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Robin Cohen
Bruce Spencer (Eds.)

Advances in Artificial Intelligence

15th Conference of the Canadian Society for Computational Studies of Intelligence, AI 2002
Calgary, Canada, May 2002
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Preface

The AI conference series is the premier event sponsored by the Canadian Society for the Computational Studies of Intelligence / Société canadienne pour l'étude d'intelligence par ordinateur. Attendees enjoy our typically Canadian atmosphere – hospitable and stimulating. The Canadian AI conference showcases the excellent research work done by Canadians, their international colleagues, and others choosing to join us each spring. International participation is always high; this year almost 40% of the submitted papers were from non-Canadian researchers. We accepted 24 papers and 8 poster papers from 52 full-length papers submitted. We also accepted eight of ten abstracts submitted to the Graduate Student Symposium. All of these accepted papers appear in this volume.

The Canadian AI Conference is the oldest continuously-held national AI conference in the world. (ECCAI's predecessor, AISB, held meetings in 1974, but these have since become international.) Conferences have been held biennially since 1976, and annually since 2000. AI 2002 again joined its sister Canadian computer science conferences, Vision Interface and Graphics Interface, enriching the experience for all participants. The joint meeting allows us to stay informed about other areas, to make new contacts, and perhaps to investigate cross-disciplinary research. This year the conferences was held on the beautiful campus of the University of Calgary, and many participants took the opportunity to tour nearby Banff and the magnificent Rocky Mountains.

To mark the second quarter-century of the conference, we invited three of the founders of the society to give invited talks: Zenon Pylyshyn, Alan Mackworth, and Len Schubert. Their foresight and efforts, at that time and continuing until this, mark a milestone in Canadian AI worth celebrating. Canadians are reputedly overly modest (although we boast about our olympic gold medals!). However, at AI 2002, we wished to applaud those who first recognized that Canadian AI researchers need a society to support them – to give them an identity, a community, and a voice.

We are grateful to many: to the American Association for Artificial Intelligence and to the National Research Council Canada for supporting the Graduate Symposium, allowing many graduate students to attend and to display and present their work; to CSCSI's president Bob Mercer for keeping the flame, and to its treasurer Howard Hamilton for tending it; to Camille Sinanan for coordinating the local arrangements for all three conferences; to Ali Ghorbani the AI 2002 chair; to the program committee and the referees for their dedication to the vital task of assessing scientific content; to the authors for contributing the material that is the main attraction; again to our invited speakers; to Alfred Hofmann and Karin Henzold of Springer-Verlag for their assistance in preparing these proceedings; to the organizers of VI and GI conferences for their collegiality while coordinating from a distance; and to the partipants, for making all of the effort worthwhile.

May 2002 Robin Cohen, Bruce Spencer

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Modeling Organizational Rules in the Multi-agent Systems Engineering Methodology

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Abstract. Recently, two advances in agent-oriented software engineering have had a significant impact: the identification of interaction and coordination as the central focus of multi-agent systems design and the realization that the multi-agent organization is distinct from the agents that populate the system. This paper presents detailed guidance on how to integrate organizational rules into existing multi-agent methodologies. Specifically, we look at the Multi-agent Systems Engineering models to investigate how to integrate the existing abstractions of goals, roles, tasks, agents, and conversations with organizational rules and tasks. We then discuss how designs can be implemented using advanced as well as traditional coordination models.

1 Introduction

Over the last few years, two conceptual advances in agent-oriented software engineering have had a significant impact on our approach toward building multi-agent systems. The first of these was identification of interaction and coordination as the central focus of multi-agent systems design. That is, interaction and coordination play a central role in the analysis and design of multi-agent systems and makes the multi-agent approach significantly different from other approaches towards building distributed or intelligent systems. This realization lead to several new methodologies for building multi-agent systems that focused on the interaction between agents as the critical design aspect. Several agent-oriented methodologies fit this form including MaSE 3, Gaia 10, and MESSAGE 7.

The second, more recent advancement is the division of the agents populating a system from the system organization 11. While agents play roles *within* the organization, they do not constitute the organization. The organization itself is part of the agent's environment and defines the social setting in which the agent must exist. An organization includes *organizational structures* as well as *organizational rules,* which define the requirements for the creation and operation of the system. These rules include constraints on agent behavior as well as their interactions. There are separate responsibilities for agents and organizations; the organization, not the agents, should be responsible for setting and enforcing the organization rules.

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Organizational design has many advantages over traditional multi-agent systems design methods. First, it defines a clean separation between the agent and the organization in which the agent works, which in turn simplifies each design. In traditional agent-oriented approaches, the rules that govern interaction must be incorporated into the agents themselves, thus intertwining the organizational design in various agent designs. Secondly, separating the organization from the agent allows the developer to build a separate organizational structure that can enforce the organizational rules. This is especially critical in open systems where we do not know the intent of the agents working within the system.

While these advances are rather recent, there have been some discussions on how to incorporate them into existing multi-agent systems methodologies. For instance, there is a proposal to modify the Gaia multi-agent systems methodology to incorporate the notion of social laws 12. Other approaches view the organization as a separate *institutional agent* 9. However, these proposals have been made at a high level and do not provide concrete guidance on how to use existing analysis and design abstractions with advanced coordination models and organizational concepts. Also, the advent of more powerful coordination models, such as hybrid coordination media, have allowed us to imagine new ways of implementing organization rules. With these advanced models, we can now embed organizational rules in the coordination media instead of implementing them internal to the individual agents 1.

The goal of this paper is to present more detailed guidance on how to integrate organizational rules into existing multi-agent methodologies. Specifically, we will look at the Multi-agent Systems Engineering (MaSE) analysis and design models to investigate how to integrate the existing abstractions of goals, roles, tasks, agents, and conversations with organizational rules. We will also briefly take a look at how we can use advanced coordination models to implement multi-agent systems that separate agents from the organizational rules that govern them. We believe that extending existing conversation-based multi-agent analysis and design approaches with organizational rules is a major step toward building coherent, yet adaptive multi-agent systems in a disciplined fashion. While one might be tempted to simply throw out the concept of conversations altogether in favor of some of the more powerful models being proposed, we resist that urge for two basic reasons. First, conversation-based approaches are widely understood and provide an easily understandable metaphor for agent-to-agent communication. Second, conversation-based approaches have shown that they are verifiable and give designers some measure of system coherence 5. Using the full power of these coordination models without restraint could lead to multi-agent system designs that are not understandable, verifiable, or coherent.

In Section 2, we discuss how to model organizational rules MaSE. In Section 2.1, we look at the analysis phase where we add the notion of organizational rules to the existing MaSE analysis models. In Section 2.1.4 we show how to map the various analysis artifacts, including organizational rules, into an enhanced design model that explicitly models the organization through the notion of organizationally based tasks. Finally, in Section 3 we show how these organizational tasks might be implemented. We end with a discussion of our results and conclusions in Section 4.

2 Modeling Organizational Rules In MaSE

In this section we show how we have extended the MaSE analysis and design phases to take advantage of the concept of organizational rules. In the analysis phase, we add a new model, the organizational model, to capture the organizational rules themselves, while in the design phase, we introduce the concept of organizationally-based tasks to carry out specific tasks that are part of the organization and do not belong to a specific agent. These tasks are often used to implement and enforce the organizational rules defined during analysis.

Throughout this paper, we will use the conference management example as defined in 11. The conference management system is an open multi-agent system supporting the management of various sized international conferences that require the coordination of several individuals and groups. There are five distinct phases in which the system must operate: submission, review, decision, and final paper collection. During the submission phase, authors should be notified of paper receipt and given a paper submission number. After the deadline for submissions has passed, the program committee (PC) has to review the papers by either contacting referees and asking them to review a number of the papers, or reviewing them themselves. After the reviews are complete, a decision on accepting or rejecting each paper must be made. After the decisions are made, authors are notified of the decisions and are asked to produce a final version of their paper if it was accepted. Finally, all final copies are collected and printed in the conference proceedings. The conference management system consists of an organization whose membership changes during each stage of the process (authors, reviewers, decision makers, review collectors, etc.). Also, since each agent is associated with a particular person, it is not impossible to imagine that the agents could be coerced into displaying opportunistic, and somewhat unattractive, behaviors that would benefit their owner to the detriment of the system as a whole. Such behaviors could include reviewing ones own paper or unfair allocation of work between reviewers, etc.

2.1 The Analysis Phase

The purpose of the MaSE analysis phase is to produce a set of roles whose tasks describe what the system has to do to meet its overall requirements. A role describes an entity that performs some function within the system. In MaSE, each role is responsible for achieving, or helping to achieve specific system goals or sub-goals. Because roles are goal-driven, we also chose to abstract the requirements into a set of goals that can be assigned to the individual roles. Our approach is similar to the notions used in the KAOS 6. The overall approach in the MaSE analysis phase is fairly simple. Define the system goals from a set of functional requirements and then define the roles necessary to meet those goals. While a direct mapping from goals to roles is possible, MaSE suggests the use of use cases to help validate the system goals and derive an initial set of roles. As stated above, the ultimate objective of the analysis phase is to transform the goals and use cases into roles and their associated tasks since they are forms more suitable for designing multi-agent systems. Roles form the foundation for agent classes and represent system goals during the design phase, thus the system goals are carried into the system design. To support organizational rules, the MaSE analysis phase was extended with an explicit organizational model, which is developed as the last step in the analysis phase and is defined using concepts from the role and ontology models.

2.1.1 Role Model

Due to space limitations, we will skip the goal and use case analysis for the conference system example and jump right to the role model. The MaSE role model depicts the relationships between the roles in the conference management system, as shown in Fig. 1. In Fig. 1, a box denotes each role while a directed arrow represents a protocol between roles, with the arrows pointing away from the initiator to the responder. Notice that while we referred to the PC chair and PC members in the problem description, we have intentionally abstracted out the roles played by those typical positions into partitioning, assigning reviews, reviewing papers, collecting reviews, and making the final decision. As we will see later, this provides significant flexibility in the design phase. The system starts by having authors submit papers to a paper database (PaperDB) role, which is responsible for collecting the papers, along with their abstracts, and providing copies to reviewers when requested. Once the deadline has past for submissions, the person responsible partitioning the entire set of papers into groups to be reviewed (the Partitioner role) asks the PaperDB role to provide it the abstracts of all papers. The Partitioner partitions the papers and assigns them to a person (the Assigner) who is responsible for finding *n* reviewers for each paper. Once assigned a paper to review, a Reviewer requests the actual paper from the PaperDB, prepares a review, and submits the review to the Collector. Once all (or enough) of the reviews are complete, the Decision Maker determines which papers should be accepted and notifies the authors.

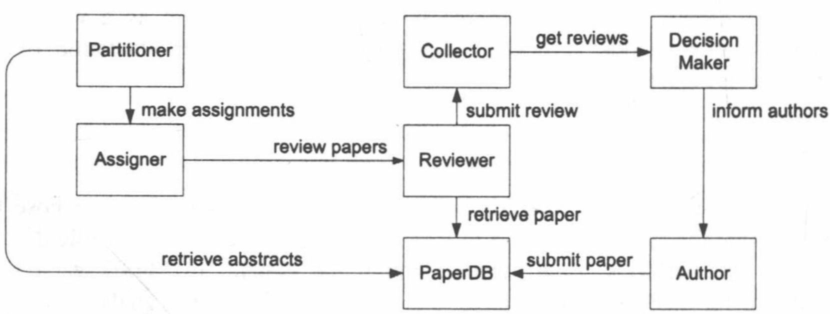

Fig. 1. Role Model for Conference Management System

Thus, we have identified seven explicit roles. However, in MaSE, we do not stop at simply identifying the roles, we also identify the tasks that the roles must perform in accomplishing their goals. Therefore, a more detailed version of the conference management system role model is shown in Fig. 2. In MaSE, we have extended the traditional role model by adding the tasks (shown using ellipses attached to each role). Generally, each role performs a single task, whose definition is straightforward and documented in a concurrent task diagram (not discussed here due to space limitations), which define agent behaviour and interaction via finite state machines. However, some roles, such as the Paper DB or Reviewer roles have multiple tasks. For instance, the Paper DB role has three tasks: Collect Papers, Distribute Papers, and Get Abstracts. While the tasks are related, they are distinct and are thus modelled separately. The Collect Papers task accepts papers, ensures they are in the right format and meet all the eligibility requirements. The Get Abstracts task extracts the abstract from submitted papers and sends them to a Partitioner. The Distribute Papers task simply distributes accepted papers to the appropriate Reviewers when requested.

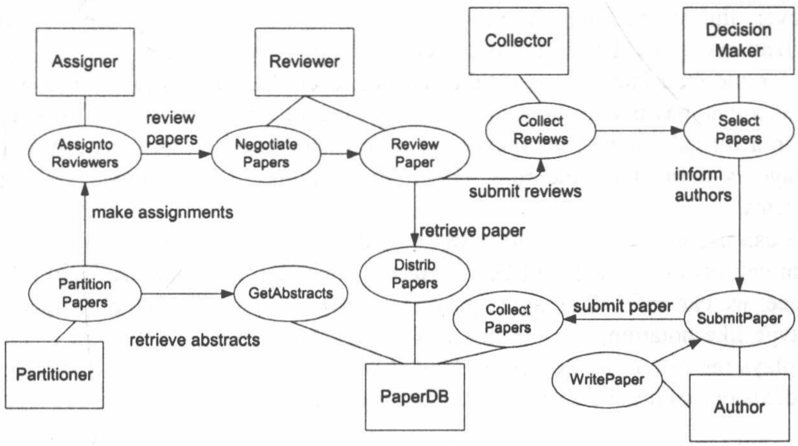

Fig. 2. Expanded MaSE role model

2.1.2 Ontology Model

The next step in the MaSE analysis phase is to develop an Ontology Model, which defines the data types and their relationships within the system 4. Fig. 3 shows an ontology model for the conference review system. The ontology is focused around the central data type, a paper, each with an associated abstract and a set of reviews. Given the ontology, we can talk about the reviews a paper has received *paperReview(p)* or a paper's abstract *paperAbstract(p)*, etc. There are also constraints placed on the data via the ontology. For instance, each abstract must have exactly one paper and each paper must have exactly one abstract. Also, a review can only exist on a single paper, while a paper may have any number of reviews on it (including none). Thus several organizational constraints can be defined in the ontology itself. Using the ontology model, we can extract a number of functions to describe the data in our system. The functions and their resulting types for the conference management system are shown in Table 1. These functions can be used in conjunction with protocol functions to describe many relationships, as we will see in the next section.

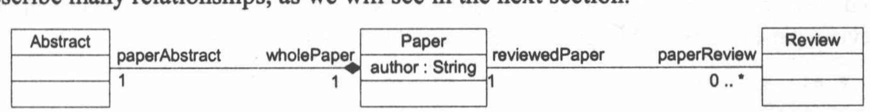

Fig. 3. Conference Management Ontology

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