Agents Modeling Agents in Information Economies

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Our goal is to design and build agents that act intelligently when placed in an agent-based information economy, where agents buy and sell services (e.g. thesaurus, search, task planning services, etc.). The economy we are working in is the University of Michigan Digital Library (UMDL), a large scale multidisciplinary effort to build an infrastructure for the delivery of library services [2]. In contrast with a typical economy, an information economy deals in goods and services that are often derived from unique sources (authors, analysts, etc.), so that many goods and services are not interchangeable. Also, the cost of replicating and transporting goods is usually negligible, and the quality of goods and services is difficult to measure objectively: even two sources with essentially the same information might appeal to different audiences. Thus, each agent has its own assessment of the quality of goods and services delivered.

Our emphasis, therefore, is not on developing market mechanisms for traditional economies with interchangeable goods/services, but rather for those where each participant might be unique and inscrutable from the perspective of others. In order to make good decisions, an agent in such an economy must: (A) Determine exactly what services other agents provide and at what price. (B) Avoid agents whose services are not reliable or needed, and form teams with those that provide needed services. (C) Decide how much to charge and whom to target. We believe these can be accomplished if an agent builds models of how others appear to be assessing quality and/or establishing prices, and even how others are modeling others in these ways. Our previous work [1] considered such recursive models, and gave algorithms that trade-off the time costs of using the deeper recursive models versus the costs of taking a possibly inferior action. However, it assumed the agents already had correct deeper models of others.

The next problem to solve is how agents can acquire models of other agents. We have built agents that provide some useful services in the UMDL, but do not charge for them. As we incorporate the ability to buy and sell, the purchasing agents will have to make more complex decisions when deciding who to buy from, while the sellers will need to make decisions about how much to charge. Our research plan is to explore this economy, by expanding our agents into three types, based on their modeling capabilities. That is, we built agents that: (1) Do not build models of other agents. (2) Build one-level or "policy" models of other agents, based on observations of their behavior. (3) Build intentional/two-level models of others, which are composed of an intentional model of the agent being modeled, and the one-level models it has of others.

It should be clear that agents with no models of other agents cannot predict what others will do. Therefore, they either try to maximize their expected payoffs, given their ignorance of others' behaviors, or try to minimize their possible losses. Agents that are capable of building simple models are able to determine which agents have, in the past, delivered the best service. They have an advantage over agents that do not model and, in fact, are able to cheat them (i.e. deliver a lower quality service) and get away with it since, with no models, no records of their actions are kept. Agents with two-level models should be able to better predict what the competition will do (i.e. to "get inside their heads") giving them a small advantage over the competition. We are testing these assertions to determine exactly when it is advantageous to use deeper models. Preliminary results show correlations between the heterogeneity of the population, price volatility, and the benefits of using deeper models.

[1] J.M. Vidal and E.H. Durfee. Recursive Agent Modeling Using Limited Rationality. *ICMAS* 95.

[2] M. Wellman, *et.al.* Toward Inquiry-based Education through Interacting Software Agents. *IEEE Computer*. May 96.

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