A Swarm Ontology for Complex Systems Engineering

Overview Slides

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OMG System Modeling Language (OMG SysML™)

- SysML is a profile and extension of the Unified Modeling Language, developed by an industry team in response to a request issued by the Object Management Group (OMG)
- Supports the specification, analysis, and verification of complex systems
- Improves the ability to exchange systems engineering information across tools
- Supports systems engineering processes
Systems Engineering Lifecycle

- Requirement
  - Functional Requirement
  - Nonfunctional Requirement
- Function
  - Subfunction
- Design element
  - Subelement
- Test & Verification

Relationships:
- Derive
- Satisfy
- Verify
- Allocate
- Communication, Coordination, Change Control
Cross Connecting Model Elements

1. Structure

2. Behavior

3. Requirements

4. Parametrics

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SysML Diagram Taxonomy

- Activity Diagram
- Sequence Diagram
- State Machine Diagram
- Use Case Diagram
- Block Definition Diagram
- Internal Block Diagram
- Package Diagram
- Requirement Diagram
- Structure Diagram

Legend:
- Same as UML 2
- Modified from UML 2
- New diagram type
System structure models for agents

• “Systems thinking” is a hallmark of both complex adaptive systems research and applied systems engineering

• Properties and functions at emergent levels is a persistent, common theme
  - Many engineering applications are increasingly recognized as complex adaptive systems, in which decentralized policies and rules generate desired outcomes

• Multi-level systems and multi-level agents can share modeling foundations
  - Basic description of state and behavior
  - Connection of working elements in local system context
  - Custom description at any level with optional linkage across levels
Swarm design goals

• Conceptual framework for agent models
• Programming support for building agent simulations
• Experimenter support for running simulations
• Nucleus for a community of agent modelers

Santa Fe Institute

Swarm Development Group
www.swarm.org
A swarm is:

- A collection of objects
- A schedule of actions over those agents
Hierarchical and Reflective Swarms
Self-constructing swarms

- Starting from an initial, minimal structure and internal schema, let the swarm itself control the creation of all internal structure and the behavior it enables.
- Similar to a process of biological development.
- Initial schema serves as an internal “genetic code” that enables agents to share blueprints for component construction and binding, including transfers across independent lifetimes.
- Behavior model to express cognition, learning, organization, growth and evolution.
A swarm is:

- A collection of objects
- A schedule of actions over those agents
- A schema that controls the development and behavior of the swarm over its entire lifetime
Problem statements from the Workshop on Biological Framings of Problems in Computing held April 17-19, 2002 at the Santa Fe Institute:

"Living Language" Problem Statement

Define a formal language that can be used to describe trajectories of development through a state space that expands as a system runs. The expanding state space must be able to include the products of innovation produced during evolution of a system and the individuals within it. This means that the formal language must be able to add new elements to whatever vocabulary it starts with [...] 

"Back to Development" Problem Statement

Create a program that can control its own future growth and form. Find an encoding/specification that can control the elaboration of computer system functions/features throughout a lifetime of ever increasing requirements and corresponding complexity.
Summary

- There are both practical and theoretical challenges to apply Modeling & Simulation to the needs of complex systems engineering.
- Building on existing modeling frameworks (Systems Engineering models, logic-based knowledge representation, agent-based modeling) can provide useful cross-fertilization and multiple bridges to existing practice.
- Because Modeling & Simulation will be fundamental to the practice of complex systems engineering, new modeling frameworks could be an important enabler.