Asian Journal of Information Technology 5(5) : 465-469, 2006
© Medwell Online, 2006

Complex System Engineering

[1]Salim Bitam and [2]Mohamed Chawki Batouche
Department of [1]Computer Science , Mohamed Khider University, Biskra, Algeria
Department of [2]Computer Science Department, Mantouri Brothers University, Constantine, Algeria

Abstract: This paper proposes a new method to study the complex system design in any domain. Complex systems are new approaches in artificial intelligence. The old techniques of artificial intelligence are considered inadequate to this type of system. This inadequacy is related to the complex systems properties: non-linearity, emergence of an unforeseeable behavior, self-organization, adaptation, irreducibility and innovation. Into consequece, it is very important to propose a new method, which organizes the design. We propose a new methodology that helps the designer to study well the complex systems, in order to put this system under a formal format. Thereafter, the designer deals with the validation, the good conformity of the conceived system and finally, he translates the system by using the existing software tools (programming languages etc). We limited the design into six phases: analysis, logical design (modeling and specification), validation, tests of conformity, implementation and use/simulation. We can call this methodology complex system engineering. In this article, we discuss also atechnique, which we consider as one of the best for the phase : Complex system modeling. It is the complex system modeling in the base of multi-agent systems. The other phases are left as prospects.

Key words: Complex system, multi-agent system, modeling, emergence, self-organization, adaptation

INTRODUCTION

The development of the computer science and in particular the artificial intelligence gave rise to the intelligent systems which have distributed topologies and heterogeneous constitutions. We shall be elaborating the complex system which offers magic solutions to the existing problems, because it represents the systems in reality. A real system is a system that can gather the preceding properties.

Therefore, any real system is a complex system that implies the need of a new discipline that has as an objective : The studying of complex systems, study their properties and functions.

This type of system treats also the forecast of the behavior's result of that system. This later, is considered as major problem because we have to answer the question : How we can study a behavior that is different from the sum of the element behaviors, which constitute the system? In this case, we study the emergence concept.

In order to study with accuracy the complex systems, their properties, their functionalities and their emerging behaviors: We must follow a clear, complete and precise methodology. Thus, we propose a method starts with the problem of a complex system design, passes by a system analysis, then a logical design. A logical design is an initial design plays the part of modeling then the specification, apart from all software techniques (physical data or concrete treatments). Moreover, in the modeling step of this work, we propose, a complex system modeling approach in the base of multi-agent systems.

This article is organized as follows: the second paragraph discusses an overview on the complex systems: definition, characteristics etc, after, we propose our design method in the third paragraph. Thereafter, we discuss the complex systems modeling by the multi-agent systems in paragraph four and finally we conclude.

COMPLEX SYSTEM: AN OVERVIEW

Definition of complex system: A complex system is a set of heterogeneous entities, in mutual interactions between them and in interactions with the external universe. The interactions allow it possible to emerge a total system behavior. This behavior has autonomy when it compared to the entities behaviors from which it results. Such a system describes a degree of complexity larger than its part. Thus, it has irreducible properties with their component entities[1].

The complexity of a complex system is the unforeseeable result of the emergent behavior of the

Corresponding Author: Salim Bitam, Department of Computer Science, Mohamed Khider University, Biskra, Algeria

system. This complexity never means the sum of all complexities of the system component entities. The all is more than the sum of the parts (Confucius).

Thus, we study the emergence property of the complex system behavior. Then, researches in this type of system are concerned much more with the major question: how we can envisage a behavior, which is not the sum of the component entities' behaviors?

Complex system characteristics: As the complex system is a set of heterogeneous entities in interactions between them and with the external universe and as the complex system has a behavior more complex than the sum of the component entities' behaviors, we expose the characteristics of the complex systems to help designer in his studies, as follows:

Non-linearity: The complex system is non-linear system i.e. it does not depend on the initial conditions of the system and its behavior is asymptotic.

Contrary to the linear systems, its behavior is symptotic ; it depends only on the structure of system (component entities), on the interactions between entities and the interacting entities-external universe. The complex system's behavior is extremely chaotic (complex) that is the case of all real systems.

If these elements have non-linear interactions, they may have an emergence of a total behavior[2].

Emergence: Emergence is a property related to the complex systems. It is the behavioral product, which floats after an exploit of interactions between the entities of the system, which couldn't be known a priori. According to the theory of the emergence, stated in 1874 by G.H. Lewes; emergence was defined as follows: the combination of the entities placed in a given level gives place to an entity of higher level where their properties are completely new[3].

Organization/self-organization: Any complex system is characterized by an initial organization, which defines the static structure imposed on the system.

The organization is defined as a structure of coordination or making-decision and communi-cation including a set of actors in order to achieve a common goal[4]. We define the organization as the static aspect, which expresses the primary structure of the system realized at the time of the initialization design. When the system is operational, it may change when it is evolved. In other words, the system can be reconstituted in a different state from its initial once. It can receive other entities (increase) as it can lose some others (reduction). In this case the system is known as dynamics. It must be reorganized in an automatic way, which we speak here about the self-organization.

Adaptation and training: The adaptation is the possibility of the system to constitute new configurations with the environmental innovations. These innovations can be purely generated by the external universe, as they can be the results of the interactions between entities or entities and the environment. Moreover, we can define the adaptation as the system's capacity to learn from new behaviors and to evolve automatically by observing the new environment conditions in order to achive the objective of the global system.

We distinguish between two types of trainings: the collective training in which the entities communicate their results[5] and the individual training which is devoted to the evolution of a society in which entities are learnt individually and separately[6].

Stability/instability (stress): The complex system, at the time of the reciprocal influences between the entities, passes by a period of instability and disturbance where the system is simplified partially or completely. It is the property to pass from a stable state to an unstable state and vice versa[7].

Irreducibility: The complexity of a complex system cannot be defined by the sum of complexities of the component entities. Therefore, the complex system is characterized by irreducible properties with those of its component entities[1].

Innovation: The complex system presents new properties and new behaviors when we compared them to each one of its component entities[8].

Natural complex systems and artificial complex systems: We distinguish between two types of complex systems. Those which appear in our everyday life: we call them: natural complex systems. Those which give scientific solutions by data processing tools to the various treating problems, we call them the artificial complex systems.

Natural complex systems: They are systems that are constituted by a set of natural entities, physical or not, in interaction between them. They have a collective behavior that is considered as the result of this interaction. This type of system studies the properties and the behaviors of the natural systems according to two parameters: space and temporal[7]. We illustrate by some examples of natural complex Systems in different disciplines:

Ecology: organization of the species, studies of the earthquake and the volcano, studies of the river…

Biology: Human anatomy, nervous system and changes in the human body…

Physics and chemistry: movement, mechanics, general chemistry, organic chemistry…

Economy: Transaction in the market, Currency, Banks, production/consumption…

Transport: Road traffic, Congestion, displacement of the vehicles…

Artificial complex systems: It is the type of complex systems which is based on data-processing modules and techniques: Objects, Actors, Agents… to model and conceive solutions in different disciplines.

This type of system is based on entities data-processing, heterogeneous, more or less autonomous, in interaction between them in order to produce by the emergence of a behavior a global solution of the treating problems.

We present some examples of simulation:

Simdelta project: a multi-agent system conceived to simulate the fishing on the central Delta of Niger (C. Cambier thesis of Paris 6 University. 1994).

Manta project: an approach, which simulates ants social organizations (A. Drogoul Thesis of Paris 6 University. 1993).

Rivage project: is a model, which describes the physical processes streaming and infiltration water, which can possibly lead to the formation of ponds, ravines or water ways. (D. Servat Thesis of Paris 6 University. 2000).

Complex systems centralization and decentralization: Complex Systems can be centralized and can also be distributed. In the first case, a supervisor entity plays the part of coordination between the entities, ensures the total management of the system and finds solutions in the case of failure. This type of system was studied within the framework of several research[9,10]

The second type of complex system is the distributed complex system. In which the system is characterized by a physical distribution of structure and function. The entities have the same degree of responsibility (not of supervision). Here, we mention that there is little research in this type of system.

COMPLEX SYSTEM DESIGN

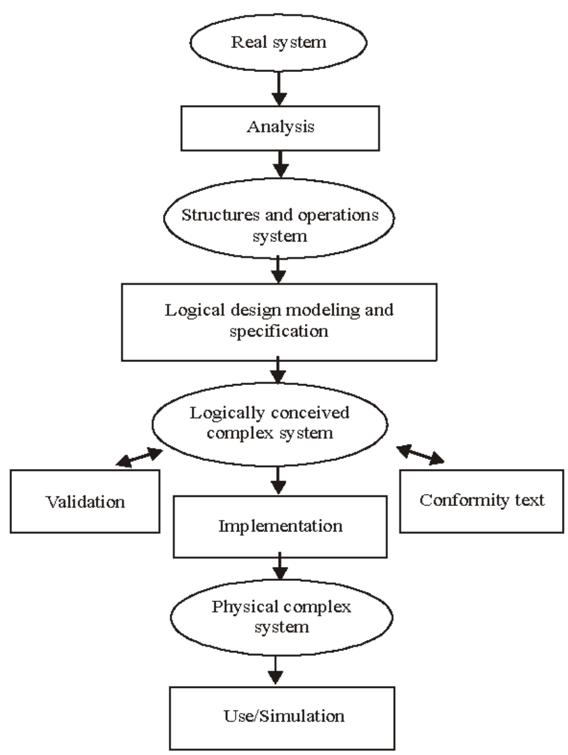
Motivation of the complex system design: The complex systems present the majority of the real systems, because the real systems are constituted of a set of heterogeneous elements. These elements are sometimes known partially by the user.

Moreover, real systems offer an unforeseeable behavior in the majority of the cases. In order to overcome this complexity related to the component entities of the systems and to their unforeseeable behaviors; it is very useful to study the complex systems: Structures and operations.

The study of the complex systems starts initially with an analysis, then a logical design is required i.e. a design which does not use physical tools of the computer science. The logical design is done in two stages: modeling and specification. The obtained format can be validated and tested to ensure that it is conforming to the primary system. After, we can implement the resulting system. Then, it will be carried out or it will be simulated whenever simulation is advised.

The obtained system helps us to overcome the system complexity, to study the total system behavior and to surmount all the difficult properties related to the complex systems.

Phases of complex system design



Analysis phase: This phase is used to determine what is known and what is to be known. We determine also the intermediate parameters that lead what is known towards what is to be known. In this phase, we expose the abstract resolution of the arising problem which could be elaborated in the following phase.

Logical design phase: This phase is divided into two staps: modeling and specification

Modeling: in this step, we try to find a formal model (mathematical for example), by using modeling tools : Differential Equations, Petri nets, Agents… etc. Here the model concludes the abstract resolution already found in the phase analysis without giving a concrete resolution with the computer science tools.

Specification: in order to make the resolution ready to be implemented using computer science tools, we must pass by a formal specification of resolution. It is the step, which uses the preceding model and makes it under data-processing format. It is a very detailed resolution in computer science viewpoint. The specification is a process of resolution which is independent from any particular machine structure.

Validation phase: This phase is used to check the syntax the semantics of the conceived system. It ensures the good properties related to the domain of study (robustness, safety… etc).

Conformity test phase: After having obtained a logically conceived system, we must test if this last answers the initial design criteria or not. In other words, we must make sure that the properties of the system are not modified and that the resulting system is in conformity with the initial requirements i.e. their functions are in the same objectives as they were before the logical design.

Implementation phase: This phase is used to transform the system conceived under a format which can be operational and executable in computer. Here the choice of implementation techniques and machines are necessary.

Use/simulation: It is the phase to put into exploitation the system that is implemented. There are two types of systems ; those which can be executed directly and those which require a simulation. The second type has been simulated for different reasons: execution difficulties, dangerous execution: nuclear system… etc. In these cases, this phase can give a vision on the outputs and the results of systems and the user can draw his conclusion.

COMPLEX SYSTEM MODELING WITH MULTI-AGENT SYSTEMS

We choose to treat in this article the modeling phase because it is one of the key phases in the design process, in the leaving the other phases for coming articles.

Why modeling by multi-agent systems?: Modeling as we saw in the third paragraph is used to present the system in the form of a resolution model (abstract resolution) so that it is ready to be studied in the following phases: specification, validation…etc.

For that, there are several modeling approaches. We choose in this article modeling by multi-agent system for the following reasons:

The difficulties of the complex systems show the inadequacy of traditional modeling techniques such as the traditional artificial intelligence and the distributed artificial intelligence[11]. These difficulties are related to the properties: Non-linearity, emergence, dynamics of the component entities of the complex system, too high complexity, heterogeneity of the component entities, non-determinism of the system by its components.

A multi-agent system is a system made up of the following elements: Environment, Objects, Agents, Relations between agents and their operations[12].

We judge the multi-agent systems as being among the techniques adequate with this type of system because they offer solutions to the preceding problems:

- A multi-agent system can represent a non-linear system[11] because a multi-agent system is constituted by a set of agents, that offer by their interactions and their structures a system that is more than the sum of their component entities (from functional viewpoint).
- A multi-agent system determines an emergent behavior that is not necessarily the sum of the behaviors of the component entities.
- The agents of a multi-agent system are not necessary in homogeneous types.
- A multi-agent system offers a distribution, coordination, communication, negotiation between the agents in order to solve the problem of the dynamics of the complex system entities.
- A well conceived multi-agent system can give the lowest possible complexity (Recursivity property in the design of a multi-agent system).

CONCLUSION

The complex systems present a new research orientation In computer science and more precisely, in the artificial intelligence. They offer satisfactory results for the real systems. It is a challenge, which was not well taken up by traditional research because of its difficulty.

The difficulty is related to the properties of these types of systems: Emergence, adaptation, non-determinism… etc

In order to treat well this type of system, we have proposed a methodology of the complex systems study (complex system engineering). This methodology has as an objective the perfect complex systems design. It is represented in six phases: Analysis, logical design, validation, conformity test, implementation and use/simulation. These proposed phases in adequate for these new types of systems.

Moreover, We have discussed in this article a modeling approach of the complex systems by the multi-agent systems. We have showed that the multi-agent systems approach is one of the most adequate for these types of systems.

REFERENCES

1. Kampis, G., 1991. Self-modifying systems in biology and cognitive science. Pergamon Press, Oxford, England.
2. Sloot, P.M.A., A. Schoneveld, J.F. De Ronde and J.A. Koandorp, 1997. "Large-scale simulation of complex system". Part1, conceptual framework.
3. Lewes, G.H., 1874. Philosophic language dictionary, Foulquié.
4. Malone, T., 1987. "Modeling coordination in organizations and markets". In Management Science, N°10.
5. Weiss, G., 1993. "Learning to coordinate actions in multi-agent systems", Proceeding of 1993 Intl. joins conference on artificial intelligence, Chambery, France.
6. Tan, M., 1993. "Multi-agent reinforcement learning: Independent vs cooperative agents", Proceeding of the 10th Intl. conference on machine learning.
7. Bertelle, C., A. Cardon, J. Colloc and D. Olivier, 2001. "Modeling and Implementation of complex system". DEA, ITA doctoral school, Rouen /Le havre, France.
8. le, J.L., 1999. Moigne. Complex Systems modeling. Dunod.
9. Bensaid, Nand P. Mathieu, 1997. "A hybrid and hierarchical multi-agent architecture model". Proceeding 2nd Inl. conference and exhibition on the practical application of intelligent agents and multi-agent technology, London.
10. Bürckert, H and K. Fischer, 2000. "Holonic transport scheduling with Tele Truck". In applied Artificial Intelligence.
11. Marcenac, P., 1997. "Modeling Complex systems with agents". Technique et science informatique, N°8.
12. Ferber, J., 1995. Multi-agent systems, toward collective intelligence. InterEdition.