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REVIEW OF MULTI-AGENT SYSTEMS (MAS), A NEW TOOL FOR THE CONTROL AND MANAGEMENT OF MODERN POWER SYSTEMS

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Abstract- In computer science, as in any other science, several new ideas, concepts and paradigms emerged over time and became the "Big idea" or "Big excitement" of the discipline. The '90s brought the concept of agents in computer science and this term is now as fashionable as object-oriented was in the '80s or artificial intelligence in the '70s. Being fashionable means that anyone who wants to be "en vogue" will use it, that maybe more expectation than needed will be put in the new concept and that there is the great risk of having an overused word. Then why agents in computer science and do they bring us anything new in modeling and constructing our applications? The answer is definitively YES and the papers contributes to justify this answer. The paper denotes a review on the past papers related to multi-agent system (MAS) and the applications in power systems.

Keywords: Modern Power Systems, Artificial Intelligence, Multi Agent Systems, Control, Management.

I. DEFINITION AND CLASSIFICATION

It would certainly not be an original thing to say that the notion of agent or agency is difficult to define. There are important number of papers on the subject of agent and multi-agent system definition and a tremendous number of definitions for agents, ranging from one line definitions to pages of agent attribute descriptions. The situation is somehow comparable with one encountered when defining artificial intelligence.

More than 30 years ago, computer scientists set themselves to create artificial intelligence programs to mimic human intelligent behavior, so the goal was to create an artifact with the capacities of an intelligent person.

Now we are facing the challenge to emulate or simulate the way human act in their environment, interact with one another, cooperatively solve problems or act on behalf of others, solve more and more complex problems by distributing tasks or enhance their problem solving performances by competition.

Artificial intelligence (AI) put forward high expectations and the comparison of actual achievements with the initial hopes brought some disappointment. But AI contributed computer science with some very important methods, concepts, and techniques that strongly influenced other branches of the discipline, and the results obtained by AI in real world applications are far from being negligible.

The agents and multi-agent systems will be one of the landmark technology in computer science of the years to come, that will bring extra conceptual power, new methods and techniques, and that will essentially broaden the spectrum of the computer applications.

The technology has the chances to compensate the failures of AI just because this new paradigm shifts from the single intelligent entity model to the multi-intelligent entity one, which is in fact the true model of human intelligence acting.

It will be very useful to examine some agent definitions and identify the most relevant features of agents. One primary characteristic that differentiate agents from an ordinary program is that the agent must be autonomous. Several definitions of agents includes this characteristic:

- "Most often, when people use the term 'agent' they refer to an entity that functions continuously and autonomously in an environment in which other processes take place and other agents exist." (Shoham, 1993);
- "An agent is an entity that senses its environment and acts upon it" (Russell, 1997);
- "The term agent is used to represent two orthogonal entities. The first is the agent's ability for autonomous execution. The second is the agent's ability to perform domain oriented reasoning." (the MuBot Agent);
- "Intelligent agents are software entities that carry out some set of operations on behalf of a user or another program, with some degree of independence or autonomy, and in so doing, employ some knowledge or representation of the user's goals." (the IBM Agent);

- "An autonomous agent is a system situated within and a part of an environment that senses that environment and acts on it, in pursuit of its own agenda and so as to effect what it senses in the future." (Franklin, Gasser, 1997).

Although not stated explicitly, Russell's definition implies the notion of autonomy as the agent will act in response to perceiving changes in the environment. The other four definitions explicitly state autonomy. But all definitions add some other characteristics, among which interaction with the environment is mentioned by most. Another identified feature is the property of the agent to perform specific tasks on behalf of the user, coming thus to the original sense of the word agent, namely someone acting on behalf of someone else.

One of the most comprehensive definition of agents, that is the one given by Wooldridge and Jennings (1995) in which an agent is:

- "a hardware or (more usually) a software-based computer system that enjoys the following properties: autonomy-agents operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state; social ability - agents interact with other agents (and possibly humans) via some kind of agent-communication language; reactivity: agents perceive their environment and respond in a timely fashion to changes that occur in it; pro-activeness: agents do not simply act in response to their environment, they are able to exhibit goal-directed behaviour by taking initiative."

Comparing the definitions above, we may identify two main trends in defining agents and agencies. Some researchers consider that we may talk and define an agent in isolation, while some others view agents mainly as entities acting in a collectively of other agents, therefore the multi-agent system (MAS) paradigm. Even if we stick to the single agent type of definition it is rather difficult to expect that an agent will exist only as a stand alone entity and will not encounter other agents (be they artificial or human) in its environment.

Personal agents, or information agents, which are not mainly supposed to collectively work to solve problems, will certainly have much to gain if interacting with other agents and soon, with the wide spread of agent technology, will not even be able achieve their tasks in isolation. Therefore, the social dimension of an agent is considered as being one of its essential features.

Although almost all of the above characteristics of agents may be considered as sharing something with intelligent behavior, researchers have tried to define a clear cut between computational agents and intelligent agents, sliding in the world of agents the much searched difference between programs and intelligent programs.

It is clear that, if in the design of an agent or multi-agent system, we use methods and techniques specific to artificial intelligence then the agent may be considered intelligent. If the agent has an explicit goal to pursue and it uses heuristics to select the best operations necessary to achieve its goal, it then shares one specific feature of AI programs and may be considered intelligent.

To apply the model of human intelligence and human perspective of the world, it is quite common in the community of artificial intelligence researchers to characterize an intelligent agent using mentalistic notions such as knowledge, beliefs, intentions, desires, choices, commitments, and obligation (Shoham, 1993).

One of the most important characteristics of intelligent agents is that they can be seen as intentional systems, namely systems "whose behaviour can be predicted by the method of attributing belief, desires and rational acumen" (Dennett, 1987). As Shoham points out, such a mentalistic or intentional view of agents is not just another invention of computer scientists but is a useful paradigm for describing complex distributed systems.

The complexity of such a system or the fact that we can not know or predict the internal structure of all components seems to imply that we must rely on animistic, intentional explanation of system functioning and behavior. It is required to apply the model of human distributed activities and behavior to more and more complex computer-based artifacts.

Such intelligent agents, mainly characterized by a symbolic level of representing knowledge and by mentalistic notions, are considered to be cognitive agents. As artificial intelligence proposed as an alternate approach of realizing intelligence the sub-symbolic level of neural networks, with many interconnected simple processing units, some researchers in multi-agent systems developed an alternate model of intelligence in agent systems, namely the reactive agents.

Reactive agents are simple processing units that perceive and react to changes in their environment. Such agents do not have a symbolic representation of the world and do not use complex symbolic reasoning. The advocates of reactive agent systems claims that intelligence is not a property of the active entity but it is distributed in the system, and steams as the result of the interaction between the many entities of the distributed structure and the environment. In this way, intelligence is seen as an emergent property of the entire activity of the system, the model trying to mimic the behavior of large communities of inferior living beings, such as the communities of insects.

Among computational agents we may identify also a broad category of agents, which are in fact nowadays the most popular ones, namely those that are generally called software agents (or weak agents, as in Wooldridge and Jennings, 1995, to differentiate them from the cognitive ones, corresponding to the strong notion of agent): information agents and personal agents.

An information agent is an agent that has access to one or several sources of information, is able to collect, filter and select relevant information on a subject and present this information to the user. Personal agents or interface agents are agents that act as a kind of personal assistant to the user, facilitating for him tedious tasks of email message filtering and classification, user interaction with the operating system, management of daily activity scheduling, etc.

II. PERFORMANCES OF MAS

Some main issues of research, specification and design in cognitive multi-agent systems, are discussed as specified in Figure 1.

The possible worlds model for logics of knowledge and belief was originally proposed by Hintikka (Hintikka, 1962) and formulated in modal logic using Kripke semantics. In this model, the agent beliefs and knowledge are characterized as a set of possible worlds, with an accessibility relation holding between them. The main disadvantage of the model is the logical omniscience problem that consists in the logic predicting that agents believe all the logical consequences of their belief.

Because of the difficulties of logical omniscience, some alternate formalisms for represented belief have been proposed, many of them including also other mentalistic notions besides knowledge and beliefs.

Konolige (Konolige, 1986) developed the deduction model of belief in which beliefs are viewed as symbolic formula represented in a meta-language and associated with each agent. Moore (Moore, 1985) formalized a model of ability in a logic containing a modality for knowledge and a dynamic like part for modeling action.

Cohen and Levesque (1990) proposed a formalism that was originally developed as a theory of intentions with two basic attitudes: beliefs and goals. The logic proved to be useful in analyzing conflict and cooperation in agent communication based on the theory of speech acts.

One of the most influential model nowadays is the one developed by Rao and Georgeff (1991) based on three primitive modalities, namely belief, desire and intentions (BDI model).

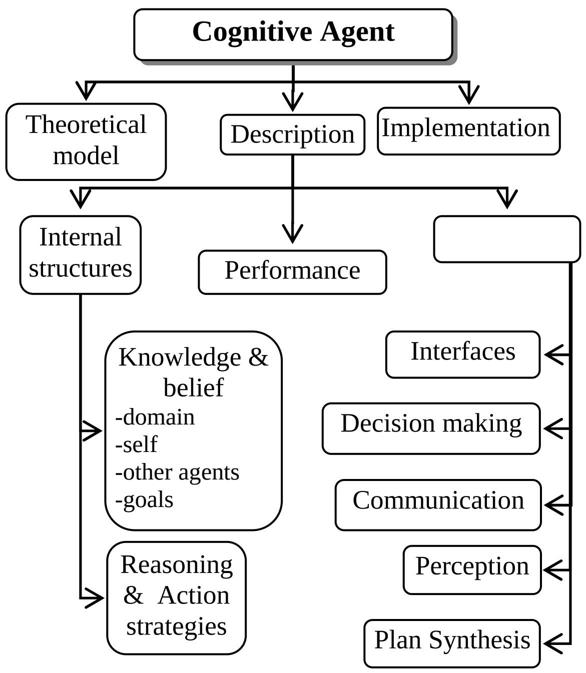

Figure 1. Levels of specification and design of intelligent agents in a MAS

III. INTERACTIONS OF MAS

A simple form of interaction such as communication is that restricted to simple signals, with fixed interpretations. Such an approach was used by Georgeff in multi-agent planning to avoid conflicts when a plan was synthesized by several agents. A more elaborate form of communication is by means of a blackboard structure.

A more elaborate type of communication that tends to be specific to cognitive MAS is communication based on the speech act theory (Searle, 1969, Vanderveken, 1994). In such an approach, interaction among agents take place at least at two levels: one corresponding to the informational content of the message and the other corresponding to the intention of the communicated message. If interaction among agents is performed by means of message passing, each agent must be able to deduce the intention of the sender regarding the sent message.

One of the best known example of interaction language based on speech act theory is the KQML (Knowledge Query and Manipulation Language) language proposed by ARPA Knowledge Sharing Effort in 1992. KQML uses the KIF (Knowledge Interchange Format) language to describe the content of a message. KIF is an ASCII representation of first order predicate logic using a LISP-like syntax.

IV. COORDINATION OF MAS

Coordination among agents is essential for achieving the goals and acting in a coherent manner. Coordination implies considering the actions of the other agents in the system when planning and executing one agent's actions. Coordination may imply cooperation and in this case the agent society works towards common goals to be achieved, but may also imply competition, with agents having divergent or even antagonistic goals.

The cooperative agents have usually individual capabilities which, combined, will lead to solving the entire problem. Cooperation is necessary due to complementary abilities, to the interdependency that exists among agent actions and to the necessity to satisfy some global restrictions or criteria of success. In a cooperative model of problem solving the agents are collectively motivated or collectively interested therefore they are working to achieve a common goal.

Another possible model is that in which the agents are self motivated or self interested agents because each agent has its own goals and may enter in competition with the other agents in the system to achieve these goals. Competition may refer to resource allocation or realization/distribution of certain tasks. In such a model, the agents need to coordinate their actions with other agents to ensure their coherent behaviour.

In distributed problem solving based on collectively motivated MAS, the contract net model was used to achieve cooperation by eliminating inconsistencies and the exchange of tentative results (Klein, 1991), multi-agent planning (Georgeff, 1984, Pollack, 1992) in which agents share information to build a common plan and distribute the plan among agents.

Negotiation is central in self interested MAS. Zlotkin and Rosenschein (1989) use a game theoretic approach to analyze negotiation in multi-agent systems. In 1991, Sycara proposes a model of negotiation in which agents make proposals and counter-proposals, reason about the beliefs of other agents and modify their beliefs by cooperation. Durfee and Montgomery develop a hierarchical negotiation protocol which allows agents to flexibly discover and solve possible conflicts. Kraus (Kraus, 1997, Kraus et. al., 1995) uses negotiation strategies for resource allocation and task distribution. Introduction of economic theory approaches in negotioan strategies for MAS is a current direction of research and investigation (Kraus, 1997, Kraus, 1996, Brafmann, Tennenholtz, 1997).

V. ORGANIZATION OF MAS

Several models of organizations in MAS were developed, varying from simple structures to more elaborate ones, and depending on the centralized or decentralized characteristic of the organization. Among the simple models we may cite the groups, the teams and the interest groups.

A more elaborate model of organizations is the hierarchical one, based on the traditional master/slave relation. In such a structure, there is a manager that is responsible for the division of tasks, assignment of subtasks to slaves, and the control of task completion. The slaves have to share the necessary information to achieve tasks and are supposed to be obedient. A refinement of a hierarchical organization is the decentralized organization or multi-division hierarchy in which the organization comprises several divisions and each division is a hierarchical organization functioning in the way described above. Top-level decision making is performed only for long-term strategic planning. Hierarchical organizations are mainly fit for cooperative-like systems and closed systems.

At a decentralized level, the predominant MAS structure is the market. The simplest market organization implies the existence of suppliers, able to perform tasks to produce goods or services, and of buyers, namely agents that need the goods or services produced by the suppliers. The basic model associated with such a structure is the competitive MAS, with self interested agents that are competing either to supply or to buy goods or services. Such a model is well suited for open systems. In such an organizations, the agents in the system are dived into groups, each group having associated a single "facilitator" to which the agents surrender a degree of autonomy. A facilitator serves to identify the agents that join or leave the system and enables the communication with agents located in other groups.

Figure 2 represents a scheme of the basic aspects that should be considered when studying and designing MAS.

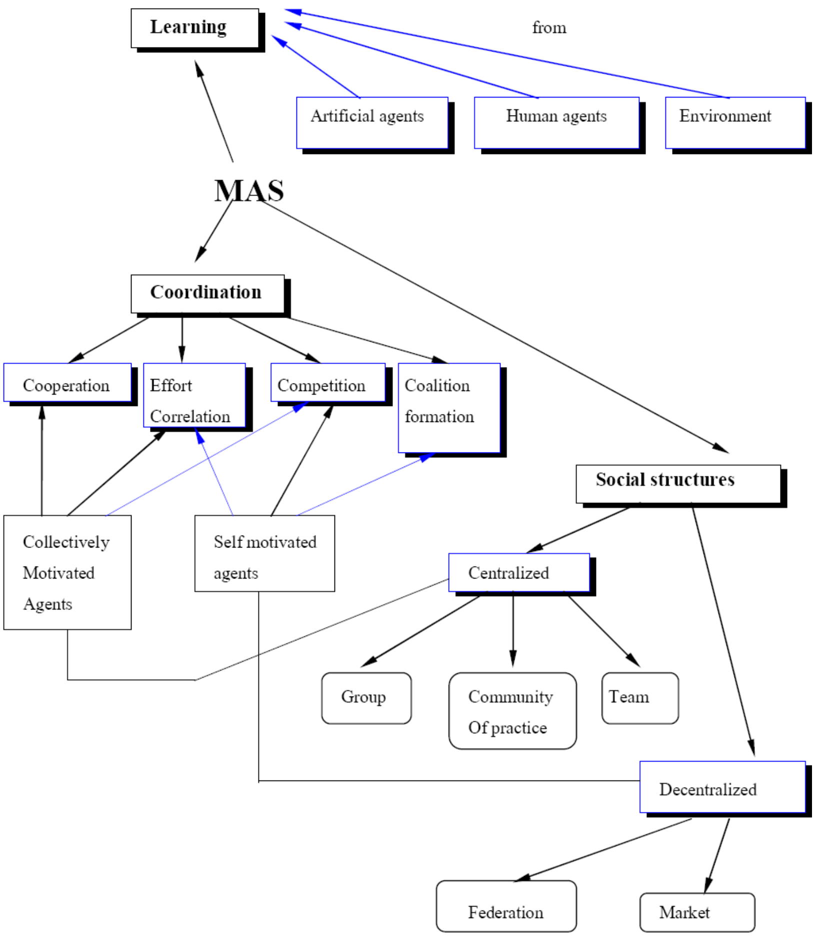

Figure 2. Cognitive interactions in a MAS

VI. CONCLUSIONS

This review presentation of basic problems is related to multi-agent systems technology and mentions two ideas that, to my opinion, are central to this new technology:

- Multi-agent systems draw from a wealth of domains such as distributed systems, distributed artificial intelligence, software engineering, computer-supported cooperative work, knowledge representation, organizational theory, sociology, linguistics, philosophy, economics, and cognitive science.
- It is widely expected that multi-agent technology systems will become the major paradigm in the development of complex distributed systems, networked information systems, and computer interfaces.

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