A Collaborative Multi-Agent Framework for Internet-Based Teleoperation Systems

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ABSTRACT

This paper presents a conceptual model of an agent (called Collaborator Agent) intended to design collaborative software architectures based on multi-agent systems. The authors’ model combines astutely two research areas: Multi-Agent Systems (MAS) and Computer Supported Cooperative Work (CSCW). The particularity of their approach is the division of the collaborative process into three spaces according to Ellis’ 3C model: communication, coordination and production. In their work, the authors extend the 3C model by adding a fourth space: collaboration. Hence, the authors present a model based on four types of agents (collaboration, communication, coordination and production) supporting the whole set of collaborative tasks. The model is used to create the conceptual software architecture of their MAS. The authors apply their conceptual model on the ARITI-C system for collaborative online robot teleoperation. Finally, the authors present a quantitative evaluation of the collaboration process in ARITI-C.

Keywords: Collaborator Agent, Computer Supported Cooperative Work (CSCW), Multi-Agent Systems (MAS), Robot Teleoperation, Software Architecture

INTRODUCTION

A Multi-Agent System (MAS) is composed of entities called agents that interact together in order to achieve a common goal. An agent, in general terms, is anything that can be viewed as perceiving its environment through sensors, and acting upon that environment through effectors (Russell & Norvig, 1995). Computational MASs consist entirely of artificial agents executing as software programs and running on a computer system. Some researchers have treated the concept of formal descriptions of MAS, while the aim is to assess their properties and formal specifications. In fact, there are formal descriptions of both agent paradigms and interaction.
paradigms; however, some formalisms provide representations of both of them. In the literature, as in Wooldridge and Jennings (2005), formal descriptions are also called theories. The MAS theories are rules that constitute a basis for specification (Glaser, 2002; Occello, 2002), design (D’Inverno, Kinny, Luck & Woolridge (1998), Ricordel & Demazeau (2002)) implementation and verification of MAS (Arlabrosse, Gleizes & Occello (2004), D’inverno, Fisher, Lomuscio, Luck, Rijke, Ryan & Woolridge (1997), Picard & Gleizes (2004)). There are other methodologies and theories dealing with this concept, such as The Multi-Agent Scenario-Based Method (Moulin & Brassard (1996), Moulin & Cloutier (1994)) that is intended to be applied in the field of cooperative work.

Moreover, software agents represent a fundamental way of considering complex distributed systems and societies of cooperating autonomous components. When building such systems, special techniques are required for their design and implementation. In our work, we aim at assisting the development of such systems by providing a model and formalism that can be used to specify the desirable behavior of MAS, where one requirement is to be able to move from specifications of such systems to implementation. The characteristics identified by using a formalism serve to measure and evaluate implementations of agent systems. On the other hand, CSCW is the field of study that examines how technology affects group interaction, and how technology can be best designed and built to facilitate group work. Activities in that domain are known as groupware.

Ellis, Gibbs & Rein (1991) defines groupware as “computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment”. While groupware refers to real computer-based systems, this means that the notion CSCW is the study of tools and techniques of groupware as well as their psychological, social and organizational effects. Some questions arise such as how to conceive and develop adequate collaborative work architectures taking into account communication, coordination and production features, and how to evaluate the developed collaborative systems. In this paper, we attempt to answer these questions by putting forward a new conceptual model of an agent called Collaborator Agent (CA) used to develop and evaluate software architectures of collaborative applications. The proposed CA is based on an approach combining astutely two research area: MAS and CSCW (Ellis, Gibbs & Rein (1991), Laurillau & Laurence (2002)). In the first area, a formal model of the MAS (Ferber approach in Ferber & Muller (1996)) is used to bring out the features of the agent. The second area provides a useful specification of collaboration based on the communication, coordination and production theories. Then, we apply our conceptual model on the ARITI-C system for collaborative online robot teleoperation. This system offers web interfaces in order to assist users in collaboration to remotely manipulate real objects via a robot.

We will proceed as follows: In section 2, we present some related work in the field of MAS in many application areas. In section 3, we present the conceptual modeling of the CA. In section 4, the design and implementation of the CA are presented and discussed. In section 5, we present the ARITI-C system for online collaborative robot teleoperation. Furthermore, we present the quantitative evaluation of the system in order to assess the collaboration process. A conclusion and future work are presented in the last section.

RELATED WORK

Various work exist in the literature that make use of MASs in many application domains. In particular, the use of software agents for robot teleoperation has been gaining much attention since many years (Lin, Song & Anderson (2005), where agents can communicate, coordinate and negotiate in order to meet their goals in a framework suitable for task execution. Also, the autonomy and intelligence of software agents have considerably increased software automation of many operational areas. For example,
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