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# Agent Interaction via Message-Based Belief Communication

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## ABSTRACT

*This work reflects continued research into "temporally autonomous" multi-agent interaction. Many traditional approaches to modeling multi-agent systems involve synchronizing all agent activity in simulated environments to a single "universal" clock. In other words, agent behavior is regulated by a global timer where all agents act and interact deterministically in time. However, if the objective of any such simulation is to model the behavior of real-world entities, this discrete timing mechanism yields an artificial reflection of actual physical agent interaction. In addition to the behavioral autonomy normally associated with agents, simulated agents must also have temporal autonomy in order to interact realistically. Inter communication should occur without global coordination or synchronization. To this end, a specialized simulation framework is developed, several simulations are then conducted from which data are gathered and it is subsequently demonstrated that manipulation of the timing variable amongst interacting agents affects the emergent behaviors of agent populations.* [Article copies are available for purchase from InfoSci-on-Demand.com]

*Keywords: Agent; Emergent Behavior; Multi-Agent Systems; Simulation; Temporal Autonomy*

## INTRODUCTION

In this article, previous simulations (Conover & Trajkovski, 2007; Conover, 2008b) involving *passively interacting* temporally autonomous agents are expanded to accommodate *active* agents which directly communicate — albeit in a primitive manner. Information is exchanged as simple messages which are reflective of an agent's internal state. Though agents may take on many states during a simulation, each agent communicates its active state with its spatially embedded neighbors. The active model is divided into two distinct subtypes. The first subtype, discussed in Section 2, is a direct extension our previously studied "Conway" *Game of Life* models (Conover, 2008a; Conover 2008b); but agents respond to events generated by neighbors rather than vivificating autonomously. The second subtype, discussed in Section 3, is a completely new model based upon temporally variant belief interaction. The models in both subtypes display interesting and rather unique behavioral characteristics.

## MESSAGE ACTIVATION MODEL

In this mode, each agent begins in a random boolean state conforming to the basic "Conway" life/death (active/inactive) rules. As with the threaded model discussed in previous work (Conover, 2008a), the agents behave autonomously within a global mean vivification delay time $d_m$ of 500ms with delay variances $d_v$ chosen to produce $d_v/d_m$ ratios $r_{vm}$ ranging from 0.0 to 2.0. However, instead of agents simply examining their neighborhood at intervals which are independent of the environment, the agents now trigger the vivification of their neighbors by sending events. To maintain temporal autonomy, agents still "vivificate" as before, but in lieu of passive examination of neighboring states, the agent queries an internal message queue for the presence of pending notifications received from other agents. If an agent is inactive, it cannot become active until it receives a notification from an active neighbor. Only active agents are capable of sending messages to other agents. When any given agent vivificates, it determines the state of its own environment and sends notifications to all neighbors, if it becomes or remains active. An agent will only send one message to each of its neighboring agents once per vivification regardless of how many messages are in the queue. Once the vivification cycle completes (all neighbors have been notified), the sending agent clears its own message queue and again awaits new messages from neighboring agents.

The primary focus of this section is an exploration of the average population density and average population age of the agents as a given trial progresses. However, in this section, the number of messages received by each agent between vivifications is considered. A summary of the data gathered in the first set of message based activation trials is shown in Table 1, ordered by $r_{vm}$. Other values include the average population density, $pd_{avg}$ the population's average age $age_{avg}$, the average number of messages received per agent $mgs_{avg}$, and the standard deviations $\sigma_{pd}$, $\sigma_{age}$, $\sigma_{msg}$, of data in each sample set grouped by $r_{vm}$.