COMPLEX ORGANIZATION MODELING AND SIMULATION APPROACH FOR OPERATIONAL SCENARIOS STUDY: APPLICATION TO HEALTH CARE ORGANIZATION

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ABSTRACT
Any complex organization is confronted to hazardous or unpredictable events which are impossible to imagine and to anticipate due to the interactions and the nature of the components of the organization (person, machine, processes, etc.). Some risky situation may then impact the performance, the integrity and the stability of the organization. Actor involved into or in charge of this organization must then be able to detect and to characterize these events, the emerging situations and the possible induced risks. This paper presents a work on progress about a composite approach allowing to model a complex organization and to analyze its behavior when facing new situations. This approach is applied to Health Care Organizations.

Keywords: verification, validation, emergence, simulation, Multi Agents Systems

1. INTRODUCTION
Healthcare organizations are today facing to the same problematic from those which were considered in the last decade by industry. Indeed, they must improve their reactivity and flexibility in order to gain efficiency and to reach customer satisfaction. However, and it is a huge difference with industrial domain, they have in same time to respect simultaneously social, human, ethical and medical rules. Inherent complexity of such socio technical organizations (various actors, various disciplines, various technologies, etc.), medical environment constraints and objectives (various operational scenarios are to be achieved due to different medical pathologies, various situations, etc.) induces the occurrence of unpredictable events for which the organization reactions may be unsuitable and may cause prejudice to the patient. It seems interesting then to help managers to characterize this kind of event more precisely and to detect resulting situations i.e. emerging states in the behavior of the entire organization.
The research work on progress presented in this paper aims to integrate in an existing modeling and verification framework a simulation technique based on Multi Agents Systems. In the first part, the paper summarizes the problematic to be solved and present some existing works about simulation of emergence concept. The second part presents the used modeling and verification framework. The modeling technique is based on System Engineering (SE) (INCOSE 2004) and Enterprise Modeling (Vernadat 1996). The verification technique allows assuming model coherence is inspired by System Verification and Validation (V&V) (NASA 2001) and enterprise risk management (CAS 2003). The third part details the current work in progress which concerns the simulation technique based on multi agents system for helping model designers to make appear some relevant and sometimes emergent scenarios of evolution of the organization.

2. PROBLEMATIC AND APPROACH POSITIONNING
The strong interaction with a moving environment, the heterogeneity and the interactions between the components (services, human resources, machines, processes, etc.) of an organization induce the possible emergence (Chalmers 2002) of new behaviors and events. This concept of emergence is a multi-field concept which has resonances in biology, philosophy, artificial intelligence, etc. It characterizes the fact that an event occurring at a given level of detail cannot be deductible from properties of entities described at a more detailed level. Emergence taxonomy has been proposed by (Fromm 2005):

- Type I describes simple emergence without top-down feedback and self-organization, and includes intentional emergence.
- Type II contains the classic phenomena of weak emergence including top-down feedback and self-organization. It is further distinguished between stable and instable forms in this class.
- Type III covers all forms of emergence through multiple feedback and adaptation in more complex adaptive systems due to evolution.
- Type IV characterizes all forms of strong emergence in evolution. The term strong emergence is liberated from any magical or unscientific meaning.

This work focuses only on emergence of type I and

II. For example, a new behavior must emerge due to interaction between actors or a new scenario may be induced by a medical surgery. So how it is possible to detect emergent operational scenarios and situation of an organization composed of several resources working in parallel, wanting to reach their own objectives?
The most appropriate technology allowing simulating the parallel evolution of various complex entities independently from each other is based on Multi Agents Systems (MAS). A Multi-Agents System as a system made up of the following elements:

1. An environment E, i.e. a space generally having metric
2. A set of Objects O. These objects are located, i.e., for any object, it is possible, at a given moment, to associate a position in E. These objects are passive, i.e. they can be perceived, created, destroyed and modified by the agents.
3. A set A of agents, who are particular objects (A is included in O), which represent the active entities of the system.
4. A set of relations R who link objects (and the agents) between them.
5. A set of operations Op allowing the agents of A to perceive, to produce, to consume, to transform and manipulate objects of O.
6. Operations charged to represent the application of these operations and the reaction of the world to this attempt to modification, that we will call the laws of the universe.

Its main characteristics are (Wooldridge and Jennings 1995):

- located – the agent is able to act on its environment starting from the sensory perception which it receives from this same environment;
- autonomous – the agent is able to act without any intervention (human or agent) and controls its own actions as well as its internal state;
- proactive – the agent must produce a proactive and opportunist behavior, and being at the same time able to take the initiative at the good time;
- able to give a response in time – the agent must be able to perceive its environment and to elaborate a response in necessary time;
- social – the agent must be able to interact with other agents (software or human) in order to achieve tasks or to help these agents to achieve theirs.

There is then a consensus on the utility and the justification of the use of the multi-agents systems whose advantages are stated by (Brandolese, Brun, and Portioli-Staudacher 2000) to represent a complex system and to simulate efficiently complex interactions in behaviors:

- Dynamic system. The MAS inherits the IA symbolic treatment, i.e. knowledge. On the other hand, contrary to the traditional approaches of the Artificial Intelligence which simulate, to a certain manner, capacities of the human behavior, the MAS allow to model a set of agents which interact. The agents are structured in order to exert an influence on each one to make evolve the system in his totality (dynamic system). We find many interactions between agents such as coordination, negotiation, co-operation (Chaib-Draa, Jarras, and Moulin 2001). This approach is particularly well adapted to the simulation of the complex systems whose total operation emerges from the actions of the individuals. The MAS allow making virtually live autonomous agents on computer and to carry out there difficult experiments, even impossible to carry out in reality.
- A significant number of agents. A great number of agents is in the centre of the problem in this type of modeling contrary to the game theory where seldom more than three actors are represented.
- Flexibility of the data-processing tool which makes it possible to modify the behavior of the agents, to add or remove possible actions, to extend information available to the whole of the agents. The Multi-Agents model is made operational thanks to a data-processing implementation that does not impose any specific analytical requirement, but the use of the advanced data-processing languages: Object Oriented Language (OOL) who allows developing the program in a modular way. The processes programming at the local level in various modules and the use of individualized entities bring a great flexibility. The modifications do not require a broad reorganization of the program. A distributed resolution of problems. It is possible to break up a problem into under-parts and to solve each one independently to lead to a stable solution. This solution is not usually optimal within the meaning of complete rationality but it can be « satisfactory » within the meaning of Simon (Simon 1969).
- The MAS can "answer" to the individual failure of one of the elements, without degrading the system in its totality.

Thanks to these characteristics, the Multi-Agents Systems provide an approach for complex systems modeling and simulation appropriate to the study of emerging behaviors.

However, it is first necessary to provide a modeling framework of the organization independently from MAS architecture in order to permit actors who are not specialists from the field to describe the functions, the structure and the behavior of the organization (Aloui 2007). Second, it is necessary to check this model before rewriting it into a MAS system. This modeling framework includes verification mechanisms and is presented rapidly in the next part.

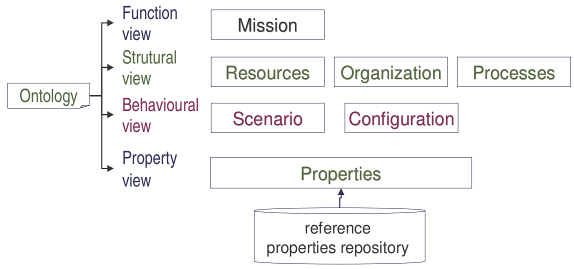
3. MODELING AND CHECKING FRAMEWORK

In order to better apprehend the complex socio technical system « healthcare organization», system engineering (SE) and Enterprise Modeling approaches are used. SE is defined according to (INCOSE 2004) by «*a co-operative and interdisciplinary approach for the progressive development and the checking of a solution for the system, balanced on the whole of its life cycle, satisfying customer expectations and acceptable by all* ». It is in particular deployed:

- To design, to make evolve and to check a system (hardware organized set, software, human competences and processes in interaction), bringing a solution to an operational need identified in accordance with measurable criteria of effectiveness.
- To satisfy requirements (quality, innovation, efficiency, delay, cost, performance, etc.) and constraints (reliability, safety, etc.) of the whole of its parts and being acceptable for the environment,
- To balance and optimize, under all the aspects, global economy of the solution on the whole life cycle of the system.

SE is based on systemic concepts and systemic reference model such as those proposed by the SAGACE approach (Penalva 1997). This approach provides particularly a grid modeling framework highlighting views. Each view gathers and formalizes the knowledge corresponding to a given aspect under which must be studied the pointed out system (here the health care organization). The resulting modeling framework is concerned by four views summarized in Figure 1. This figure shows the adapted modeling grid used in the following and the different modeling languages used in order to provide the models contained in each view. These views are:

- Functional: What is the mission of the organization? What is its finality i.e. why does it exists? How are we sure the organization provides the good mission with the appropriate level of performance? What are the functions the organization must fulfill in order to provide its mission?
- Behavioral: what are the possible evolution scenarios and configurations of the resources? How it evolves taking into account the environments and events? How it may be adapted and controlled in order to avoid damage in case of emergency?
- Structural: what are the processes which formalize the functional view of the organization? What are the current resources and their interaction in order to support these processes? How these resources are themselves organized during the organization life-cycle?



Functional view: *KAOS Methodology, IDEF 1*
Mission, finality, objectives
Structural view: *UEML, CEN 200*
Resources : Human, material, software
Organization : organizational units (service, department, etc.)
Processes
Behavioral view: *Synchronous Statechart, eFFBD (Enhanced Functional Flow Block Diagram)*
Scenarios, Configurations, Rules, adaptation and anticipation
Property view : *LUSP and Properties Reference Repository*
Modeling properties and identified risks

Figure 1: modeling framework synthesis

- Property: this view allows users to enrich the organization model by specifying properties the organization and its model must respect. A property (Chapurlat, Kamsu-Foguem, and Prunet 2003) expresses functional or non functional requirements (modeling requirement such as coherence rules of a model or semantic construction rules, organization requirement such as attribute evolution rules and limitation, expected behavior, functioning rule, constraint or objective), or potential risky situation. In this case, the concept of Cindynogenic Systemic Deficiencies (CSD) (Kervern 1994) has been used to model different kind of risks causes. A property is formally defined by a causal and typed relation linking two sets of events and data coming from each of the three over views of the organization model. Figure 2 shows an example of such property.

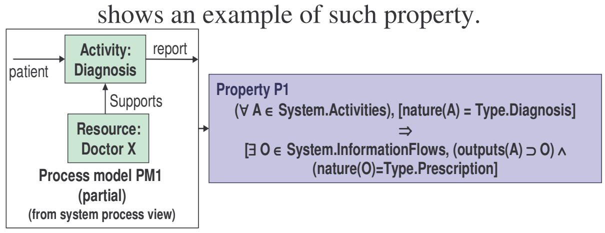


Figure 2: Property modeling a Cindynogenic Systemic Deficiency

This formal causal model allows checking the organization model coherence by using formal verification tools such as model checker or theorem prover.

Each of these four views may be expressed by different actors (modelers, engineers, specialists in the field to study here pharmacist, doctor, nurse, etc.)

involved into the organization. They have to explain and describe their own point of view thank to their own objectives. For this, a common and unique health care organization modeling ontology has been first defined. This one gathers commonly used and shared terms by all these actors for describing the main characteristics of the pointed out organization. In the same way, this ontology represents a unique, coherent and sufficient set of concepts and relations between concepts required for representing each view of the entire organization. In other terms, respecting the Model Driven Architecture (MDA) paradigm and avoiding interoperability problem between modeling languages, this ontology is built taking into account a unique and unified meta model. This one allows us to adapt and to unify some existing and pre selected modeling languages issued essentially from enterprise modeling and system engineering domains suitable to each view. For example, functional view uses the objective modeling language proposed by KAOS (Bertrand, Darimont, Delor, Massonet, and Van Lamsweerde 1998) and the IDEF-0 functional modeling language (Menzel and Mayer 1998). Unified Enterprise Modeling Language (UEML) (UEML 2003) allows describing resources organization, capabilities, processes and activity description and enhanced Functional Flow Block Diagrams (eFFBD) (Oliver, Kelliher, and Keegan 2004) permit to describe operational scenarios.

When the model is built, properties are checked on it in order first to assume its coherence, second to detect some potential causes of disturbances in the organization behavior.

If a property cannot be verified, the analysis process provides a counter example indicating the reasons for which the property is unsatisfied. Some properties allow detecting modeling errors or mistakes. These ones are used for checking the coherence of each view (coherence of the data and knowledge collected into a view and describe by using an unique modeling language dedicated to this view), and between each views (coherence of the data and knowledge collected and/or used in two separated views i.e. between models represented by using different modeling languages).

The proposed checking technique is based on a formal knowledge representation language called Conceptual Graphs (Sowa 1984) such as proposed in (Chapurlat and Aloui 2006). The technique is the following: The vocabulary used in the Conceptual Graph is formally extracted from the ontology. It is described with two lattices called respectively concepts lattices and relations lattices. Taking into account these lattices and a formal re writing algorithm presented in (Aloui 2007), the entire organization model i.e. all the models composing each view are translated into a unique conceptual graph. So this one gathers all the knowledge represented in the multi view and multi language modeling framework. This allows unifying the representation format of the required knowledge. Then it becomes possible to use mathematical foundations and associated mechanisms (Cogitant 2005). These ones allow to handle and to verify each property one by one and themselves translated under separated conceptual graphs. It remains however necessary to find a compromise between a completely formal verification, thus, exhaustive, and an ad hoc verification and validation technique. So simulation by using Multi Agents Systems has been chosen.

4. ANALYSIS FRAMEWORK: EMERGENCE AND MULTI AGENTS SYSTEMS

The following steps are proposed for simulating the behavior of a complex organization:

1. Rewrite the model in the form of an interacting network of agents. Cognitive agents are specifically developed in order to describe resources and processes behavior. For this, a set of mapping rules have been proposed to ensure the rewriting step of the Healthcare organizational model into Multi Agents System. Figure 3 shows this step.

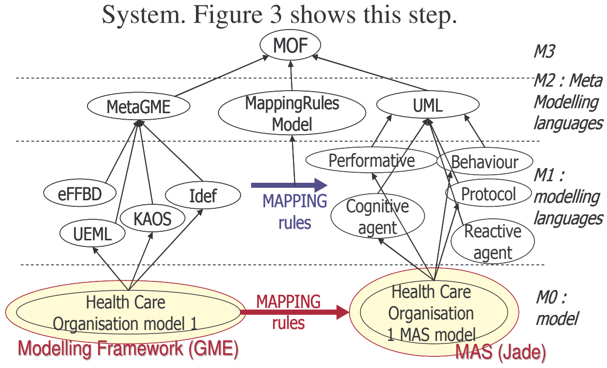


Figure 3: rewriting step

   Models described in the behavioral view are translated in the form of agents thanks to the information gathered into the functional and organizational views and according to the partial meta model shown in figure 4.

2. Some operational scenarios have been described such as those proposed in Figure 5. The goal is to simulate evolution of resources and processes all along this scenario and to make appear possible divergence between the proposed scenario and the scenario proposed by the MAS system. This requires the observation of the evolution of the different agents.
3. On each evolution ‘step’, try to prove properties with an impact on the behavior of the agents: properties on the interactions between agents, on the behavior of each agent considered separately, etc. This allows to modify and to adapt the behavior of each cognitive agent. Indeed each property may induce new events and the required psychological evolution of the modelled resources. So, during the next evolution step, the behavior of the organization may evolve from an unpredictable manner.

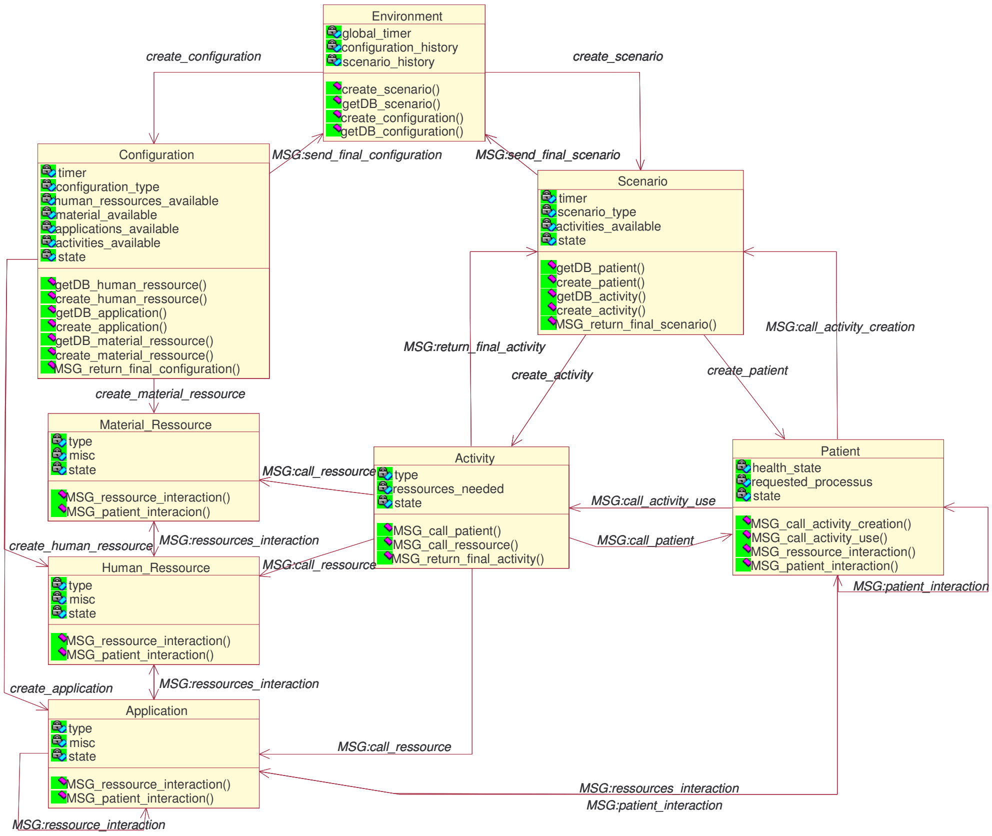


Figure 4: Meta model (partial view)

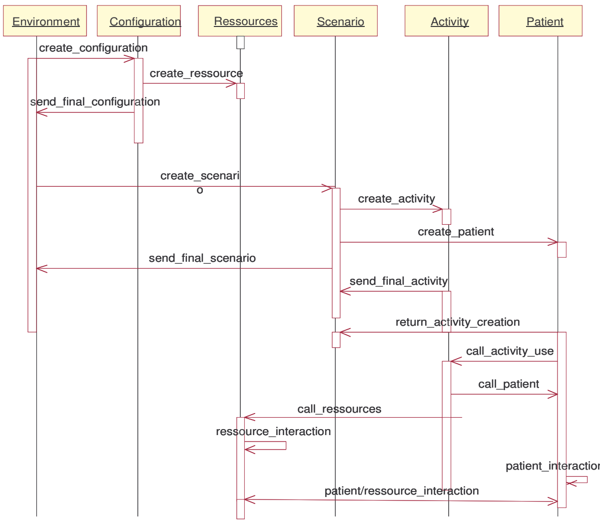


Figure 5: scenario example

4 The idea of this step is to improve the model by executing it. By considering a set of simulations results, the original organization model may be improved by taking into account the new potential scenarios.

A new cycle of modeling phase, coherence analysis phase by properties proof and simulation phase can start as summarized in Figure 6. For this, many MAS architecture have been developed and the one witch interest us is based on Believe, Desire and Intention paradigm (BDI) (Bratman, Israel, and Pollack 1988; Rao and Georgeff 1995). This architecture allows the description of the behavior of each agent as a set of learning rules and behavioral constraints inspired by the properties to be verified all along the life cycle of the organization. During the simulation, each agent must be then able to prove these properties and eventually may modify and adapt its behavior. That's why, in BDI profile, we propose to put formalized properties in the form of rule and to adopt a JESS mechanism of reasoning as proposed in (Cardoso 2007). JESS can be used as a decision component of an agent, which is implemented in a declarative way.

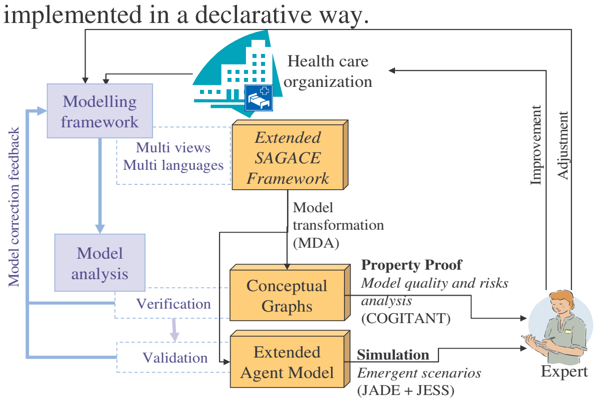


Figure 6: Approach synthesis and resulting framework

The proposed implementation consists of embedding an instance of the JESS engine inside the agent behavior. Since the agent must remain able to continuously reason, a formal proof mechanism is added whose action consists of running the Jess engine and verify in each time the set of required properties. In other words, partial and local dynamic evolution rules (described as a temporal property) can interact on the local agent behavior modifying then the resulting global behavior when one cannot precisely describe this global behavior.

So, each agent is equipped with a clean system of local proof properties (trade, normative and interoperability) that makes it possible on each evolution of its environment to test its current configuration, then to decide and/or improve, to extend or reduce this configuration, impacting its behavior. The goal is to facilitate a phenomenon of adaptation even of auto-organization. But this behavioral evolution of each agent is not possible all the time and evolution situation is then blocked due to the difficulty for agent to adapt their behavior. So organization is facing a new emergent risky situation having to be studied.

5. CONCLUSION AND FUTURE WORKS

In this paper, we have summarized existing results concerning health care organization modeling and analysis frameworks, verification technique developed for assuming model coherence. The current work in progress is presented. It concerns the dynamic validation of property based on BDI architecture of MAS using JESS engine as a mechanism of formal proof.

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