Two Different Perspectives about How to Specify and Implement Multiagent Systems

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Abstract—**This article review has as a goal to demonstrate that exists two different perspectives considering the actual literature about frameworks to specify and implement multi-agent systems in a formal way. On the one hand, there are those specific frameworks/methodologies for MAS where those obligatory requirements to guarantee the system correctness are encapsulated on the tool. On the other hand, there are those frameworks/methodologies that are based on those existing one and they are adapted to the multi-agent specificities, where those mechanisms to verify and validate the system are inherited from the original method/tool. On this paper are presented two methodologies based on the first perspective, considering three different dimensions on specifying MAS, and two adapted tool, Petri Nets and AUML, considering the second perspective.**

I. Introduction

Modern computational problems are inherently distributed. In these cases, a solution can be obtained through some kind of composition between parts dispersed in a real or virtual environment. A example like these is the recomposition of an electrical network after a blackout, and the control of a team of robots that play soccer. Problems like these share some pattern features [1]: they are physically and/or conceptually distributed, in the sense that their global state is composed by the aggregation of partially independent local states; and the tasks involved in solving these problems refer to different levels of abstraction, varying from global coordination protocols to local perception/action procedures, that use sensors to perceive the world state and effectors to act in the world. The relevance of these problems can be measured through the number of new methods/techniques or even new knowledge areas developed to treat them. It can be cited Pervasive and Ubiquitous Computing, Smart Grids and Multiagent Systems. All these issues has its fundamental knowledge based on the distributed systems theory.

One main reason for this situation is the absence of some pattern method/technique to develop this kind of solution. In this sense, it is necessary to establish some benchmarks about formal methods of specification to MAS. According to this study, it can be said about MAS:

- a MAS can be conceived from three dimensions: the agent itself, the communication/interaction aspects (environment and agents) and the organization model;
- The existing formal methods can be classified on two categories: those methods that was develop specifically as a multi-agent framework and has its own tools to verify and validate the system based on some kind of logic proof.

From this perspective, this paper has as a goal to define the minimal constraints about a formal method to specify, develop and implement MAS.

II. Requirements for a Multiagent Specification

A specification is formal if it is expressed in a language composed of the following three elements: rules for determining the correct formation of sentences (*syntax*); rules for interpreting sentences in a precise and meaningful regarding the considered domain (*semantics*), and rules to infer useful information from specifications (the *proof theory*). In a broad context, can be identified some metrics for evaluation of formalisms:

- *Expressiveness and required coding* - Expressiveness relates to the ability of the model to express formal aspects present in the real system;
- *Constructability, management and evolution* - The constructability is a ability to adapt to a system with modularized and incremental development processes;
- *Usability* - The usability concerns the ease with which the specification is performed;
- *Communicability* - Along the same idea of the previous criterion, the communicability allows well-trained people read and verify high quality specifications.

A multi-agent formalism should take into account three basic steps in their specification: requirements, design and implementation. In order to go from one step to another are necessary rules or propositions, i.e., a logical-mathematical formalism that enables the correlations the three stages.

III. Logic-based Formalism for MAS

In a MAS, there are three dimensions to consider:

- the *individual agents*, where the agent is able to sense changes in the environment, act according to its goals causing changes in the environment, communicate to coordinate your actions with other agents;
- the *communication and interaction* between agents, in other words, this dimension can be understood as protocols regulating the interactions between agents, enabling agents to use the functionality of others or allowing it access to external resources;
- the *social organization* carry out the agents representation such individuals inside a group organized

by concepts like roles, groups, norms and global and individual plans/missions.

Each of the two methods/formalisms/frameworks presented below represents some of these three dimensions.

A. Model of Organization for multI-agent SystEms+

The organizational specification of a MAS is useful to improve the efficiency of the system since the organization constrains the agents behaviors towards those that are socially intended: their global common purpose [2].

The MOISE+ has an explicit global plan and little dependency between the structure and functioning. The objective is an organization centered model where the first two dimensions can be specified almost independently of each other and after properly linked by the deontic dimension.

The organizational models that follow the organizational centered point of view usually are composed by two core notions: an Organizational Specification and an Organizational Entity. An Organization Entity is a population of agents functioning under an Organization Specification [3]. An Organization Entity is then created as the agents adopt the roles specified in the organization Specification.

A MOISE+ Organizational Specification is formed by a Structural Specification, a Functional Specification, and a Deontic Specification [3]. The three organizational dimensions of MOISE+ [4]:

- Structural Dimension (roles, groups, relations): A role is conceived as a set of behavioral constraints that an agent accepts since it joins a group in the organization;
- Functional Dimension (goals, global plans, missions): It defines a set of global plans for the MAS, which are structured in a social schema, as a goal decomposition tree, where each goal may be decomposed in sub-goals, and the responsibilities for the sub-goals are distributed in missions;
- Deontic Dimension (obligations, permissions): It specifies the relations between the structural specification and the functional specification, establishing which missions each role is obliged or has the permission to realize.

Through the levels shown, note that the MOISE+ may represent a real organization, showing a good degree of expressiveness. It has good evolution because the concepts of missions, set of plans and goals where all this concepts are assembled in a Social Scheme, thus, also has good usability, mainly by tree decomposition distributing the responsabilities in missions.

B. Social Commitments

Most agent communication languages are no longer defined in terms of the agents' mental attitudes, but in terms of social commitments [5]. However, commitments has not a clear and unequivocal character, and are not completely unrelated to the agent's reasoning, but this situation can be remedied through the combination of logic BDI with a logic of what is publicly grounded between agents.

By means of a reducionist logical characterization of social commitments, and due that individual mental attitudes are not enough to characterize social commitments, it should be combined a logic of individual mental attitudes with a logic accounting for the social and public feature of social commitments. Using the logic of grounding which extends a BDI-like logic by a modal operator of what is publicly established in a group of agents, as opposed to private mental attitudes.

Castelfranchi reduces social commitment of the debtor i to the creditor j w.r.t. the action α using mutual knowledge: "i and j mutually know that i intends to do α and this is j's goal, and that as for α j has specific rights on i (j is entitled by i to α)" [6] [5]. Replacing mutual knowledge with the notion of grounding, captures only the public feature of the i's intention, and also does not imply that this attitude holds.

Due to the combination of the BDI logic with a logic of what is public grounded between agents, the expressiveness is good, but is affected by the notion that commitment does not have a clear and unambiguous characterization. The constructability can be achieved through the theory of speech acts, formalizing commitments not only as effects of speech acts, but speech acts creating and managing commitments. The specification for presenting the logic grounding, modal operators and other special features, such as propositional social commitments still has low usability. In the communication part, it can be said that social commitments are more mature, however, must be well understood by well-trained people.

IV. Inherited Formalism for Multiagent Systems

This section describes two formalisms inherited from classic models of system specification: UML and Petri Nets.

A. Agent Unified Modeling Language (AUML)

MAS are often characterized as an extension of object-oriented systems, but unlike objects, agents are autonomous and interactive. Agents based on their internal states, its activities include goals and conditions that guide the execution of defined tasks. While objects require external control to execute its methods, agents know the conditions and the effects of their actions.

Participants of the FIPA Modeling Technical Committee and OMG-AUML Agent Work Group initially identified two areas for development of detailed specifications. These specifications are as follows: Class Diagrams - specify the internal behavior of an agent and relating it to the external behavior of an agent using and extending UML class diagrams; Interaction Diagrams - a generic term that applies to several types of diagrams that emphasize object interactions. These include collaboration diagrams, sequence diagrams, and the overview diagram of interaction.

According to FIPA Modeling Technical Committee, the areas of AUML Modeling are [7]: *Multiagent vs. single agent, Goal and soft goals, Social aspects, Environment, Workflow/Planning, Levels of abstraction, Temporal constraints, and Deployment and Mobility.*

We note that the AUML with its graphical notation, their extensions and adaptations is able to express and model the various MAS, leaving the designer of such systems better able to lift requirements, design, build and implement, namely, has usability. And, through the various UML notations adapted one can have an overview of the system, i.e. the AUML shows a good degree of expressiveness, and has high constructability and it can be, in most situations, codified in a way more agile.

B. Petri Nets based Formalism for Multiagent Systems

The specification language is based on PN for structuring knowledge in various abstract levels and also provides generic mechanisms for use of several types of knowledge representation formalisms.

This model assumes that the agent, based on their mental model of the world, establishing priorities and setting goals for your performance environment, and to establish these goals, the agent has the job of identifying the best sequence and coordination of actions to achieve them.

The planning is directly linked to socialization, namely the role of the agent seeks to achieve the aims of agents society of which he is part. This model is modular, and from the planning module are defines the current goals of the agent that are passed on to the coordination module that selects the necessary actions to the module action can act on the environment.

The individual knowledge and the role that the agent has in society defines its personal strategy and together with the collective strategy of the society of agents, the agent performs their individual actions on behalf of social goal.

[1] proposed an approach to specify individual and social levels through the same formalism. This formalism is based on a specific model of High Level PN developed to interface between experienced professionals in the domain to be modeled and frameworks used to implement the system. Moreover, the proposed PN allows you to create and verify formally the mapping between individual and social levels through a hierarchical formalism that integrates the knowledge of the entire system.

The proposed model presents important aspects in the process of acquiring knowledge:

- The graphical representation allows minimizing communication problems between knowledge engineers and professionals in the area concerned. The model allows specifying concurrent tasks, as well as individual and social contexts;
- The mathematical model of PN can be used to check for problems such as inconsistencies, ambiguities and redundancies;
- It is possible to automatically transform the information in a knowledge base.

The use of PN is justified because it is a specification tool ideal for systems that require specifying competition and timing. In addition, knowledge based systems, as is the case with MAS, can be viewed as discrete event systems because changes state, or the occurrences of new events are driven by time. Aiming to represent a knowledge-based system using PN, it becomes necessary to extend the capability of representativeness tokens allowing manipulations represent the knowledge base when a rule is triggered. To meet this purpose, High Level PN are appropriate. This type of network allows associating preconditions and post-conditions that control the loading and firing of transitions. The transition firing entails a change in the knowledge base, which is updated by the manipulation of the chips. The distribution of tokens represents the state of the knowledge base.

V. Conclusion

In this paper is argued that the formalism to specify, implement and validate MAS can be classified on those that are specific for this kind of paradigm and those that are inherited from other methods. In this sense, four different methods were analysed considering some basic metrics for this kind of formalization.

The difference between AUML and the representation by PN seems to revolve around the adaptability of AUML, which can be shaped by the designer of the MAS in the way most suitable to represent the MAS in question, beyond AUML have a friendly graphical view system that makes coding more agile and simple, without forgetting, of course, that AUML can represent a wider variety of MAS.

Visually, PN and Moise are similar. Both transmit on its behalf, a great knowledge about the system as a whole. But Moise is very limited to such representation, once it only models the system, defining the rules of operation, structure and organization of MAS. PN go beyond, allowing the development of execution control, the system working at the individual level and global.

The main fact concluded from this work is the totally absence of frameworks/methodologies and even languages which encompass all dimensions of a MAS.

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