Selection of Conflict Resolution Strategies in Dynamically Organized Sensible Agent-based Systems

T.H. Liu and K.S. Barber

The Laboratory for Intelligent Processes and Systems
The University of Texas at Austin
Austin, TX 78712
thliu@lips.utexas.edu, barber@mail.utexas.edu

A Multi-Agent System can be seen as a group of entities interacting to achieve individual or collective goals. In the past two decades, researchers have developed various MAS architectures, one being the Sensible Agent (SA) model (Barber 1996). Because one specific level of autonomy is not suitable for all situations in dynamic environments, SAs are equipped with the capability to reason about and switch among levels of autonomy. Typical autonomy levels (which are assigned to goals instead of agents) include: command-driven, master, consensus, and locally autonomous.

The challenge of coordination and conflict resolution in SA-based systems arises from the dynamic organizational structures; when SAs switch their autonomy levels, they also modify their roles and organizational structures. No existing single coordination technique can satisfy such a variety of needs. Results of previous research on various Conflict Resolution (CR) strategies do provide a foundation to solve this problem, but there is limited research focusing on how agents can select proper one. In the work of Adler and his colleagues (Adler, et al. 1989), agents can select one of the following strategies: arbitration, self-modification (independence), centralization, negotiation, priority convention, and mutual accommodation. The criteria agents use to select CR strategies is the network performance. When network traffic is heavy, agents use arbitration for resolving conflicts; when the load is light agents may try negotiation as well as other CR strategies. For dynamically organized Sensible Agents systems, a more advanced decision process is necessary.

We propose that a SA should dynamically select a suitable conflict resolution strategy according to: 1) the nature of conflicts (e.g. goal conflict, plan conflict, or belief conflict), 2) the agent's social roles (represented by its autonomy levels), and 3) its solution preferences (based on an agent's local view). In addition to using utilities to evaluate potential solutions, agents also use certain indexes to evaluate available CR strategies, and finally agents conduct some trade-off reasoning between solutions and CR strategies. The following simplified formula (may not be linear) shows how an agent can estimate alternative combinations of specific solutions and CR strategies:

$$TotalValue = U_{weight} \times Utility - M_{weight} \times Cost_{\mathrm{modify}} - CR_{weight} \times Cost_{\mathrm{CR\ strategy}}$$

Utility is the total weighted utility value of a specific solution for its attributes. $Cost_{\mathrm{modify}}$ is the estimated cost of modifying the agent's existing plans and $Cost_{\mathrm{CR\ strategy}}$ is the estimated cost of applying CR strategies eliminating conflicts. U_{weight} , M_{weight} , *and* CR_{weight} are their associate weight factor functions. The indexes used to evaluate CR strategies include: 1) effectiveness, the complexity and uncertainty involved, 2) performance, the time/messages needed and the desired quality of solution, 3) agent properties, agents' preferences for CR strategies as well as capabilities/resources required to execute a CR strategy, 4) system properties, measure of the extent to which the system provides coordination mechanisms (e.g. available mediator/arbitrator, design convention, and priorities.) for helping agents to resolve conflicts.

Three kinds of decision making styles can be made by tuning the weight factors: CR strategies are selected before or after solutions, balanced consideration between solutions and CR strategies. In our preliminary experiments (Liu, et al. 1997) we designed a CR strategy selection algorithm for robot path planning. The results show that the system can endure highly dynamic and uncertain environments.

The decision making approach proposed here can also be applied to other conflict resolution problems in Multi-Agent Systems which require the flexibility of applying multiple CR strategies. Currently we are working on a series of experiments following the third decision style and results will be reported in the near future. We are also considering the use of cased based reasoning techniques (or other learning methods) for tuning weight factors and increasing agents' abilities to adapt to environment changes

References

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* This research was supported in part by the Texas Higher Education Coordinating Board (#003658-415)