Coupling of artificial intelligence methods in the development of hybrid intelligent systems

Ranka Stanković, Ivan Obradović, Nikola Lilić

COUPLING OF ARTIFICIAL INTELLIGENCE METHODS IN THE DEVELOPMENT OF HYBRID INTELLIGENT SYSTEMS

Ranka Stanković, Ivan Obradović, Nikola Lilić
Rudarsko-geološki fakultet Beograd

Abstract: In this paper we present an approach which couples various artificial intelligence (AI) methods in the solution of complex problems that cannot adequately be solved by a single AI method. We argue that the resulting, hybrid intelligent systems (HIS) can be successfully implemented with the use of available AI software libraries. Different coupling methods are analyzed and a classification of hybrid systems based on the chosen method is given. Two case studies of hybrid systems used in mining engineering are presented: a system for planing and analysis of mine ventilation, as an example of intercommunicating hybrid systems, and a system for the analysis of area air pollution load, with characteristics of both function-replacing and intercommunicating hybrid systems.

Key words: hybrid intelligent systems, coupled systems, artificial intelligence methods, mining applications of artificial intelligence

1. Introduction

AI methods and techniques, such as experts systems, case-base reasoning, machine learning, neural networks or genetic algorithms have successfully been used for solving certain types of problems in a wide area of applications. However, each of these methods has both its advantages and its shortcomings, which makes it suitable for only a particular class of problems. Complex problems often cannot be solved by any of the existing AI methods alone. Hybrid intelligent systems [1] are an attempt to solve these complex problems by coupling two or more AI methods, but also by integrating AI methods and conventional computer systems, such as database or spreadsheet applications. In this paper we present two hybrid intelligent systems which couple expert systems, neural networks and genetic algorithms in order to solve some complex problems in the area of mining engineering. In the realization of these systems we have used existing software: the Kappa-PC expert system shell, and the dynamic libraries for neural networks (NeuroWindows) and genetic algorithms (Gene Hunter).

In Section 2 we give a brief overview of the approaches to the coupling of AI methods in hybrid systems and their classification based on the coupling method used. An outline of the development process follows. Section 3 describes the main features of an intercommunicating hybrid system for mine ventilation planing and analysis. The architecture of the system is outlined as well as the characteristic of its components. Another hybrid intelligent system is presented in section 4. This is a hybrid system with both function-replacing and intercommunicating characteristics used for the prediction of the endangerment of an area by air pollution. The paper ends with a few concluding remarks.

2. Hybrid intelligent systems

The motivation for coupling one or more AI methods into a hybrid system is, in general, one of the following [6]:

1) *Function-replacing* - enhancing one AI method by means of another in order to overcome the limitations of the former;

2) *Method intercommunication* - when problems with multiple objectives (subproblems) solvable by different methods are encountered;

3) *Polymorphism* - development of polymorphic systems which display properties of different intelligent methods within a single architecture.

Hybrid systems can be classified accordingly, on basis of their functionality, processing architecture and communication needs (fig.1).

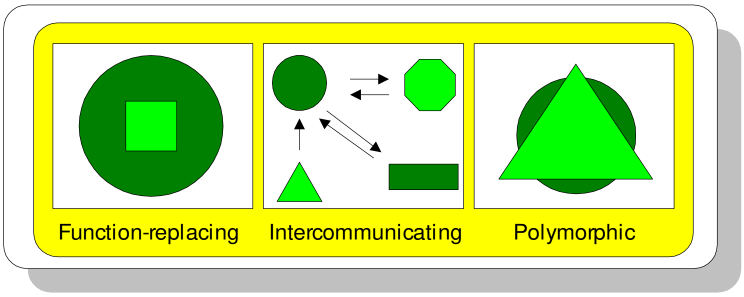

Fig.1 Three proposed hybrid classes

Hybrid systems belonging to the first class are associated with particular methods: a selected AI method is being improved by coupling with another AI method. Enhancement of the basic method usually results either in faster execution or increased reliability. For instance, a common type of NN, the back propagation NN often exhibits problems with leaving local minima once it reaches one, which prevents it from successfully reaching the global minimum. This shortcoming of back propagation NN can be eliminated by coupling it with another AI method such as the genetic algorithms (GA). Namely, GA may be very helpful in approaching the global minimum, where the neural network can take over and proceed until it reaches the minimum itself.

The development of a hybrid system usually consists of the following six stages:

1) Problem analysis;
2) Identification of the properties required by an intelligent method in order to solve the given problem, followed by the selection of appropriate method(s);
3) Selection of an appropriate hybrid system type;
4) Implementation;
5) Validation;
6) Maintenance.

As we have already mentioned, hybrid intelligent systems represent not only a combination of different intelligent methods, but also their integration with conventional computer systems: database applications, spreadsheet applications, GIS environment, CAD/CAM, etc., with the ability to interchange data with different processes using different media.

3. A hybrid system for mine ventilation planing and analysis

Ventilation planing and analysis is one of the most complex problems in mining engineering. We approached it by decomposing the global problem into several tasks, each of them solvable by a different method. These methods were then coupled in various ways which resulted in a hybrid system named INVENTS [5]. Figure 2 illustrates its architecture which, with its interactive use of computational fluid dynamics (CFD) software, presents a novel concept in complex mine ventilation network analysis. INVENTS is composed of a number of integrated software packages, which couple both well known numerical optimization and various artificial intelligence methods. By introducing heuristics into the knowledge base existing mathematical models are upgraded with knowledge acquired through engineering practice.

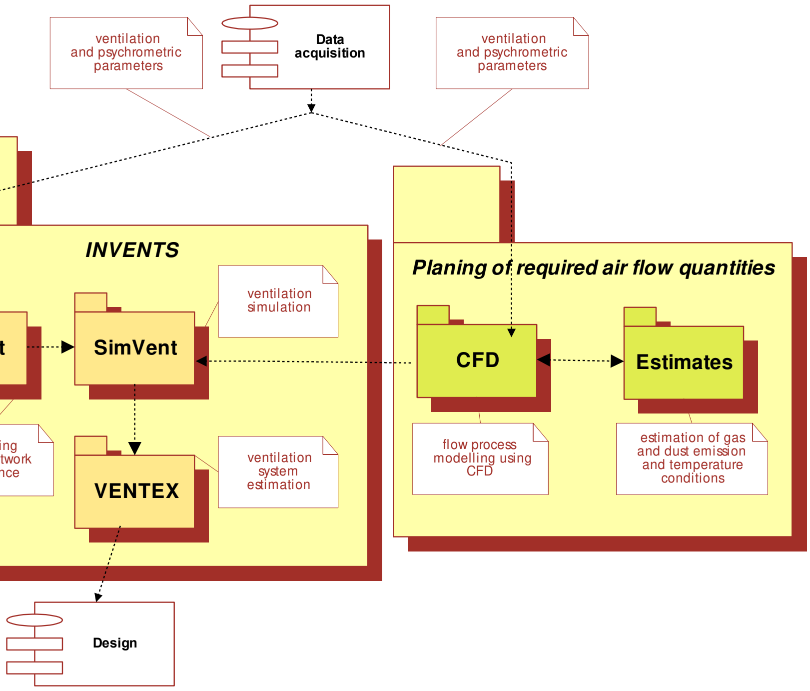

Fig. 2 Structure of the hybrid system for mine ventilation planing and analysis

INVENTS consists 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.

ResNet is a software 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.

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 modules:

1) The module for the evaluation of air flow and pressure distribution in the ventilation system;
2) The module for the analysis of the heat pattern in the mine;
3) The module for the analysis of temperature and heat depression distribution in the case of a fire in the mine;
4) The module for the analysis of gas distribution in the ventilation system.

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.

The VENTEX [2] 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*. The numerical part consists of SimVent simulation routines and the symbolic part of the mine ventilation expert's knowledge. VENTEX was developed using an expert systems shell, the KAPPA-PC applications development system. The interface developed for VENTEX 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.

4. A hybrid system for the analysis of area air pollution load

Companies often require reliable air pollution estimates that cannot be obtained by continual measuring, due to a need for expensive equipment and trained personnel, which in its turn asks for considerable funding. In this section we describe a hybrid system which enables reliable air pollution prediction by using neural network (NN) trained through a combination of genetic algorithm (GA) and the back propagation method.

The global structure of the air pollution protection system is depicted in Figure 3. The system combines AI methods (GA and NN) coupled in PollutNet [3] with CFD modeling to attain a reliable estimation of air pollution distribution. The relations between GA, NN and CFD are largely influenced by the scale and quality of data as well as the required analysis and estimation results. The distribution of pollutant imission is further being analyzed by an expert system (AIRPRESS), which then suggests measures for air pollution regulation. In the development of the system we have used NeuroWindows, GeneHunter and VisualBasic for data processing and NN training.

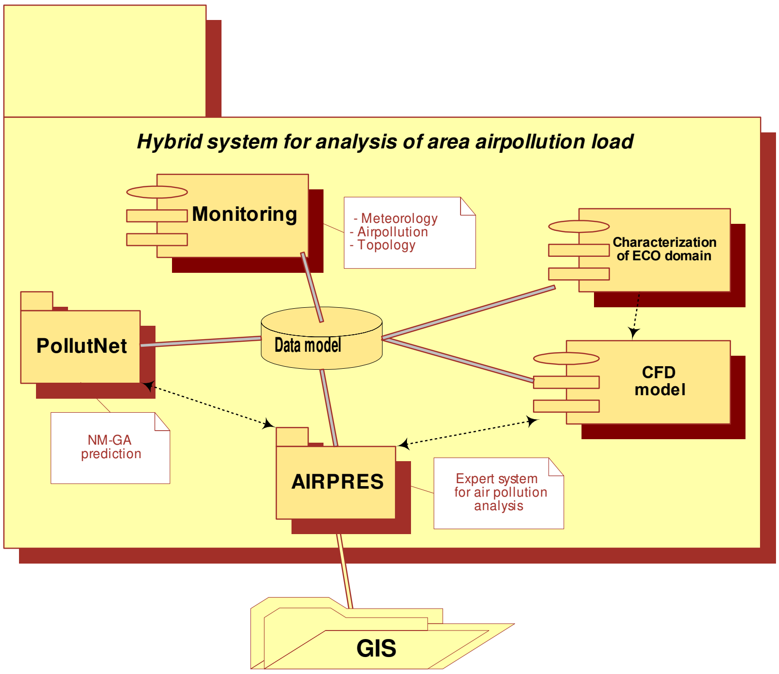

Fig. 3 Structure of a hybrid system for analysis of area air pollution load

Basically, the estimation procedure uses NN prediction capabilities. However, it has been noted that in certain cases the NN classically trained through back propagation (BP) tends to access a local minimum and cannot proceed towards the global one. This is usually the case when the starting point for NN is randomly selected, and therefore can be far from the global minimum. Having this in mind we decided to couple the NN with GA in PollutNet to overcome this possible shortcoming, which makes PollutNet itself a function-replacing hybrid system. Namely, GA can be used to select the initial state for the network in such a way that it is much closer to the global minimum thus avoiding possible local minima problems [4].

We have used two approaches in PollutNet for training the NN. The first was the classical one, in which the network weights were adapted by the back propagation algorithm (starting from a random distribution of weights). In the second one the initial values of network weights were a result of an optimization process performed by GA. These algorithms mimic the natural evolution process. Namely, they optimize a "population" through several "generations" by changing adaptable parameters so that the population fits best an accepted criterion function. Thus, the initial weights of the NN were determined by the genetic algorithm on basis of the training set using the minimum of the mean square error as the optimization criterion. It should be stressed that good result can be achieved through a small number of generations processed by GA, because the error is significantly smaller for the same number of iterations when combined GA and BP are used for NN training. This justifies the coupling of GA and NN for obtaining a more reliable prediction.

Further extension of this system through an expert system which, on basis of the results obtained by the neural network, analyses and refines estimations and suggests activities for improving air protection on the analyzed locality, is in progress. Existing legal regulations and engineering practice will be used for building its knowledge base.

The reliability of results obtained by the proposed hybrid system was tested on a test set, and the resulting correlation coefficient was 0.88, which means that the prediction accuracy is satisfactory.

5. Concluding remarks

Hybrid intelligent systems promise to become a powerful tool, which will broaden the scope of the application of AI methods. Their successful application in the case studies presented here encouraged our further research of their potentials. Specific attention is given to coupling methods as well as techniques for securing data and information transfer between system components. As for the implementation issues, we found the approach based on existing software libraries a useful and promising one. Both systems were developed and are operational on single-user PC platforms under Windows. However, further research will also be focused on issues pertaining to the functioning of hybrid systems in network environments.

LITERATURE

[1] Goonatilake S., Khebbal S., (1995) *Intelligent Hybrid Systems*, John Wiley & Sons.

[2] Lilić N., Obradović I., Stanković R., (1997), "Ventex: An Expert System for Mine Ventilation Systems Analysis", *Mining Technology*, Vol. 79, No 915, pp. 295-302.

[3] Lilić N., Stanković R., Obradović I., (1998), "An Outline of a Hybrid Intelligent System for Air Pollution Prediction", *ICAMC '98 ASRTP'98,* High Tatras, Slovak Republic, pp. 658-661.

[4] Lilić N., Stanković R., Obradović I., (1999), "Coupling intelligent methods in hybrid system for air pollution prediction", InfoJISA, vol.2-3, pp. 41-43.

[5] Lilić N., Stanković R., Obradović I., (2000), *Hibridni sistem za planiranje i analizu ventilacije rudnika*, monografija, Rudarsko-geološki fakultet, Beograd.

[6] Stanković R., (2000), *Sprezanje metoda veštačke inteligencije u cilju razvoja jednog hibridnog inteligentnog sistema*, magistarski rad, Matematički fakultet, Beograd.