Negotiating Agents: From Full Autonomy to Dynamic Degrees of Delegation

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ABSTRACT

The modularization of negotiating agents as proposed by the C-IPS approach provides a sound base for a concept that we call *dynamic degrees of delegation*. Agents following this concept enable their users at runtime to delegate particular subsets of decision to their artificial agents. We extend the specification and implementation of fully autonomous agents to capture this concept. We have successfully implemented such a system for a sociological experiment.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*Intelligent agents, Multiagent systems*

General Terms

Human Factors, Design, Experimentation

Keywords

Degrees of Delegation, Negotiation, Artificial Agents

1. INTRODUCTION

Artificial agents get more and more sophisticated. They bid in auctions on behalf of users and they pursue the objectives of their users in negotiations on appointments or on other resources. These systems are often multi-agent systems where artificial agents meet artificial agents. In some application also humans act in these artificial worlds. To do so, people use agents that do not have any autonomy; these agents provide an interface such that the user can trigger and control all important actions of the agent. The more autonomy agents gain, e.g. not only negotiate but also chose the issue and the partner for negotiations, the less appropriate such an all-or-nothing policy for agent autonomy is. The more decisions agents take the more situations may arise where users want to delegate only a subset of these decisions to the agent. If additionally the delegation decision is desired do be done at runtime then *dynamic degrees of delegation* are requested for artificial agents.

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2. C-IPS AGENT SPECIFICATION

The C-IPS approach [1] proposes a modularization of the decision component of negotiating agents and requires an explicit specification of the dynamic interdependencies between these modules. It distinguishes between external constraints (C) restricting the agent's decisions, and an agent's internal reasoning process. The reasoning itself is structured by three separate thought mutually dependent modules for the selection of negotiation issues (I), partners (P), and particular negotiation steps (S). We term the set of joint decisions the agents are able to negotiate on, *negotiation space* N. For large negotiation spaces it seems useful to restrict the negotiation to sub spaces of N. The selection of such a sub space is done by the issue component. The partners for a negotiation are not automatically given by the set of agents that suffer from a conflict. From the set of *candidates* C the partner component selects appropriate partners for a negotiation. The solution of conflicts by negotiation requires interactions between the agents. These interactions are selected by the step component from the set of *feasible steps* F defined by a protocol. This is not restricted to single interactions, but may also include the selection of plans, i.e. sequences of steps, or complete strategies. The negotiation space, the candidates and the feasible steps result from external constraints. Also the interdependencies between the modules are influenced by external constraints. *Static interdependencies*, which specify feasible combinations of decisions by the different modules, have to be considered within the decision processes of the separate modules. *Dynamic interdependencies*, who specify the activation of modules due to decisions in other modules or due to the perception of interactions from other agents, are given by *IPS dynamics*.

IPS Dynamics. The *IPS state* is the most important concept and is defined as a three dimensional vector $(I, P, S) \in (N \cup \perp) \times (C \cup \perp) \times (F \cup \perp)$. Each element can either have a specific value or is undefined, which is marked by a $\perp$. The IPS state represents the current state of the negotiation decisions of the agent. It is interpreted by the execution or action component that actually performs the decisions. We extend the specification that is introduced by [1]. Since the

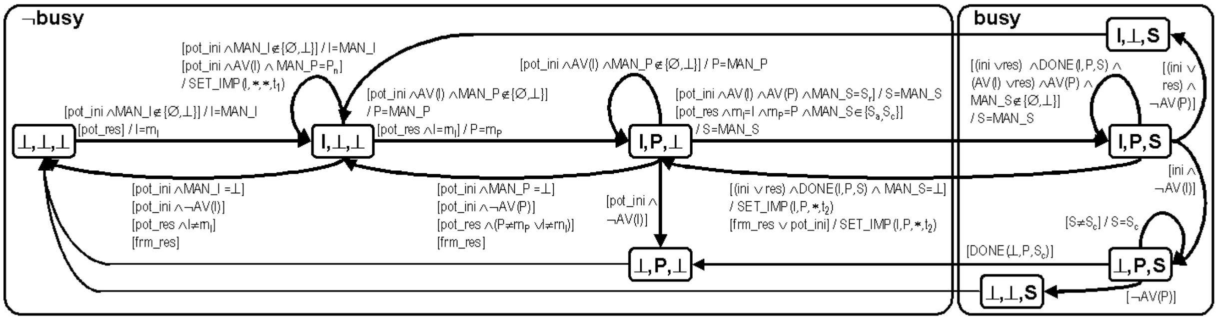

Figure 1: The negotiation state chart

C-IPS-based specification realizes a modularization according to different sub-decisions, we implemented degrees of delegation by enabling those modules to be independently controlled by a human user. We now show how the specification has to be systematically changed to enable users to manually trigger and control state transitions.

Actions MAN_I, MAN_P, and MAN_S implement the link to a graphical user interface. Because a user may delay his decision, these actions cannot only result in a partner or $\perp$, but can additionally return $\oslash$. Value $\perp$ represents states, where the user has cleared an element of the IPS state, while the value $\oslash$ represents states, where the user has not done anything. An intelligent design should distinguish between relevant transition where the user should be involved and transitions that can still be triggered automatically. The user must have the feeling to be involved for the most relevant aspects of the negotiation, but must not be burdened with decisions that have a clear cut. Because the user should be able to switch from manually controlled decisions to automation of decisions, i.e. dynamic degrees of delegation, the automatic components must be aware of the action the user did in the past. This is especially important for the recognition of impossible states. For instance, after switching to automated decision the agent should not request a negotiation that was manually requested already shortly before. Hence, despite the user is not required to care about the automatic impossible judgments the manual component still does these judgments. We now describe the changes of the IPS dynamics and assume to keep all transitions that are not explictly mentioned.

Manual issue component (MIC). In MIC we replace the transition that automatically chooses an issue by a transition that depends on a user's choice. The transition should not be done if the user does nothing, i.e. $MAN_I = \oslash$. Human users may rethink decisions and after choosing an issue finally want to switch to another issue. We therefore add a user-triggered transition that removes the issue from the IPS state. For a responder nothing changes, because the initiator determines the issue. Because the user should not be bound to the impossible judgment of the automated decision processes, we have to remove the transition that automatically removes an issue that is recognized to be impossible.

Manual partner component (MPC). In MPC we have to replace the transition that automatically chooses a partner by a transition that depends on user's choices and that is independent of the automatic judgements about impossibilities. For the same reason we remove the transition that automatically removes a partner that is recognized to be impossible with the given issue. To allow users to reconsider their decisions about partners until the negotiation is actually requested we add a manually triggered transition from $(I, P, \perp)$ to $(I, \perp, \perp)$, nevertheless for the case that a negotiation has been finished we keep the automated transition. Making it manually triggered, the user would feel bothered with decisions that are obvious. If MPC is combined with an automatic issue selection then the MPC should enable the user to signal situations where the user does not find a suitable partner. In these cases, when MAN_P returns P_n, the issue is recognized as temporarily impossible.

Manual step component (MSC). In MSC the request for a negotiation and the responder's agree are changed to manually triggered transitions. The initiator is not required to stick to any impossible judgments. Also the transition that chooses negotiation steps is changed to a user-triggered one. The MSC still automates some decisions. Choosing to wait for partner's reactions is still done automatically; it is a more technically aspect of agent negotiations. But the user can interrupt this waiting by canceling the negotiation, i.e. signalling a timeout. The interface that finally mediates user interactions takes care that only those negotiations steps are chosen that follow the protocol. The MSC automatically recognizes when a negotiation cannot be continued according to the protocol; then the transition to $(I, P, \perp)$ is automatically triggered.

Implementation. The agents have been implemented on a Java/Jade platform (jade.tilab.com). The agent's interface supports different degrees of delegation and reflects the different subsets of decisions that can be delegated to the agent. Since not in every state all the selections are possible, the different parts of the GUI are activated and deactivated according to the IPS dynamics. Deactivation of parts of the GUI is also used if corresponding transitions are automated. Then, those areas are used to visualize the automatically taken decisions. Results of automated decisions are displayed as if the user had taken them.

3. REFERENCES

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