# HYBRID EXPERT SYSTEM AGENTS

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*Abstract*

In previous works, we have developed a novel class of agents called expert system agents. We have presented applications of the expert system agents in medicine. The medical expert system agents eliminate some disadvantages of the medical expert systems. The possibility to use medical expert system agents in flexible hybrid medical diagnosis systems proves practically their intelligence. In this paper, we propose the endowment of the expert system agents with hybrid components. The proposed agents are called hybrid expert system agents. A hybrid expert system agent can solve more efficiently a larger variety of problems than the expert system agents can.

***Keywords:*** *hybrid agent, expert system agent, neural network, expert system, intelligent agent, cooperative problem solving, multiagent system, complex system, knowledge-based system, medical diagnosis system, medical decision support system*

## 1. Introduction

*Expert systems* are used for many difficult problems solving. As examples of applications of the expert systems, we mention the medical diagnoses elaborations. In previous works, we have proposed a novel class of agents called *expert system agents* [3, 4, 5, 12, 13]. The expert system agents (1) represent expert systems endowed with agents' capabilities like, increased autonomy in operation, autonomous learning capability and cooperation capability with humans and other agents.

$$\textit{Expert System Agent} = \\ < \textit{Expert System} > + < \textit{Agents' Capabilities} >. \\ (1)$$

The expert system agents eliminate some disadvantages of the expert systems. In the following, we mention advantages of the expert system agents versus the expert systems [4, 12, 13]. One of the main advantages consists in the increased autonomy in operation. The expert system agents can perceive the environment using their sensors, and can modify the environment using their efectors. The expert system agents can communicate with other agents and humans. The communication allows the endowment with cooperation capability in the problems solving. An expert system agent can cooperate with other agents and humans. The expert system agents can solve more flexibly and precisely problems than the traditional expert systems. The increased precision of the obtained problems solutions result from the cooperative problems solving. The flexibility in the problems solving, result from the cooperative problem allocation between the agents. If an agent cannot solve a problem, than may transmit the problem or subproblems of the problem for solving to other agents. Expert system agents can be endowed with capabilities to help the humans in different problems solving. These agents are called *assistant expert system agents* [3, 4, 7].

The expert system agents can be endowed with medical diagnosis capability [3, 4, 5, 6, 11, 12, 21]. These agents are called *medical expert system agents*. Medical expert system agents can

diagnosis in some situations more precisely illnesses than the medical expert systems [4]. Medical assistant expert systems can help the physicians in the diagnostics elaborations [3, 4]. They can verify details in a diagnostic elaboration that can be ignored by the physicians (for instance, important contraindications of a medicine). The use of the medical assistant expert systems increase the diagnostics accuracy elaborated by physicians [4]. In many situations, the cooperative diagnosis systems can elaborate diagnostics with a higher accuracy than the agents that operate in isolation [12].

In the papers [3, 4] are analyzed different aspects related with a novel hybrid diagnosis system. The novelty consists in the diagnosis system architecture, members and the cooperative diagnostics elaborations. The proposed diagnosis system is composed from physicians, medical expert system agents and medical assistant expert system agents. The cooperative problem solving in the diagnosis system is partially based on the *blackboard-based problem solving* [15]. The diagnosis system is proposed for difficult problems solving, like the diagnoses of combinations of illnesses (patients that suffer from combinations of illnesses).

In the papers [5, 6] are analyzed different aspects related with a novel hybrid diagnosis system. The novelty consists in the diagnosis system architecture, the diagnosis system members and the cooperative diagnostics elaborations. The proposed diagnosis system is composed from physicians and medical expert system agents. The cooperative problem solving in the diagnosis system is based on a novel general cooperative problem solving described in [14]. The novel cooperative problem solving is partially based on the *contract net task allocation protocol* [19]. The main advantage of the proposed diagnosis system consists in the flexibility in solving of a large variety of diagnosis problems. Each diagnosis problem is transmitted to an agent member of the diagnosis system. In the following, the system will handle autonomously the problem, by finding step-by-step the capable agents to contribute to the problem solving.

The expert system agents can solve intelligently difficult problems [13]. The use of the expert system agents in the hybrid medical diagnosis systems described in [3, 4, 5, 6] proves practically their intelligence. Expert system agents can solve flexibly and precisely medical diagnosis problems.

*Neural networks* are used for many problems solving [1]. The neural networks as opposite to the agents do not interact directly with the environment. They cannot sense the environment with sensors and cannot execute actions in the environment. The neural networks cannot learn autonomously. A neural network cannot solve cooperatively problems with other artificial systems or humans. The capabilities mentioned before are necessary in some problems solving, which motivate the necessity to endow the neural networks with agents' capabilities.

In the next section, we propose a novel class of agents called hybrid expert system agents. The hybrid expert system agents represent expert system agents endowed with hybrid components. We consider the situation when the hybrid expert system agent contains neural network components. These hybrid expert system agents extend the traditional neural networks, making possible the use of them in a larger variety of situations. The hybrid expert system agents eliminate some disadvantages of the expert system agents.

## 2. Proposed Hybrid Expert System Agents

*Hybrid agents* can be well adapted for different problems solving [10]. We propose the endowment of the expert system agents with hybrid components. The proposed agents are called *hybrid expert system agents*. Figure 1 illustrates the architecture of a proposed hybrid expert system agent.

Formally, a proposed hybrid expert system agent can be described as (2).

*Hybrid Expert System Agent* =
< *Expert System Component* > + < *Neural Network Component* > + < *Other Components* > + < *Agents' Capabilities* > .
(2)

The environment where can operate a hybrid expert system agent may have different computational and physical components. In the same environment may operate humans and other agents. *Sensor* represents the agent's sensor. The sensor perceives the state of the environment. *Efector* represents the agent's efector. *Efector* can execute different actions in the environment. *Communication* represents the component capable of communication with other agents and humans.

The informations and data transmitted by the sensor and communicated by other agents and humans are overtaken by the *Decision* component of the agent. *Expert system* represents a component that solves problems like the traditional expert systems. *Neural network* represents a component that solves problems like the traditional neural networks. *Other* illustrates the possibility to endow the agent with other hybrid components. *Expert system*, *Neural network* and *Other* are the problems solving components of the agent. We denote $PSC = \{PSC_1, PSC_2,\ldots, PSC_n\}$ the problems solving components of the agent. A proposed hybrid agent is endowed with a set $SP = \{SP_1, SP_2,\ldots, SP_n\}$ of specializations. The agent can solve using its specializations a set $CL = \{CL_1, CL_2,\ldots, CL_n\}$ of classes of problems. Each specialization $SP_k$ allows the solving of a class $CL_k$ of problems (3).

$$CL_k \Rightarrow SP_k, \quad k = 1 .. n . \tag{3}$$

Each specialization $SP_k$ is detained by a problems solving component $SPC_j$ of the agent. A problem-solving component $SPC_i$ detains a set $\{SP_{i1}, SP_{i2},\ldots, SP_{im}\}$ of specializations. An expert system component may detain more specializations in medical diagnosis. As examples of medical specializations of an expert system component, we mention specializations in subdomains of: dermatology, cardiology and general medicine.

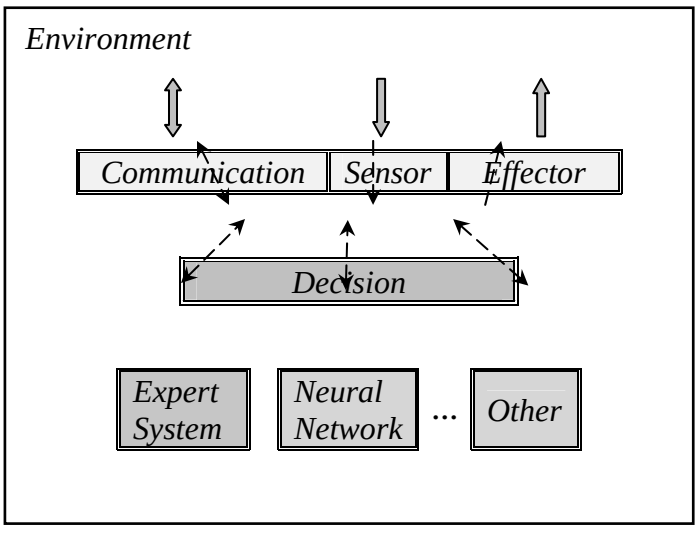


**Figure 1.** *The hybrid expert system agent architecture*

The proposed hybrid agents can perceive and interact with the environment. They can communicate with other agents and humans that allow the cooperative problems solving. They

can learn and execute different actions in the environment autonomously. At the creation, a hybrid expert system agent is endowed with an initial set of knowledge. The agent can improve its knowledge in order to eliminate the erroneous and imprecise knowledge. He can learn new knowledge during its life cycle. The learning capability can be implemented in the *Decision* component of the agent. *Decision* can learn from communicated informations, by perceiving the environment and the consequences of executed actions by the efector. The understanding of the consequences of executed actions is necessary for an intelligent agent [17].

The algorithm called *Problem Solving by a Hybrid Expert System Agent* describes a problem $PR_k$ solving by a proposed hybrid expert system agent denoted *HA*.

*Algorithm - Problem Solving by a Hybrid Expert System Agent*

*Step 1 - The problem's description overtaking.*

*@Communication* overtakes the knowledge *CK* communicated by other agents and humans.

*@Sensor* perceives the state *SE* of the environment.

*Step 2 - The problem's data transmission to the decision component.*

*Decision* $\Leftarrow$ *Communication* (*CK*).

*Decision* $\Leftarrow$ *Sensor* (*SE*).

*Step 3 - The problem formation.*

$PR_k$ = *Decision* (*CK*, *SE*).

$PR_k$ = < $Type_k$, $Description_k$ >.

*Step 4 - The establishment of the problem-solving component that will solve the problem.*

*@Decision* establishes the problems solving component $PSC_j$ that can solve the problem $PR_k$.

*Decision* ($PR_k$) $\Rightarrow$ $PSC_j$.

*Step 5 - The establishment of the problem solving specialization.*

*@*$PSC_j$ establishes the specialization $SP_i$ necessary for the problem $PR_k$ solving.

*Step 6 - The problem solving.*

*@*$PSC_j$ solves the problem $PR_k$, using the specialization $SP_i$, obtaining the solution $SOL_k$.

$PSC_j$ ($SOL_k$) $\Rightarrow$ *Decision*.

< *MSG*, *DEST* > = *Decision* ($SOL_k$).

*If* ({*MSG*} $\neq \varnothing$) *then*

*Decision* (*MSG*, *DEST*) $\Rightarrow$ *Communication*.

*Communication* (*MSG*) $\Rightarrow$ *DEST*.

*EndIf*

[$AC_1$, $AC_2$,…, $AC_k$] = *Decision* ($SOL_k$).

*If* ({$AC_1$, $AC_2$,…, $AC_k$} $\neq \varnothing$ ) *then*

*Decision* ({$AC_1$, $AC_2$,…, $AC_k$}) $\Rightarrow$ *Efector*.

*@Efector* executes the actions $AC_1$, $AC_2$,…, $AC_k$.

*EndIf*

*EndProblemSolvingHybridExpertSystemAgent.*

In the following, we explain the *Problem Solving by a Hybrid Expert System Agent* algorithm. The *Communication* component overtakes the communicated knowledge *CK* by other agents or humans. The *Sensor* component overtakes the state of the environment *SE*. Based on *CK* and *SE* the *Decision* component establishes the problem $PR_k$ that must be solved. $PR_k$ has a type (class) $Type_k$ and a description $Description_k$. $PR_k$ can be specified explicitly ($PR_k$ is transmitted for solving by an agent or human) or implicitly (based on the informations communicated and/or informations transmitted by the sensor).

After the problem $PR_k$ establishment the *Decision* component establishes the problem-solving component $PSC_j$ capable to solve the problem $PR_k$, and transmit the problem for solving to $PSC_j$. $PSC_j$ establishes the specialization $SP_i$ necessary for the problem $PR_k$ solving. $PSC_j$ solves the problem $PR_k$ using the specialization $SP_i$, obtaining the solution $SOL_k$ of the problem. $SOL_k$ may contain knowledge (information and data) *MSG* that must be transmitted to one or more destinations *DEST* and/or actions $AC = \{AC_1, AC_2, \ldots, AC_k\}$ that must be executed by the effector. As examples of informations that must be transmitted to other agents based on a problem solution, we mention: the solution of the problem (the obtained solution must be transmitted to the problem sender), some informations extracted from the problem solution must be transmitted to an agent or a human etc. As examples of actions that can be executed after a problem solving, we mention the movement of the agent in the environment.

A problem solving by a proposed hybrid expert system agent is realized at more levels. The first level corresponds to the problem *PR_L1* formation based on the informations *CK* communicated by other agents or humans and informations *SE* obtained from the effectors. The second level corresponds to the problem *PR_L1* processing by the decision component. After the problem *PR_L1* processing by the *Decision* component is obtained a new problem *PR_L2*. The third level corresponds to the problem *PR_L2* solving by the selected problem-solving component *Solving* using the existent specializations. *Solving* will obtain the problem solution $SOL_k$.

The problem solving can be described formally as follows:

*Level 1 of processing*

$$Communication\ (CK,\ SE) \Rightarrow Decision\ ,$$

$$Decision\ (CK,\ SE) \rightarrow PR\_L1\ .$$

*Level 2 of processing*

$$Decision\ (PR\_L1) \rightarrow PR\_L2\ ,$$

$$Decision\ (PR\_L2) \Rightarrow Solving\ .$$

*Level 3 of processing*

$$Solving\ (PR\_L2) \rightarrow SOL\ .$$

## 3. Conclusions and future work

In previous works, we have proposed a novel class of agents called *expert system agents* [3, 4, 5, 6, 12, 13]. Expert system agents and assistant expert system agents endowed with medical knowledge are used in novel hybrid medical diagnosis systems [3, 4, 5, 6]. Advantages of the expert system agents versus the traditional expert systems are analyzed in [4, 12]. The intelligence of the expert system agents is analyzed in [13]. The use of the expert system agents in hybrid medical diagnosis systems proves practically their intelligence.

In this paper, we have proposed a novel class of hybrid agents called hybrid expert system agents. Hybrid expert system agents represent expert system agents endowed with hybrid components. A hybrid expert system agent can be endowed with problems solving components like, neural network components. Each problems solving component of an agent can be implemented as a well-adapted problems solving method for a class of problems. For example, an expert system component can be well adapted for medical diagnosis [3, 4]. A neural network component can be well adapted for problems solving like noisy image recognition. A hybrid expert system agent can be better adapted for some problems solving versus the expert system agents. A hybrid expert system agent can solve efficiently a large variety of problems.

A neural network component of a hybrid expert system agent solves problems like the neural networks. Hybrid expert system agent that uses neural network components has advantages in the problems solving versus the traditional neural networks. As opposite to the traditional neural networks, they can cooperate with other agents and humans in the problems solving. They can perceive and interact with the environment. A hybrid agent can be endowed with more neural network components. Each neural network component can be adapted for solving efficiently a class of problems. In the case of a transmitted problem, a neural network component will select the best-fitted specialization (neural network) for the problem solving. Using the proposed architecture the neural networks can be used more flexibly in the problems solving.

In the literature, there exist many definitions of the agents' intelligence [2, 13, 16, 18]. A proposed hybrid expert system agent can be endowed with capabilities like, adaptability and efficient cooperation capability with humans and other agents. These capabilities many times are considered components of an intelligent behavior. A hybrid expert system agent may adapt its behavior in order to solve more efficiently problems or to solve new problems. The adaptation of an agent can be realized by learning. A hybrid agent can be endowed with the intelligence necessary in different problems solving [10]. An agent must have only the necessary intelligence in the problems solving (problems that must be solved by the agent) [8, 9]. For an agent that must solve a very simple problem it is not necessary to be intelligent. The cooperative agents' intelligence can be considered at the level of multiagent system where they operate. If the agents cooperate, they can solve intelligently difficult problems [2, 3, 4, 8, 11, 18, 20].

The next research includes the use of the proposed hybrid expert system agents as members of the novel medical diagnosis system described in [3, 4]. A proposed hybrid expert system agent can be adapted for solving cooperatively with physicians, a larger variety of problems than the expert system agents can.

## BIBLIOGRAPHY


[1] C. Enachescu. *Economic Data Analyze Using Neural Networks*. Proceedings of the 2nd International Conference on Economics, Law and Management, pp. 28-41, 2006.

[2] J. Ferber. *Multi-Agent Systems: An Introduction to Distributed Artificial Intelligence*. Addison Wesley, 1999.

[3] B. Iantovics. *A Novel Diagnosis System Specialized in Difficult Medical Diagnosis Problems Solving*. Proceedings of the Emergent Proprieties in Natural and Artificial Dynamical Systems a workshop within European Conference on Complex Systems, (EPNADS'05), M.A. Aziz-Alaoui, C. Bertelle. (Eds.). Le Havre University Press, Paris, pp. 107-112, 2005.

[4] B. Iantovics. *A Novel Diagnosis System Specialized in Difficult Medical Diagnosis Problems Solving*. Understanding Complex Systems, Springer-Verlag, pp. 187-197, 2006.

[5] B. Iantovics. *A Novel Medical Diagnosis System*. Proceedings of the 4-th International Conference on Theory and Applications in Mathematics and Informatics, *Acta Universitatis Apulensis*, 10, pp. 315-330, 2005.
[6] B. Iantovics. *A Novel Medical Diagnosis System*. Proceedings of the European Conference on Complex Systems, P. Bourgine, F. Kepes, M. Schoenauer (Eds.). Paris, pp. 150-151, 2005.
[7] B. Iantovics. *Problems Solving Using Assistant Agents*. Scientific Bulletin of the Petru Maior University, Tg. Mures, XVIII, pp.173-179, 2006.
[8] B. Iantovics. *Intelligence of the multiagent systems*. Petru Maior University Press, Tg. Mures, XV-XVI, pp.125-129, 2002-2003.
[9] B. Iantovics. *Intelligent agents*. Petru Maior University Press, Tg. Mures, XVII, pp. 265-271, 2004.
[10] B. Iantovics. *Intelligent hybrid agents*. Petru Maior University Press, Tg. Mures, XVII, pp. 259-263, 2004.
[11] B. Iantovics. *Cooperative Medical Diagnosis Systems*. Proceedings of the International Conference Interdisciplinarity in Engineering, pp. 669-674, 2005.
[12] B. Iantovics. *Medical Diagnosis Systems*. *Proceedings of the International Conference Several Aspects of Biology, Chemistry, Informatics, Mathematics and Physics*, Oradea, Romania, 2005.
[13] B. Iantovics. *The Intelligence of the Expert System Agents*. Proceedings of the 2nd International Conference on Economics, Law and Management, pp.91-101, 2006.
[14] B. Iantovics. *A New Task Allocation Protocol in Distributed Multiagent Systems*. Proceedings of 4th International Conference in Education/Training and Information/Communication Technologies, pp.1-6, 2005.
[15] V. Jagannathan, R. Dodhiawala, L.S. Baum. (Eds.). *Blackboard Architectures and Applications*, Academic Press, San Diego, 1989.
[16] P. Mccauley-Bell. *Intelligent agent characterization and uncertainty management with fuzzy set theory: a tool to support early supplier integration*, Journal of Intelligent Manufacturing, 10, pp. 135-147, 1999.
[17] R. Pfeifer, C. Scheier. *Understanding Intelligence*, MIT Press, September, 1999.
[18] W. Shen, F. Maturana, D.H. Norrie. *MetaMorph II: an agent-based architecture for distributed intelligent design and manufacturing*. Journal of Intelligent Manufacturing, 11, pp. 237-251, 2000.
[19] R.G. Smith. *The Contract Net Protocol: High Level Communication and Control in a Distributed Problem Solver*, IEEE Transactions on Computers, C-29(12), pp. 1104-1113, 1980.
[20] G. Weiss. (Ed.) *Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence,* MIT Press, Cambridge, Massachusetts London, England, 2000.
[21] B. Iantovics, *Agent-Based Medical Diagnosis Systems*, Computing and Informatics, Slovak Academy of Sciences, Bratislava, (2007). (accepted paper)