INVENTS: an hybrid system for subsurface ventilation analysis

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Abstract: *Ventilation system analysis is a complex process based on the calculation and analysis of numerous parameters. These problems can be successfully solved by the SimVent numerical package, but a full understanding and use of the obtained results require the involvement of an experienced specialist in the ventilation field. The solution was found in the creation of a hybrid system INVENTS, whose knowledge base represents a formalization of the expert knowledge in the mine ventilation field. In this paper we present the design methodology of the hybrid system INVENTS, as well as system structure and user interface.*

Keywords: hybrid systems, mine ventilation, expert systems

1. Introduction

The methodology of mine ventilation planing and design in contemporary mine theory and practice differs substantially from the traditional approach. The novel approach uses all possibilities offered by computer hardware and software that are at the disposition of mine engineers. Software packages for mine ventilation simulation obtained a key role in the process of mine ventilation planing and design.

Ventilation design is just one element or phase of the novel design approach. The component diagram on Fig.1 illustrates the proposed method that can be divided into six separate components.

The first phase of the outlined methodology is data acquisition. In contemporary mining practice extensive and exhaustive investigations of ore deposits are undertaken in order to collect as much information as possible for the planing and design of technological systems for deposit exploitation.

System planing is an introduction to the mine design process. In the planning process key relations are defined that have to be taken into account in the mine design phase. The initial step in the mine ventilation planing and design process is the establishment of a basic or initial network and an appropriate database related to this network.

The ventilation design process has to continue throughout the construction of the mine ventilation system as well as its maintenance, in order to secure the highest possible level of system use and effectiveness.

The final phase in the outlined design process is state evaluation and modification. All parameters of mine ventilation obtained by monitoring have to be compared with designed parameters and when differences are identified, specific changes must be made in the planning process.

2. The INVENTS hybrid system

Following the outlined strategy of planing, analysis and management of mine ventilation, a hybrid system named INVENTS has been developed, its architecture and concept being the subject of this book. Figure 2 illustrates the place hybrid system INVENTS has in contemporary approach to mine ventilation planing, as well as its architecture which, with its interactive use of CFD software, presents a novel concept in complex mine ventilation network analysis. Namely, the hybrid system for planing and analysis of mine ventilation INVENTS is composed out of a number of integrated software packages, such as ResNet, SimVent and VENTEX (Figure 3). These packages integrate both well known numerical optimization and various artificial intelligence methods which allow for an introduction heuristics into the knowledge base, thus upgrading existing mathematical models with knowledge acquired through engineering practice.

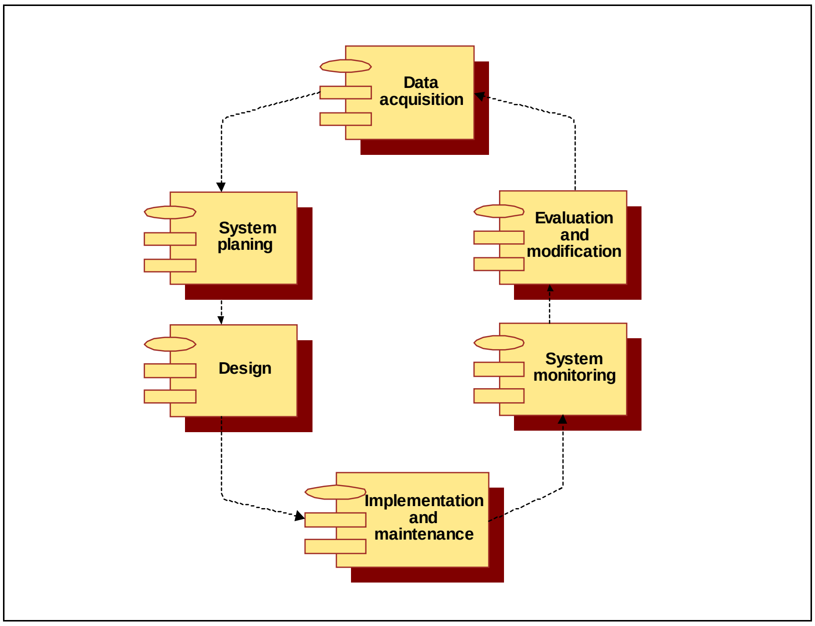

Fig. 1. Component diagram of the novel design concept

The outlined system (Figure 3) permits an aerodynamic definition of mine ventilation network based on psychrometric recordings and the use of ResNet software, i.e. the establishment of actual aerodynamic resistance of mine chambers and thus the configuration of the basic network. CFD software can be applied in parallel for a detailed analysis of necessary airflow volumes for the ventilation of individual workplace locations, often with a very complex geometry. The application of CFD software improves the reliability and quality of the apprehension and verification of air amounts needed for the ventilation of workplaces. Beforehand, determination of air amounts relied on the engineering experience or an analogy with similar examples in encountered in practice and specific empirical relations defined.
After the input data for planing and analysis of the entire ventilation system have been analyzed and checked in detail, INVENTS offers a number of possibilities for the analysis of mine ventilation networks with the help of SimVent. Among these possibilities the following should be stressed:

- determining air flow distribution throughout the ventilation network,
- simulation of climate conditions in mine chambers,
- modeling of fire incidence in ventilation networks as well as
- gas distribution in ventilation network.

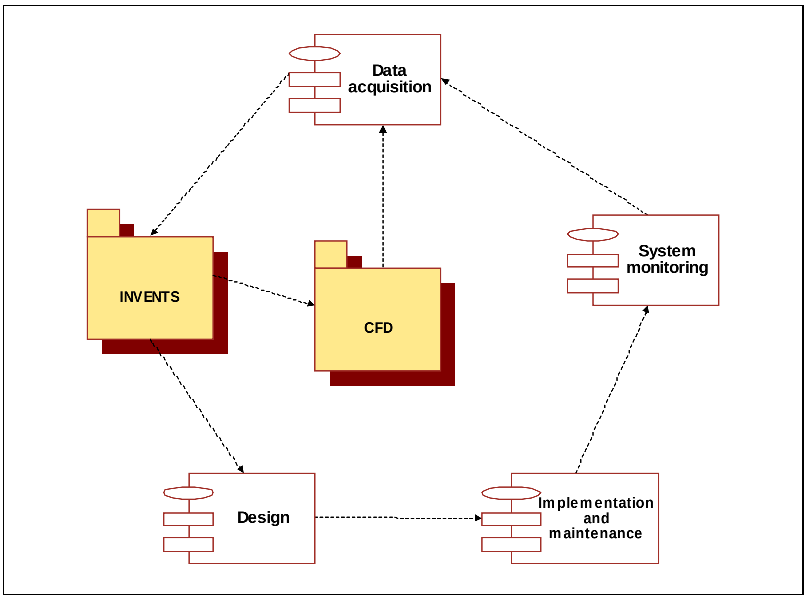

Fig. 2. Global concept of mine ventilation planing and design

The results obtained after the desired analysis by SimVent can be exported to VENTEX – a diagnostic expert system that performs the analysis of obtained results according to a number of criteria. The result of such an expert analysis is an estimate of the validity and effectiveness of the ventilation system followed by suggestions for its improvement. The architecture of the system and the software environment in which the system was developed enable a dynamic communication between different phases of the outlined concept, leading to unlimited possibilities for testing different modifications of the system until a final solution satisfying the established criteria is obtained.

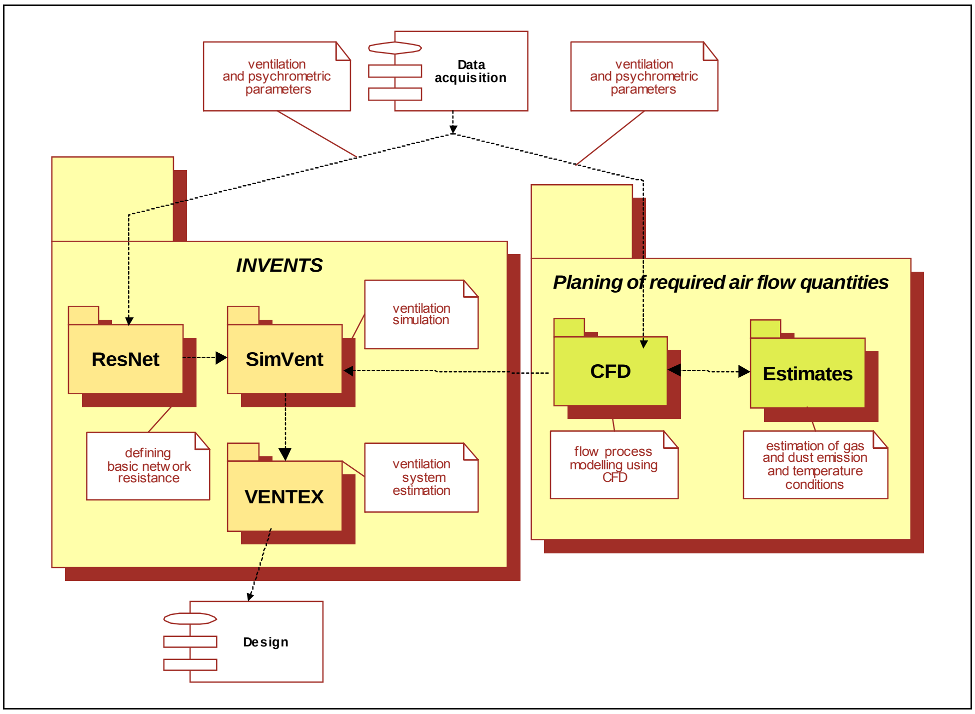

Fig. 3. Architecture of the hybrid system INVENTS

3. Software implementation of INVENTS

The hybrid system INVENTS for planing and analysis of mine ventilation is composed of three program modules: a software package for aerodynamic definition of mine ventilation networks - ResNet, a software package for ventilation simulation in complex mine ventilation networks - SimVent and a diagnostic expert system for the analysis of ventilation systems - VENTEX. Software packages ResNet and SimVent as well as the expert system Ventex are developed for IBM PC and compatible computer systems.

ResNet is a program that enables the calculation of aerodynamic resistance values on basis of measured ventilation parameters in underground mining workings. Aerodynamic resistance determined in such a way is the first and basic condition for the validity of any further analysis of concrete ventilation systems. The main interface form of the ResNet software package is shown on figure 4.

SimVent is a software package that enables mine ventilation simulation in underground exploitation of ore deposits. The global structure of the mathematical model for ventilation simulation in mine ventilation networks, transformed into the SimVent software package is composed of the following blocks:

1. a block for the analysis of air flow and pressure distribution in the ventilation network,
2. a block for the analysis of climate conditions in mine chambers,
3. a block for temperature and heat depression analysis in fire incidence conditions,
4. a block for gas distribution analysis in the ventilation network.

All blocks are mutually interactively connected and the software package can successfully be used in the analysis of ventilation system stability for mine defense and rescue plan verification within mine ventilation services, design and research companies.

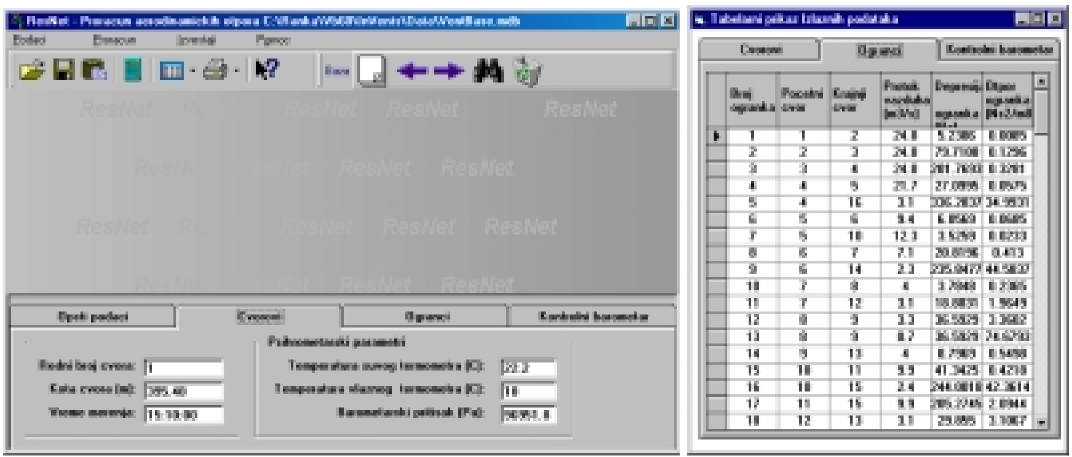

Fig. 4. Examples of interface forms for the ResNet software package

The object-oriented approach in system structuring and modeling was used as the strategy for defining the model of processes and data in the development of INVENTS. In this paper UML (Unified Modeling Language), as a standard language for visualization, specification, constructing and documenting of data on software was adopted for the software development analysis phase. The task of visual modeling of the system is to define the objects and logic of the real system using the adopted graphic notation.

In view of the fact that SimVent was developed in Visual Studio 6.0 programming environment, the package was presented through UML notation in the form of three-level class diagrams architecture. This architecture supports the object-oriented approach in model development for complex applications. Its main characteristic is the separation of domain model and user interface. The domain model is represented by business services and data services, while the user interface is represented by user services.

Figure 5 depicts the three-level class diagram architecture of the SimVent package.

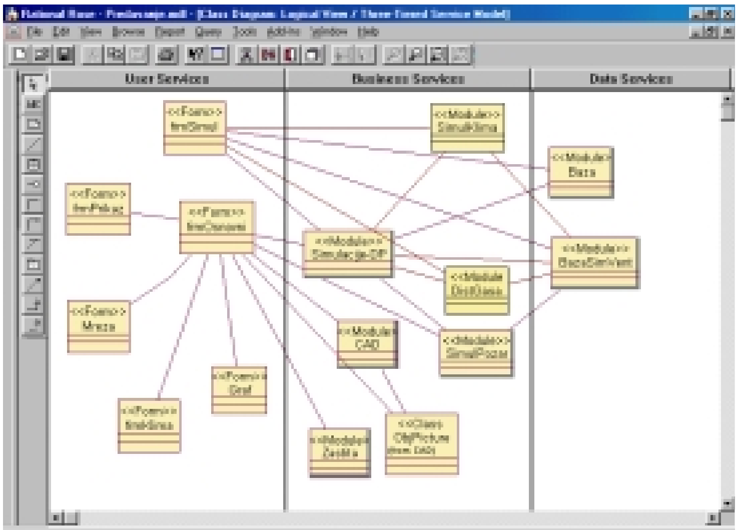

Fig. 5. Three level class diagram architecture of the SimVent package

Five class forms can be identified within the user services of SimVent: frmOsnovni, frmPrikaz, frmSimul, Graf and Mreza. These classes represent interface forms for entering, viewing and searching the data, a form for drawing the ventilation system linear scheme, a form for graphical representation of results and a form for communication with other packages within the hybrid system INVENTS. These classes communicate with classes from the business service level by sending messages and thus initiating the execution of the application process logic.
Figure 6 depicts main interface forms containing various controls that enable text search and editing, picture presentation, communication with data base, creation of business diagrams, etc.

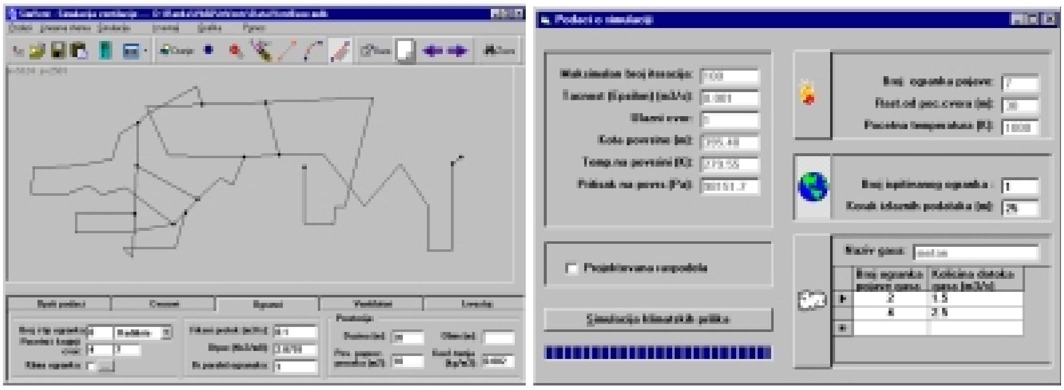

Fig. 6. Interface forms of the SimVent software package

Seven classes can be identified within the business services of SimVent: Zaštita, Simulacije-DP, CAD, ObjPicture, ObjCvor, ObjOgranak and ObjPoint. The first three are Visual Basic application modules while the remaining pertain to drawing and manipulating the picture of the linear ventilation scheme.
In figure 7 an activity diagram depicts the dynamic model of the Simulation-Fire class that encompasses characteristic procedures in the execution of logic for the airflow calculation model in the conditions of fire incidence in complex mine ventilation networks.

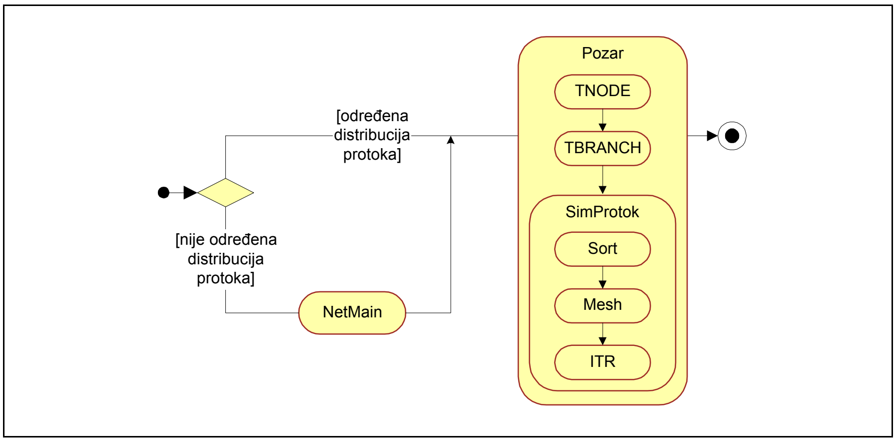

Fig. 7. Activity diagram for the dynamic Simulation-Fire class model

Date services secure data maintenance, data access and modification. In view of the fact that the INVENTS system is based on an integrated database, two classes are defined within the SimVent data service: Baza and BazaSimVent, which represent modules.
In view of the complexity of the INVENTS system's global model data structure, which had to model all relevant parameters of complex mine ventilation networks, the design and realization of database was executed in the MSAccess relational database management system. The system offers safe data archiving for complex data models as this one, as well as all procedures for data manipulation. The use of SQL as a standard query language for data manipulation secures the openness of the hybrid system INVENTS for a connection with different environments.
Figure 8 depicts the structure of the database part relevant to SimVent through the MSAccess Relationships panel.
The VENTEX system was developed as a knowledge-based (symbolic) upgrade of the SimVent numerical package and it thus belongs to the category of *coupled numerical and symbolic systems* (Kowalik, 1986). The numerical part consists of SimVent simulation routines and the symbolic part of the mine ventilation expert's knowledge.

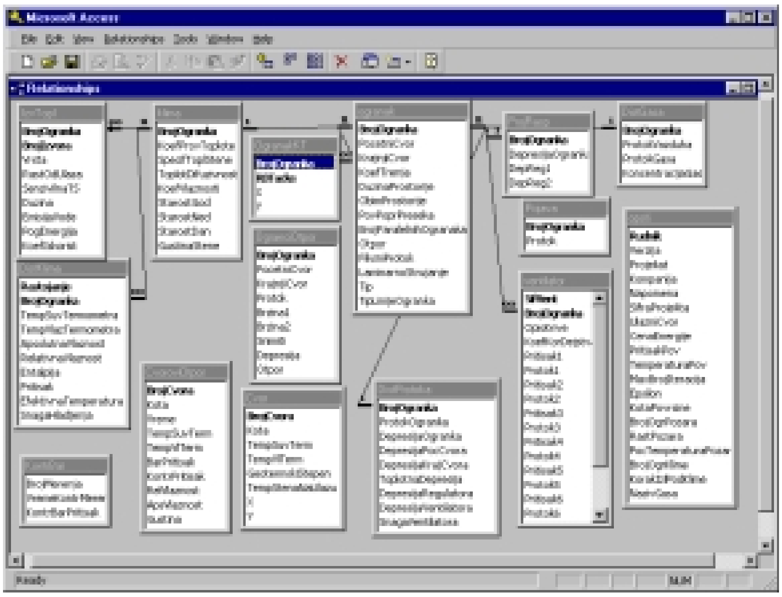

Fig. 8. Database structure of the SimVent package

Successful implementation of a coupled system requires the solving of a number of complex problems in order to obtain efficient communication between the symbolic and the numerical part of the system. In order to cope with this problem a separation of processes in coupled systems into independent modules is suggested. Furthermore, information interchange, i.e. communication among modules, is strictly defined and reduced to the lowest possible degree. Communication between two modules is allowed only through previously defined external links, while all implementation details remain "hidden" within the module itself. These requirements can be met successfully through the modified object-oriented approach proposed in this paper with the object as the modular unit of the system. Objects consist of attributes (structures representing their internal data), methods (procedural components), and rules (declarative components).

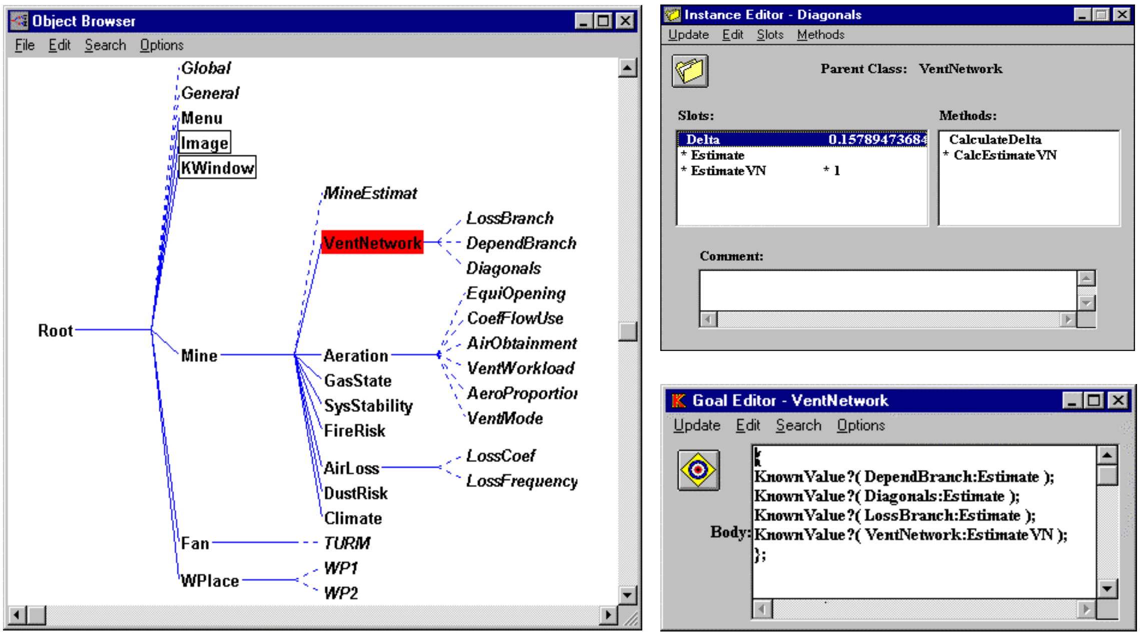

Fig. 9. VENTEX objects, instance editor and goal editor

The object/attribute approach is often mapped into the frame/slot paradigm, which can be successfully used for its implementation (Rich, 1983). In the same way the characteristics of an object are represented by its attributes, frame characteristics are represented by its slots. Namely, slot values describe attributes of the object represented by the frame and its relations to other frames (objects) in the system. The object-oriented approach implemented as a system of frames offers a suitable formalism for the proposed decomposition of the ventilation state evaluation problem, since they both posses a hierarchical structure. The outlined features of the knowledge base alleviate both the coordination of knowledge within the knowledge base and the communication between the symbolic and the numerical part of the VENTEX system.

VENTEX was developed using an expert systems shell, the KAPPA-PC applications development system. KAPPA-PC is a MS Windows application which provides a wide range of tools for constructing and using applications by means of a high-level graphical environment which generates standard C code. In the KAPPA-PC system, the components of the domain are represented by objects that can be either classes or instances within classes (Fig.9). The relationships among the objects in a model can be represented by linking them together into a hierarchical structure. Thus the modified OOA model based on the strategy for evaluation of the general ventilation state of the mine could be easily mapped onto the appropriate elements of KAPPA-PC.

The interface developed for VENTEX in KAPPA-PC fully exploits the GUI (graphical user interface) technology available for MS Windows applications. It enables a straightforward and easy manipulation of input data and control over parts of the problem-solving process. It also offers suggestions and recommendations to the user for the improvement of the overall performance of the mine ventilation system.

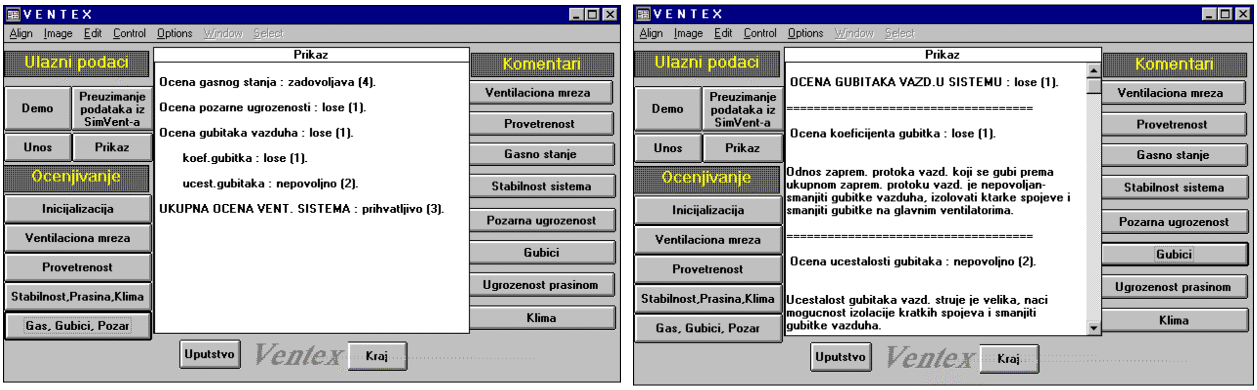

Fig. 10. VENTEX main interface panel with estimated values and suggestions for possible corrections

4. CONCLUSION

In this paper we present an approach to the solution of the mine ventilation planing and analysis problem using a hybrid system composed of three entities: a package for aerodynamic definition of mine ventilation networks - ResNet, a package for ventilation simulation in complex mine ventilation networks - SimVent and a diagnostic expert system for ventilation system analysis - VENTEX.

Besides the architecture of a hybrid system for mine ventilation planing and analysis the software implementation of this system is described, which comprises a symbolic upgrade of the existing simulation packages SimVent and ResNet. The development of a frame-based knowledge base presents a natural approach to the realization of a hierarchically structured strategy.

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