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Mario Marchand (Eds.)

Advances in Artificial Intelligence

19th Conference of the Canadian Society for Computational Studies of Intelligence, Canadian AI 2006
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Preface

This volume contains the papers presented at AI 2006, the 19th conference of the Canadian Society for the Computational Study of Intelligence (CSCSI). AI 2006 has attracted a record number of 220 paper submissions. Out of these, 47 high-quality papers were accepted by the Program Committee for publication in this volume. In addition, we have invited three distinguished researchers to give talks about their current research interests: Geoffrey Hinton from University of Toronto, Fred Popowich from Simon Fraser University, and Pascal Van Hentenryck from Brown University.

The organization of AI 2006 has benefited from the collaboration of many individuals. Foremost, we express our appreciation to the Program Committee members and the additional reviewers who provided thorough and timely reviews. We thank Dirk Peters for his technical assistance with Paperdyne: the conference management system used by AI 2006 to manage the paper submissions and reviews. Finally, we thank the Organizing Committee (Laurence Capus, Mamadou Koné, François Laviolette, Nicole Tourigny, and Hospitalité Québec) and the members of the CSCSI Executive Committee for all their efforts in making AI 2006 a successful conference.

June 2006

Luc Lamontagne and Mario Machand
Program Co-chairs, AI 2006

Guy Mineau
Conference Chair, AI 2006

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AI 2006 was organized by the department of Computer Science and Software Engineering of Université Laval and CSCSI (the Canadian Society for the Computational Study of Intelligence).

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Integrating Information Gathering Interaction into Transfer of Control Strategies in Adjustable Autonomy Multiagent Systems

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Abstract. In this paper, we present a model that allows agents to reason about adjusting their autonomy in multiagent systems, integrating both full transfers of decision making control to other entities (users or agents) and initiations of interaction to gather more information (referred to as partial transfers of control). We show how agents can determine the optimal transfer of control strategy (which specifies which entities to transfer control to, and how long to wait for a response), by generating and evaluating possible transfer of control strategies. This approach extends earlier efforts in the field by explicitly demonstrating how information seeking interaction can be integrated into the overall processing of the agent. Through examples, we demonstrate the benefits of an agent asking questions, in order to determine the most useful transfers, or to improve its own decision making ability. In particular, we show how the model can be used to effectively determine whether or not it is beneficial to initiate interaction with users. We conclude with discussions on the value of the model as the basis for designing adjustable autonomy systems.

1 Introduction

Multiagent systems with the ability to adjust the autonomy of their agents, over time, are referred to as adjustable autonomy systems[4]. The need for adjustable autonomy systems has been reinforced by work such as that of Barber et al.[1] that show the value of dynamic levels of autonomy for agents, compared to static ones, for improving the performance of a system. Researchers in such application areas as space exploration (e.g. Martin et al.[7]) also emphasize how critical it is to allow for robots working with human users to have their autonomy adjusted, at times. Agent-based adjustable autonomy systems[6] are ones in which agents are provided with the ability to reason about adjusting their own autonomy. One promising approach for the design of these systems is that of Electric Elves (E-Elves)([9]: a model for agents to reason about whether to retain autonomy or to transfer decision-making control to another entity (user or agent).

In this paper, we present a new model that allows agents to initiate interactions with other entities, to gather more information, before ultimately selecting which entities to approach for transferring decision making control. With questions to entities included as possible actions from agents, the resulting model is in essence one of a *hybrid* transfer of control: either there is a full transfer of decision making control to another entity, or there is *partial* transfer of control, where input is obtained from another entity by

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asking a question, but the agent still retains decision making control. This approach therefore allows an agent to make use of run-time information (in the form of responses from entities) to drive the choice of which entities should be given decision making control, resulting in a more principled basis for deciding whether to adjust autonomy. This approach contrasts as well with those of researchers (e.g. Fleming and Cohen [3]) that have agents initiating interactions with other entities, but always retaining ultimate control over the decision making, themselves. We demonstrate the value of allowing an agent to reason about both decision making and interaction, towards the goal of maximizing the expected utility of its strategies.

2 Background

In the E-Elves model, which serves as the starting point for our work, the central notion is that of a *transfer-of-control strategy*, an agent's planned sequence of decision-making transfers, together with times indicating how long it should wait for the delegated entity to respond, before transferring control away to another entity, or perhaps back to itself. For example, the strategy $e_1(5), e_2(11), Agent$ denotes a strategy where the agent will first transfer control to entity e_1, and if e_1 hasn't responded with a decision by time point 5, then the agent will transfer control to entity e_2, which has until time point 11 to respond, before the agent gives up, and decides autonomously.

In E-Elves[9], each agent seeks to maximize the expected utility (EU) of its transfer-of-control strategy, by modeling two key factors for each entity in the system: the expected quality of a decision made by the entity, and the probability of the entity responding at a point in time to the delegation of decision making control[1]. The formula for evaluating potential agent strategies is the following: $EU = \int_0^\infty P_\top(t) \times (EQ^d_{e_c}(t) - W(t))dt$, where $P_\top(t)$ denotes the probability that the entity currently in control, e_c, will respond at time point t, $EQ^d_{e_c}(t)$ denotes the expected decision quality of the entity, e_c, for decision d at time point t, and $W(t)$ denotes the cost of waiting until time t to make a decision.

3 A Hybrid Transfer of Control Model

In our hybrid transfer-of-control model, we differentiate between two types of transfers-of-control (TOC), namely *full transfer-of-control* (FTOC), and *partial transfer-of-control* (PTOC). The transfers in the E-Elves [9] model are FTOCs, where the agent completely gives up decision-making control to some other entity. A PTOC denotes a new type of transfer where the agent queries another entity for information that can used in the problem solving process, while still retaining decision-making control.

Humans face problems of too much data and plans of too much complexity, while agents have the problem of under-specified domain information. As such, PTOCs are particularly useful in domains where neither the human user nor the agent are very

[1] In this paper, we factor out discussion of deadline delaying actions, which are also part of the E-Elves framework.

capable of making a good decision alone, while together they can. Another way PTOCs are useful is to make the overall strategy more flexible, to be better able to handle a dynamic (uncertain) environment. For example, an agent can query about a user's location, in order to determine whether or not it is still useful to transfer control to that user (in case the user changed locations and may no longer be responsive to transfers).

A critical difference between an FTOC and a PTOC is that a successful FTOC (i.e., the entity to whom control has been transferred to actually responds) means that a decision has been made, and so strategy execution ends. In contrast, a successful PTOC does not mean that a decision has been made, only that information has been gathered that can help lead to a good decision. As such, the strategy execution continues after a PTOC, with the agent performing other transfers.

The output of our model will be a *hybrid transfer-of-control (HTOC) strategy*, that the agent should follow to maximize overall expected utility. We use the term 'hybrid' to emphasize the fact that our agents can employ strategies containing both full transfers-of-control, and partial transfers-of-control. Visually, one can picture an HTOC strategy as a tree, with two types of nodes, *FTOC nodes* and *PTOC nodes*.

An FTOC node represents the agent fully transferring control to some entity at some time point t_i and waiting until time point t_{i+1} for a response. It is sequential in the sense that if the entity does not respond to the requested control transfer by time point t_{i+1}, then there is only one next step - i.e., execute the next node in the transfer-of-control strategy. For simplicity's sake, we will regard the case of the agent deciding autonomously as an FTOC to the agent itself. Note that for this special FTOC case, we do not need to plan for any transfers afterwards, since the decision will definitely have been made (i.e., the agent can be sure that it will respond to itself).

A PTOC node represents the agent partially transferring control by asking some entity a query at some time point t_i and waiting until time point t_{i+1} for a response. Each possible response to a query will be represented as a branch from the PTOC node to a strategy subtree (also referred to as a substrategy in this paper) representing what the agent should do when it receives that particular response. We will use the following terminology. Q_j denotes a particular query, and $r_{j,1}, r_{j,2}, ...r_{j,n}$ denote its possible answer responses. We also include "I don't know" as a valid response, denoted as $r_{j,?}$, and also allow for the 'no response' case, $r_{j,\neg resp}$, which occurs when the entity does not respond in time (i.e., by time t_{i+1}).

Figure 1 illustrates an example HTOC strategy where the agent is responsible for rescheduling a presentation meeting time. In this example, the agent is uncertain about which factor it should prioritize when selecting a meeting time. So, it does a PTOC to the group leader Bob, asking query Q_1 = "When rescheduling a meeting time, which factor should be prioritized?", with the possible answer responses being $r_{1,1}$ = "Prioritize having the meeting earlier", $r_{1,2}$ = "Prioritize having as many people being able to attend the meeting", and $r_{1,3}$ = "Prioritize having the meeting be convenient for the presenter". Depending on the response it gets back from Bob, the agent will do different things. For example, if the response is $r_{1,3}$, then the agent figures that the presenter, Ed, is much more capable to make a good decision and so does an FTOC to Ed, asking Ed to make the meeting time decision, and waiting until time T_2 for the response. If time T_2 arrives and Ed still hasn't responded back yet, then the agent will just decide itself (to