Open Giant Intelligent Information Systems and Its Agent-Oriented Abstraction Mechanism

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Abstract

As a new science of complex intelligent information systems, an open giant intelligent information system is a special kind of complex software systems. In this paper, we first presented conception and complexities of open giant intelligent information system, and then we discussed the challenges of agent-based computing for dealing with the above systems' software complexities. For the facts of limitations of the mainstream agent-oriented abstraction, a new abstraction mechanism, which is empirically recounted in terms of four aspects – methodology of agent-oriented abstraction, artificial multi-agent society, agent society frameworks and component patterns, and social interactions, is introduced for agent-oriented open giant intelligent information systems.

1. Introduction

The research of open complex systems has been increasingly popular. With the emergence of a specific kind of complex software system, open giant intelligent information system(OGI^{2}S) [1], society and human involvement are two unavoidable internal elements, which bring new, open subjects for software researchers.

Complexity of an open complex system is embodied in its distribution, globalization and interaction, as well as human involvement. For dealing with the above problem, it is unsuitable to build an autonomous intelligent information system that is simply composed of today's computers. A feasible and effective way is to combine human qualitative intelligence which cannot be simulated by current computers with quantitative intelligence which can be efficiently simulated by computers, and build an open giant intelligent information system, which is actually a human-computer-cooperated intelligent information system.

Agent technology has been taken as a new paradigm for dealing with complex systems [2]. In the interest of building agent-based complex software systems, more and more researchers in agent field recognize the importance of organizational abstraction[3]. However, most of the researchers take the agent roles as the focus of the abstraction; as a result, the organizational abstraction has actually been a process of modeling of organizational roles, skipping the sociality of an MAS.

In this paper, we first introduce this type of specific system and its characteristics. Then a strong emphasis is laid on our proposed approach for dealing with open giant intelligent information systems: building an agent-based open giant intelligent information system. To this end, we discussed challenges to mainstream agent-oriented abstraction from open giant intelligent information systems in section three. In section four, we present a social abstraction mechanism for agent-oriented OGI^{2}S in four aspects in details. Section five summarizes our major work and provides indications for further research.

2. Complexities of Open Giant Intelligent Information Systems

For an open giant intelligent information system, the intelligence emerged at the system level is not equal to the addition of that of its individuals, it is an emergence of interactions among components and environment. As a result, an OGI^{2}S shows certain anti-intuition characteristics, such as the paradox, self-reference, unstability, uncomputability, interrelationship, and emergence, which is called "surprise-growing mechanisms". Complexities of an OGI^{2}S come from its societal characteristics, which result in various kinds of unpredictable outcomes. The system complexities of OGI^{2}S are further shown as follows.

Open: there are exchanges of energy, information or material in a system and among a system and its environment. The open environment is inaccessible, nondeterministic, and dynamic.

Hierarchical: there are many different levels existed from components, which are clearly recognized in individual level, to system in terms of the macro level. For some cases, it is not clear how many levels there are in a system. On the other hand, there are various types of organizational structures in a system and its subsystems, for instance, the peer, hierarchical, matric, loop, or linear; or even to the extent that it is not clear what the structure is, such as a combination of some basic patterns.

Social: a system is made of social agents, which are shown to be autonomous, parallel, distributed(of data, logic, or subsystems), and flexible. Components with specific roles cooperate, interact, and undertake problem-solving through certain communication language based on specific(local or global) organizational rules(e.g., social rationality principle).

Evolutionary: it is not easy to determine the runtime exchange, interaction, and behaviors of the components, subsystems, and system at design time; some unpredictable characteristics or status at the system level may emerge from the partial units and incomplete information after some period, such as some self-organization patterns, etc.

Human-computer-coexisted: the problem cannot only be solved by machines autonomously; or in other words, human beings has been one constitute part in an OGI^2S, and serves as the key element of the problem solving for his and the collective commonsense knowledge and thinking in images.

As a typical instance of OGI^2S, the Internet is a large-scale, distributed, dynamic, and evolutionary intelligent information system, which is consisted of users and computer systems [4].

3. Limitations of current agent-oriented abstraction mechanisms

As for the above complexities of OGI^2S, the computing models currently available for building complex information systems, such as the object-oriented computing, the component-based computing, can be used to do limited things for dealing with OGI^2S.

Furthermore, it can be seen that multi-agent embodies potentials of abstraction and computing mechanisms for coping with complexities of OGI^2S. It is suitable and feasible for agent-oriented paradigm to be taken as the computing model of OGI^2S.

The software engineering complexity of agent [5] can be seen as resulting from the following three key sources, the nature of the environment in which the agents are situated, the nature of the interaction the agent has with its environment, and the nature of the task the agent is intended to accomplish. As for the mainstream agent-oriented abstractions, they are based on the following foundations for dealing with these complexities. (i) It is from inside to outside for analysis of relationships between agent and its society. So, it is the agent but not the society that serves to be the base for analyzing and understanding the global behaviors of MAS. (ii) An MAS holds relatively simple coordination with relatively small number of agents in a closed, semi-closed or semi-open environment. (iii) The ability of autonomy and interaction of an agent is predefined and limited in an MAS. (iv) Interaction is taken as one of the key mechanisms in an MAS. However, the societal behaviors of a system are explained as the aggregate of scattered individuals' behaviors. (v) The current organizational abstraction, which proposed to embody the society of a multiagent system, is mostly based on role models, attention is paid to the relationships among roles. (vi) It is insufficient for the logic-based agent-oriented abstraction to represent the flexible, situated and dynamic interactions between agents, agents and environment. (vii) It is mainly focusing on localization and individuals for the situatedness-based method, however open systems are societal in general.

All above features show that (i) the mainstream MAS is basically not societal; however, an OGI^2S is a human-contained living organization, the problem-solving MAS for an OGI^2S should have the ability to deal with sociality of knowledge and interaction; (ii) the current agent theory is a hybrid one, and is based on different objectives and abstractions which are inconsistent and incompatible with each other. Thus, the mainstream agent is unsuitable for coping with OGI^2S.

Furthermore, there are following problems which cannot be escaped when discussing analysis and design of agent-oriented open giant intelligent information systems.

(i) Based on the above complexities, what kind of analysis and design mechanisms should be invented for agent-oriented OGI^2S?
(ii) Abilities of thinking in images of the embedded human beings, such as inspirations, experiences, and commonsense, and other elements such as the motions, role and functionalities, authority and interests, are very important and even key to accomplishing system objectives; then, how does agent-based abstraction support the human-computer-cooperated problem-solving?

All above challenges come from the immaturity of agent technology, the complexities of OGI^2S and the emergent problems when combined the two objects.

4. A new abstraction mechanism for agent-oriented open giant intelligent information systems

As a matter of fact, the unsuitability of current agent-oriented abstractions for large-scale open systems results not only from facts that each abstraction does things in its own ways, but also from the poor foundation of the mainstream agent-oriented abstractions. In order for underlying theoretical improvement of agent-oriented abstraction, foundations and modeling approaches of current agent-based abstractions should be extended or even surpassed, some new original shape, theory foundation, abstraction mechanism of viewing, simulating, abstracting, analyzing the nature of agent society should be built according to a natural simulation of human cognition and intelligence. In a word, a new science of agent should be established for dealing with systems like open giant intelligent information systems.

4.1 Methodology of agent-oriented abstraction

Nowadays, attention has been paid to a natural and hopeful way, which takes human organizations and social systems as the original shapes of new artificial agent-based systems. For this approach, some new theory hypothesis should be emphasized in terms of problem domains, theory foundations, and methodology of the agent-based computing: (i) the environment of an OGI^2S is very complex, nondeterministic, and changing; moreover, a system is shown to be human-computer-coexisted, so complexities of this kind of system is beyond that of the general ones in nature sciences; (ii) theory foundations of agent-based computing should be beyond that of the mainstream computer science and artificial intelligence, and should assimilate nutrition from some interdisciplinary theory such as organization theory, sociology, social psychology, cybernetics of social systems, system sciences, and science of complexity, etc.; some mathematic tools, such as statistics, graph theory, and analysissitus, should be used for formalization; (iii) there should be mechanism for supporting interactions and interfaces between human agents and artificial agents; (iv) the methodology of reductionism is not powerful for OGI^2S, a new one called systematism combining advantages of reductionism (micro-level) and holism (macro-level), should be introduced. Based on these hypothesises, a new societal abstraction should be established for agent-oriented OGI^2S.

As for agent-oriented OGI^2S, the methodology for dealing with them should not only be from inside to outside (i.e. from individual to society, the global characteristics is explained from the aspects of individuals), but also be out in (i.e. from society to individual, the individuals is explained according to the society), this direction is based on the sociality of an OGI^2S. For the latter, there are two aspects which should be concerned: (i) a new agent-oriented abstraction of artificial social agent-based systems should be abstracted from real organizations and social systems; (ii) the ability of problem-solving should focus on the societal characterizations.

Moreover, the design of multi-agent systems based on social abstraction for solving OGI^2S can utilize the following paradigms: (i) synthesis of multiple aspects and multilevels of system engineering, such as multiple methods of representation, inferring, and learning, perception and cognition, and synthesis of all these results; (ii) synthesis of design approaches between top down and bottom up; (iii) synthesis and fusion of interdisciplinary knowledge; (iv) human-computer cooperation where man is centered for solving problems; (v) mutualism of rationality and sensibility, synthesis of logic-based, connectionism, and behaviorism.

4.2 Artificial multi-agent society

There are many practical open giant intelligent information systems in real world, for instance, an Internet-based cooperative information system in a transnational corporation, a virtual organization, etc. It is unsuitable for the mainstream MAS to embody and express the sociality of these systems. A new science of MASs should be established in terms of sociality of MASs, which focuses on relationships of MAS organization and its environment. The starting points of this new MAS are as follows: (i) it is in the viewpoint of systematism that the structures, behaviors, and intelligence of an MAS system is viewed, and the same is true for analysis and design of an MAS; (ii) the relationships between an MAS organization and its environment, and the sub-systems in an MAS are viewed open; (iii) the evolutionary viewpoint is used for viewing the generation, representation, searching, interaction, feedback, reorganization and regeneration of behaviors and patterns in an MAS; (iv) it is based on the theory of organization and sociology that the time and space relationships of an MAS is analyzed, the same is true for analyzing roles and interaction patterns, ways of communications, behavior rules, and mechanisms of abstraction, modeling and formalization.

Therefore, a new science of MASs is beyond the theory, technology, techniques of mainstream MASs. A new theory foundation and modeling mechanism of MASs should be established: (i) An individual agent is simultaneously at two interrelational levels: agent level and societal level; an agent is an integrator of its individual roles and its societal roles. (ii) Social interaction is an inherent and unified mechanism for viewing the relationships between agents and agent society, and the evolution and emergence of collective intelligence of an MAS. (iii) A dependence network of agents emerges based on the dynamically and richly societal interrelations in an MAS. (iv) There is a dynamic adaptation between the MAS organization and its environment. Environment has certain ability of selection; however, an MAS organization can adapt to and even change its environment; an MAS organization can go after profits but avoid losses, and finally obtain its objects based on collective learning, mutation and variation, etc. Moreover, the dynamic adaptation is two-way changeable, it may be shown as environment-selected or MAS organization-directed corresponding to the two extremes respectively. As a result, the system acts as an artificial computational ecosystem.

4.3 Society frameworks and component patterns

A framework or pattern represents the same or similar information or knowledge which can be observed or reused at time or space dimension; they can be further classified in terms of some methods. It is also true that there are same or similar society frameworks and component patterns in agent-oriented OGI^2S, each corresponds to different granularities and levels of abstraction: (i) a society framework represents common properties at macro-level of agent society; however, (ii) a component pattern focuses on the general things showing at the agent-level.

4.3.1 Agent society framework. A multi-agent system is an artificial organization, or named a multi-agent society, which is viewed as a composition of an MAS organization and its environment. The more complex an MAS is, the more obviously society frameworks and relationships emerge. In the case of the societal information in an MAS, an society framework may be nominated as partially or globally logical relationships, topological structures or control mechanism, which exhibits same or similar information in a specific problem domain. The possible forms of an organizational scheme in a specific problem domain includes: (i) software architecture of an MAS; (ii) organizational structures or relationships existed in an MAS, such as the self-organizational and evolutionary ways; (iii) structures and relationships between MAS organization and its environment; (iv) same or similar features emerge at the branch level (e.g., group, sub-system) of the society; (v) interaction mechanisms and norms existed at the societal level.

4.3.2 Agent component patterns. Component patterns of an MAS focus on: (i) component creational patterns: such as the type, role, and attribution that an agent embraces, etc.; (ii) some basic structures of a type of agents; (iii) interaction patterns between agents, such as how an agent cooperates with its partners; (iv) interaction patterns between agent and its environment. The following pitfalls should be avoided when studying or designing the component patterns of MASs: (i) applying the object-oriented design patterns mechanically in an MAS; (ii) thinking that the granularity of an agent should be as fine and fixed as possible; (iii) defining the agent patterns from the aspect of individual level.

A kind of social agent computing based on agent society frameworks/component patterns may emerge in analysis and design of agent-oriented OGI^2S, which is on the basis of an established catalogue and libraries of society frameworks and component patterns in a specific problem domain. In this case, the development of an agent-based system looks more like a process of assemblage of agent components and its society frameworks, plus some user specific customization, which just looks like finished at the software factories: first, determining the reusable agent components according to a specific society framework; then, specializing the chosen agents and its society framework, and developing specific types of agents according to the problem domain; finally, assembling an MAS with certain frameworks, components and specific agents out of the above systems (as shown as the figure 1).

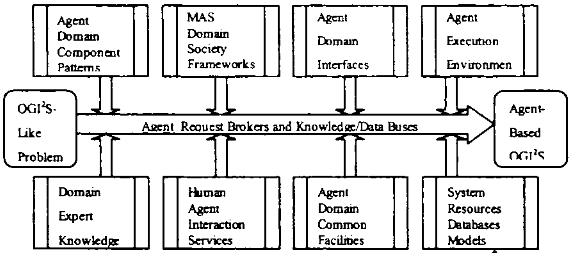

Figure 1 Assemblage of agent-oriented OGI^2S

4.4 A unified mechanism—social interactions

It is unsuitable for the mechanism of Turing machine to deal with interaction behaviors between agent and agent, agent and environment in artificial multi-agent systems, where interaction is more powerful than algorithms. Interaction can be viewed as an inherent mechanism of structures, functionalities, behaviors and the emergence of intelligence in multi-agent systems both at agent level and macro level. Interaction serves two roles and functions: (i)it reflects the interrelational way among constitute components, and also is a process throughout the life cycle of an agent-based system; (ii) it is a kind of internal working mechanism of agent-oriented OGI^2S, which present system complexities such as open, hierarchical, societal, evolutionary and human-computer-coexisted; in addition, it is also a key problem which should be solved properly in analysis and design of an artificial multi-agent organization. Thus, we argue that interaction is social. Moreover, social interactions show following characterizations: (i) it is a compound conception and mechanism, which integrates inspirations of computer science, artificial intelligence, sociology, and system sciences, etc.; (ii) it interrelates the systems of rationalism and empiricism; as a matter of fact, the interrelation may not be a rational one, but be empirical; reasoning may just be as a conferring; a real multi-agent system may not be a rationally balanced one; (iii) the senses and actions of agents may be based on partial or incomplete knowledge or information; (iv) it is non-monotonous, the decomposition of a system may create interactive and unexpected sub-systems; on the other hand, the integration of sub-systems may emerge some non-interactive algorithms; (v) the process of social interaction may be shown as a self-organizational or a self-referential one, many visual society framework may emerge at the system level; (vi) the outcomes of the social interactions may be in the forms of certain emergent behaviors or intelligence, which can be beyond all expectations of design objectives and designers.

Furthermore, an artificial social agent-based open giant intelligent information system presents following key and inherent characterizations: (i) computing in a system is parallel; (ii) the constituent components is distributed logically or physically; (iii) components collaborate with each other, and interact with their uncontrollable environment; (iv) a system has open and powerful functionalities for handling all possible user's requests. All above aspects make up a four-dimension feature space consisting of parallelism, distribution, interaction and openness. To some degree, a system may be fuzzy or even at the edge of chaos as a collective emergence from the cyberspace of artificial multi-agent society. It is thus evident that the modeling and problem solving of an OGI^2S is based on the mechanism of interactive computing. In other words, social interaction is a unified computing mechanism of an agent-oriented artificial OGI^2S.

5. Conclusions and future work

As a type of complex software systems, one suitable way to deal with an OGI^2S is based on the agent technology, for instance, an agent-based macro-economic decision-making system[6] structured on the Internet. In this paper, we preliminarily discuss analysis and design of agent-based OGI^2S.

However, some practical challenges from agent-oriented OGI^2S block the direct usage of mainstream multi-agent technology. For this reason, we propose the extension of today's agent-oriented abstraction. We further discussed four aspects of agent-oriented open giant intelligent information systems: methodology and theory foundation, artificial multi-agent society, agent society frameworks and component patterns, and social interaction.

Actually, for the immaturity of agent-oriented abstraction and complexities of OGI^2S, and the emergent software engineering complexities of agent-oriented OGI^2S, all discussions in this paper is empirical and preliminary. However, we believe it is possible and we can go in depth to build a new science of agent-oriented analysis and design of open giant intelligent information systems. Our future work includes but not limited to:

(i) explicitly defining the concepts and notations of social abstraction;
(ii) practical methods and tools for analyzing, designing and evaluating agent-oriented OGI^2S.

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