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Int. J. Human-Computer Studies 61 (2004) 567–599
International Journal of Human-Computer Studies
www.elsevier.com/locate/ijhcs

Organizational building blocks for design of distributed intelligent system

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Received 12 February 2003; accepted 27 March 2004

Available online 4 June 2004

Abstract

In this work we present a framework for multi-agent system design which is based both on human organizational notions and principles for distributed intelligent systems design. The framework elaborates on the idea that notions from the field of organizational design can be used as the basis for the design of distributed intelligent systems. Concepts such as task, control, job, operation, management, coordination and organization are framed into an agent organizational framework. A collection of organizational design activities is presented that assist in a task oriented decomposition of the overall task of a system into jobs and the reintegration of jobs using job allocation, coordination mechanisms and organizational structuring. A number of coordination mechanisms have been defined in the organizational design literature. For the scope of this work we concentrate on: Direct Supervision where one individual takes all decisions about the work of others, Mutual Adjustment that achieves coordination by a process of informal communication between agents, and Standardization of Work, Output and Skills. Three organizational structures are discussed, that coordinate agents and their work: Machine Bureaucracy, Professional Bureaucracy and Adhocracy. The Machine Bureaucracy is task-driven, seeing the organization as a single-purpose structure, which only uses one strategy to execute the overall task. The Professional Bureaucracy is competence-driven, where a part of the organization will first examine a case, match it to predetermined situations and then allocate specialized agents to it. In the Adhocracy the organization is capable of reorganizing its own structure including dynamically changing the work flow, shifting responsibilities and adapting to changing environments. A case study on distributed supply chain management shows the process from task decomposition via organizational design to three multi-agent architectures based on Mintzberg's organizational structures.

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doi:10.1016/j.ijhcs.2004.03.001

1. Introduction

In this paper, we discuss a framework for the design of distributed intelligent systems. The framework is based on human organizational notions and principles, aimed at managing relations between organizational agents[1] and the activities they perform, rather than at the design of individual agents. The framework elaborates on the idea that notions from the field of organizational design can be used as the basis for the design of distributed intelligent systems. Already in the eighties, links between human organizations and computational systems were suggested (Fox, 1981; Malone, 1987). Since then, organizational approaches have become themes in research areas for supporting coordination and framing control relations. Hewitt has pointed out that *in organization lies power* (Hewitt, 1991). Indeed, despite the differences between software agents and humans a number of concepts, mechanisms and patterns can be used as principles for distributed intelligent systems design (Fox, 1981). Different agent-oriented modeling techniques and methods have been presented, see for an overview (Wooldridge et al., 2000). For example, GAIA specifies agent systems in terms of interaction roles. Roles are defined with responsibilities, permissions and protocols into a role model. An interaction model defines a protocol for each type of inter-role interaction (Wooldridge et al., 2000). However, GAIA only implicitly uses the notion of organizations and should be enhanced with organizational structures (Zambonelli et al., 2000). Research efforts on agents and organizations have been reported in the organizational design literature, including research on electronic institutions (Esteva et al., 2001), computational and mathematical models of organizations (Carley and Gasser, 1999) and organizational views on multi-agent systems (Ferber, 1999). State of the art in multi-agent research can be found in (Luck et al., 2003).

Fox sees an organizational structure for a distributed system as the collection of processes (i.e. agents), communication paths and a control regime that coordinates the whole (Fox, 1981). Therefore, research efforts in the agent field have dealt with the problem of enabling interactions among agents, middleware components (mediator, information brokers) and infrastructures. For example, agent interaction allows agents to transfer information and knowledge. However, the approach of the research efforts reported in the agent literature is on the system (implementation) perspective.

Distributed artificial intelligence (DAI) has looked at overcoming limitations of individual agents by tackling problems through running distributed computational processes. For this reason, research in (distributed) knowledge models, communication and reasoning techniques have led to ways in which agents can participate in societies of agents, i.e. agencies. We see an agency as a society of agents, in which each of them can be specialized with knowledge, one or more skills and has a sort of mechanism that permits interaction with others. Examples of agencies are collections of individuals, including humans, machines and computational processes such as web services and agents. A specific type of agency is a multi-agent system, which is

[1] In this paper, we use "agents" to refer to intelligent software agents.