A formal approach to MASQ

(Extended Abstract)

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ABSTRACT

MASQ (Multi-Agent Systems based on Quadrants) is a generic meta-model that proposes an integral view of interaction in a multi-agent system. It defines four perspectives according to two axes: internal/external and individual/collective.

This paper identifies a set of MASQ principles and analyzes how a formal model can be built based on them. We outline the most important design choices that have to be made and their impact on the architecture of the resulting multi-agent system.

Categories and Subject Descriptors

I.2.11 [**Distributed Artificial Intelligence**]: Languages and structures, Multiagent Systems

General Terms

Theory

Keywords

MASQ, multi-agent systems, group, institution, environment, mind

1. INTRODUCTION

This paper continues the work started in [3]. Section 2 identifies a set of seven principles that are at the core of the MASQ approach. Section 3 analyzes how based on MASQ and the identified principles we can build a formal model of interaction in a multi-agent system. Finally, section 4 emphasizes the future directions of research.

2. IMPORTANCE OF MASQ

The MASQ meta-model [3] proposes a new integral view of agent interaction based on a 4-quadrant approach. We believe that such an approach is absolutely necessary when modeling complex hybrid multi-agent systems (humans and artificial agents acting together in an environment). In this context, all the concepts in MASQ inspired from philosophy and social sciences are of great value.

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MASQ offers an intuitive map of agent-based interaction by integrating many elements that much of the time have been studied in isolation. But above all, MASQ comes with a set of principles for building complex multi-agent systems, which are identified below:

1. Quadrant-Relationship principle. Based on the 4-quadrant model by Wilber[4] there are only two categories of elements in a multi-agent system: a) *quadrant* elements: belonging to only one quadrant and conforming to its semantics; b) *relationship* elements: connecting quadrant elements from adjacent quadrants.

2. Mind vs. Body principle. The decision making component should be separated from the parts that depend on specific environments.

3. Influence-Reaction principle: A mind can only influence an environment by sending *commands* to its bodies. The environment will react and will influence back the mind under the form of *sense data* sent by bodies [1].

4. Environment Partition principle. In order to tackle the complexity of environments they must be partitioned into smaller units called *spaces*. They contain the *objects* that compose the environment and their nature can be physical, social, organizational, etc.

5. Brute vs. Cultural principle. A culture is a set of elements that are shared by a group of minds. Cultural elements (such as shared knowledge, ontologies, behavioral patterns, norms, etc.) should be separated from elements that exist in the environment (for example an organizational structure).

6. Immersion principle. Agents can interact with each other in a meaningful way (interpret interaction in the same way) only by being immersed in a same culture.

7. Institutional principle. The institutional reality (internal representation of an agent about its environments) is created from the brute reality (sense data received from bodies) through the use of *count-as* rules [2] : X counts as Y in a context C.

A detailed discussion of the above principles is needed but due to space restrictions it's not possible. We only emphasize that the 1st principle is very important as it's the only one that considers a MAS in its entirety. Applying this principle is strongly dependent on the semantics given to each quadrant. The rest of the principles apply to a quadrant or to a relationship between two quadrants.

The seven principles identified above aid in better understanding MASQ and at the same time guide the design process of a system based on MASQ.

3. TOWARDS A FORMAL APPROACH

The MASQ meta-model has been introduced in an informal manner and the seven *MASQ principles* identified in the previous section come to reinforce what has been said in [3]. But if we want to build concrete multi-agent systems based on MASQ, or any other model, we need some sort of formal specification.

The use of a formal model when designing a MAS has several advantages such as: better understanding the model itself and how to construct a system based on it; a detailed analysis of properties of the resulting MAS can be performed in advance; help in creating unambiguous links to other models; etc.

MASQ is very generic and trying to give a formal specification of it will lead to design choices that have to be made. These choices in turn will introduce additional constraints that were not originally present in the model and the result will be a "constrained model of MASQ". That is why from now on we will talk of formal models based on MASQ and not a formal model of MASQ.

In the following subsections we will briefly analyze some of the choices that have to be made when creating a formal model of interaction based on MASQ. The analysis is structured in four parts, each of them corresponding to a semi-plane of the MASQ 4-quadrant map.

3.1 Exterior quadrants

The basic elements MASQ defines for the exterior quadrants are: *objects*, *bodies* and *spaces*. In conformance with the 4th principle, a *BelongTo* relationship exists between objects (bodies are special objects) and spaces. There are two possibilities concerning the nature of a space: a) a space is a "first class" element in our formal model; b) a space is special kind of object. This choice is important because it will have a great impact on the structure of the environment.

The first option will basically create a two-level environment: the spaces level and the objects level. The second on the other hand will produce an interesting hierarchical structure in which each space exists as an object inside another "parent" space. We can image this hierarchy having at root a space that contains itself which can be considered the *universe* space.

Objects have states and there are mainly two ways of modeling them: a) through distinct elements, like a finite state machine; b) through a set of *attributes* or *properties* that have *values*. The former is more suitable for a theoretical approach while the latter allows for a straightforward implementation.

3.2 Individual quadrants

According to the 2nd MASQ principle, *minds* are separated from bodies and in this subsection they will be considered as atomic elements. Only their relationship with the second quadrant is analysed.

The *HoldBody* relationship between a mind and its bodies comes with a bi-directional communication through *influences* and *sensations* (MASQ 3rd principle). When defining a body two parts must be specified: the part that "lives" in the environment (its state, dynamics, etc.) and the part that enables the communication with the mind. The last part is itself composed of two sub-parts: one that sends *sense data* to the mind, which is composed of *sensors*, and another that receives *influences*, composed of *effectors*.

Giving a formal definition of sensors is not an easy task. That is because the type of sense data that a sensor is capable to send to a mind has a great impact on the way a mind *perceives* the environment. A few examples of choices are: admitting that the environment has a state that changes, is the scope of a sensor limited to one state or does it include multiple states (sense environment dynamics)? can a sensor sense that an object is a body (that there is a mind connected to it) or that another body performed an action (instead of only the result of the action)?

Concerning effectors, the easiest way to model them is as a set of basic atomic capabilities that are associated to a body by the environment.

3.3 Interior quadrants

When creating a formal model, one of the first choices we have to make regarding the mind is the way it stores the information (about itself, environment or even other minds). A classical approach is to use sentences in a *representation language* such as first order logic, RDF, modal logic, etc. Also, according to the 6th principle, a mind can be immersed in a culture so it must be able to create *cultural interpreters*.

The sense data that reaches the mind forms the *brute reality* that a mind perceives. There are basically two ways of using this brute reality: a) interpret it directly; b) store it and then interpret it.

The first choice requires that all cultural interpreters know how to handle sense data while the second requires the representation language to be flexible enough to represent, at the same time, the brute and the institutional reality.

3.4 Collective quadrants

According to the 5th principle the cultural elements have to be separated from the environment. But there is an important choice that has to be made: a) cultures can exist independently of minds; b) cultures exist only in the minds of a group of agents; c) a mixed existence.

The first choice will require the culture to be a "first class" element in the formal model, having its own structure. The second one will turn cultures into a view of what's inside the minds of multiple agents. In both cases, the representation language used must be expressive enough to represent the cultural elements.

4. CONCLUSIONS

The seven *MASQ principles* and the above analysis provide a solid base that enables further research to be done into creating formal MAS models for specific domains, based on MASQ.

5. REFERENCES

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