An Ontology for Agent-based Modeling and Simulation

Scott Christley, Xiaorong Xiang, Greg Madey
Dept. of Computer Science and Engineering
University of Notre Dame

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Overview

• Motivation
• Ontology
• Agent-based Modeling and Simulation
• Ontological Reasoning
• Inference and Automation
• Future Work
Motivation

• Formalize the process, take a knowledge-based approach to simulation
• Underlying assumptions in the model can manifest into artifacts in the simulation results, so formalizing the model makes them more explicit.
• Reasoning can provide the modeler with feedback/methodology direction and can automate some of the tasks.
• Agent-directed Simulation, computer assisted problem-solving, support tools
Ontology

- Establish common vocabulary
- Knowledge-based representation of concepts and relationships between those concepts
- Allows for automated reasoning
- Ontology Web Language (OWL) using Protégé editor.
Agent-based Model

- Agents interacting with other agents and its environment within a spatial structure.
- Agent is the conceptual unit of interest, defines a boundary between what is internal to the agent versus what is external.
- Environment represents global and/or local state information that is external to agents. Abstracts entities in the model that we do not want to explicitly represent as agents.
- Spatial structure has implicit notions of locality based upon measures, holds only state specific to those measures.
- Multiple agents, environments, and spaces are valid concepts in the model.
Modeling and Simulation Process

- Scientific inquiry
- Conceptual Model; verbal, abstract model that states the theory or hypotheses for the agent-based model and the goals and objectives of the simulation.
- Communicative Model; domain-specific ontology that fits within the general agent-based ontology.
- Programmed Model; software representation of the Communicative Model, in particular an Agent Based Simulation.
- Experimental Model; design of experiments using the Programmed Model to produce Simulation Data.
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Ontological Reasoning

- Reasoning with our knowledge base about the process of modeling and simulation, and ultimately about the domain of interest.
- Inference of model assumptions and parameters.
- Check model consistency
- Automated software programming
- Automated design and execution of experiments
- Automated validation of simulation results
Inferred Assumptions

- **Data Assumptions**, data collection and analysis
  - InputModeling, representation of empirical data with an analytic distribution.
- **Structural Assumptions**, model composition and representation
  - Ontology representation, CommunicativeModel
  - Software representation, ProgrammedModel
- Reasoner can extract these assumptions from the properties and relationships of the concepts in the ontology.
- Knowledge of these assumptions implies possible validation tests.
Inferred Parameters

• Parameter  
  – Input to the model that is persistent through the whole simulation.

• InitialCondition  
  – Values for state variables for just the start of the simulation.

• Value assigned as part of ExperimentalModel, may be obtained through ParameterEstimation or attached to a DataSource like a RNG.

• Reasoner can infer parameters from the knowledge base; logical query on the properties of agents, environment, and space.
Automated Programming

• CommunicativeModel -> ProgrammedModel
• Declarative versus Procedural debate
  – Declarative, “what to do”, high-level specification language, ontology and reasoning
  – Procedural, “how to do it”, standard programming language
• Intermediate approach
  – High-level structure generated automatically
  – Detailed behaviors implemented procedurally by modeler.
• Ontological representation of programming constructs
  – Java RePast, ObjC Swarm, classes, instance variables, methods
Model Composition

• Composition of multiple, separate CommunicativeModels into a single ProgrammedModel.
• Two CommunicativeModels represent same real world phenomena or different real world phenomena.
• Merge of domain-specific ontologies requires knowledge of the semantics of interaction.
  – Semantics in both models
  – Semantics in one model
  – Semantics in neither model
• Structural equivalence
Automated Experiments

• Iterative process of hypothesized model, experimentation, validation and analysis, leading back to changes to the model.

• Experimental design as manipulation of the ProgrammedModel
  – Value assignment for parameters
  – Enable/disable Actions for the agents, environment, and space
  – Different implementations

• Reasoning about the value of information, produce experiments to test assumptions.
Automated Validation

• Compare the implications of a model against the real world phenomena but also applies to all data/structural assumptions.
• Subjective tests like FaceValidity
• Statistical tests like GoodnessOfFit, TestOfMeans, ConfidenceIntervals, TimeSeriesAnalysis
• ModelToModelComparison
  – Same CommunicativeModel different Programmed Model
  – Different CommunicativeModel
• Reasoner has knowledge about statistical tests and can apply them to the experimental results.
Emergence

• Local interaction rules that produce global structure or behavior.

• Recognition

• Conditions for implication and existence
Future Work

• Uncertainty and probabilistic reasoning
• Learning
• Tools
  – Integration with Agent-based toolkits, visualization, and statistical packages
  – eScience, Web Services, model composition