Using Ontologies in Conceptual Model Validation

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Thesis

• The ideal for VV&A of a model is to demonstrate that it is “correct,” or at least correct for some use.

• For extremely complex models, V&V may be essentially impossible, requiring the substitution of “suitable” for “correct.”

• For models of social interactions, e.g., war, peace keeping, nation building, etc., the theoretical basis of the social sciences does not support many decisions on “correctness.”
  – For these models, V&V concentrates on improving the users’ understanding of the model – its good and bad points.
  – One part of the validation process (of the conceptual model) devolves to an examination of the theoretical support that does exist.
  – The organizational support for this examination consists of an ontology of the Social Domain, which describes all of the possible elements that might be covered by a social model.
Some Definitions

• **M&S**
  - **Model:** an abstraction of reality – can be mental, physical, computer code.
  - **Simulation:** a model that addresses change over time – can be acted out manually or run on a computer.
  - **Conceptual Model:** (general usage) the model that is intended to be implemented in computer code.

• **VV&A**
  - **Verification:** is the process of determining that a model or simulation implementation accurately represents the developer's conceptual description and specification. Verification also evaluates the extent to which the model or simulation has been developed using sound and established software engineering techniques.
  - **Validation:** is the process of determining the degree to which a model or simulation is an accurate representation of the real-world from the perspective of the intended uses of the model or simulation.
  - **Accreditation:** is an official determination that a model is acceptable for a specific purpose.

• **Ontology**
  - **Taxonomy:** a description of a domain characterized by a tree structure, each element having a single parent
  - **Ontology:** a domain description in which each element may have multiple parents and which may incorporate other descriptive elements (properties, part-of relations, etc.)
Ontology Concepts

McGuinness Spectrum

Ontology Languages

<table>
<thead>
<tr>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>OWL 2 Web Ontology Language</td>
</tr>
<tr>
<td>RDF Schema</td>
</tr>
<tr>
<td>Individuals</td>
</tr>
<tr>
<td>RDF and RDF/XML</td>
</tr>
<tr>
<td>XML and XMLS Datatypes</td>
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<tr>
<td>IRIIs and Namespaces</td>
</tr>
</tbody>
</table>
General Social Models
High Level Conceptual Diagram

Description of the world:
- States of being
- Context of action
- Protocol for action
- Natural environment
- Natural and human actors with identities, relationships, and decision-making processes

Operational Environment

Environment includes interventions, events, and ongoing processes (DIME+)

Actors

State Variable

Perceived by: Operational Environment

Affects: Operational Environment

Described by: State Variable

Operational Environment includes actors, environment (natural and man-made), and interventions, events, and ongoing processes (DIME+). The state variable is described by the operational environment, affecting the environment, which is perceived by the state variable.
PMESII stands for Political, Military, Economic, Social, Information, Infrastructure, Top levels of a taxonomy of metrics for the social domain
Social Ontology

- 633 Metric Classes
- Linked to 545 Operational Environment Elements
  - 83 Actors, with actor ontology
  - 313 Actions, with action ontology
  - 165 Environment Elements, with environment ontology
  - Several in multiple categories
- Each class and element is linked to one or more subcategories of the PMESII+ paradigm (political, military, economic, social, information, infrastructure, kinetics, environment)
- Definitions include links to 13 sources (lists, taxonomies, ontologies)
- Each metric class is (potentially) linked to one or more Lines of Effort (LOEs) from one or more of the several LOE Owners (e.g., US Govt, US DoD, Afghan National Police)
- Each metric class is linked to one or more semantic terms to allow computer inferencing
- For VV&A purposes, these are collapsed into 408 elements
VV&A Process Flow

Define the System

Define the Theories

Link the Data to Subcategories

Define the Data Sources

Define the System Requirements & Functions

Define the People / Corporations

Define the Test Event

Define the Dynamic Tests

Assign Tests to Test Stations

Define the Test Stations

Define the Fixed Events

Create the Test Schedule

Perform Dynamic Tests

Evaluate All Tests

Make Accreditation Decisions
• The Deployable Exercise System II (DEXES-II) is an example of a social model
• Part of the VV&A process is “Defining the System”
• This involves identifying each part by defining the names and version numbers, defining the “part-of” relationships, and defining the connections within the system
Another part of the VV&A process is defining the theories. Each theory, social, physical, or human expertise stand-in, must be defined, given citations, and rated as to approximate level of validity.

### Theory Validity

<table>
<thead>
<tr>
<th>Theory Validity Abbreviation</th>
<th>Theory Validity Description</th>
<th>Theory Validity Value</th>
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</thead>
<tbody>
<tr>
<td>Nil</td>
<td>Uncodified</td>
<td>0</td>
</tr>
<tr>
<td>Nil+</td>
<td>Codified but amorphous</td>
<td>0.5</td>
</tr>
<tr>
<td>WAG</td>
<td>Wild Assed Guess</td>
<td>1</td>
</tr>
<tr>
<td>WAG+</td>
<td>WAG plus some science</td>
<td>1.5</td>
</tr>
<tr>
<td>SWAG</td>
<td>Scientific WAG</td>
<td>2</td>
</tr>
<tr>
<td>SWAG+</td>
<td>SWAG with some review</td>
<td>2.5</td>
</tr>
<tr>
<td>PeerRvw</td>
<td>Peer reviewed theory</td>
<td>3</td>
</tr>
<tr>
<td>PeerRvw+</td>
<td>Well reviewed theory</td>
<td>3.5</td>
</tr>
<tr>
<td>Accepted</td>
<td>Generally accepted theory</td>
<td>4</td>
</tr>
<tr>
<td>Proved-</td>
<td>Close to proven theory</td>
<td>4.5</td>
</tr>
<tr>
<td>Proved</td>
<td>Scientifically proved theory</td>
<td>5</td>
</tr>
</tbody>
</table>

- **Subject Matter Expert**: Loren Cobb, CMVValue=2.5
- **Subject Matter Expert**: DEXES Experience, CMVValue=3.0
- **Social/economic/political content areas**
  - Demographic dynamics, cmv = 4.0
    - Age-specific birth rate: gamma distribution centered at age ten, Valkovics, 1983; Kendelski, 1988
    - Age-specific mortality rate: union of infant mortality and adult mortality, logistic model of Thatcher with a modification for infant mortality
  - Migration and refugee dynamics, cmv = 1.5
  - Educational system, cmv = 2.5
    - Flow model of movement of students into, through, and out of education system, Cobb, 1999
  - Public health (epidemics), cmv = 3.5
  - Governance and corruption, cmv = 2.0
  - Public opinion dynamics, cmv = 3.0
  - Developmental economics, cmv = 3.0
  - Juvenile gangs and organized crime, cmv = 2.0
  - Ethnic relations, cmv = 2.5
Perform the Static Conceptual Model Validation

- The final part of the conceptual model validation process is linking the ontology elements that are used in the model (covered) to the theories.

- Each ontology element is considered:
  - Is it relevant to the model and its use? [yes or no]
  - Is it covered by the model? [implemented in some fashion]
  - Which theory or theories are used in the implementation?
  - This information is entered into the VV&A Tool.
Validation Process

Ontology Elements

Determine covered elements

Conceptual Model

Theories

Link theories

Theories

Theory 1

Theory 2

Theory 3

Theory 4

Theory 5

Theory 6

Theory 7

Theory 8

Rebuild bridges & tunnels
Perform the Static Conceptual Model Validation

• The final part of the validation process (for this presentation) is linking the ontology elements that are used in the model (covered) to the theories.

• Each ontology element is considered:
  – Is it relevant to the model and its use? [yes or no]
  – Is it covered by the model? [implemented in some fashion]
  – Which theory or theories are used in the implementation?
  – This information is entered into the VV&A Tool.

• Various charts and reports are generated:
  – The following charts show gross averages at the PMESII level of the theory validity coverage.
  – Other more detailed charts are available and required for full understanding
  – Detailed reports describe each and every connection between the elements and the theories.
Sample Charts for Validation Visualization

System Validation Metrics

Model Validation Metrics

Inter-Model Connections
Summary

• Social Ontology
  – Provides an organizational structure for defining the coverage of a model
  – Provides a meaningful connection between the model and the theories it uses

• Benefits
  – Defines the domain coverage of the model
  – Defines the theories underpinning the model
  – Defines the maximal theoretical validity of the model
  – Supports better understanding (validation) of the nature of the conceptual model that underlies the computer system
From the hills of East Tennessee

Questions?

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