A Framework for Problem Solving Activities in Multi-Agent Systems

D. C. Han, T. H. Liu, K. S. Barber

The Laboratory for Intelligent Processes and Systems
Department of Electrical and Computer Engineering, ENS 240
University of Texas at Austin
Austin, TX 78712-1084
{dhan, thliu, barber}@lips.utexas.edu

The basic research issues in multi-agent systems (MAS) include problem decomposition, task distribution, communication, plan synthesis, coordination, conflict resolution, and organization design. For practical implementation, there is a need for an integrated framework that can help MAS designers to select appropriate techniques for building their specific systems. Difficulties in the integration of techniques for each of these issues is due to the interdependencies among the issues themselves. We propose a framework that describes the activities that occur during problem solving. This framework is based upon the premise that meta-level reasoning about the agents' activities adds flexibility to each agent, allowing them to adjust to changes in their environments or operating conditions.

Generally speaking, to accomplish a specific goal, agents must perform a sequence of actions that trigger events and change certain states. A strategy is a decision-making mechanism that provides long-term consideration for selecting actions toward specific goals which can help agents to observe the environment, evaluate alternatives, and prescribe and schedule actions. Since different strategies may be more or less appropriate in different situations and within different agent organizations, meta-level reasoning is required for strategy selection.

Problem solving activities can be decomposed into three phases: organization design, coordinated planning, and plan execution. Strategies have been developed to address the problems posed by each of these phases. Allowing the agent to select the strategy to apply towards a problem increases flexibility and responsiveness to new situations. For this purpose, each phase can follows the three levels of reasoning described above; reasoning on actions, strategies, and strategic decision making. Coordination during each phase occurs through communication.

Upon considering goals the agent wishes to achieve, the agent (or the system designers) must decide the manner in which it will interact with other agents. The result could be static or dynamic organizational structures that are designed for each goal or all goals the agents consider. Organization design may result in an agent being the master of other agents, a peer of other agents, command driven by other agents, or independent.

The coordinated planning phase is composed of three tasks: (1) *Plan Generation*: The agents must select the actions that must be taken to achieve the goal. This may take the form of any planning algorithm. (2) *Task Allocation*: The agents must allocate responsibility for tasks to individual agents. (3) *Plan Integration*: The agents must coordinate the solutions to each agent's subtasks in order to prevent conflicts. This involves the integration of partial plans while preventing "clobbering", scheduling each agent's actions to avoid resource conflicts, and so on.

During the plan execution phase, agents must monitor (1) the execution of their chosen actions to insure that the intended effects are achieved, and (2) the states of the environment (as well as behaviors of other agents) to insure that resources are available and cooperation (if there is any) is still working. If agents realize certain planned actions are not available or the plan is not achievable, the agent may restart planning at an earlier phase.

The problem-solving framework proposed here is aids in the design of MAS, such as Sensible Agents (SA) (Barber, 1996). SA use Dynamic Adaptive Autonomy (DAA) for organization design. SA have the ability to choose between and use both hierarchical planning strategies and operator search based strategies for plan generation (Barber and Han, 1998). Conflicts may be resolved using multiple strategies such as negotiation, arbitration, or self modification. Continuing development of the SA capabilities are currently being implemented and tested in the Sensible Agent Testbed.

References

Barber, K. S. 1996. The Architecture for Sensible Agents. In *Proceedings of the International Multidisciplinary Conference, Intelligent Systems: A Semiotic Perspective*, 49-54. Gaithersburg, MD: National Institute of Standards and Technology.

Barber, K. S. and Han, D. C. 1998. Multi-Agent Planning under Dynamic Adaptive Autonomy. In *Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics*, 399-404. San Diego, CA, USA: IEEE.

This research is sponsored in part by the Texas Higher Education Coordinating Board #003658-415