Agent-Based Modeling and Distributed C2

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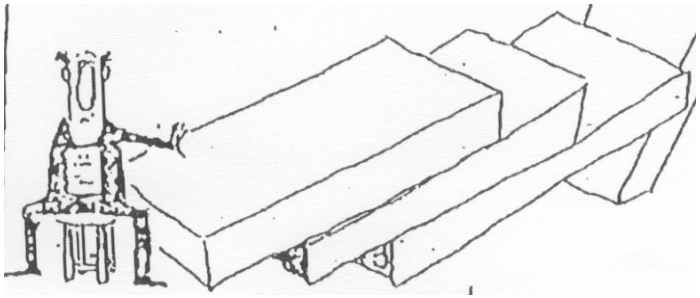
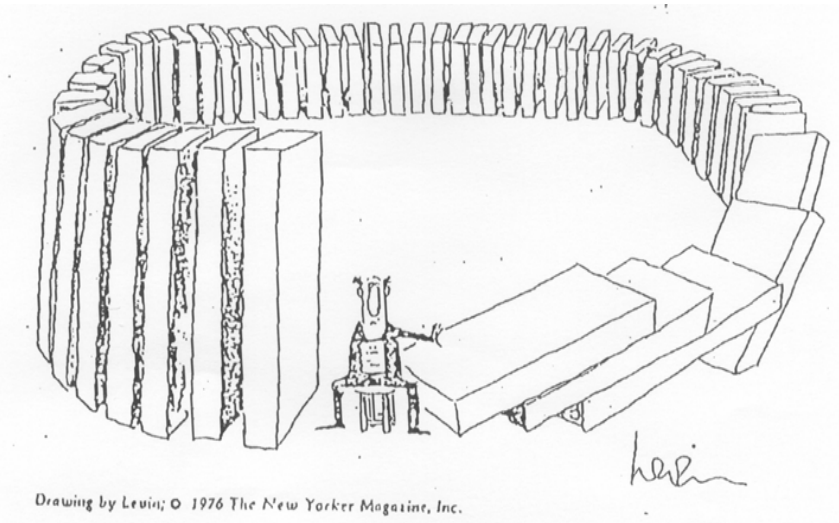
June 2003

Outline

- The Challenge
- The Agent-Based Modeling Approach
- Illustrative Examples:
  - Flows
  - Logistics
  - Self-organized task allocation
  - Operational Risk
  - Computer Security
  - Agent-Based Evidence Marshalling
  - Emergent behavior by design
- Summary

Challenge 1: The Whole is More than the Sum of the Parts





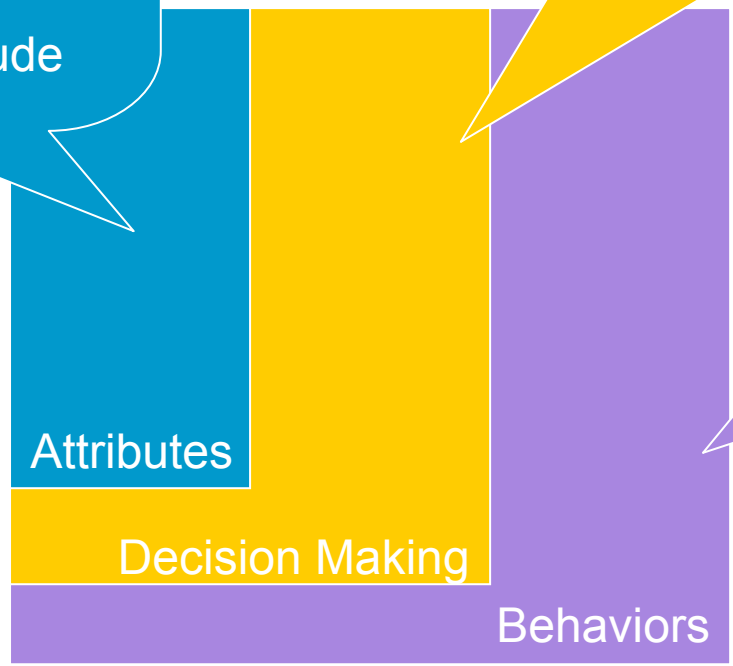
Bottom up approach needed to capture interactions between bricks: only then can you hope to predict the collective dynamics of the system.

Plus, what if the bricks have more complex behavior, learn and adapt??

Challenge 2: Behavior is kind of important!

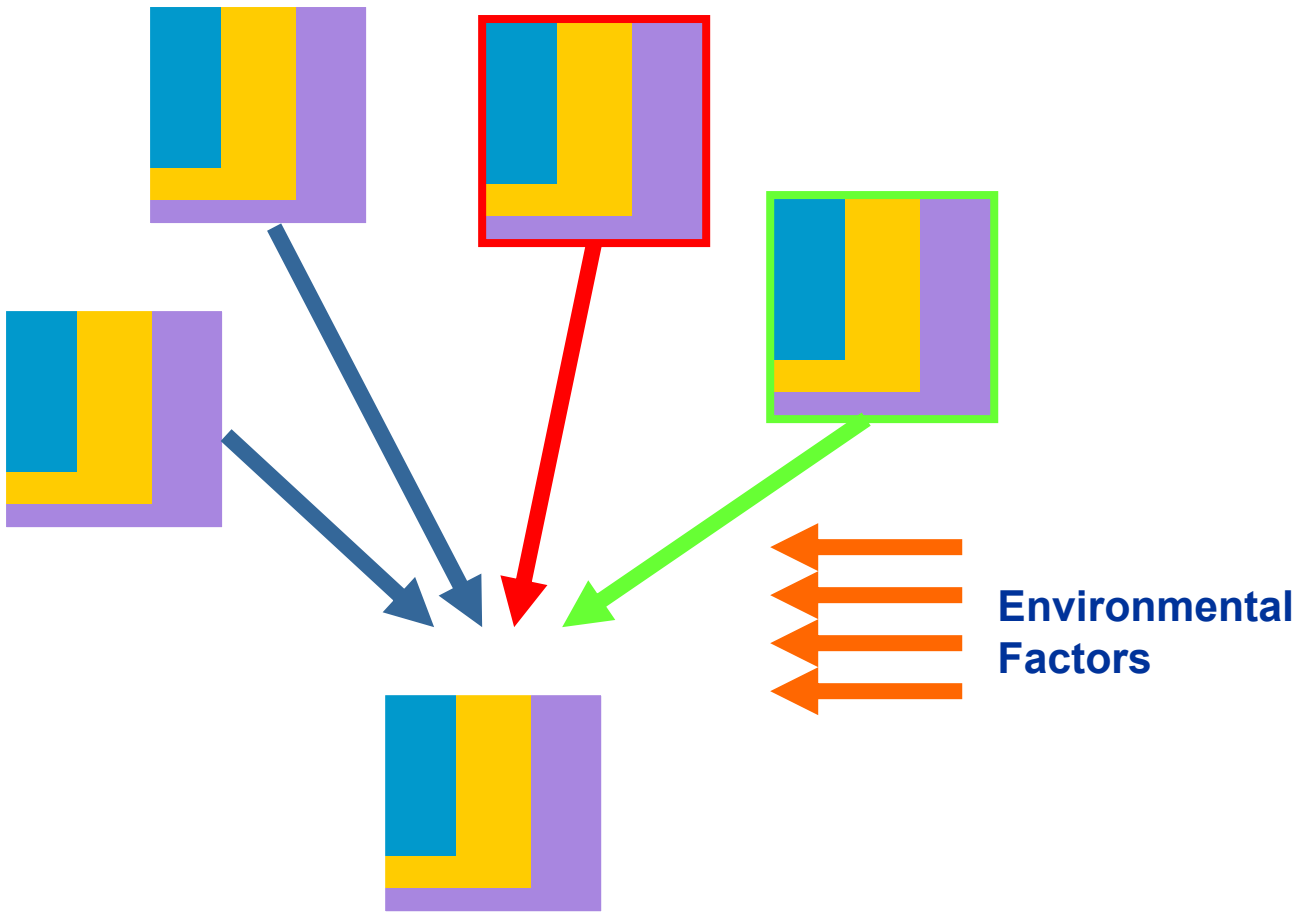
Fundamental, defining characteristics of an agent. Can be static or dynamic (time), independent or dependent (other agents/events). e.g. Sex, Age, Attitude

How an agent processes external and internal information when faced with an opportunity to act. e.g. When and what to prescribe



What an agent actually does in a given situation. e.g. prescribe X or Y, talk to other physician

Agents interact in an interconnected system …



Neglecting *how* decisions are made is dangerous

Attributes:
60% Male
40% Female

Behavior:
60% Product A
40% Product B

All Males

All Females

Product A

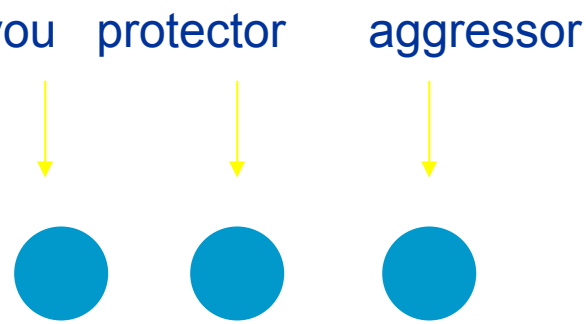
Product B

Buy from Rep
of same sex

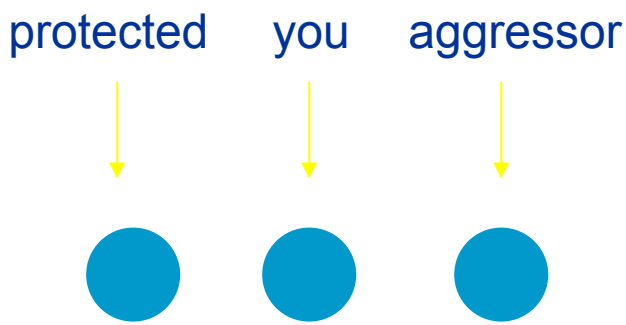
Attributes:
Co A employs all Male Reps
Co B employs all Female Reps

Simple rules of behavior can generate complexity

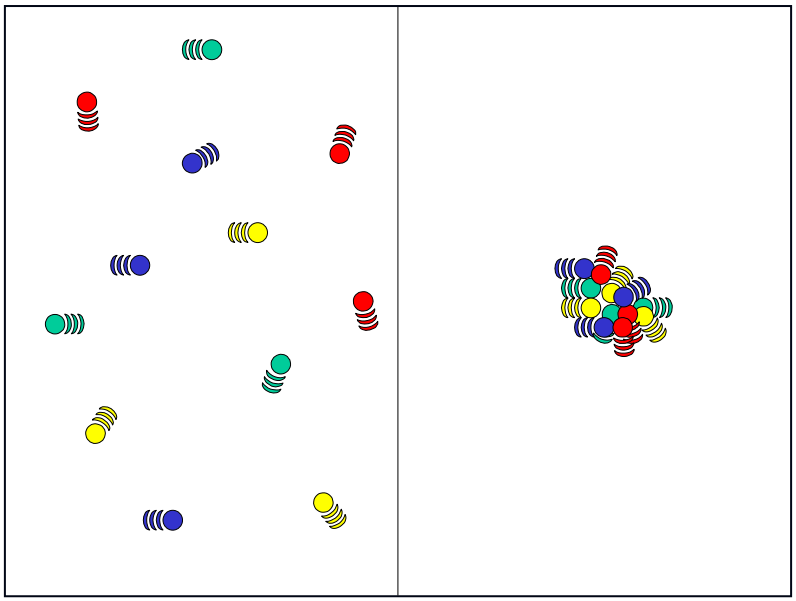
- Game 1: pick a protector and an aggressor, then move so that your protector is always located between you and your aggressor.



- Game 2: pick a protected and an aggressor, then move so as to be always located between your protected and his/her aggressor.



The outcome…

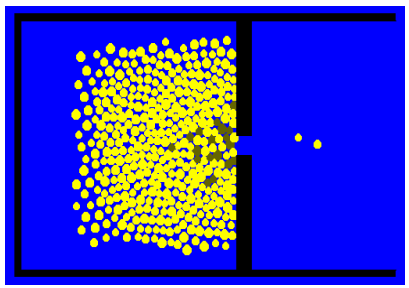


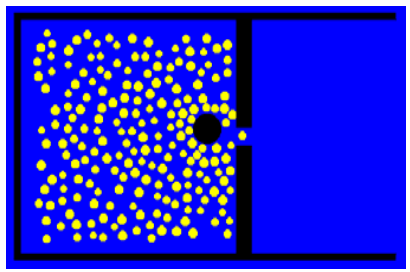
… can be predicted by ABM

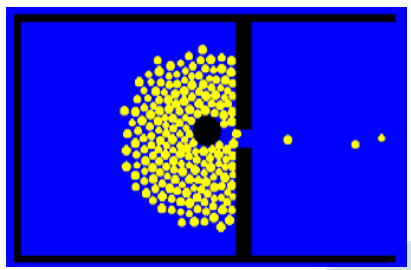
Evacuation, fire escape

Evacuation of a public space (stadium, city, …)

or fire escape



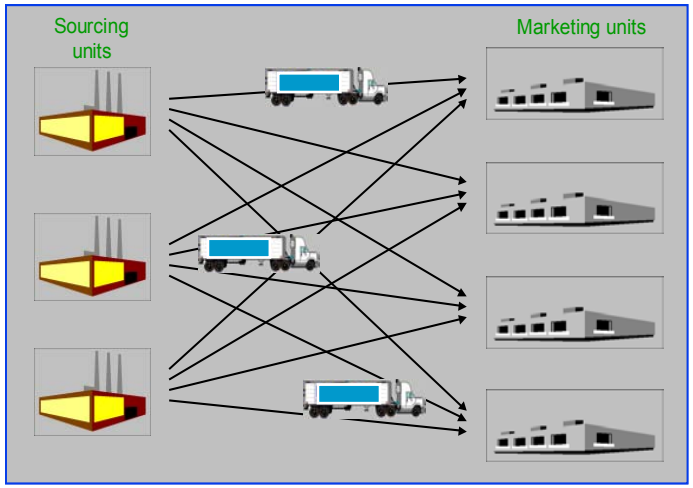




45 s simulation, stampede, 200 people	# Escaped	# Injured
Without column, injured people don't move	**44**	**5**
With column, injured people don't move	**72**	**0**

From Helbing

Stock management rules at FMCG mfr

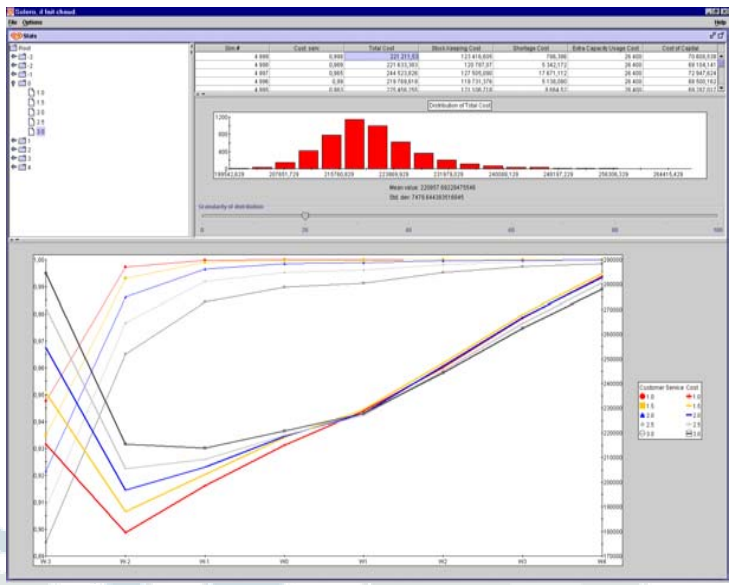


Problem

- Find stock management rules for dealing with conflicting goals of satisfying customer demand at Marketing Units while minimizing SC costs in a highly seasonal and weather sensitive business (global rather than local optimization)

Approach

- ABM of Supply Chain from production to consumer demand
- Analysis of impact and robustness of stock management rules on the trade-off between customer service and SC costs under 1000's of scenarios



Results

- 5% improvement in shorts at current cost…
- … or 10% cost reduction at current shorts

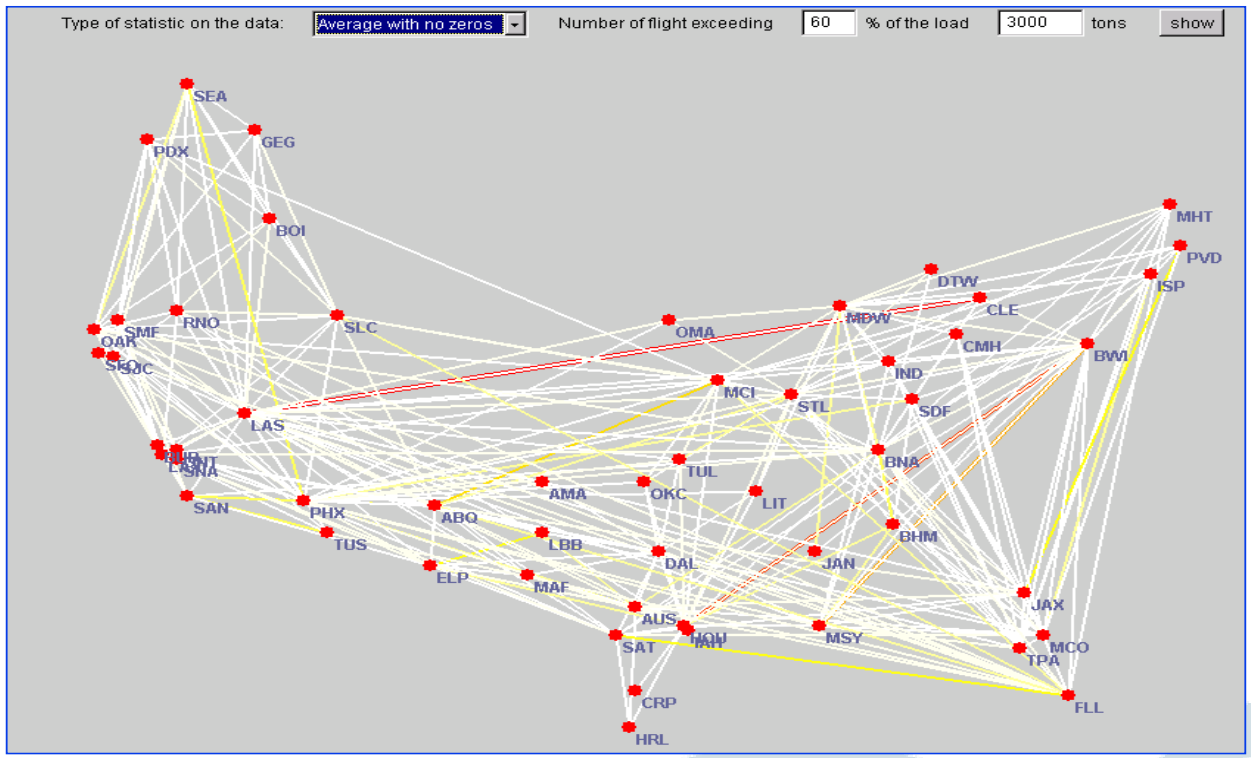
Southwest Airlines

Problem

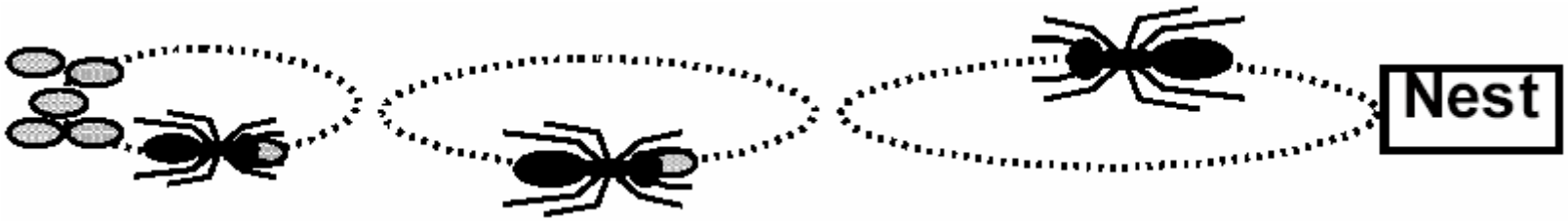
- Optimize cargo routing (easy)
- Robustly (difficult)
- Simple rules (very difficult)

Results

- 71% improvement
- At least $2m/yr

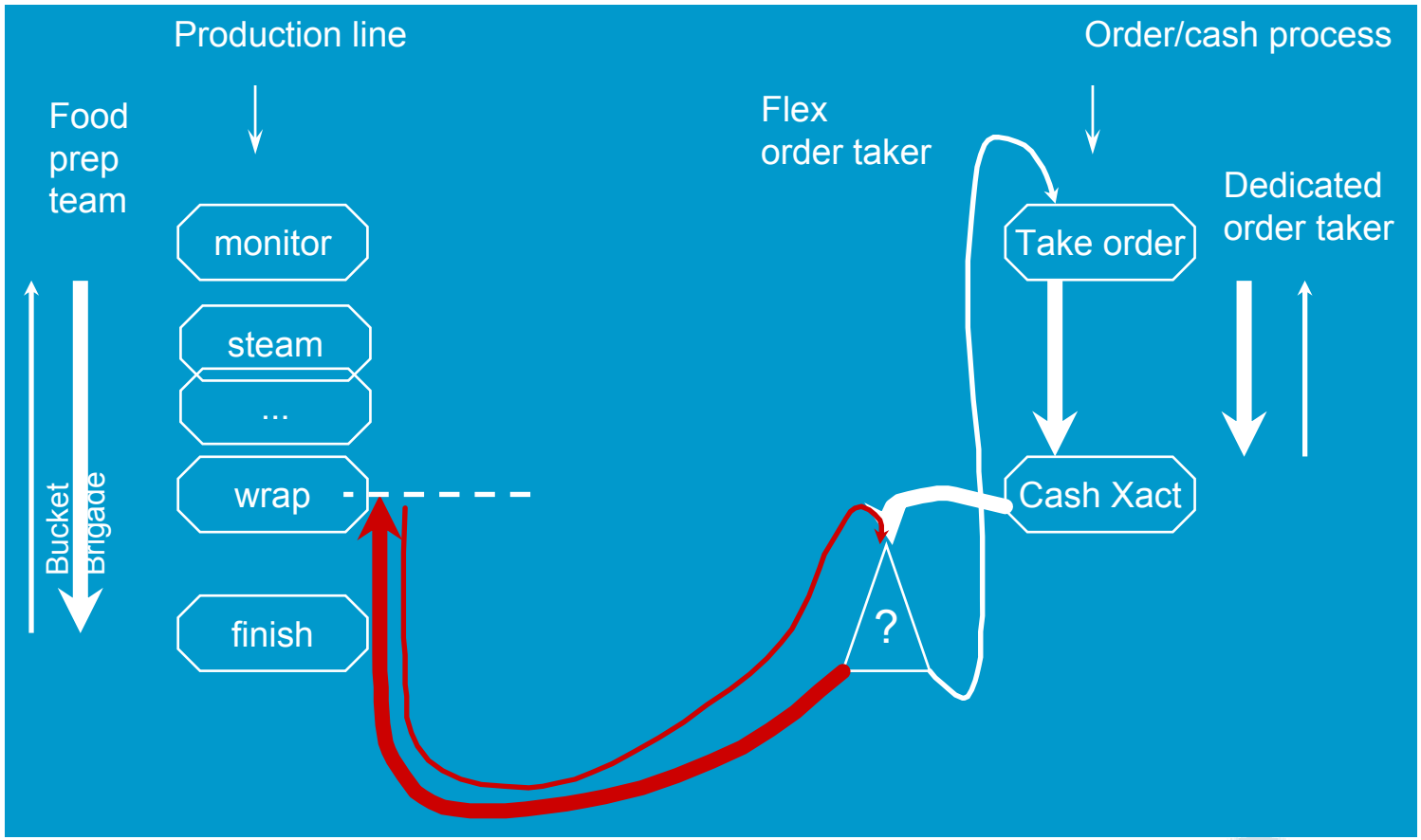


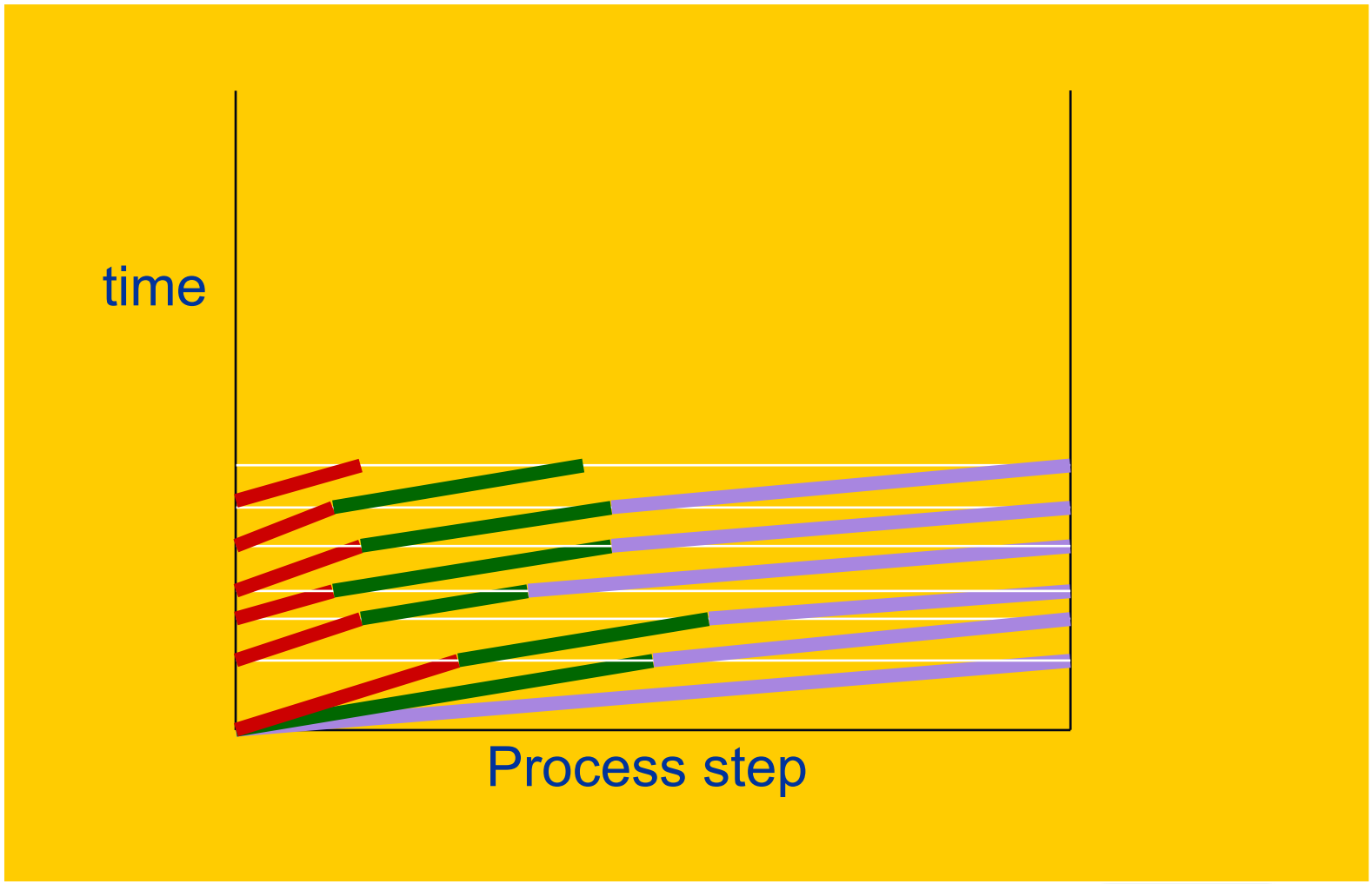
Distributed C2: Bucket brigades in harvester ants



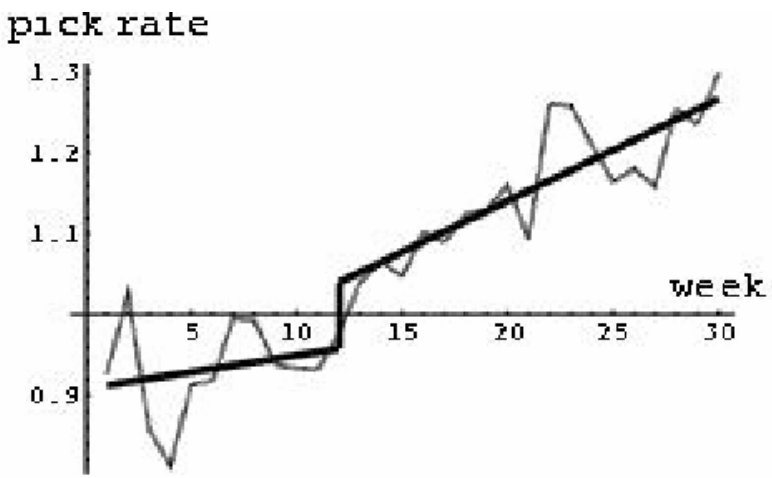
- *Messor barbarus* in southern Spain retrieve seeds from a source in a bucket brigade of up to six workers.
- The first and smallest ant collects a seed from a source and starts to carry it along a trail towards the nest until it meets a larger worker.
- This larger worker takes the seed from the ant and continues to transport the seed towards the nest while the smaller ant turns and walks back towards the seed source. And so on.

Bucket brigades at Taco Bell



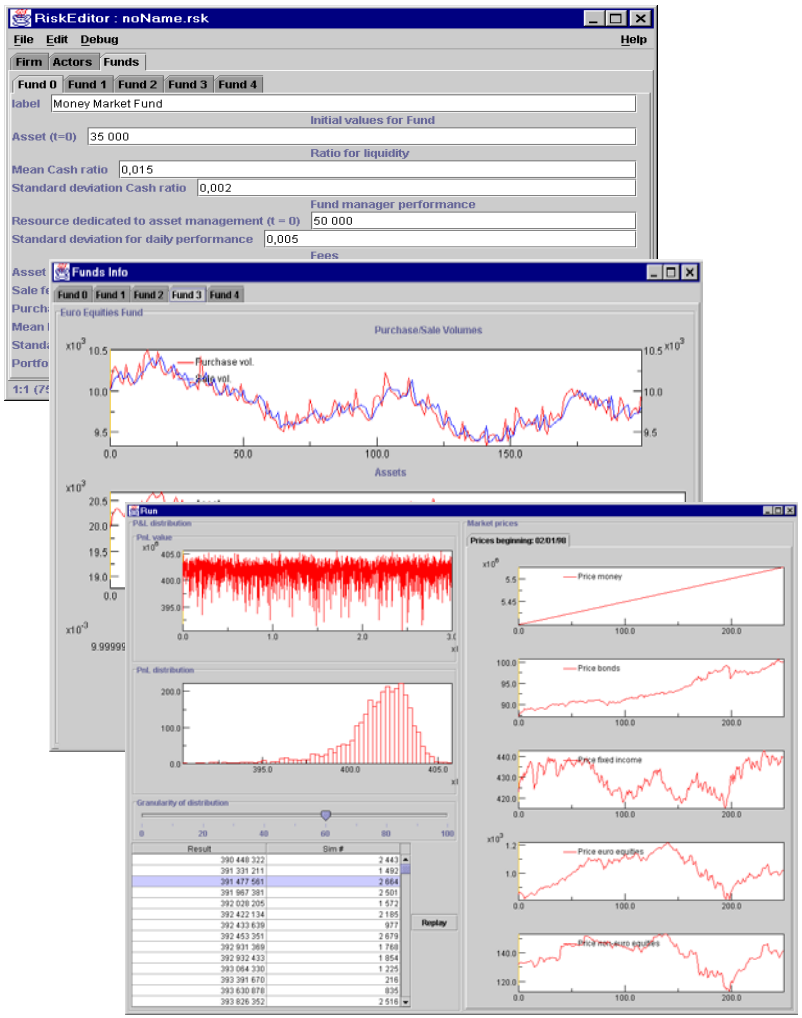


Optimal work-sharing emerges spontaneously



Average pick rates as fraction of work standard both before, and after, switching from zone picking to bucket brigades (in week 12) at the national distribution center of *Revco Drugstores* (now *CVS*). Achieved 34% increase in throughput among order-pickers after converting to bucket brigades.

Operational Risk – Financial Institution



Problem

- Measure and manage operational risk
- No data - past is not necessarily sufficient for prediction anyway!

Approach

- Agent-based simulation:
  - risk applies to agents
  - simulation of activities rather than processes
- Analysis of outcomes:
  - Identify error accumulation and propagation (cascades and loops)
  - Identify causes of large losses

Results

- Measure of value-at-risk
- Identification of causes
- Capital allocation by activity
- Self-assessment tool

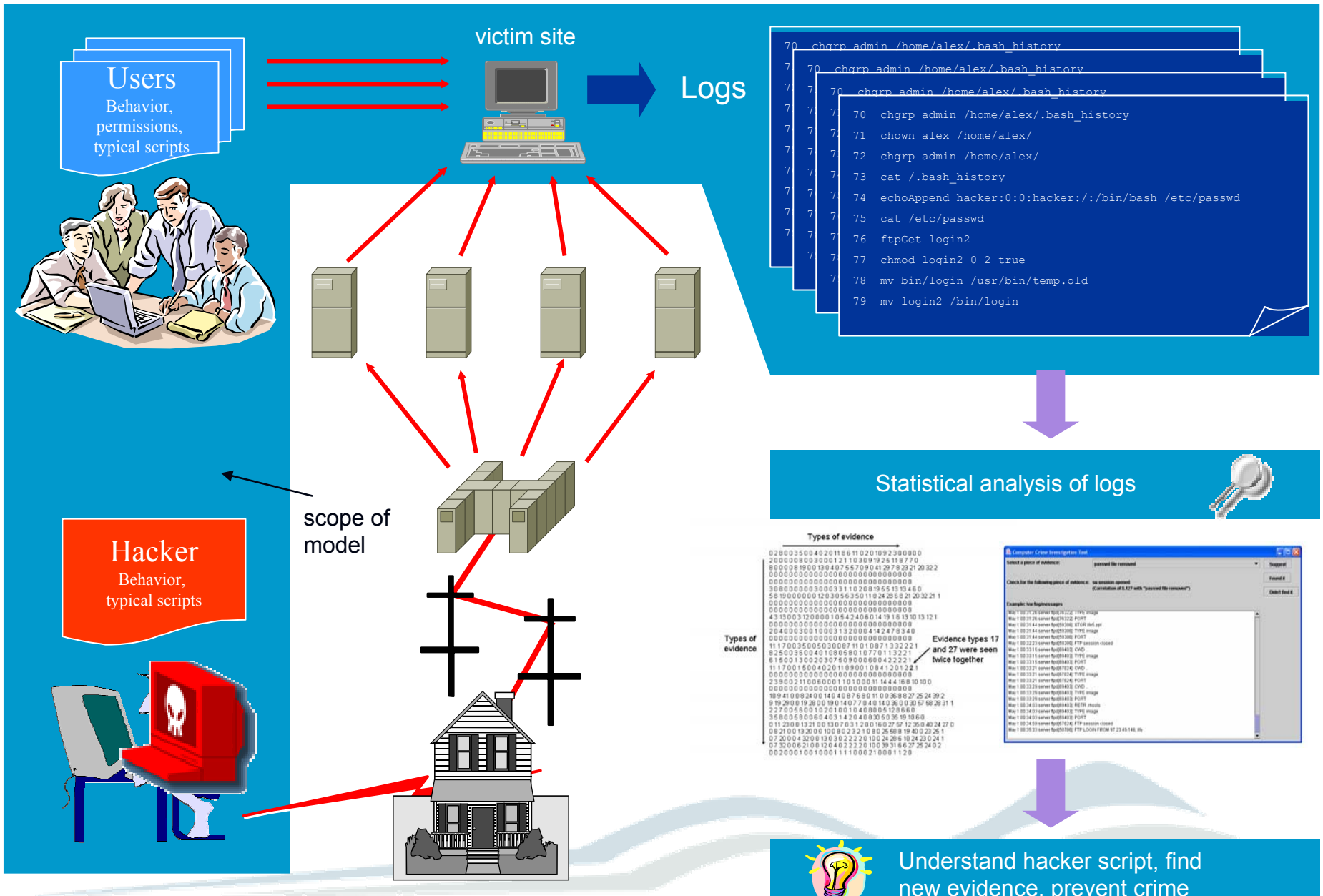
Objective

- Characterization of hacker behavior outcomes
- Automation of “hacker” detection

Approach

- Develop agent-based model of intrusion behavior to explore space of possible intrusions
- Run large number of simulations to create “synthetic” data corresponding to hacker activity
- Analyze results in order to generate hacker detection

Computer Security – Hacker Model (US Army CCIU)



Agent-Based Evidence Marshalling (ABEM)

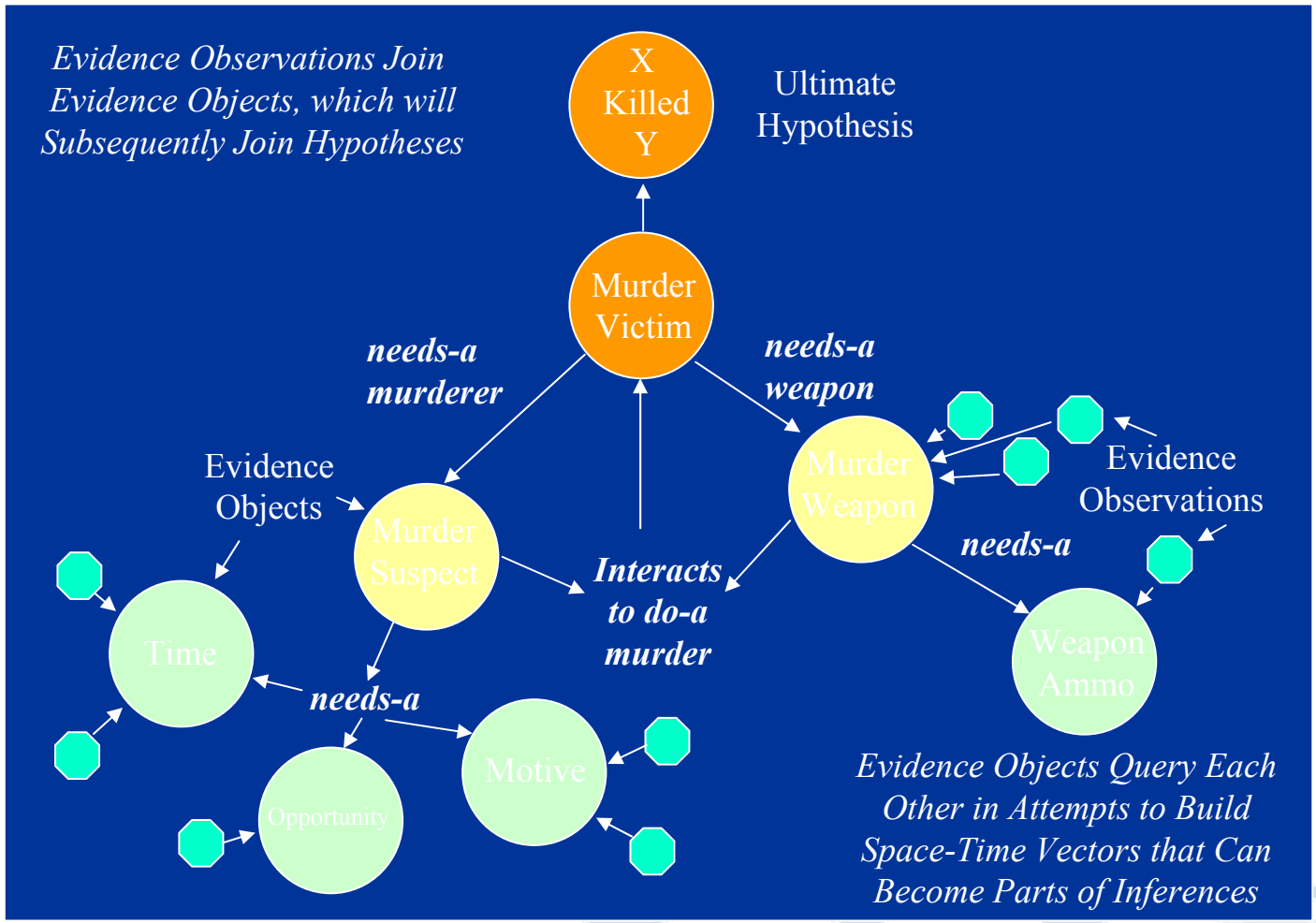
- Goal of overall process: To construct a self-organized crime scenario or story that suggests ways for interaction of evidence and environment, and proposes new query
  - Informs us about ***what we don't yet know***

- Every observed element (computer, vehicles, people) becomes a Java object

Which triggers us to form a new query!

- Objects "justify their existence" and attempt to construct their *space-time vectors* in the domain of investigation - stolen computer attempts to figure out its own trajectory

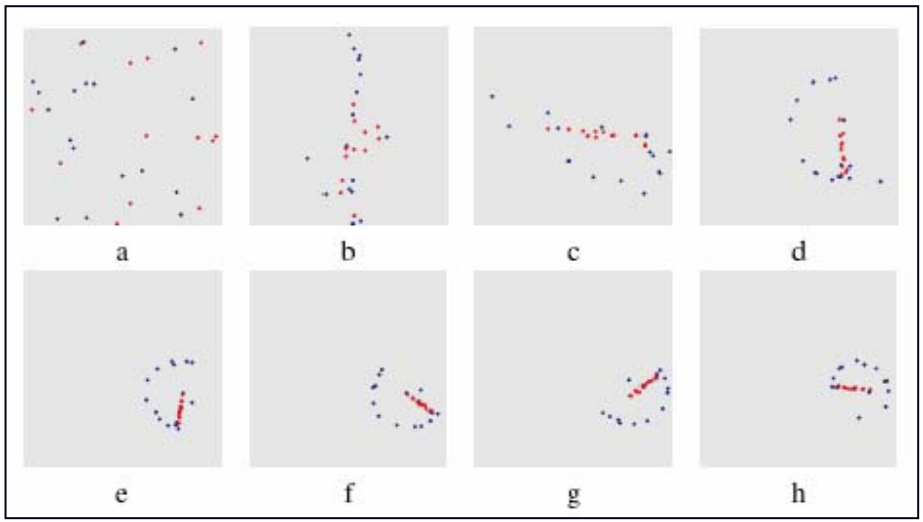
A Simple ABEM Graph



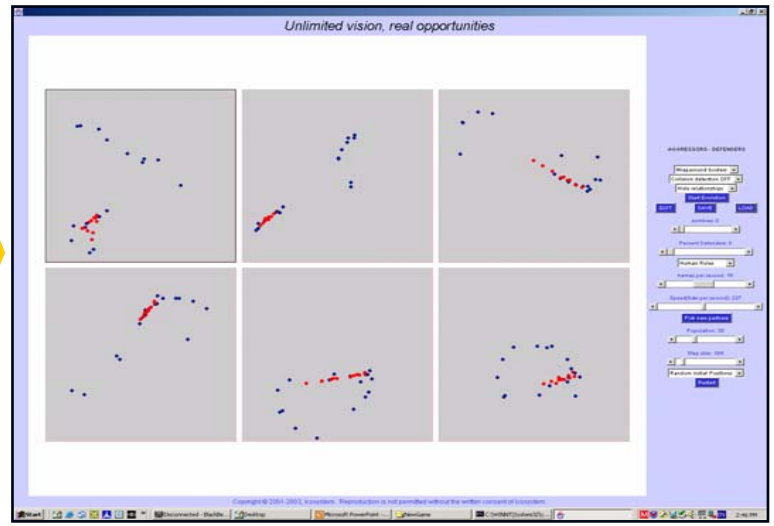
A cautionary tale about decentralized C2

Circular mill in army ants: a circle of ants continuously following each other round and round in circles until death (Schneirla). Beebe (1921) observed a mill in Guyana that measured 1200 feet in circumference with a circuit time for each ant of about 2½ hours. The mill persisted for two days, with ever increasing numbers of dead bodies littering the route, but eventually a few workers straggled from the trail thus breaking the cycle, and the raid marched off into the forest.

Emergent behavior by design



1. Predictive power with ABM



2. Design with interactive evolution

3. Test in the real world

Summary

- ABM's "bottom-up philosophy" captures emergent behavior and counter-intuitive phenomena
- ABM can be used to test and design Command and Control interventions to produce desired aggregate, system-level output
- Good to test *in silico* first!