Agent-Based Intelligent System Modeling

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INTRODUCTION

An intelligent system is a system that has, similar to a living organism, a coherent set of components and subsystems working together to engage in goal-driven activities. In general, an intelligent system is able to sense and respond to the changing environment; gather and store information in its memory; learn from earlier experiences; adapt its behaviors to meet new challenges; and achieve its pre-determined or evolving objectives. The system may start with a set of predefined stimulus-response rules. Those rules may be revised and improved through learning. Anytime the system encounters a situation, it evaluates and selects the most appropriate rules from its memory to act upon.

Most human organizations such as nations, governments, universities, and business firms, can be considered as intelligent systems. In recent years, researchers have developed frameworks for building organizations around intelligence, as opposed to traditional approaches that focus on products, processes, or functions (e.g., Liang, 2002; Gupta and Sharma, 2004). Today's organizations must go beyond traditional goals of efficiency and effectiveness; they need to have organizational intelligence in order to adapt and survive in a continuously changing environment (Liebowitz, 1999). The intelligent behaviors of those organizations include monitoring of operations, listening and responding to stakeholders, watching the markets, gathering and analyzing data, creating and disseminating knowledge, learning, and effective decision making.

Modeling intelligent systems has been a challenge for researchers. Intelligent systems, in particular, those involve multiple intelligent players, are complex systems where system dynamics does not follow clearly defined rules. Traditional system dynamics approaches or statistical modeling approaches rely on rather restrictive assumptions such as homogeneity of individuals in the system. Many complex systems have components or units which are also complex systems. This fact has significantly increased the difficulty of modeling intelligent systems. Agent-based modeling of complex systems such as ecological systems, stock market, and disaster recovery has recently garnered significant research interest from a wide spectrum of fields from politics, economics, sociology, mathematics, computer science, management, to information systems. Agent-based modeling is well suited for intelligent systems research as it offers a platform to study systems behavior based on individual actions and interactions. In the following, we present the concepts and illustrate how intelligent agents can be used in modeling intelligent systems.

We start with basic concepts of intelligent agents. Then we define agent-based modeling (ABM) and discuss strengths and weaknesses of ABM. The next section applies ABM to intelligent system modeling. We use an example of technology diffusion for illustration. Research issues and directions are discussed next, followed by conclusions.

INTELLIGENT AGENT

Intelligent agents, also known as software agents, are computer applications that autonomously sense and respond to environment in the pursuit of certain designed objectives (Wooldridge and Jennings, 1995). Intelligent agents exhibit some level of intelligence. They can be

used to assist the user in performing non-repetitive tasks, such as seeking information, shopping, scheduling, monitoring, control, negotiation, and bargaining.

Intelligent agents may come in various shapes and forms such as knowbots, softbots, taskbots, personal agents, shopbots, information agents, etc. No matter what shape or form they have, intelligent agents exhibit one or more of the following characteristics:

- **Autonomous:** Being able to exercise control over their own actions.
- **Adaptive/Learning:** Being able to learn and adapt to their external environment.
- **Social:** Being able to communicate, bargain, collaborate, and compete with other agents on behalf of their masters (users).
- **Mobile:** Being able to migrate themselves from one machine/system to another in a network, such as the Web.
- **Goal-oriented:** Being able to act in accordance with built-in goals and objectives.
- **Communicative:** Being able to communicate with people or other agents thought protocols such as agent communication language (ACL).
- **Intelligent:** Being able to exhibit intelligent behavior such as reasoning, generalizing, learning, dealing with uncertainty, using heuristics, and natural language processing.

AGENT-BASED MODELING

Using intelligent agents and their actions and interactions in a given environment to simulate the complex dynamics of a system is referred to as agent-based modeling. ABM research is closely related to the research in complex systems, emergence, computational sociology, multi agent systems, evolutionary programming, and intelligent organizations. In ABM, system behavior results from individual behaviors and collective behaviors of the agents. Researchers of ABM are interested in how macro phenomena are emerging from micro level behaviors among a heterogeneous set of interacting agents (Holland, 1992). Every agent has its attributes and its behavior rules. When agents encounter in the agent society, each agent individually assesses the situation and makes decisions on the basis of its behavior rules. In general, individual agents do not have global awareness in the multi-agent system.

Agent-based modeling allows a researcher to set different parameters and behavior rules of individual agents. The modeler makes assumptions that are most relevant to the situation at hand, and then watches phenomena emerge from the interactions of the agents. Various hypotheses can be tested by changing agent parameters and rules. The emergent collective pattern of the agent society often leads to results that may not have been predicated.

One of the main advantages of ABM over traditional mathematical equation based modeling is the ability to model individual styles and attributes, rather than assuming homogeneity of the whole population. Traditional models based on analytical techniques often become intractable as the systems reach real-world level of complexity. ABM is particularly suitable for studying system dynamics that are generated from interactions of heterogeneous individuals. In recent years, ABM has been used in studying many real world systems, such as stock markets (Castiglione 2000), group selection (Pepper 2000), and workflow and information diffusion (Neri 2004). Bonabeau (2002) presents a good summary of ABM methodology and the scenarios where ABM is appropriate.

ABM is, however, not immune from criticism. Per Bonabeau (2002), "an agent-based model will only be as accurate as the assumptions and data that went into it, but even approximate simulations can be very valuable". It has also been observed that ABM relies on simplified models of rule-based human behavior that often fail to take into consideration the complexity of human cognition. Besides, it suffers from "unwrapping" problem as the solution is built into the program and thus prevents occurrence of new or unexpected events (Macy, 2002).

ABM FOR INTELLIGENT SYSTEMS

An intelligent system is a system that can sense and respond to its environment in pursuing its goals and objectives. It can learn and adapt based on past experience. Examples of intelligent systems include, but not limited to, the following: biological life such as human beings, artificial intelligence applications, robots, organizations, nations, projects, and social movements.