EXPERT SYSTEM BASED ON THE FUZZY DIAGNOSTIC MODEL TO SUPPORT COAL MINE VENTILATION OPERATOR'S DECISIONS

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ABSTRACT: The effective procedures of decision-making plan to be discussed. The idea is concluded in fuzzy models and algorithms application to gas-dynamic situations identification under conditions of partial measurements with use of expert estimations.

1 INTRODUCTION

With the depth of underground mining process the gas emission, stratum temperature and gas-dynamic incidents activity are being increased. Under such conditions the resolving of questions of permanent monitoring and controlling mine atmosphere parameters complexity is very important for correct functioning of ventilation and degasification systems. The construction and modernization of the Ventilation Automated Control System (VACS) don't eliminate the human-operator participation in control contour. So the traditional programming support of VACS has to be added by a new programming system as intellectual supporting of VACS operator under complex non-formal tasks resolving.

The constructing of models and algorithms and the VACS operator intellectual supporting system realizing is an actual scientific task.

2 COAL MINE VENTILATION OPERATOR SUPPORTING SYSTEM: EVOLUTION OF IDEA

Coal mine atmosphere is a complex object of monitoring and control. Complexity of object is caused by the fact that object can't be completely observed; the most part of information being received from the object under monitoring is stochastic, non-structured, that causes impossibility of synonymous interpretation of occurrences and, consequently, of difficulties in effective control decision making by operator of system.

From the other hand, there are skilled operators and experts being able to interpret complex occurrences on the base of own knowledge by means of identification of the situation under partial measurement.

The decision-making support, in aspect of coal mine atmosphere monitoring and control problem, is a task of artificial intelligence which has a solution as a constructing of expert system being able to diagnose a current state of mine atmosphere and to make grounded references for possible actions of the operator.

VACS and ventilation operator perform the control function. The participation of operator in control cycle consists in determining of prognosis levels of gas contents having registered by Automated Gas Protection System (AGPS) actions, supervising on work of VACS, operative decision making under atypical situations and following of exact performance of the Accident Liquidation Plan (ALP) under emergency situations. Analysis of question of operative and correct decision-making under mine atmosphere monitoring and control shows the necessity of models and algorithms of gas-dynamic occurrences identification for mine atmosphere state control. Pointed models and algorithms present the base of intellectual supporting system of ventilation operator decision-making under mine atmosphere monitoring and control.

The idea to apply intellectual methods to resolve problem of coal mine atmosphere monitoring and control isn't original. In the middle of 80-th there were elaborated and constructed 3 expert systems for methane and dust concentration control of mine atmosphere (UFEL, SHEARER, IDSS) in the USA and in the UK. At the same time there were elaborated and constructed 2 prototype expert systems for methane concentration control in mine atmosphere: one was based on the principles of situational control under uncertainty (Provetrivanie), and the other was based on analysis of quantitative symptoms and expert estimation of gas-dynamic parameters realization (METEX). [2, 3]

3 FUZZY MODELS

Models and algorithms of called above systems are based on production and frame methods of knowledge representation. Logical methods of knowledge representation didn't used in expert systems of coal mine atmosphere control till now days. [3]

By the aim of elaborating of effective model of intellectual supporting system, the tasks, resolved by operator of ventilation in monitoring and control process, were formed:
- Supervising gas-dynamic situation on the working face;
- Solving tasks of identification of Mine Ventilation System (MVS) parameters for control correction;
- Determining of causes of gas-dynamic situation variations (changing);
- Decision-making in the case of considerable methane deviations;
- Emergency ventilation controlling;
- Statistical reports forming.

Gas-dynamic situation on the working face, in its turn, depends on a number of mining-geological, mining-technological and mining-technical factors and displays in a form of gas-dynamic processes in MVS and in a form of emergency situations.

So, we have logical form of mine atmosphere monitoring and control total task:

$$F1 \wedge F2 \wedge F4 \rightarrow F3 \vee F5,$$

Where F1 - mining-geological parameters,
F2 - technological processes parameters,
F3 - gas-dynamic processes in MSV,
F4 - technical parameters of MSV,
F5 - emergency situations

From the logical form of mine atmosphere monitoring and control total task the logical form of ventilation operator local task can be given off as a task of determining of possible causes of methane concentration deviations.

$$F2 \wedge F4 \rightarrow F3$$

Under decision-making operator uses the following information:
- Methane concentration records, obtained (recorded) from different points of working faces;
- Mining technology;
- Planned and actual states of mining;
-Ventilation scheme of working face and MVS topology;
- Points of methane concentration sensors have been placed;
- Information about disturbances in ventilation and degasification systems.

Such volume of information is enough for operative technological situation restoring and identification of causes of methane concentration deviation, because single mining-technological and technical factors form certain classes of occurrences having got typical gas-dynamic spectrum. Such a fact allows the occurrences to be given off from hindrances carried by apparatus and connection channels disturbances.

Choice of Fuzzy Diagnostic Model (FDM) under resolving of gas-dynamic situation interpretation task is based on following premises:
- Complexity of diagnostic object, because the object isn't completely observed;
- Inexactitudes carried by sensors and connection channels disturbances;
- Stochastic nature of information received from the diagnostic object;
- Impossibility of synonymous interpreting of situations because of possible combinations of occurrences;
- Possibility of model parameters expert estimating, because skilled expert is able to interpret a situation, having used partial measurements.

So, choice of FDM is based on presenting of fuzzy vagueness and possibility of expert estimation. [3, 4]

The development of traditional object fuzzy diagnostic model is occurred in several directions:

- Vector of anomalies and vector of symptoms are introduced to the model:
$\{Si\}$, $i=[1,m]$, $\{Bj\}$, $j=[1,n]$, $Bj=[0;1]$;

- Matrix of symptoms masking is introduced to the model:
$v(Si \rightarrow Bj^*)=R^*ij$;

- Matrixes of minimum and maximum influence of anomalies onto symptoms are introduced instead of the matrixes of influence and relations:
$v(Si \rightarrow Bj)=Rij$;

- The environmental anomalies are added to a list of anomalies of object, if they can be causes of symptoms appearance;

- The advanced expert information can be taken into account;

- Algorithms of logical inference are given connecting anomalies, symptoms, matrixes of influence and masking**.**

Auxiliary axioms of diagnostic model are following:
1.If there are no grounds for symptom then it does not appear.
$\neg V\ (Si \wedge (Si \rightarrow Bj)) \supset (\neg\ Bj \vee \neg T\ Bj)$, 1<=i<=m, 1<=j<=n

2.If there are grounds for symptom and there are no grounds for it being masked then it appears.
$\{V\ (Si \wedge (Si \rightarrow Bj))\} \wedge \{\neg\ V\ (Si \wedge (Si \rightarrow Bj^*))\} \supset (Bj\ V\ \neg TBj)$, 1<=i<=m, 1<=j<=n

3.The connected implications between causes follow from cause links between them.
$(Si \rightarrow Sk)) \supset (Si \supset Sk)$, 1<=i<=m, 1<=k<=m

A global axiom of diagnostic model is presented by disjunction of above-mentioned axioms.
$G \equiv \wedge\ (Ej \wedge Fj)$, 1<=j<=n

Truth of decision is functions of inter-logical distribution causes and symptoms (logical analogue of maximum verisimilitude method in Statistics).
$v(G)=\varphi(s,b,r)$,
where $v(Si)=si$, $v(Bj)=bj$, $v(Si \rightarrow Bj)=Rij$.

So, the basis of the fuzzy model is to resolve the next extreme tasks:

$d(b) = \max \varphi\ (s,b,r)$
$si(b) = \max \{si: \varphi(s,b,r) = d(b)\}$,
$si(b) = \min\ \{si: \varphi(s,b,r) = d(b)\}$.

Or, another words, for given vector b=(b1,...,bn), 0<= bj<=1, 1<=j<=n it is required:

1. To define such a maximum d, 0<=d<=1, for which the system of max-min equations (1-2) has at least one decision s=(s1,...,sm), r=//rij// in interval 0<= si <=1 , rij'<=rij<=rij'' , 1<=i<=m;

bj-(1-d)<= maxmin(si,rij), 1<=j<=n, 1<=i<=m (1)
min{maxmin(si,rij),1-maxmin(si,rij*)}<= bj+(1-d), 1<=i<=m (2)

2. To define exact minimum and maximum values of system coordinates correspondent to d=dmax.

In diagnostic systems the direct-flow (from symptoms to diagnosis) and the counter-flow (from hypothesis of diagnosis to primary data) inference engines are used. Algorithms of the direct-flow and the counter-flow logical inferences are quite different from traditional diagnostic algorithms, where the diagnosis can be received from a number of symptoms by using of single (incoherent) implications processing. Elaborated algorithms are logical interpretation of Zade composite rule and it's turning. [1]

The general unit of decision-making is Inference Engine Unit used for tasks resolving. Under decision-making it uses axioms and rules from Knowledge Base and Fact Graphical Data Base. KB presents a number of axioms and mathematical inference rules, and FDB presents expert knowledge tables. Such structure of intellectual system is quite adaptable.

The important question connected with organization and turning of knowledge base is procedure of expert estimation forming.

For receiving information from a group of experts, a table "Occurrences- symptoms" of judgment truth estimation "Occurrence Si causes symptoms Pj" was used. Everybody of experts filled in the table. Then the processing of expert data could be made. The results of processing were used for Fact Graphical Knowledge Base (FKB) tables. Expert data correction has been made under intellectual system functioning.

4 FINDINGS AND CONCLUSIONS

1.The actual aspect of coal mine atmosphere monitoring and control problem - elaborating of models, algorithms and programs of intellectual supporting system of ventilation operator - is resolved.

2.The logical form of total task of coal mine atmosphere monitoring and control and local task resolved by ventilation operator is made.

3.Analysis of quantitative nature of information used by ventilation operator under decision-making is made. Analysis shows affectivity of fuzzy models and methods application.

4.Fuzzy diagnostic model of continuous object is elaborated. Constructed model allowed to take into account possibilities of occurrences combinations and symptoms masking. Except it, prior information (if it is necessary) about causes of possible gas-dynamic occurrences can be taken into consideration.

5.Algorithms of the direct-flow and the counter-flow logical inference are elaborated. Algorithms are not traditional because they are logical interpretation of Zade composite rule and its turning.

6.A shell of problem-independent intellectual system is constructed. Programs are written on C++ in Windows environment.

7.Capacity for work of system is confirmed by results of laboratory tests, including gas-dynamic realizations processing by experts with the aim of identification of possible technological and technical causes of considerable fluctuations of gas-dynamic parameters.

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