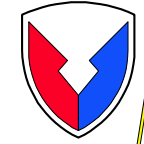


AGENT-BASED SYSTEMS: MATHEMATICAL MODELS AND ARMY NEEDS

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MODELING



- Current understanding of agent-based systems is roughly at the level where understanding of physics-based mathematics was 150-200 years ago.
 - Widely applicable quantitative models based on first/basic principles are not yet available.
 - Development of such models requires modeling in complicated frameworks (equations on complicated, perhaps nonsmooth, manifolds?).
 - Classical metrics (often rms-based) are insufficient. New metrics based on first/basic principles are needed.
 - Analysis in “metrics” that are not mathematical metrics? (L_p for $0 < p < 1$, other non-convex “metrics”?)



EMERGENT BEHAVIOR



- Objective is to understand “emergent behavior,” that is, how simple rules of agents result in complex, seemingly intelligent network behavior.
- Once understood, optimize for human goals.
- Once understood and optimized, this behavior will probably no longer be called “emergent behavior”.



MODELS BY ANALOGY



- Models adopted from physics-based areas risky, for example:
 - Classical fluid-flow (Navier-Stokes-like) models for “flows” produced by agent systems have been proposed.
 - Classical fluid-flow models are based on conservation of mass and Newtonian mechanics $F = ma$ (+ thermodynamics + electromagnetics).
 - Why should agent-based systems be well modeled by conservation of mass and Newton mechanics?



MODELS BY FIRST PRINCIPLES



- Models based on first/basic principles are needed.
 - Interactions in agent-based systems may lead to models similar to classical physics-based models (if so, great).
 - Interactions in agent-based systems may lead to models different from classical physics-based models.
 - In continuum limit, partial differential/integral equations on manifolds? Maybe, maybe not.
 - What is (are) the “metrics”?



AGENT-BASED SYSTEMS RESEARCH



- Many layers
 - Physical substrate (computers, sensors)
 - Network
 - Human interactions
 - Human intentions
- Many disciplines
 - Human factors expertise may need to be included. (“What is the model?” and “What is the metric?” are not just questions about physical issues.)



ARMY INTERESTS IN AGENT-BASED SYSTEMS



- Army/DoD interests

- Data fusion (large arrays of microsensors—sensorwebs)
- Dynamics of sensor/actuator networks
- Information mining (next step beyond data mining)
- Cooperative information dynamics
- Discovering collaborative behavior (detection of terrorist collaboration—asymmetric conflict)
- Network tomography
- Swarming; social behavior of robots
- Design of networks for optimal performance under overload