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RESEARCH ARTICLE

Theory of interaction, insertion modeling, and cognitive architectures

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Abstract
The paper presents a new cognitive architecture based on insertion modeling, one of the paradigms of a general theory of interaction, and a basis for multiagent system development. Insertion cognitive architecture is represented as a multilevel insertion machine which realizes itself as a high-level insertion environment. It has a center to evaluate the success of its behavior, which is a special type agent that can observe the interaction of a system with external environment. The main goal of a system is achieving maximum success repeated. Considered as an agent this machine is inserted into its external environment and has the means to interact with it. The internal environment of intelligent cognitive agent creates and develops its own model and the model of external environment. If the external environment contains other agents, they can be modeled by internal environment, which creates corresponding machines and interprets those machines using corresponding drivers, comparing the behaviors of models and external agents. Insertion architecture is now under development on the base of Insertion modeling system, developed in Glushkov Institute of Cybernetics. The nearest application will be the cognitive intellectual agent for software understanding.

Introduction

The *general theory of information interactions* begins with neural networks of McCulloch and Pitts (1943). The theory of neural networks led to the emergence of abstract automata theory, a theory that allows us to study the behavior and interaction of evolving systems, regardless of their structure. Originally, automata theory was developed as a theory of finite automata and Kleene-Glushkov algebra (Glushkov, 1960; Kleene, 1956) served as the primary means of describing the behavior of automata. The automata theory study focused on issues of analysis and synthesis, the study of generalized finite and infinite automata and complexity issues. Automata networks studied in applied areas related to the design of electronic circuits in computer

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engineering. Interaction in an explicit and general form appeared only in the 70s as a theory of interacting information processes. It includes CCS (Calculus of communicating processes) of Milner (1980, 1989), and his π-calculus (1991), CSP (Communicating Sequential Processes) of Hoare (1985), ACP (Algebra of Communicating Processes) of Bergstra and Klop (1984), and many other branches of these basic theories. A rather complete review of the classical theory of processes is presented in Bergstra, Ponce, and Smolka (2001). At the same time new models of parallel computation appeared in response to practical queries of parallel programming. The most abstract models are Petri nets (Petri, 1962), Actor model of Hewitt, Bishop, and Steiger (1973), as well as the widespread ideas of object-oriented (parallel) programming. They occupy an intermediate position between the network models (neural and automata networks, data flow diagrams) and the models of the process theory. More specialized models are connected with agent-oriented programming. The Gaia approach (Wooldridge, Jennings, & Kinny, 2000) unifies different directions of agent-oriented programming. In Gaia models interaction components are specified flexibly and explicitly. But this approach is closely connected with the traditions of software development.

Insertion modeling originated in the 90s as one of the trends in the general theory of interaction. Original name is ''the model of interaction of agents and environments''. Basic concepts of insertion modeling (environment, agents, insertion function) were introduced in the papers of Gilbert and Letichevsky (1996), Letichevsky and Gilbert (1998, 1999). The main idea of insertion modeling can be found even in the model of interacting control and operational automata proposed V.M. Glushkov back in the 60s (Glushkov, 1965; Glushkov & Letichevsky, 1969) to describe the structures of computers, as well as its development in the theory of discrete processors developed in 70s . In these models, the system is represented as a composition of two automata — a control and information automata. Control automaton plays the role of agent and information automaton — the role of the environment in which the agent is inserted. The model of macroconveyor parallel computations studied in the 80s (Kapitonova & Letichevsky, 1988), is even closer to the present model of interaction of agents and environments. In these models, processes corresponding to parallel branches can be viewed as agents interacting in the environment of distributed data structures.

The models studied in the theory of processes, can be equivalently represented as the composition of the environment and agents inserted into this environment. Various proposals for unification of the general theory of interaction in distributed systems are being actively discussed, starting from the 1990s. In particular these include purely mathematical studies based on coalgebras (Rutten, 2000), the approach proposed by Hoare (Hoare & Jifeng, 1999) to unify theories of programming, the logic of conditional rewriting by Meseguer (1992) etc.

In the recent years, insertion modeling becomes a tool to develop application systems for the verification of requirements and specifications of distributed interacting systems (Baranov, Jervis, Kotlyarov, Letichevsky, & Weigert, 2003; Kapitonova, Letichevsky, Volkov, & Weigert, 2005; Letichevsky et al., 2005a). System VRS, developed in Ukraine by order of Motorola with the participation of the Glushkov Institute of Cybernetics was used for the verification of requirements and specifications in the field of telecommunication systems, embedded systems and real-time systems. The new system IMS of insertion modeling (Letichevsky, Letychevsky, & Peschanenko, 2011), which was developed at the Glushkov Institute of Cybernetics, should expand the scope of insertion modeling.

Cognitive architectures is a rapidly growing trend in recent years in artificial intelligence. The purpose of this direction is to build a model of the human mind, which has the same features as the universal human mind. Unlike specialized artificial intelligence systems that can effectively solve specific classes of problems, cognitive architecture must adapt to a variety of new, often unexpected situations that arise because of interaction with the environment, to learn, to set goals, improve their behavior, etc. Within the framework of Biologically Inspired Cognitive Architectures, a comparison was made of a large number of existing cognitive architectures, and the main features required for such architectures (Samsonovich, 2010).

Studying modern systems used to build cognitive architectures, we found many similarities in these systems and software systems development tools based on formal methods. This fact has stimulated the beginning of work on a new cognitive architecture ICAR (insertion cognitive architecture) based on insertion modeling and IMS system.

There are two main approaches to model human mind which we distinguish as low level and high level modeling. The low level modeling is based on reengineering of the human brain on a base of neural networks, high level is the reproducing of intelligent human behavior abstracted from the details of the brain structure, but motivated by the analyses of human cognition. The cognitive architecture ICAR relates to the second direction. The paper presents the basic principles of insertion modeling and the concept of the cognitive model, which is created on the base of these principles. The main idea that distinguishes this architecture from others is the algebraic refinement of the notions of behavior and behavior models, and the development of cognitive insertion machines for manipulating of behavioral models of different levels of abstraction.

The development of ICAR model was greatly influenced by ''the general algorithm of mind'' described by Amosov (2002) as a high level model. This model has been partially implemented in 70s; currently representatives of Amosov School are working on new BICA based on neural networks (Rachkovskij, Kussul, & Baidyk, 2013).

Basic concepts of the theory of interaction such as transition systems and bisimilarity, the algebra of processes and behaviors, the sequential and parallel composition of transition systems are assumed familiar (Bergstra et al., 2001; Letichevsky, 2005).

Agents and environments

Insertion modeling is concerned on building of models and studying the interaction of agents and environments in complex distributed multi-agent systems. Informally, the main