Engineering Regulated Open Multiagent Systems

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In this thesis, we focus on the development of normative open multiagent systems. They are systems in which heterogeneous and autonomous agents may need to coexist in a complex social and legal framework that can evolve to address the different and often conflicting objectives of the many stakeholders involved. This thesis presents ROMAS, a set of methods and tools for analyzing and designing systems of this kind. ROMAS integrates the analysis, design and verification of these systems by means of a metamodel, a methodology that includes specific development guidelines and a model-driven CASE tool.

Keywords: Multi-Agent Systems, Software engineering, Contracts, Model-Driven Software Development, Model Checking

1. Introduction[1]

Due to the increase in collaborative work and the decentralization of processes in many domains, there is an expanding demand for large-scale, flexible and adaptive software systems to support the interactions of people and institutions distributed in heterogeneous environments. Commonly, these software applications should follow specific regulations meaning the actors using them are bound by rights, duties and restrictions. Common to other works, we use the term *normative open systems* to refer to systems of this kind, and the term *normative context* to refer to all the norms and contracts that restrict the behaviour of the systems' entities.

This thesis[2] is focused on the analysis and design of normative open systems using Multiagent systems (MAS) technology. Currently there are some agent-oriented software engineering methodologies that deal with the development of systems of this kind [2,3]. However, after analyzing to what extent agent methodologies support the analysis and design of these systems, we can conclude that there are some open issues in the topic. Some of these open issues are the integration of the normative context of the system during the whole development process; the lack of guidelines to identify and formalize this normative context; and the lack of validation and verification techniques that ensure the coherence of the final design and the requirements of the system and the coherence between the individual objectives and restrictions of each entity and the global system.

The main objective of this thesis is to offer methods and tools that cover the analysis and design of normative open MAS dealing with the highlighted open issues. Thus, the main contribution of this thesis is the ROMAS proposal (Regulated Open Multi-Agent Systems) which is described in the following section.

2. ROMAS proposal

ROMAS covers the analysis and design of normative open MAS by means of three main contributions.

Our first contribution was to propose a new MAS architecture and metamodel for developing normative open MAS. In ROMAS, *agents*, *roles* and *organizations* are defined through a formal social structure based on a service-oriented open MAS architecture. Here, organizations represent a set of individuals and institutions that need to coordinate resources and services across institutional boundaries. *Norms* defined as permissions, obligations and prohibitions restrict the behavior of the entities of the system. *Contracts* are used to formalize the relationships between entities. In our approach, we differentiate between two types of contracts: (1) *Contractual agreements* that represent the commitments between several entities in order to formalize an interchange of services or products. (2)

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[2]*http://www.gti-ia.upv.es/sma/thesis/pdf/TesisMariaEmilia.pdf*

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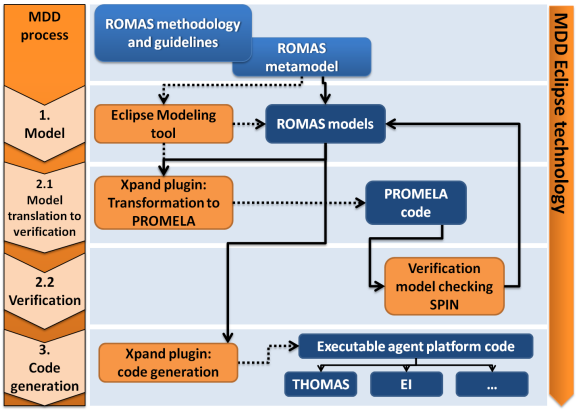

Fig. 1. Thesis contributions

Social contracts that can be defined as statements of intent that regulate behaviour among organisations and individuals.

Our second contribution was the ROMAS methodology. It defines an agent-oriented development process and provides specific guidelines for identifying and formalizing: (1) the normative context of the system, (2) the entities' communications and interchanges, and (3) both the global behavior of the system and the individual features of each entity. The methodology is specified using the template proposed by the FIPA Design Process Documentation and Fragmentation Working Group [1]. So, it can be extended with other method fragments described using the same template.

Our third contribution is a model-driven CASE tool that integrates the analysis, design and formal verification of these systems, as is shown in Figure 1. The CASE tool includes a textual and graphical modeling tool based on the ROMAS metamodel and methodology. It also includes a verification module that allows verifying the coherence of the normative context of the designed models. This verification module is executed in two steps: (1) Translate the ROMAS models into PROMELA code and LTL formulas which are the language of the model-checker SPIN; (2) Verify the coherence of the legal context at design time using a SPIN plug-in which is integrated in the CASE tool [7]. The reasons why we chose this model checker were that SPIN is a well-tested open-source software tool and that it provides an Eclipse plug-in easily adaptable to our CASE tool. The ROMAS tool architecture is prepared to integrate other plug-ins based on Xpand to generate transformation mapping rules expressed at metamodel layer to translate from the models designed with the modeling tool to a programming language of an agent platform. Outside the scope of this thesis a translator from ROMAS models to executable code for the Thomas agent platform has been developed [8].

3. Conclusions

This thesis has contributed to the state of the art of the analysis and design of normative open systems. The approach that we present here is distinct in that: (1) It offers a methodology that includes specific guidelines for identifying and formalizing the normative context of the system. (2) This methodology is supported by a MDA case tool that facilitates the graphical modelation of the systems, its verification and the automatic generation of code. (3) Both the methodology and the case tool integrates the concepts of organizational systems, individual agents, open systems and regulated environments (norms, contracts). They formalize not only the individual specifications of each agent, but also their social structure and regulations. ROMAS has been tested by means of the analysis of the results of designing different case studies from different application domains [6,4] and its comparison with other methodologies [5].

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