A Framework for Organization-Aware Agents

Open systems are characterized by the presence of a diversity of heterogeneous and autonomous agents that act according to private goals. Organizations, such as those used in real-life to structure human activities such as task allocation, coordination and supervision, can regulate the agents’ behavior space and describe the expected behavior of the agents. Assuming an open environment, where agents are developed independently of the Organizational structures, agents need to be able to reason about the structure, so that they can deliberate about their actions and act within the expected boundaries and work towards the objectives of the organization. In this paper, we present the AORTA reasoning framework and show how it can be integrated into typical BDI-agents. We provide operational semantics that enables agents to make organizational decisions in order to coordinate and cooperate without explicit coordination mechanisms within the agents. The organizational model is independent of that of the agents, and the approach is not tied to a specific organizational model, but uses an organizational metamodel. We show how AORTA helps agents work together in a system with an organization for choosing the best tender for a building project.
A Framework for Organization-Aware Agents: JAAMAS Extended Abstract

This short paper introduces and summarizes the AORTA reasoning framework that can be integrated into BDI-agents to enable organizational decision-making. This work has recently been published in the Journal of Autonomous Agents and Multi-Agent Systems (JAAMAS), as [3].

General information

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Delft University of Technology
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Main Research Area: Technical/natural sciences
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Interfacing Agents to Real-Time Strategy Games
In real-time strategy games players make decisions and control their units simultaneously. Players are required to make decisions under time pressure and should be able to control multiple units at once in order to be successful. We present the design and implementation of a multi-agent interface for the real-time strategy game STARCRAFT: BROOD WAR. This makes it possible to build agents that control each of the units in a game. We make use of the Environment Interface Standard, thus enabling different agent programming languages to use our interface, and we show how agents can control the units in the game in the Jason and GOAL agent programming languages.

Plan-Belief Revision in Jason
When information is shared between agents of unknown reliability, it is possible that their belief bases become inconsistent. In such cases, the belief base must be revised to restore consistency, so that the agent is able to reason. In some cases the inconsistent information may be due to use of incorrect plans. We extend work by Alechina et al. to revise belief bases in which plans can be dynamically added and removed. We present an implementation of the algorithm in the AgentSpeak implementation Jason.
The AORTA Reasoning Framework - Adding Organizational Reasoning to Agents

Intelligent agents are entities defined by, among other things, autonomy. In systems of many agents, the agents’ individual autonomy can lead to uncertainty since their behavior cannot always be predicted. Usually, this kind of uncertainty is accommodated by imposing an organization upon the system; an organization that defines expected behavior of the agents and attempts to restrict the agents’ behavior to let it match the expectations. Restrictions can lead to a decrease in autonomy, contradicting one of the pillars of intelligent agents.

This thesis presents the AORTA reasoning framework, which is a practical component (founded in logic) that enriches intelligent agents with organizational reasoning capabilities. We take the agent’s perspective by devising a component that integrates with the agent’s usual reasoning capabilities in a non-intrusive way. This results in agents that are both organization-aware and autonomous. The reasoning component makes them organization-aware, and their autonomy is intact because the component does not change the existing reasoning mechanisms. As such, it allows the agents to decide whether to adhere to the system’s expectations.

The ability to reason about organizations has previously been successfully integrated into agent programming languages. However, the operationalization of an organization is usually tailored to a specific language. This makes it hard to apply the same approach to other languages and platforms. The AORTA reasoning framework distinguishes itself by being a generic framework that allows different kinds of agents to reason about different kinds of organizations.

We present our results in three main parts. In the first part, we present the theoretical foundations for the AORTA framework, which consists of semantics of norms, an organizational metamodel, and the AORTA reasoning component. The reasoning component is characterized by being completely decoupled from the cognitive agent, by its automated reasoning about norms and organizational options, and by the reasoning rules specified by the designer to act upon norms and options. We specify the reasoning component using structural operational semantics providing us with a formal, rigid description of the behavior of the component during execution. This enables us to precisely specify each reasoning phase (using transition rules), and it makes the implementation of the system quite straightforward.

The second part moves from theory to practice: we present an implementation of the framework and integrate it into various agent platforms. We show that the same configuration of the component can be used for different agent platforms, providing evidence for its use as a general tool for organization-awareness. Furthermore, we use practical verification to show various properties of an implementation of agents and of the system in general.

In the last part, we discuss a potential issue with our framework. The possibility to commit to organizational objectives can affect the agent’s autonomy, which contradicts our main goal. We propose a model that solves this problem by adding a filter to the agent’s decision procedure that takes consequences of fulfilling a goal into account before deciding to commit to it. By considering both the agent’s preferences and the expected outcome of fulfilling the goal, we show that it was possible for the agents to make qualified context-dependent decisions.

We claim that by using the AORTA reasoning framework, agents become organization-aware. The reasoning component provides capabilities to reason about organizations and our decision procedure ensures that the autonomy of the agents is still intact.
AORTA: Adding Organizational Reasoning to Agents: Extended abstract

Open systems are characterized by a diversity of heterogeneous and autonomous agents that act according to private goals, and with a behavior that is hard to predict. They can be regulated through organizations similar to human organizations, which regulate the agents’ behavior space and describe the expected behavior of the agents. Agents need to be able to reason about the regulations, so that they can act within the expected boundaries and work towards the objectives of the organization.

This extended abstract introduces AORTA, a component that can be integrated into agents’ reasoning mechanism, allowing them to reason about (and act upon) regulations specified by an organizational model using simple reasoning rules. The added value is that the organizational model is independent of that of the agents, and that the approach is not tied to a specific organizational model.

The AORTA Architecture: Integrating Organizational Reasoning in Jason

Open systems are characterized by a diversity of heterogeneous and autonomous agents that act according to private goals, and with a behavior that is hard to predict. They can be regulated through organizations similar to human organizations, which regulate the agents’ behavior space and describe the expected behavior of the agents. Agents need to be able to reason about the regulations, so that they can act within the expected boundaries and work towards the objectives of the organization. In this paper, we propose the AORTA architecture for making agents organization-aware. It is designed such that it provides organizational reasoning capabilities to agents implemented in existing agent programming languages without being tied to a specific organizational model. We show how it can be integrated in the Jason agent programming language, and discuss how the agents can coordinate their organizational tasks using AORTA.
organizations, which regulate the agents' behavior space and describe the expected behavior of the agents. Agents need to be able to reason about the regulations, so that they can act within the expected boundaries and work towards the objectives of the organization. In this paper, we describe the AORTA (Adding Organizational Reasoning to Agents) architecture for making agents organization-aware. It is designed such that it provides organizational reasoning capabilities to agents implemented in existing agent programming languages without being tied to a specific organizational model. We show how it can be integrated in the Jason agent programming language, and discuss how the agents can coordinate their organizational tasks using AORTA.

A Comparison of Organization-Centered and Agent-Centered Multi-Agent Systems

Whereas most classical multi-agent systems have the agent in center, there has recently been a development towards focusing more on the organization of the system, thereby allowing the designer to focus on what the system goals are, without considering how the goals should be fulfilled.

We have developed and evaluated two teams of agents for a variant of the well-known Bomberman computer game. One team is based on the basic Jason system, which is an implementation in Java of an extension of the logic-based agent-oriented programming language AgentSpeak. The other team is based on the organizational model Moise+, which is combined with Jason in the middleware called J-Moise+.

We have investigated whether taking the organization-oriented approach had any clear advantages to the classical way of implementing multi-agent systems. Although not decisive the investigation did indicate that the agent-oriented approach has a number of advantages when it comes to game-like scenarios with just a few different character types.
Belief Revision in the GOAL Agent Programming Language

Agents in a multiagent system may in many cases find themselves in situations where inconsistencies arise. In order to properly deal with these, a good belief revision procedure is required. This paper illustrates the usefulness of such a procedure: a certain belief revision algorithm is considered in order to deal with inconsistencies and, particularly, the issue of inconsistencies, and belief revision is examined in relation to the GOAL agent programming language.

Deciding between Conflicting Influences

This paper investigates an approach of decision making internally in an agent where a decision is based on preference and expectation. The approach uses a logic for qualitative decision theory proposed by Boutilier to express such notions. To make readily use of this we describe a simple method for generating preference and expectation models that respect certain rules provided by the agents, and we briefly discuss how to integrate the approach into an existing agent programming language.
Deciding Between Conflicting Influences
This paper investigates an approach of decision making internally in an agent in which a decision is based on both preference and expectation. The approach uses a logic for qualitative decision theory proposed by Boutilier in order to express such notions. To make readily use of this we describe a simple method for generating preference and expectation models that respect certain rules provided by the agents.

Dimensions of Organizational Coordination
It is hard, if not impossible, to assume anything about agents' behavior in a society with heterogeneous agents from different sources. Organizations are used to restrict and guide the agents' actions such that the global objectives of the society are achieved. We discuss how agents can be supported to include organizational objectives and constraints into their reasoning processes by considering two alternatives: agent reasoning and middleware regulation. We show how agents can use an organizational specification to achieve organizational objectives by delegating and coordinating their activities with other agents in the society, using the GOAL agent programming language and the OperA organizational model.
**Engineering a Multi-Agent System in GOAL**

We provide a brief description of the GOAL-DTU system, including the overall design, the tools and the algorithms that we used in the Multi-Agent Programming Contest 2013. We focus on a description of the strategies and on an analysis of the matches. We also evaluate our experiences with the GOAL agent programming language. Our strategies worked well in general and we earned a second place in the contest only losing to the winning team. Finally we provide some suggestions for future contests.

**General information**

State: Published  
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Technical University of Denmark  
Authors: Villadsen, J. (Intern), Jensen, A. S. (Intern), Christensen, N. C. (Ekstern), Hess, A. V. (Ekstern), Johnsen, J. B. (Ekstern), Woller, Ø. G. (Ekstern), Ørum, P. B. (Ekstern)  
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**Formalizing Theatrical Performances Using Multi-Agent Organizations**

Theatrical performances usually follow strict scripts and actors are not allowed to deviate. A Danish theatrical group, Theater 770° Celsius, has invented a new method called In Real Life, in which only certain events in the storyline are specified and the actors are supposed to improvise to reach these events. The method bears a resemblance to multi-agent systems and we show how it can be formalized using the multi-agent organizational model OperA.

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Main Research Area: Technical/natural sciences  
Conference: 12th Scandinavian Conference on Artificial Intelligence (SCAI 2013), Aalborg, Denmark, 20/11/2013 - 20/11/2013
Multi-Agent Programming Contest 2013: The Teams and the Design of Their Systems

Five teams participated in the Multi-Agent Programming Contest in 2013: All of them gained experience in 2012 already. In order to better understand which paradigms they used, which techniques they considered important and how much work they invested, the organisers of the contest compiled together a detailed list of questions (circa 50). This paper collects all answers to these questions as given by the teams.

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Technical University of Denmark, Federal University of Santa Catarina
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Publication date: 2013

On Programming Organization-Aware Agents

Since it is difficult (or even impossible) to assume anything about the agents’ behavior and goals in an open multi-agent system, it is often suggested that an organization is imposed upon the agents, which, by abstracting away from the agents, specifies boundaries and objectives that the agents, by enacting roles, are expected to adhere to. In practice, this is usually done by creating a middleware, which acts as a bridge between an organizational specification and the agents, often taking away too much of the agents’ autonomy. This project investigates how to make agents organization-aware, thus removing the middleware and letting the agents directly reason about the organization. In this paper, we discuss the results so far, and describe the future goals and research direction for the project.

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Authors: Jensen, A. S. (Intern)
Pages: 287-290
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Reimplementing a Multi-Agent System in Python

We provide a brief description of our Python-DTU system, including the overall design, the tools and the algorithms that we used in the Multi-Agent Programming Contest 2012, where the scenario was called Agents on Mars like in 2011. Our solution is an improvement of our Python-DTU system from last year. Our team ended in second place after winning at least one match against every opponent and we only lost to the winner of the tournament. We briefly describe our experiments with the Moise organizational model. Finally we propose a few areas of improvement, both with regards to our system and to the contest.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Technical University of Denmark
Authors: Villadsen, J. (Intern), Jensen, A. S. (Intern), Ettienne, M. B. (Intern), Vester, S. (Intern), Andersen, K. B. (Ekstern), Frøsig, A. (Ekstern)
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Number: IfI-13-01
ISSN: 1860-8477
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Links: http://www.in.tu-clausthal.de/fileadmin/homes/techreports/ifi1301koester.pdf
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Multi-Agent Programming Contest 2012 - The Python-DTU Team

We provide a brief description of the Python-DTU system, including the overall design, the tools and the algorithms that we plan to use in the agent contest.

General information
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Organisations: Department of Informatics and Mathematical Modeling, Algorithms and Logic, Department of Applied Mathematics and Computer Science, Algorithms and Logic, Technical University of Denmark
Authors: Villadsen, J. (Intern), Jensen, A. S. (Intern), Ettienne, M. B. (Intern), Vester, S. (Intern), Balsiger Andersen, K. (Ekstern), Frøsig, A. (Ekstern)
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Source: dtu
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Publication: Research - peer-review › Report – Annual report year: 2012

Paracconsistent Computational Logic

In classical logic everything follows from inconsistency and this makes classical logic problematic in areas of computer science where contradictions seem unavoidable. We describe a many-valued paraconsistent logic, discuss the truth tables and include a small case study.

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Editors: Blackburn, P., Jørgensen, K. F., Jones, N., Palmgren, E.
Main Research Area: Technical/natural sciences
Conference: 8th Scandinavian Logic Symposium, Roskilde, Denmark, 20/08/2012 - 20/08/2012
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Source: dtu
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Publication: Research - peer-review › Article in proceedings – Annual report year: 2012
Improving Multi-Agent Systems Using Jason

We describe the approach used to develop the multi-agent system of herders that competed as the Jason-DTU team at the Multi-Agent Programming Contest 2010. We also participated in 2009 with a system developed in the agent-oriented programming language Jason which is an extension of AgentSpeak. We used the implementation from 2009 as a foundation and therefore much of the work done this year was on improving that implementation. We present a description which includes design and analysis of the system as well as the main features of our agent team strategy. In addition we discuss the technologies used to develop this system as well as our future goals in the area.

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Organisations: Department of Informatics and Mathematical Modeling, Algorithms and Logic, Technical University of Denmark
Authors: Vester, S. (Intern), Boss, N. S. (Ekstern), Jensen, A. S. (Intern), Villadsen, J. (Intern)
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Scopus rating (2013): SJR 0.405 SNIP 0.89 CiteScore 0.94
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ISI indexed (2012): ISI indexed yes
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Scopus rating (2011): SJR 0.416 SNIP 1.084 CiteScore 0.78
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Scopus rating (2006): SJR 0.547 SNIP 1.064
Scopus rating (2005): SJR 0.663 SNIP 1.325
Scopus rating (2004): SJR 0.542 SNIP 1.614
Building Multi-Agent Systems Using Jason

We provide a detailed description of the Jason-DTU system, including the used methodology, tools as well as team strategy. We also discuss the experience gathered in the contest. In spring 2009 the course "Artificial Intelligence and Multi-Agent Systems" was held for the first time on the Technical University of Denmark (DTU). A part of this course was a short introduction to the multi-agent framework Jason, which is an interpreter for AgentSpeak, an agent-oriented programming language. As the final project in this course a solution to the Multi-Agent Programming Contest from 2007, the Gold Miners scenario, was implemented. Finally we decided to participate in this year’s contest with an implementation made in Jason as well.

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Scopus rating (2015): SJR 0.562 SNIP 0.94 CiteScore 0.93
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.532 SNIP 1.333 CiteScore 1.08
Web of Science (2014): Indexed yes
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ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.367 SNIP 1.012 CiteScore 0.65
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.416 SNIP 1.084 CiteScore 0.78
Multi-Agent Programming Contest 2010 - The Jason-DTU Team

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Organisations: Algorithms and Logic, Department of Informatics and Mathematical Modeling, Technical University of Denmark
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Number of pages: 4
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Developing Artificial Herders Using Jason

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Authors: Boss, N. S. (Ekstern), Jensen, A. S. (Intern), Villadsen, J. (Intern)
Pages: 193-197
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Source: orbit
Source-ID: 256989
Publication: Research - peer-review › Book chapter – Annual report year: 2009

Projects:

Organization-Oriented Programming in Multi-Agent Systems
Technical University of Denmark
Period: 15/03/2012 → 21/09/2015
Number of participants: 5
Phd Student:
Jensen, Andreas Schmidt (Intern)
Main Supervisor:
Villadsen, Jørgen (Intern)
Examiner:
Bolander, Thomas (Intern)
Christiansen, Henning (Ekstern)
Hindriks, Koen V. (Ekstern)

Financing sources
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Name of research programme: Institut stipendie (DTU)
Project: PhD