Organization Models and Behavioural Requirements Specification for Multi-Agent Systems

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Abstract

The main question addressed in this paper is how requirements on the dynamics of a multi-agent systems and individual agents can be related to the dynamics of high level concepts given by an organisation model, such as groups, roles within groups, and role interaction.

1. Introduction

Requirements Engineering is a well-studied field of research. In recent years requirements engineering for distributed and agent systems has been studied, e.g., [1], [2], [5], [7]. The approach introduced in this paper is especially relevant for requirements engineering for distributed and agent systems. At the level of the multi-agent system, requirements concern the dynamics of interaction and cooperation patterns. At the level of individual agents, requirements concern agent behaviour. Due to the dynamic complexity, analysis and specification of such requirements is a difficult process. The importance of using more abstract and intuitive notions in requirements specification, as opposed to more directly formulated behaviour constraints, is emphasised in, e.g., [1]. Because of their intuitive meaning and conciseness, such notions are easier to understand. In this paper organisational concepts are proposed to serve this purpose.

Organization modelling aims at abstracting from the interactions between the agents of a complex multi-agent systems and their fundamental and recurrent patterns [3], [4]. For doing so, organization modelling introduces the notions of role, interaction and group structure (or organization for some authors). The notion of role becomes independent of any particular agent, an agent playing several roles and a role being played by several agents if needed. The interactions define the relationship linking the roles to each other. Finally a group structure is a set of roles and interactions between these providing a common context and rationale. The notion of group structure can capture goal-oriented organizations, points of view on a multi-agent system or design patterns in a software engineering perspective. The advantage of organization modelling is to deal with complexity, in particular multi-agent systems with heterogeneous global behaviours.

In this paper, in relation to an organisation model four different types of requirements are identified (Section 3). These requirements abstract from assignments of agents to groups and roles. It is briefly discussed how the different types of requirements are logically related to each other (Section 4).

2. Organisation Modelling

For description of actual multi-agent systems from the organisational point of view, we use the "agent/group/role" model, which has been detailed in (Ferber and Gutknecht, 1998). In this definition, an organization is viewed as a framework for activity and interaction through the definition of groups, roles and their relationships. But, by avoiding an agent-oriented viewpoint, an organization is regarded as a structural relationship between a collection of agents. Thus, an organization can be described solely on the basis of its structure, i.e. by the way groups and roles are arranged to form a whole, without being concerned with the way agents actually behave, and multi-agent systems will be analyzed from the outside', as a set of interaction modes. The specific architecture of agents is purposely not addressed in the organizational model.

3. Behavioural Requirements within an Organisation Model

Based on an organisational structure, the following types of requirements are distinguished: single role behaviour requirements, intragroup interaction requirements, intragroup communication succesfulness requirements,

intergroup interaction requirements. To be able to specify ongoing interaction between two roles for which multiple appearances exist, the notion of *role instance* is used. This notion abstracts from the agent realising the role as actor, but enables to distinguish between appearances of roles.

- **Single role behaviour requirements**

For a given role within a group, role behaviour requirements specify the dynamics of the role within the group. They are typically expressed in terms of temporal relationships between the *input* and *output* of the role instance, according to the following pattern:

if role instance I:R receives as input ....
[and in the past as input of I:R it received ...
and in the past at the output of I:R it was generated ...]
then some time later role instance I:R generates as output ….

- **Intragroup role interaction requirements**

Intragroup role interaction requirements specify the temporal constraints on the dynamics of the interaction protocol between two roles within a group. Intragroup role interaction requirements between two roles instances *I:R1* and *J:R2* in one group instance are typically expressed in terms of the *output* of both role instances, according to the following pattern:

if role instance I:R1 generates as output ....
[and in the past at the output of I:R1 it was generated ...
and in the past at the output of J:R2 it was generated ...]
then some time later role instance J:R2 generates as output ....
or role instance I:R1 generates as output ....

In the simplest situations no references to the past are made, and the pattern takes the form of a direct reactiveness relation:

if role instance I:R1 generates as output ....
then some time later role instance J:R2 generates as output ....

- **Intragroup communication successfulness requirements**

Intragroup role interaction requires communication within the group. Therefore, in order to function properly, requirements are needed that communications are succesful. These requirements have the following pattern:

if role instance I:R1 generates as output a communication directed to J:R2
[and ...]
then some time later role instance J:R2 receives as input this communication

- **Intergroup role interaction requirements**

Intergroup role interaction requirements specify the temporal constraints on the dynamics of the interaction protocol between two role instances within two different group instances. They are typically expressed in terms of the *input* of one of the role instances and the *output* of the other one, according to the following pattern, in which I:R1 is a role instance within group instance GI1:G1 of group G1, and J:R2 is a role instance within group instance GI2:G2 of group G2:

if role instance I:R1 receives as input ....
[and in the past at the input of I:R1 it was received ...
and in the past at the output of J:R2 it was generated ...
and in the past at the input of J:R2 it was received ...]
then some time later role instance J:R2 generates as output ....

4. Logical relations

Behavioural requirements can be formalised, for example, as in [5]. From a verification perspective (e.g., [6]), the intragroup interaction requirements are logically implied by single role behaviour requirements and communication successfulness requirements. Single role behaviour requirements and intragroup interaction requirements are implied by agent behaviour requirements and group member and role assignments. The global properties of the system are implied by intergroup interaction requiremnents and intragroup interaction requirements.

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