Workshop on Agent Supported Cooperative Work (ASCW01) at 5th International Conference on Autonomous Agents, Montreal, Canada, May 29, 2001

From Work Practice Models and Simulation To Implementation of Human-Centered Agent Systems

Maarten Sierhuis
RIACS/USRA
NASA/Ames Research Center
Mail Stop 19-39
Moffett Field, CA 90435
USA
(+01) 650-604-4917
msierhuis@mail.arc.nasa.gov

Ron van Hoof
QSS
NASA/Ames Research Center
Mail Stop 269-3
Moffett Field, CA 90435
USA
(+01) 203-531-4741
rvanhoof@mail.arc.nasa.gov

William J. Clancey
NASA/Ames Research Center
Computational Sciences
Mail Stop 269-3
Moffett Field, CA 90435
USA
(+01) 650-604-2526
bclancey@mail.arc.nasa.gov

Mike Scott
QSS
NASA/Ames Research Center
Mail Stop 269-3
Moffett Field, CA 90435
USA
(+01) (212) 941-1845
mscott@ptolemy.arc.nasa.gov

ABSTRACT
In this paper we describe an agent-based software development environment for developing agent systems that are fundamentally based on a holistic analysis of the human and software agent organization and work practices for which the agent system is to be developed. Brahms is an agent modeling, simulation and development environment developed at NASA Ames Research Center. Brahms stems from a decade of research on modeling and simulating human work practices. As a result of this research, partly at NASA Ames and partly in industry, we are now working on extending the environment to allow for the design and implementation of software systems that are fundamentally based on work practice and include software agents that have a dynamic representation of the human- and software agents it is collaborating with.

Keywords
multi-agent, modeling, simulation, intelligent agents, work practice, activity

1. Modeling and simulating work practice

Work practice is a concept that originates in socio-technical systems, business anthropology, work systems design, and management science.

The notion of "practice" is central to work systems design, which has its roots in the design of socio-technical systems, a method developed in the 1950s by Eric Trist and Fred Emery [1]. *Socio-technical systems design* sought to analyze the relationship of the social system and the technical system, such as manufacturing machinery, and then design a "socio-technical system" that leveraged the advantages of each. *Work systems design* extends this tradition by focusing on both the formal features of work (explicit, intentional) and the informal features of work (as it is actually carried out "in practice," analyzed with the use of ethnographic techniques) [2] [3] [4] [5, chapter 16].

A work practice is defined as the collective activities of a group of people who collaborate and communicate, while performing these activities synchronously or asynchronously. Most often, people view work merely as the process of transforming input to output, i.e. a Tayloristic view of work. For example, when building a house the input and output of the work is well defined. Sometimes however, it is more difficult to describe the input and output of the work. For example, consider a soccer match between two professional soccer teams. It is difficult to define the input and output of this type of work, although most of us would agree that professional soccer players are working. To describe the work of a soccer team we quickly fall into descriptions about teamwork and collaboration on the field.

We claim that the individual activities that make up the work not only have to do with the transformation of input to output, but more importantly with the collaboration between individuals in action, in pursuit of a goal. Imagine soccer players who collaborate in their activities of kicking a soccer ball, in pursuit of scoring a goal. Just focusing on the in- and output of each individual activity of a soccer player would not only be very difficult, if not impossible, it would also miss the opportunity to understand what is really going on in this work. However, in the past century work has been defined as the transformation of input to output, starting with Frederick W. Taylor's view of work to Michael Hammer's view of business processes [6].

We take a different view, and are interested in describing work as a practice, a collection of psychologically and socially situated collaborative activities between members of a group. We try to understand how, when, where, and why collaborative activities are performed, and identify the effects of these activities, as well as to understand the reasons why these activities occur in the way they do. Therefore, the central theme is to find a representation for *modeling work practice*. Many researchers in the social sciences use the word practice as if it is a well-defined concept that everyone understands. However, it is difficult to describe what a practice is. People notice when something is not a practice, and can often describe why. Although it can be said that a group of people has developed a practice, when asked to describe what that practice is, and what it consists of, we find it difficult to describe in words. As such, practice is part of our tacit knowledge [7].

An ad hoc definition of the word practice is: *The (collaborative) performance of situated activities in real life situations, by making use of knowledge previously gained through experience in performing similar activities.*

In short, practice is doing in action [8]. Scientists have described how a practice develops, like Wenger, who defines the creation of a practice as follows [9]:

Being alive as human beings means that we are constantly engaged in the pursuit of enterprises of all kinds, from ensuring our physical survival to seeking the most lofty pleasures. As we define these enterprises and engage in their pursuit together, we interact with each other and with the world and we tune our relations with each other and with the world accordingly. In other words, we learn. Over time, this collective learning results in practices, which reflect both the pursuit of our enterprises and the attendant social relations. These practices are thus the property of a kind of community created over time by the sustained pursuit of a shared enterprise.

Everybody knows what Wenger means when he says, "this collective learning results in practices", but what is it that results? Can it be described? Can it be modeled? To do this we need to be able to describe practice at an epistemological level we call the *work practice level*. In the rest of this paper, we will discuss a representational language to represent models of work practice. These models can be simulated in order to show the effects of the activities of people and their communication, being situated in a geographical environment, and using tools and artifacts to perform their collaborative work.

Work practice includes those aspects of the work process that make people behave a certain way in a specific situation, at a specific moment in time, in the real world. To describe people's situation-specific behavior we need to include those aspects of the situation that explain the influence on the *activity behavior* of individuals (in contrast with problem-solving behavior), such as *people's collaboration, "off-task" behaviors, multi-tasking, interrupted and resumed activities, informal interaction, knowledge and geography* [10] [11].

Brahms is a modeling and simulation environment for representing work practice in a rule-based agent language, which can be simulated using the Brahms rule-based, multi-agent simulation engine. At NASA we have used Brahms to model and simulate the work practices of the Apollo astronauts, as well as the human-robot collaboration for a semi-autonomous robotic mission to a planetary surface [12] [13] [14].

To model a work practice we develop seven models, as described by the World Modeling Framework [15]. First, we design the *Agent Model* in which we represent the group-agent membership hierarchy of all the agents in the work system. The Agent Model describes to which groups the agents belong and how these groups are related to each other. After the Agent Model, the next model that needs to be designed is the *Object Model*. In this model we design the class-hierarchy of all the domain objects and artifacts.

Now that the agents, objects and real-world artifacts are represented, the next model is the *Geography Model* in which the agents and artifacts are located during the simulation. In Brahms we model geographical locations using two concepts, *area-definitions* and *areas* [16]. Area-definitions are user-defined types of areas. Areas are instances of area-definitions. An area is an instance of a specific location in the real world that is being modeled. Furthermore, areas can be part-of other areas. With this representation scheme we can represent any location at any level of detail.

The fourth model is the *Activity Model*. In the Activity Model we describe the behavior of agents and objects in terms of the activities they perform over time. Agent or object activities are mostly represented at the group-level or class-level respectively, but can also be represented down at the agent and object level. Activities at the group- and class-level are inherited at the lower levels. Related to this, we describe the constraints of when these activities can be performed in the *Timing Model*. Such activity constraints are represented in the form of preconditions of situation-activity rules. We call such situation-activity rules *workframes* [16]. A workframe executes an agent's activity when its preconditions match against the agent's individual belief-set. Because activities take time, a workframe instantiation has a duration. However, activities, and thus workframes, can be interrupted and resumed, making the actual length of an activity performance situation dependent.

Next, we can represent an agent's reasoning behavior as forward-chaining production-rules in the *Knowledge Model*. Such production rules can also be represented at the group-level, and is also inherited at lower levels. In Brahms, production-rules are called *thoughtframes* [16].

The last model we distinguish is the *Communication Model*. In this model we represent the agent and object communication. In Brahms we represent communication as speech-acts, i.e. situation-specific communication-actions of agents' beliefs to/from other agents or artifacts [17].

2. From simulation to agent systems

We have recently reimplemented the Brahms environment in Java. As part of this effort we have made three enhancements, which will allow us to use the Brahms language as a full-fledged agent language for developing intelligent human-centered agent-based systems. The first enhancement is the creation of a real-time Brahms execution engine—the Brahms Virtual Machine (VM). The VM is similar to the simulation engine, but does not include time synchronization between agents and objects by a centralized scheduler. Each agent and object operates autonomously using its own discrete event engine. This allows each agent to execute as an independent Java-thread and run as fast as possible, without having to be synchronized by the scheduler.

The second enhancement is a Brahms Java-activity type, with which a modeler can implement any agent or object activity in Java. This allows moving execution from a Brahms agent to Java. The third enhancement is that of a Java-API for the development of Brahms proxy-agents in Java. Brahms proxy-agents allow moving execution from Java to Brahms.

3. References

[1] F. E. Emery and E. L. Trist, "Socio-Technical Systems," in *Management Sciences, Models and Techniques*, C. W. C. a. o. (eds.), Ed. London: Pergamon, 1960.

[2] P. Ehn, *Work-Oriented Design of Computer Artifacts*. Stockholm, Sweden: Arbetslivcentrum, 1988.

[3] J. Greenbaum and M. Kyng, "Design at Work: Cooperative design of computer systems," . Hillsdale, NJ.: Lawrence Erlbaum, 1991.

[4] W. A. Pasmore, *Creating Strategic Change: Designing the Fliexible, High Performing Organization*. New York: Wiley, 1993.

[5] M. R. Weisbord, *Productive Workplaces: Organizing and Managing for Dignity, Meaning, and Community*. San Francisco, CA: Jossey-Bass Inc., Publishers, 1987.

[6] M. Hammer and J. Champy, *Re-engineering the Corporation*. New York, NY: Harper Collins Publishers, Inc., 1993.

[7] M. Polanyi, *The Tacit Dimension*. Magnolia, MA: Peter Smith, 1983.

[8] L. A. Suchman, *Plans and Situated Action: The Problem of Human Machine Communication*. Cambridge, MA: Cambridge University Press, 1987.

[9] E. Wenger, *Communities of Practice; Learning, meaning, and identity*, (Draft) ed: Cambridge University Press, 1997.

[10] M. Sierhuis, "Modeling and Simulating Work Practice," in *Social Science and Informatics*. Amsterdam, The Netherlands: University of Amsterdam, 2001 forthcoming, pp. 350.

[11] W. J. Clancey, P. Sachs, M. Sierhuis, and R. van Hoof, "Brahms: Simulating practice for work systems design," *International Journal on Human-Computer Studies*, vol. 49, pp. 831-865, 1998.

[12] M. Sierhuis, "Modeling and Simulation of Work Practices on the Moon," presented at Computational Analysis of Social and Organizational Systems 2000, Carnegie Mellon University, Pittsburgh, PA, 2000.

[13] M. Sierhuis, W. J. Clancey, R. v. Hoof, and R. d. Hoog, "Modeling and Simulating Human Activity," presented at Autonomous Agents 2000 workshop on Intelligent Agents for Computer Supported Co-operative Work: Technology and Risks, Barcelona. Spain, 2000.

[14] M. Sierhuis, W. J. Clancey, R. v. Hoof, and R. d. Hoog, "Modeling and Simulating Human Activity," presented at 2000 AAAI Fall Symposium on Simulating Human Agents, North Falmouth, MA, 2000.

[15] M. Sierhuis and A. M. Selvin, "Towards a framework for collaborative modeling and simulation," presented at presented at the Workshop on Strategies for Collaborative Modeling and Simulation, CSCW '96, Boston, MA, 1996.

[16] R. van Hoof and M. Sierhuis, "Brahms Language Reference,": http://www.agentisolutions.com/documentation/language/ls_title.htm, 2000.

[17] J. Searle, R., *Speech Acts*. Cambridge, UK: Cambridge University Press, 1969.