Agents – Return to a computational science perspective?

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The use of the related terms "agent-based", "multi-agent", "software agent" and "intelligent agent" have witnessed significant growth in Geographic Information Science (GIScience) literature in the past decade. These terms usually refer to both *artificial life agents* that simulate human and animal behavior and to *software agents* that support human-computer interactions. While a computational science perspective does not preclude the former, Distributed Artificial Intelligence (DAI) researchers who originally coined the term and provided the semantic framework were contemplating the latter. Therefore, its extension to and usage in complexity theory research requires as a first step acknowledgement of ongoing research in the DAI community. In turn, GIScience researchers have much to offer to ongoing work on inter-agent communication languages and enforcing stronger notions of autonomy. But this will require GIScience and complexity theory agent modelers to venture into debates located deep within the unfamiliar territory of computational science.

Software agent research itself arose from the DAI community. This community was disillusioned by monolithic approaches to modeling human intelligence and believed that knowledge could be distributed into elemental components that generated emergent and intelligent behavior through interaction (Hayes-Roth and Hayes-Roth 1979, Hayes-Roth 1985, Huhns 1987, Bond and Graesser 1988). Current research on this topic within DAI builds on this basic idea using recent advances in user/software interface development (Etzioni and Weld 1994, Maes 1994), network mobility (Kotz and Gray 1999) and Internet data- and information-mining algorithms (Knapik and Johnson 1998).

Consensus amongst DAI researchers suggested that to be considered an intelligent agent, the software/computer model must possess the following four properties: (a) autonomous behavior, (b) ability to sense its environment and other agents, (c) ability to act upon its environment alone or in collaboration with others, and (d) possession of rational behavior (Woolridge and Jennings 1995, Woolridge 1999). To aid in inter-agent collaboration and communication, specific Agent Communication Languages, for example, Knowledge Query and Manipulation Language (Labrou et al. 1999), have also been developed. Additionally, researchers have pointed out that intelligent agents should not only be able to respond to, but also learn from, their environment (Maes 1994). Humanistic characteristics such as beliefs, desires, intentions (Shoham 1993), and emotions and trust (Maes 1994) also could form a part of agent behavior.

The first area of contribution by GIScience researchers can and should be in the area of inter-agent communication languages. For example, the Knowledge Query and Manipulation Language (KQML) is designed both as a messaging format and a message-handling protocol to support run-time knowledge sharing among agents. In its current format, it also includes higher level communication strategies such as contracts and negotiations. However, the ability to define spatial constructs and objects using KQML is severely limited and often non-existent. GIScience researchers, familiar with the spatial query language debate of the early 1990s (e.g., Egenhofer 1994), could capture past research on this topic to inform the expansion of KQML into its spatial equivalent (SKQML?) and in turn, enrich their own agent-modelling experience by building communicative artificial life agents.

A second area where GIScience agent researchers can assist DAI research is in implementing a "strong" notion of autonomy within artificial life agents, perhaps using virtual environments such as "Second Life" (secondlife.com) as test beds. A weak notion of autonomy suggests that agents must, in addition to being reactive, be in control of their state and persist beyond the completion of a single task (Tosic and Agha 2004). But this is true of many common software applications such as firewalls and virus scanners, and in the geospatial realm, of Internet Map Servers. A strong notion of autonomy requires the agent to have goal-directed behavior and be proactive in achieving those goals. Humans or application instantiate them but agents continue to run even after the instantiation mechanism has been terminated or is no longer present. Once instantiated, the agent must have knowledge of its goals, be in control of its actions, be able to make rational decisions in uncertain and open environments without prior knowledge about each and every situation they encounter, and require no assistance from human operators. However, in this definition, strong autonomy implies that agents have explicit spatial cognition, combined with a spatial ontology, of the virtual environments in which they operate. Spatial cognition and ontology are familiar terms to all GIScience researchers, and therefore topics on which there is much to inform the DAI community.

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