results from the mining rules, standards, allowances, instructions, etc. – and they should be transformed into a logical sequence of the propositional calculus.

The case-based reasoning can supplement the reasoning in the expert system, which helps in planning and designing of the development and exploitation works in the coal mine. This reasoning is a computer method imitating the human mind way of solving problems and generating solutions of new problems by adapting the solutions, which were applied in the past in the similar situations. This type of reasoning is specially important at the development of the expert system for the needs of the mine workings design. Certain stages, constituting the cycle, can be singled out from this method:

- retrieval – from the knowledge base – the case similar to the new one,
- application of the ready solution or adapting it for the needs of the new case,
- verification whether the suggested solution is a true one,
- retaining and learning of the verified solution.

A retrieval must be realised according to the rule indicating which attributes (features) must for sure coincide, which should coincide partially and which do not need to coincide at all. When searching for the previous case in the data base for the new case the similarity measure of both cases should be at first determined. The proper operators used for comparing can be defined, from hard ones – requiring the attributes identity, to soft ones – allowing approximate comparisons, e.g. on the bases of belonging to a certain value interval.

On the bases of experts' assessments the following features (hard operators) influencing significantly the long-wall faces comparability were singled out [4]: seam thickness, roof fall-down, degree of a crump hazard, longwall face height, longwall face length, roof control (caving or backfilling), mining (one- or two-directional), disposable time in a longwall face, effective work time of a longwall face, number of production shifts.

In a similar fashion, on the bases of experts' assessments, the following features (hard operators) influencing significantly the comparability of development openings [4]: stone fraction in the heading cross-section, coal workability, degree of a crump hazard, heading face height, heading face width, lining scale, mining direction (up, horizontal, dip), mining method (blasting materials or coal combine), output feeding method, disposable time in a heading face, effective work time of a heading face, number of production shifts – were singled out.

If there is a compatibility within hard operators the solution of the given case can be considered the solution of the new case (occurrence of such compatibility, however possible, is improbable in the case of mining works). In the majority of cases, on account of uniqueness of all attributes (features) of the natural, geological-mining, technical-organisational and economical-financial character, the solution chosen from the base must be subjected to the appropriate correction.

The solution obtained in the inference process must be subjected to the verification by the designing team and only after its acceptance can be considered to be the proper one.

If such verification reveals the correctness of the new solution, this new case together with its verified solution, can be introduced into the existing base.

Reasoning in the expert system supporting planning and designing the development and exploitation workings can be also realised by means of the fuzzy logic. This is a difficult task due to its scope, diversity, wideness and uncertainty of features characterising development and exploitation works in the coal mine.

## 4. Conclusions

An inference engine will not substitute a man, will not do everything for him and will not absolve him from the responsibility for the accepted design solutions. It can only accelerate finding these solutions, which require however, the final verification by the planning and designing team. On account of a broad scope of conditions of the natural, geological-mining, technical-organisational and economical-financial character, which should be taken into account at creating the expert system supporting planning and designing the development and exploitation workings in the coal mine and also due to uncertainty and fuzziness of information, building the interpreter is difficult, however possible. Research on inference engine in the expert system supporting the design of the development and exploitation workings in the hard coal mine is continued in the Department of Economics and Management in Industry, AGH, University of Science and Technology within the research project No. NN524 468939, entitled: „Preparation of the bases for the system supporting the planning the development and exploitation workings in the hard coal mines". The bases of building the knowledge base for the needs of planning mining works in the coal mines are given in paper [1]. On account of volumetric limits of this paper it is not possible to give more detailed information on studies undertaken at building the interpreter, which constitutes the element of the expert system being currently under development.

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