Local Search in the Coordination of Intelligent Agents*

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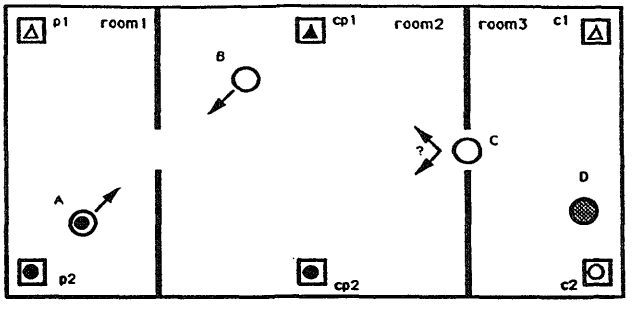
In a world inhabited by numerous agents pursuing distinct goals, conflicts are inevitable. To succeed in the environment, an agent must explicitly reason about the behaviors of other agents as well as itself, and be prepared to find new behaviors that are more coordinated. Because traditional AI has had great success viewing problem solving as a *search* in a *problem space*, we have chosen to represent the process of coordination as a distributed search (Durfee *et al.* 1994). In searching through a joint behavior space for coherent coordination patterns, an agent must observe three kinds of constraints: its abilities, its goals, and the activities of other agents in the environment.

The nature of the third constraint is dependent on the abilities and goals of the other agents in the environment. Knowledge of other agents' planned actions is often sufficient for conflict avoidance; however, the ability to reason about alternative activities not only for oneself but for *other* agents requires deeper modeling of them. Our concept of the *behavior* as a modeling structure contains not only spatial and temporal information about agents' actions but also represents their goals and capabilities. With this modeling information an agent can reason from other agents' goals and capabilities to arrive at likely alternative behaviors for them and itself. We call this *local search*. Depending on the distribution of knowledge among the agents, local search might occur at any number of agents. Our approach complements the distributed search process of (Durfee & Montgomery 1991), which emphasized the efficient propagation of information among agents rather than the local search of an individual agent.

We are investigating local search in the **producer-consumer-transporter** (PCT) domain, by implementing a search for coordination patterns for solving package delivery problems. In a PCT problem, "producers" create objects that must be delivered by "transporters" to "consumer" agents, who cause the objects to disappear. Representing coordination schemes as a hierarchy of behaviors, we have been able to generate many different agent organizations by decomposing according to agent *goals* and agent *capabilities*, respectively. Using the former decomposition we arrive at an analog to "product hierarchies", in which agents are grouped according to the products they help make. Using the latter decomposition gives rise to "functional hierarchies", in which agents are grouped according to their capabilities. Our use of taxonomic knowledge of capabilities and goal-subgoal relationships also allows us to represent *hybrid* organizations that incorporate features of both kinds of hierarchies. We have identified instances in which a hybrid organization outperforms any "pure" form. Our ongoing analysis is focusing on the evaluation of organizational forms in terms of coordination costs (the amount of run-time communicating and thinking), production costs (overall throughput), and vulnerability costs (the effect on performance if some agent breaks down).



We are working to characterize these factors with the aim of automating the generation and search of a behavior space for this coordination task. In a broader context, we hope to shed light on issues such as the effect of different task decompositions on the complexity of local processing, and the effects that different coordination costs have on effective agent organization.

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References

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