MA-IS: Design of Information System in a Multi-Agents Environment

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ABSTRACT

The complexity of the information systems has recently had a remarkable increase, mostly thanks to the enormous impact that it has had in the multi-agent system (MAS) area; hence the need to integrate two systems and obtain an IS that takes advantage of the potentialities of the MAS. To this purpose, a methodology to analyze and design a multi-agent system is needed. In order to define such a methodology, which should take into account all the aspects of the MAS, first we need to establish not only a conceptual model of the system but also a communication level model. In this paper we propose the use of DDS framework for the communication level and the use of the BWW ontology for representation and design of the domain knowledge base. The idea of the above-mentioned methodology was conceived in the SISTDE project, which uses the ontology for the description of the domain, so as to provide the agents with a knowledge base that concurs to define their behaviour according to external events. In addition to this, the experience we have matured in the IS modelling using the BWW ontology is a key-point of our approach.

Keywords: Multi-Agents, Information System, Architecture, BWW, Ontology

1. INTRODUCTION & BACKGROUND

In the last few years, in the computer science field multi-agent systems have received much attention. The multi-agent systems consist of multiple entities that can interact with one another. The most important elements of such systems are:

- decisional aspects related to the agent: the actions that an agent starts in function to external events;
- delocalization of the execution: possibility that more agents collaborate together for executing elementary actions, in order to complete a complex task;
- interactions among agents: information exchange among the agents in data distributed environment;
- Evolution towards more and more elements endowed with autonomy: agents that in full autonomy succeed in perceiving their own scope.

Through these four aspects, we can determine multi-agent system issues. First we have the need to identify the simultaneous modalities of action for agents in a heterogeneous environment.

Every single agent, in a multiple agent environment, must be able to realize the more suitable actions to obtain its scope. Such attitude to the decision is related to a *mental state* [1] that reflects the perceptions, the representation, the convictions and a certain number of “psychical” parameters (desires, tendencies…) of the agent.

For the multi-agent systems it is necessary to study the nature of the interactions that might bring the opportunity or ties to the system definition. The problematic of interaction deals with the modalities, with the analysis and with the conception of the interaction forms among agents. Cooperation and collaboration notion is a fundamental issue.

With regard to the issues listed above, in order to delineate architecture for a multi-agent system, two layers are needed:

- *Communication layer*: currently the most qualified is standard FIPA-ACL [2] (Agent Communication Language) created from the Foundation for Intelligent Physical Agents (FIPA). Such standard is founded on the linguistic action theory, elaborated by John Searledi [3]
- *Conceptual model layer*: analysis and modelling methodology that allows, the generation of a description that contains the elements to represent the interactions between the agents and the domain, in which they act. Such methodology will have to intersect the analysis of the agents’ behaviour for the fulfillment of their purpose, with the analysis of the domain in which they will interact.

In relation to the necessary work of analysis for the definition of the two afore-mentioned levels, the complexity deriving from the domain modelling and the complexity of an area in continuous increase and expansion must be considered. Currently in the software engineering field there are some methodologies that try to define the rules for this modelling type, for examples:

- *BDI Model [4]* (Beliefs-Desires-Intentions): it considers the agent environment belief, which is the result of its knowledge and perceptions, and a set of Desires. Intersecting these two sets, we obtain a new set of intentions, which can become actions.
- *Tropos* [5]: a software development methodology founded on concepts used to model early requirements. In particular, the proposal adopts Eric Yu's modelling framework, which offers the notions of actor, goal and dependency, and uses these as a foundation to model early and late requirements, architectural and detailed design [6]. The language used in Tropos for the conceptual modelling is formalized in a meta-model described with a set of UML class diagram.

In literature there are several articles that examine the software engineering paradigm applied to the multi-agent system, among them a paper of Pratik K. Biswas [1] describes extensively the multi-agent system elements and their correlations, confronting them with UML paradigm that it reuses for their modelling.

The mentioned methodologies and the literature articles only approach the communication the description of the interaction among the agents, or define a methodology (Tropos) that, entering too much in the detail, supplies a notation that is heavy and difficult to use.

The multi-agent systems are currently used, above all, in the telecommunications area and in the military industry, for the

definition of systems that can be replaced to the acts of a human customer.
Currently, the multi-agents system level lacks a methodology for the high level analysis for the modelling of the agents' interactions and of their behaviour in the domain where they operate.
In this paper the possibility of using the multi-agent system in the Information Systems (IS) area is discussed; the aim is to define a new methodology with respect to the agents' behavioural peculiarities and their interaction systems.
This would lead to realize an IS where several elements collaborate with one another in more independent and transparent way for the user.

2. INFORMATION SYSTEM ARCHITECTURE: OPEN ISSUE

For modelling an information system firstly its domain must be analyzed, to identify the involved actors and therefore to define the rules of interaction and the necessary processes to earn the prefixed purpose. From this brief description it is evident that there are many common aspects between an IS and a multi-agents system (MAS) in both systems there are the subjects (actors in IS and agents in the MAS) that interact with one another and with the domain, in order to earn a scope; both in IS and in the MAS it is necessary to define communication rules among the subjects, that can be individualize in the IS process as events which the agents have to answer.
As already said in the introduction, two are the fundamental aspects to examine in the MAS area:

- Communication Layer;
- Conceptual Modelling Layer.

Both points must be modelled and implemented in order to obtain a complete methodology to describe a MAS in its entirety and to be able to insert it inside an IS.
The idea to develop in separate way the communication and the conceptual modelling of the MAS and define the exchange of the information between the two elements is the base of the methodology definition to support of the IS modelling in multi-agents area. In this way, the conceptual modelling methodology will be independent of the support of communication technology, typically used by the single agents, and will guarantee that the model derived from the domain and agents analysis will not have to be modified if the communication technology changes.
In the next two subsection the candidates to assume the role of methodological base for the communication, and the conceptual modelling of the information systems with multi-agent imprint will be described.

Communication Layer
The OMG standard DDS (Data Distribution Service) [7], based on the Data Centric paradigm, and the Publish-subscribe middleware seem suitable frameworks for the communication layer. This platform has a strong and complete level of distributed data and asynchronous exchange. In particular it offers:

- Predictable and reliable data distribution with minimum overhead
- The lack of central server guarantees the absence of *Single Point of Failure*
- The single message does not demand a confirmation answer
- Possibility to define and to specialize the QoS parameters for a corrected use of the communication and system resources so as to obtain predictable and reliable applications
- Suitable for *intermittent connectivity* scenarios:
  - Plug & Play of the system Nodes
  - Dynamic and automatic discovery of the Nodes/Services

Therefore we use the DDS framework for the *communication layer* and so every agent implements a DDS layer that allows to define the format of the data to exchange on the communication; is information are set in the *Topic,* base element of the *data distribution service*. The communication mechanism is shown in Figure 1.

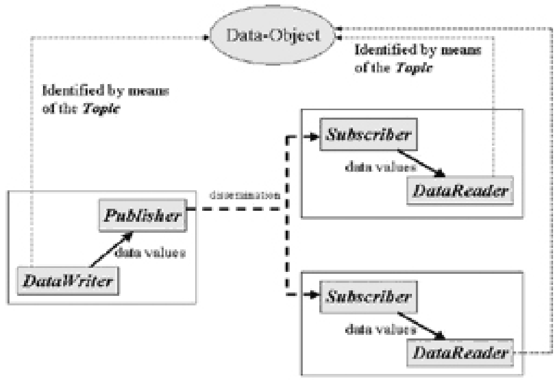

Figure 1: DDS Overview

Conceptual Model Layer
First a modelling methodology needs to identify the base elements to use for the system analysis and modelling, defining and characterizing their semantic and syntactic meaning so as to create a meta-model as an instrument of the methodology.
Once the methodology is defined, the match rules between the generated model and the agents' communication level must be characterized. In the specific presented case, where we consider the DDS like communication framework, defining the model elements that will constitute the Topic necessary to the exchange of the data through the *Publish-subscribe middleware*.
The first step to follow for the methodology definition is the choice of a language that allows representing the conceptual modelling. Such language has to be simple (and therefore comprehensible from all system actors), formal (in order to prevent free interpretations) and complete (in order to concur to represent the total model).
Today for the conceptual modelling, in the international panorama, the UML-Like representation is used; this structure obliges to follow ties and formalisms of the application level. To overcome this limit, which associates the domain to a much binding vision, we addressed the search of a model based on the Ontology.
Among the several ontologies present in literature, the ontology of Bunge, Wand, Weber (BWW) [8] [9] is the one that provides very precise rules for the elements location and the categorization that constitute the domain of interest.
Through BWW ontology, it has already been defined a meta-model for the conceptual modelling of application domain, using the OWL language so as to supply to the meta-model an apt structure to being as flexible as possible [10].
The good results obtained applying the BWW ontology to the classic IS [11], and the fact that the domain modelling results to be more objective in comparison to the UML approach, encouraged us to explore the possibility that such ontology might as well be suitable for the modelling of the information systems with multi-

agent imprint. In the next section a short description of BWW will be given.

BWW in to nutshell

Ontology BWW (Bunge-Wand-Weber) has like main element the thing, which models the *things* that have a physical existence in the real world. The things are characterized through the Properties. Every Thing has at least one *Property* and every *Property* belongs at least one Thing.

The properties can also be classified in *Intrinsic Property*, that regard a single thing, and *Mutual Property* that is shared between two or more things. The *Law* can bind the value of the property. The Law of two types: *Natural* (laws of physics) or *Human* defined by designer. A property can have only one type of law (or Natural or Human).

The values assumed from the property define the thing *state*. The state can change because an *Event* acts on its thing. The chronological collection of the several states constitutes the *History*, while the set of events constitutes the *Process*. If the change of the property of a thing involves the change of an other property into another thing a two thing are defined *Coupled*. The things that have common properties can be collected in class. The *System* is the collection of things that are defined the coupled. More things can form a *Composite* thing when they are essential parts of its existence (as an example the thing machine is a composite thing because composed from the thing to engine, wheels, etc.).

3. PROJECT DESCRIPTION

In the context described in the previous sections, the scientific collaboration within project SISTDE (Safe Computer system for the Treatment and the management of high critical Heterogeneous Data), (the leading company is SSI, Space Software Italy, SpA in collaboration with the University of Salento) play a major role. This project has the scope to define, to develop and to validate an application platform for the realization of the operating network-centric systems in a scenario where highly critical data are dealt with. The domain of the project regards a clean-landmine system by means of robot swarms, where the several agents, must cooperate in order to achieve the purpose of the mission that, in this case, is the reclamation of critical areas

Therefore the system is wanted to have:

- Access to the ubiquity and adaptable data: possibility to supply approached the data in any place and with any technology;
- Control of sensitive Access to the role and the operating context: based on the requirements of agent action it must be able to establish the level of more suitable QoS;
- Dynamic creation of Data Services: the data must be published in the moment in which they are available;
- Publication/Recording for given services: the agents must be able, in independent way to record their presence and to publish the data demands from other agents;
- Management/planning of the sessions customer and service: separation of the roles and the relative tasks to the single agents of the system
- Integrated management of the Security and QoS: possibility to specify the quality of the service according to the actions to carry out
- scalable level of Members/Nodes of Network-Centric System: the system must know how to recognize and to acquire the presence/absence of agents
- Support to the Interoperability with Legacy Systems so as to render the system totally compatible with existing applications

Based on the afore-mentioned specification, there is the necessity to define a communication system between the agents and a knowledge base where the possible events which the agents must answer, are classified.

With regard to the communication system, we will use the Date Distribution Service (DDS), standard OMG described in paragraph 2.1, that guarantees a good level of robustness and supplies functionality, such us the definition a specific QoS for every connection.

For the definition of the knowledge base necessary to describe the project domain, we are using the ontology, which supplies a powerful and flexible instrument in order to define the knowledge base easily updating, beyond inserting an abstraction layer that facilitates the interaction between the user and the application.

The Research Approach

The experience matured with the ontological language in the domain description, has encouraged us to estimate the possibility to use the ontology of Bunge-Wand-Weber in order to define the meta-model to describe the domain of the SISTDE project. In fact, considering the elements of BWW ontology we can characterize them in the analogous elements in the MAS philosophy,

Moving towards this direction it has been observed that:

- The *Thing* is adapted well to the concept of Agent, in fact the agents are the fundamental elements of the system and they have a real existence.
- The Capabilities and the peculiar attributes of the agents can be defined through the *Property*.
- The BWW's *Event* appropriately fits the concept of the domain events, which can be introduced during the development of task from the MAS. In fact an event is the occur of an action that changes the state of a thing.
- The BWW's *History* holds trace of the thing state changes, and therefore, traces its evolution inside the system; candidates to assume the role of memory of the agent.
- Through the definition of *Coupled* the interactions among the agents can be identified. In fact when the state of an agent undergoes a change (the BWW's state coincides just with the collection of the thing values in a time), a change of state in another agent who depends from it can be triggered.
- The BWW 's *State* are a good candidates for the description of the *mental state* of an agent, in fact the mental state defines the agent ability, convictions and decisions all referable to property and therefore representing a state.

It can be noticed that the elements of the *Coupled* relation can identify the data that constitute the *topic* of the DDS in the communication layer.

Moreover the used semantic and syntax, turn out to be similar, and they express concepts equivalent to the natural language used for the domain analysis, therefore they allow getting the necessary abstraction degree to a good modelling.

Thus, it begins to emerge, beyond the meta-model for the conceptual modelling, also the definition of the necessary rules layer to create a connection between the communication layer with the *conceptual modelling* layer (figure 2).

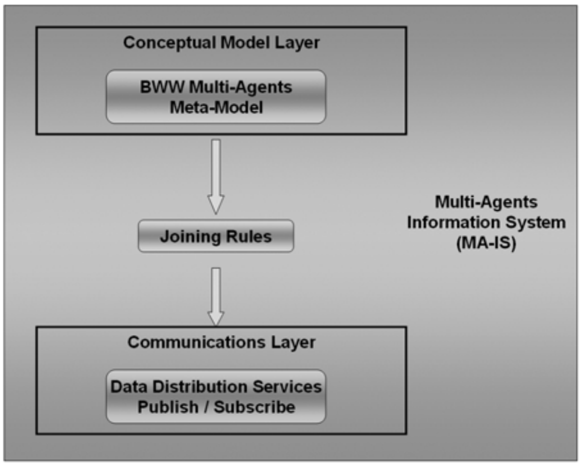

Figure2: Layer MA-IS

4. CONCLUSIONS

The abstraction level supplied from the BWW ontology for the domain modelling guarantees an objective conceptual model.
Moreover, the employment of the same ontology for the description, both of the classic IS domain and of the MAS domain, supplies the base to define a merge between the two systems, so as to be able to reach a methodology that concurs to redefine the IS in MAS modality.
Obviously the research work is hardly at the beginning, and a refining of the concepts will be necessary, as well as their description and their validation, besides the necessity to define the rules layer necessary for the connection between the conceptual model and the communication level own of the systems MAS.

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