Introducing Swap-Based Negotiations in the Contract Net Protocol

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1 Introduction

When several agents are placed within an environment to carry out tasks, they may cooperate to decrease the execution costs. In particular, a *self-interested agent* is inclined towards maximizing its own profit and thus is open to cooperation only if it is an advantage for itself.

The Contract Net Protocol (CNP) [Smith, 1980] is an approach to negotiation in multi-agent systems, inspired by a market-like model. In the design alternatives proposed in the literature, tasks are always sold for money.

In this paper we outline a negotiation protocol which conforms the contract net paradigm to environments where the only possible type of contract is the swapping. The agents we consider are self-interested and bounded rational; they may have different skills and cost evaluation functions, and must carry out different missions. Thus, the utility of a given swap may differ substantially for the different agents. Since no agent owns models of the others, and there is no money to establish a common cost metric, an agent has no means of estimating the utilities for the other agents. This causes the swap-based protocol to be more stable than the sale-based one.

2 Swap-Based Negotiation Protocol

Let A be an agent and S be the set of its current tasks. Given a task s, its *relative marginal cost* (RMC) for A is the cost paid by A to execute s. The *utility* for A in swapping its task $s_2 \in S$ with task s_1 assigned to agent B is measured as the difference between the cost paid to execute the tasks in S and that paid to execute the tasks in $S \cup \{s_1\} - \{s_2\}$. A swap is said to be *individual rational* for an agent if its utility is positive.

Like the CNP, our protocol consists of three phases:

Announcement. The announcing agent formulates an announcement consisting of one task and broadcasts it to the other agents.

Bid. Each agent receiving the announcement formulates a bid consisting of one or more tasks and broadcasts it to the announcer. A swap is proposed only if it is individual rational.

Award. The announcer collects the bids for a fixed time. When this time expires it determines, among all the bids received, the swap having the highest utility. If the utility is positive, then the swap is individual rational for both the announcer and the bidder; an award is sent to the winner and the negotiation session is over.

This protocol does not offer any dominant strategy since the bidder can formulate its bid in different ways. For instance, it can decide to propose only the swaps offering higher utilities: in this case, the average utility of the swaps for the bidder is increased, but the probability of a successful negotiation is decreased. Besides, the protocol offers a good trade-off between complexity and utility, where complexity deserves a particular attention due to the bounded rational nature of the agents.

The strategies which the contractors may adopt may be described as follows:

- The announcer, in selecting the task to negotiate, cannot calculate the utility it will receive; thus, it may choose the task with the highest RMC.
- The bidder can calculate the utilities it will get by swapping the task announced with each of its tasks. After dropping all the non-individual rational swaps, it will decide how to formulate the bid. The most "politically correct" strategy it can adopt is to include in the bid all the individual rational swaps; alternatively, the bidder can decide to include only the most convenient swap(s).

3 Conclusion

As confirmed by experimental tests performed in the robotic domain, using the swap affects the efficiency of negotiations by introducing some possibilities which would not be individual rational if the sale were used, and which allow local maxima in the utility functions to be overcome.

Due to the absence of a common metrics to evaluate utility, the swap-based protocol has a higher stability than the sale-based one. In fact, the agent that artificially reduces its bid not only takes the risk that the announcer will award some other agent, but also that the swap it proposes will not be individual rational for the announcer.

References

[Smith, 1980] Reid G. Smith. The Contract Net Protocol: high-level communication and control in a distributed problem solver. *IEEE Transactions on Computers*, C-29(12):1104-1113, December 1980.