Engineering Multigroup Agents for Complex Cooperative Systems

(Doctoral Consortium)

Denise M. Case
Multiagent and Cooperative Reasoning (MACR) Laboratory
Kansas State University, College of Engineering
Manhattan, KS USA 66506
dmcase@ksu.edu

ABSTRACT

Intelligent agents and multiagent systems (MAS) provide a scalable approach to distributed artificial intelligence [3]. Analogous to intelligent biological entities, agent-based computational systems may become quite complex. Some may consist of multiple cooperating groups, each providing a specialized subset of the total required functionality [4, 6]. My work focuses on engineering *multigroup* agents in cooperative intelligent systems. A reusable multigroup agent architecture has been developed, along with a simulation framework and recommended software engineering practices, to support the implementation of multigroup applications. The architecture is being used to evaluate power quality control algorithms for electrical power distribution systems (PDS).

Categories and Subject Descriptors

D.2.11 [**Software Engineering**]: Software Architectures

General Terms

Design

Keywords

Agent architectures, organization-based agents, distributed artificial intelligence, agent-oriented software engineering

1. INTRODUCTION

Agents are autonomous interactive software entities that may work cooperatively or competitively within the structure of a MAS [4]. The behavior of the MAS is typically driven by a set of goals that are generally decomposed and ultimately assigned to individual agents [8].

In some MAS applications, it may be helpful to design the system as a collection of specialized groups [5], a system we refer to as a *complex MAS*. In a complex MAS, each group may have its own set of specialized goals, and the groups work cooperatively to achieve overall objectives.

Multigroup agents participate in multiple groups and may get assignments from more than one. Standard mechanisms can be helpful for assessing goal consistency and managing the appropriate evaluation, negotiation, and acceptance of tasks before incorporating them into the agent's workflow.

A multigroup agent may represent a complete group within a different group. In some cases the groups may designed recursively, and agents may form remote groups of more distributed agents with an agent representing the distributed organization in a higher-level, more centrally-located group. In our approach, we have designed our multigroup agents as *both an organization and an agent*. This concept of an agent as an organization provides the foundation for our approach to managing the complexity of multigroup agents through implementing a reusable agent architecture.

2. AGENT ARCHITECTURE

Our architecture builds on the Organization-based Agent Architecture (OBAA) [9] designed to support reactive and proactive organization-based agents. Each OBAA agent has a general-purpose Control Component (CC) and an application-specific Execution Component (EC), allowing separation of the general features needed for group participation from the execution of application objectives.

The goal of the multigroup $OBAA^{++}$ architecture is to extend similar reusability to multigroup agents. To do so, we've designed each $OBAA^{++}$ agent as a goal-driven *self organization* of sub-agents [2]. To clarify the distinction between the agent and its sub-agents, we introduce the term *persona* for the sub-agents. Each agent has one persona for each affiliated group and one *self persona* that acts as the central, goal-directed brain of the agent, responsible for initiating and managing the roles and commitments within that affiliated group. Each agent is initialized with a set of goals that drives the behavior of the self persona. They include

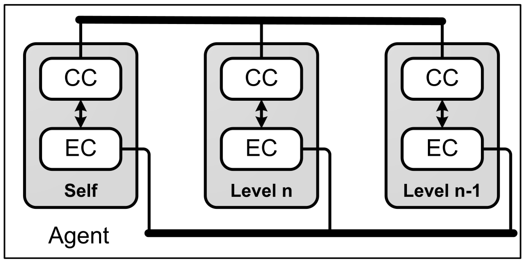
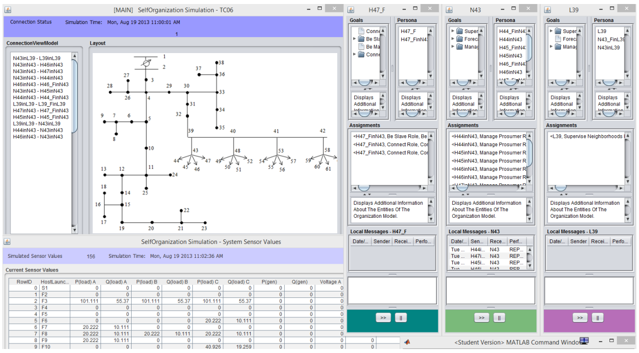


Figure 1: $OBAA^{++}$ agent architecture

Appears in: *Alessio Lomuscio, Paul Scerri, Ana Bazzan, and Michael Huhns (eds.), Proceedings of the 13th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2014), May 5-9, 2014, Paris, France.*



[MAIN] SelfOrganization Simulation - TC06

Connection Status Simulation Time: Mon, Aug 19 2013 11:00:01 AM

1

ConnectionViewModel

N43inL39 - L39inL39
N43inN43 - H46inN43
N43inN43 - H47inN43
N43inN43 - H44inN43
H46inN43 - H46_FinN43
N43inN43 - H45inN43
H44inN43 - H44_FinN43
L39inL39 - L39_FinL39
H47inN43 - H47_FinN43
H45inN43 - H45_FinN43
L39inL39 - N43inL39
H44inN43 - N43inN43
H46inN43 - N43inN43

Layout

SelfOrganization Simulation - System Sensor Values

Simulated Sensor Values 156 Simulation Time: Mon, Aug 19 2013 11:02:36 AM

Current Sensor Values

RowID	HostLaunc...	P(load) A	Q(load) A	P(load) B	Q(load) B	P(load) C	Q(load) C	P(gen)	Q(gen)	Voltage A
0	S1	0	0	0	0	0	0	0	0	0
1	F2	0	0	0	0	0	0	0	0	0
2	F3	101.111	55.37	101.111	55.37	101.111	55.37	0	0	0
3	F4	0	0	0	0	0	0	0	0	0
4	F5	0	0	0	0	0	0	0	0	0
5	F6	0	0	0	0	20.222	10.111	0	0	0
6	F7	20.222	10.111	0	0	0	0	0	0	0
7	F8	20.222	10.111	20.222	10.111	20.222	10.111	0	0	0
8	F9	20.222	10.111	0	0	0	0	0	0	0
9	F10	0	0	0	0	40.926	19.259	0	0	0

H47_F

Goals: Conn... Be Sla... Be Ma... Conn...

Persona: H47_F, H47_FinN4...

Displays Additional Information

Assignments

<H47_FinN43, Be Slave Role, Be
<H47_FinN43, Connect Role, Co
<H47_FinN43, Connect Role, Co

Displays Additional Information About The Entities Of The Organization Model.

Local Messages - H47_F

Date/...	Sender	Recei...	Perfo...

N43

Goals: Super... Forec... Manag...

Persona: H44_FinN4..., H44inN43, H45_FinN4..., H45inN43, H46_FinN4..., H46inN43

Displays Additional Information

Assignments

<H44inN43, Manage Prosumer R
<H44inN43, Manage Prosumer R
<H45inN43, Manage Prosumer R
<H45inN43, Manage Prosumer R
<H46inN43, Manage Prosumer R
<H46inN43, Manage Prosumer R

Displays Additional Information About The Entities Of The Organization Model.

Local Messages - N43

Date/...	Sen...	Rece...	Perf...
Tue ...	H44i...	N43	REP...
Tue ...	H47i...	N43	REP...
Tue ...	H45i...	N43	REP...

L39

Goals: Super... Forec... Manag...

Persona: L39, N43_FinL39, N43inL39

Displays Additional Information

Assignments

<L39, Supervise Neighborhoods

Displays Additional Information About The Entities Of The Organization Model.

Local Messages - L39

Date/...	Sender	Recei...	Perfo...

<Student Version> MATLAB Command Windo

Figure 2: Recursively-optimized IPDS Simulation.

goals for joining and maintaining membership in specified affiliated groups. When a self persona determines that its agent requires a new affiliation, the self persona creates a new persona to join the group. Self persona function similarly for each agent in a complex MAS.

$OBAA^{++}$ assists the designer by providing some key communication and control features as resuable components, sub-agents, and capabilities. Agents can be designed, implemented, and tested individually by supplying appropriate configuration information including the list of affiliated groups, whether the agent is responsible for initially running any of those groups, and how the agent should contact and begin participating in the group. Application-specific behavior is designed and implemented as in OBAA using goals, role behaviors, and capabilities.

3. AOSE & MAS SIMULATION

To enable efficient development and feedback on increasingly complex test cases, my work includes the development of the *AO-MaSE* Agent-Oriented Software Engineering (AOSE) process, an agile-based adaptive methodology compliant with the Organization-based Multi-agent System Engineering process [1] that provides architects and developers a structured approach for iteratively adding functionality to create complex adaptive systems.

4. POWER DISTRIBUTION HMAS

$OBAA^{++}$, *AO-MaSE*, and the MAS simulation framework are being used as the basis for the *Intelligent Power Distribution System* (IPDS) project that aims to evaluate control algorithms in electrical power distribution systems. The work involves the development of a *holonic* multiagent system (HMAS). *Holonic* is the merger of *holos* (whole) and *on* (parts) [7], and indicates a single agent may recursively represent an entire lower group of agents while acting as part of a higher-level group. This allows our agents to optimize locally in lower-level distributed groups first while progressively optimizing towards increasingly higher-level centrally-viable solutions. A portion of the IPDS HMAS simulation is shown in Figure 2; current test cases include 62 hosts, 124 agents, 46 organizations, and 110 inter-agent connections.

5. INTERDISCIPLINARY ASPECTS

My research in cooperative intelligent systems supports several interdisciplinary interests. Our architecture was designed to emulate installation in intelligent *cyber-physical systems* (CPS). Communication, cooperation, validation, and management of goal consistency are crucial. Inspiration comes from recent work in the areas of complex biological systems, human and agent cooperation, game theory, machine learning, and natural and artificial intelligence.

6. FUTURE WORK

Future work is focused on managing goal consistency among multigroup agents supporting the objectives of multiple groups while reflecting differing degrees of selfishness and cooperation. We hope to develop additional architectural aspects and processing algorithms to assist with managing goal consistency in complex systems. We hope to extend the functionality of the evaluated control algorithms in the IPDS project and are planning on scaling test cases to 400 hosts and 800 agents to evaluate the effects of spatial correlations in the distributed control application and further assess the scalability of the IPDS architecture. We also plan on extending the agent-based simulation framework to include additional MatLab-powered *sensor simulators* and *actuator adapters* as a configurable set of standard interfaces to the simulated environment.

7. ACKNOWLEDGMENTS

We thank the US National Science Foundation for providing support for the work via Award No. CNS-1136040.

8. REFERENCES

[1] D. M. Case and S. A. DeLoach. Applying an O-MaSE compliant process to develop a Holonic Multiagent System for the evaluation of Intelligent Power Distribution Systems. In *Engineering Multi-Agent Systems*, pages 78–96. Springer, 2013.

[2] D. M. Case and S. A. DeLoach. OBAA++: An Agent Architecture for Participating in Multiple Groups. In *Proceedings of the 13th Intl Conference on Autonomous Agents and Multiagent Systems*, 2014.

[3] J. Ferber. *Multi-Agent Systems: an Introduction to Distributed Artificial Intelligence*, volume 1. Addison-Wesley Reading, 1999.

[4] J. Ferber, O. Gutknecht, and F. Michel. From agents to organizations: an organizational view of multi-agent systems. In *Agent-Oriented Software Engineering IV*, pages 214–230. Springer, 2004.

[5] B. Horling and V. Lesser. A survey of multi-agent organizational paradigms. *The Knowledge Engineering Review*, 19(4):281–316, 2004.

[6] S. Kauffman. *At Home in the Universe: The search for the laws of self-organization and complexity*. Oxford University Press, 1996.

[7] A. Koestler. *The Ghost in the Machine*. Macmillan, 1968.

[8] A. Van Lamsweerde. Goal-oriented requirements engineering: A guided tour. In *Requirements Engineering, 2001. Proceedings. Fifth IEEE Intl Symposium on*, pages 249–262. IEEE, 2001.

[9] C. Zhong and S. A. DeLoach. Runtime models for automatic reorganization of multi-robot systems. In *Proceedings of the 6th Intl Symposium on Software Engineering for Adaptive and Self-Managing Systems*, pages 20–29. ACM, 2011.