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Identifying multi-level emergent behaviors in agent-directed simulations using complex event type specifications.

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Summary: Agent-directed simulations (ADS) are used in many domains to study complex systems. These are systems where non-linear effects can result from these emergent behaviors, making them difficult to analyze and predict. Correspondingly, in ADS, as well as explicitly specified behaviors of individual agents, higher level behaviors can emerge spontaneously from agent action sequences and agent-agent interactions. We have previously introduced the complex event formalism for specifying emergent behaviors in dynamically executing ADS [1, 2]. Based on the formalism, we also described a method for detecting and analyzing emergent behaviors in multi-agent simulations, giving us an effective means of studying, and a more reliably way of predicting, these systems. Complex event types define sets of multi-dimensional structures of interrelated events arising from the actions of one or more agents. They are therefore directly related to the agent specifications, which determine the behavior of individual agents. Although the abstract constructs of the formalism have already been introduced in [1] and [2], they have not yet been related to a specific agent-based specification language. Here, we define the constructs in terms of the X-machine formalism, which is widely used to specify multi-agent systems. This extends the existing X-machine framework to model higher level emergent behaviors as well as agent-level state transitions. Thus, emergent behaviors at any level of abstraction can be specified for detection and analysis in a dynamically executing ADS.

Keywords: agent-based modeling; agent-directed simulation; complexity; complex systems; emergence; multi-agent systems; system dynamics
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