Developing Human Social Cultural and Behavioral (HSCB) Ontologies to Support Simulations

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ABSTRACT: *Most constructive simulation developers have historically focused primarily on military platforms that are structured into well defined organizations. The organizations or individual platforms have been modeled as entities that move, shoot, and communicate. However, the realities of recent conflicts have produced new demands for simulations that represent counterinsurgency operations. These applications' requirements create new challenges for the simulation community. It is difficult to develop consensus perspectives on the Human Social Cultural and Behavioral (HSCB) domain in order to develop conceptual models for the simulations. Ontologies can be used to formally specify controlled vocabularies and to unambiguously describe semantic relationships. Ontologies are being developed by the U.S. Army to represent and characterize portions of the HSCB domain. These ontologies are potentially useful for simulation development activities including conceptual modeling, data interchange, and interoperability. The Web Ontology Language – OWL provides an open non-proprietary method for describing these ontologies.*

1. Introduction

Irregular Warfare (IW) continues to be an increasingly important domain for modeling and analysis by the DoD. Recent conflicts have primarily involved irregular warfare. Military analysts interested in IW require models, methods, and tools (MMT) including simulations. Unfortunately, there are recognized shortfalls in the methodology, tool, data, and intellectual capital for modeling and simulation (M&S) needed to support the IW analysis community [1]. The DoD M&S community is encountering new challenges as it incorporates Human Social Cultural and Behavioral (HSCB) requirements into simulations of Irregular Warfare (IW) [2].

Conceptual Models

Conceptual models are critically important products in the development of M&S tools. They can document the abstractions and the state variables used to describe a domain and reference the authoritative sources for design decisions. Many types of conceptual models are used in simulation design, development, and Verification, Validation, and Accreditation (VV&A) [3]. Mechanisms are needed to support communication among social scientists, modelers, and eventually software applications [4]. Social conceptual models are needed for IW tool VV&A and for identifying the computational social science theories being examined [5].

Counterinsurgency (COIN) is one form of IW. COIN strategies vary and are often controversial. However, many of them recognize that the emphasis needs to be on representing critical HSCB aspects of the population and measuring progress in moving the current state of affairs in the direction of a more stable and secure desired state.

The DoD uses the term "operational environment" to refer to a "composite of the conditions, circumstances, and influences that affect the employment of capabilities and bear on the decisions of the commander" [6]. Operational environment state variable descriptions represent one component of a conceptual model for a simulation that models HSCB factors. The state variables, sometimes referred to as metrics, may correlate to dependent variables represented in analysis simulations.

Ontologies can be used to support a variety of M&S information representations [7][8]. Conceptual models for the social science community can be represented in ontologies using OWL – the Web Ontology Language [9]. By representing portions of the conceptual model in an ontology, formal specifications can be used and some of the semantics of the content can be computer readable.

TRAC Research

The U.S. Army's TRADOC Analysis Center (TRAC) is developing models, methods, and tools (MMT) to support analysts as part of their Irregular Warfare Analytic Capability (IWAC) Program. As part of this effort, they recognized the need to formalize descriptions of operational environment state variables that form a portion of the conceptual model. These state variables describe portions of the domain commonly referred to in the DoD as political, military, economic, social, information, and infrastructure (PMESII).

TRAC is formalizing the description of metrics to help measure the effects of tactical operations. TRAC is employing a collaborative process to consolidate existing metric taxonomies/ontologies, develop initial metric categorizations, and define initial ontological relationships.

The results of TRAC's work should provide applications and benefits to the general simulation community. The metrics ontology will support future HSCB conceptual modeling efforts by providing reuse opportunities and links to authoritative references. The ontology may also support data interchange by providing a standard data interchange format for scenario data. Eventually, the ontology may support interoperability by leveraging inferencing to help align heterogeneous data models.

2. Background

Ontology development efforts should have a well-defined scope that is specified through requirements. The requirements must be interpreted within the context of how the ontology will support applications (analysis simulations in our case). A high level conceptual model is useful in scoping the domain and beginning the ontology design effort.

Requirements

Conceptual models are modeling artifacts that should be used by simulation developers and referenced by analysis simulation users. Therefore, they should be detailed, unambiguous, relevant, authoritative, and support traceability. Many of these requirements can be supported by the ontology by explicitly representing this information. Conceptual models, like the simulations that they support, must deal with variables at varying levels of resolution and fidelity.

Simulations incorporating HSCB factors may focus on a wide variety of state variables. It is impossible to enumerate all possible variables *a priori*. Therefore, the ontology must support a variety of perspectives and be extensible to allow the definition of new variables. Also, modelers will employ different approaches to representing the factors, so the ontology must support varying perspectives.

State variables are not always easily quantifiable. For example, the level of animosity felt by the population towards the counterinsurgency forces may be measured by survey. However, such data is rarely readily available and may need to be represented by a more abstract set of enumerated values.

State variables store values associated with the conditions of the operational environment at a specific time or over a specified timeframe. Therefore, there must be a way to associate the elements of the operational environment being described to their state variables. For example, a voter turnout metric might be associated with a particular province or an entire nation.

Eventually, analysts need to use simulations to experiment with the effects of particular actions on the state of the operational environment. Therefore, the ontology should support linkages between actors, actions, and their effects as described by the state variables.

Conceptual Model Support to MMT Development

Verification, Validation, and Accreditation (VV&A) of irregular warfare simulations is critical in establishing their credibility. The context diagram shown in Figure 1 is based on Robert G. Sargent's work in the 1990s. Our user-centered philosophy focuses on the analysts (represented at the center of the diagram).

The diagram shows how the "real world" problem space is used as the basis for analysis and modeling activities that result in the creation of a conceptual model. The conceptual model is used to code and implement analyst tools including simulations.

The analysts must also be able to refer to the conceptual model to understand the simplifying assumptions and theories implemented in the simulation.

The conceptual model supports VV&A by providing an artifact to validate against the "real world". A verification task can analyze how well the conceptual model was implemented in the MMT. An operational validation effort can look at how well the MMT represent the "real world".

Simulation tools are coded and implemented using a conceptual model that documents the abstraction of the "real world" problems space (in this case the operation environment). The conceptual model includes descriptions of the state of the simulated "world". The state variables can be organized using an IW metrics ontology.

The IW Metrics Ontology helps standardize key elements of the conceptual model by describing state variables for the operational environment.

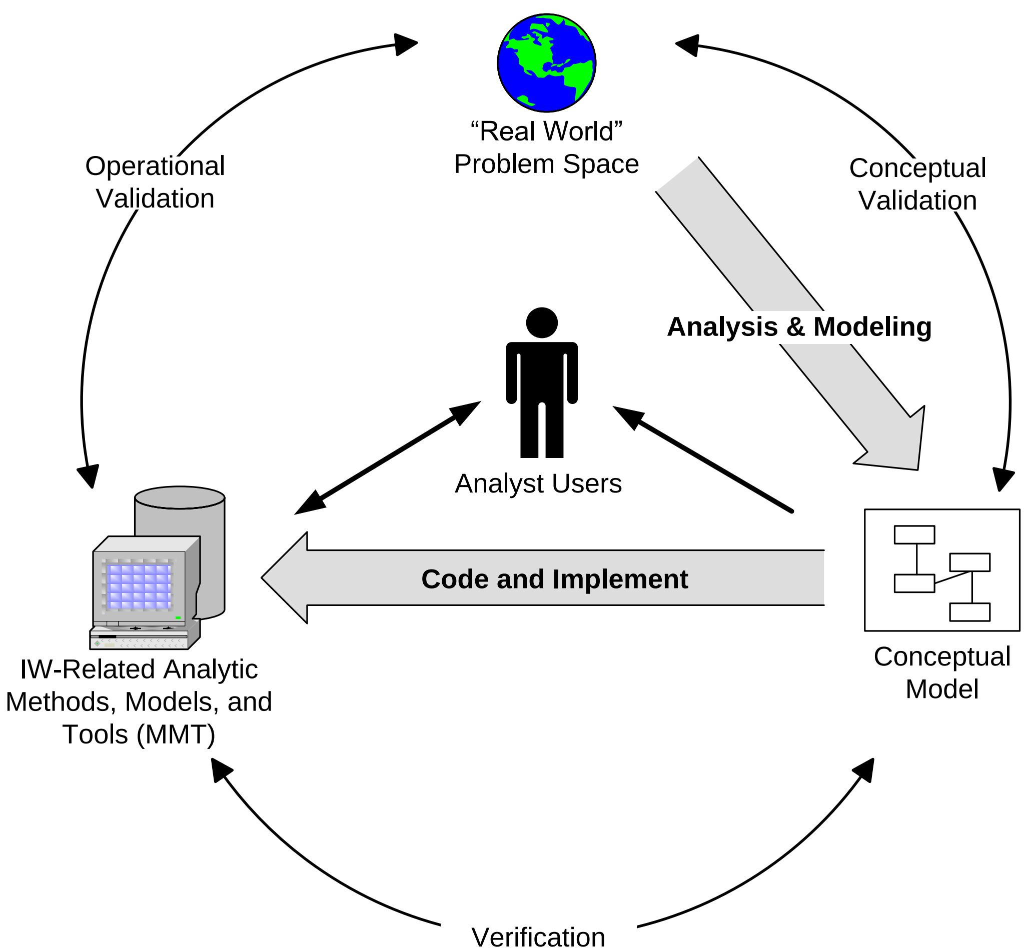

Figure 1. Conceptual Model Supports MMT Development

High Level Concept Diagram

A key step in developing an ontology is to identify and bound the domain being described. The scope of the ontology can be described with the help of a high level concept diagram. Figure 2 provides a high level perspective of IW domain elements. The operational environment consists of the natural environment, man-made environment, actors, and actions performed by actors. The actions affect the state of the overall operational environment.

The operational environment is described by a set of state variables that change over time. The state variables are perceived by actors within the operational environment.

The effects of actions on the operational environment are identified by changes in the values of state variables. Some variables (e.g., measures of performance) are used for assessment purposes. However, it is important not to overvalue metrics because they are "simply quantified or symbolic adjectives" [10]

Analysts need to understand how actions performed by actors affect the state of the operational environment so that they can determine if things are moving in the right direction.

Actors may include friendly forces, the population, the host nation, and insurgents. Actors may also represent natural occurrences such as a major storm, famine, or epidemic.

3. Related Prior Efforts

Ontology development efforts should leverage existing descriptions. Several prior research efforts have produced a legacy of potentially reusable concepts for describing the operational environment and state variables. Previous efforts have developed descriptions of the operational environment and state variables used to describe the operational environment.

Operational Environment Representation

The operational environment can be thought of as an aggregation of the natural and man-made environments, actors (humans, organizations, and nature), and the actions performed by the actors that affect the state of the operational environment.

The simulation community has invested heavily in developing methods for describing the natural and man-made environment. SEDRIS is an example of an effort to formalize environmental data representations and interchange environmental data sets [11].

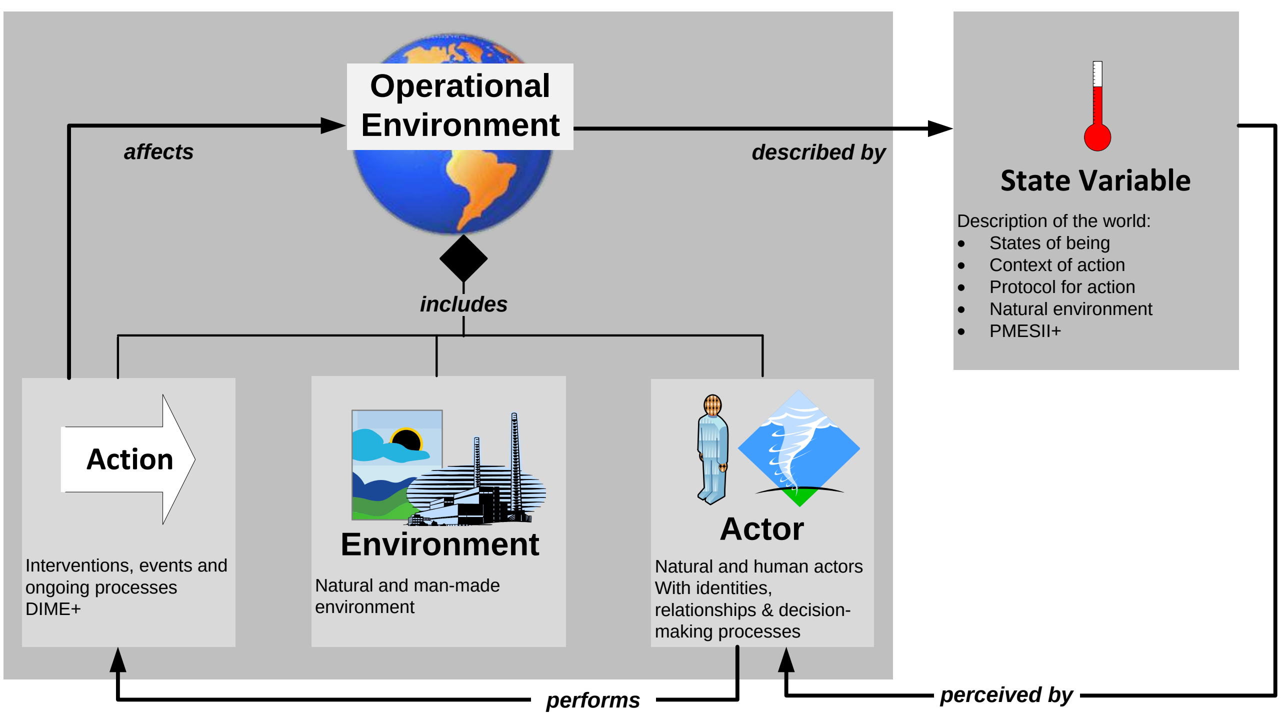

Figure 2. High Level Concept Diagram

Actions in traditional kinetic-focused simulations are often associated with military tasks such as those listed in the Army Universal Task List (AUTL). However, Irregular Warfare actions may be more complex and harder to describe. Categories of actions that affect the operational environment described by the state variables have also been developed:

- Diplomatic, Information, Military, and Economic (DIME) levers of power
- Field Manual (FM) 3-24.2 Lines of Effort (LOE), and
- Post-Conflict Reconstruction Essential Tasks [12].

Operational Environment State Variables

A variety of efforts have defined sets of metrics and taxonomies to help describe the operational environment. These items help provide a foundation for the ontology design and development effort. They include:

- Interim Semi-static Stability Model (ISSM) Variables,
- Measuring Progress in Conflict Environments (MPICE),
- DIME/PMESII Modeling Requirements,
- HSCB Taxonomy,
- Human Dimensions of the Battlespace,
- DIME/PMESII VV&A Tool variables,
- Kilcullen Counterinsurgency Book, and
- Canadian Quarterly Report.

These efforts vary in scope, focus, specificity, and structure and are described in the following paragraphs.

The ISSM was created before the DIME/PMESII organizational terminology was invented. However, it explicitly defines state variables and action variables that are involved in IW [13][14]. These variables include those defined by Hayes and Sands [15] in the *Doing Windows* book, supplemented by variables defined by the operational reports from places such as Bosnia and Iraq. The ISSM also includes the inferential connections among the variables required to track the status of an intervention given inputs of observable variables.

The MPICE framework is a hierarchical metrics system of outcome-based goals, indicators and measures. Collected data is meant to be aggregated to provide indications of trends toward the achievement of stabilization goals over time. [16]. The indicators are distributed into five categories: Political Moderation and Stable Democracy, Safe and Secure Environment, Rule of Law, Sustainable Economy, and Social well-being. MPICE developers recognized the need to adapt metrics to the specific policy goals, conflict dynamics, and cultural peculiarities relevant to each conflict setting

The U.S. Navy led an effort to identify the core, high-level requirements for modeling DIME actions and PMESII effects [17]. As part of this effort, participants identified 135 broad descriptive requirements associated with actions, effects, and overarching factors. The effects requirements may be particularly useful in developing an ontology of operational environment state variables. These requirements were used along with other sources to create an HSCB taxonomy [18].

The U.S. Marine Corps envisions five cultural dimensions of the battlespace: physical environment, economy, social structure, political structure, and beliefs and symbols [19]. The documented explanations of these dimensions could form the beginning of a taxonomy for describing the human dimension of the battlespace [2].

The DIME/PMESII VV&A Tool variables consist of the concepts that must be accounted for in examining a DIME/PMESII model. These concepts are the PMESII state variables and DIME actions initially derived from the ISSM variables and augmented by additional variables out of the ISSM scope, including kinetic actions and additional environmental state variables [20][21][22][23].

Prior TRAC-related efforts in 2009 and 2010 have also resulted in draft products that help provide a starting point for the state variable ontology discussions. These efforts helped TRAC recognize the importance of being able to connect metrics to actions in the ontology.

In his latest book, Kilcullen [24] recommends four categories of metrics associated with key counterinsurgency factors: population, supported (host nation) government, security forces (military and policy), and the enemy. He further identifies potential indicators within each of those categories. For example, he suggests tracking the price of exotic vegetables as a surrogate for population confidence and perceived security metric because of the need to bring distant products to market.

Canada publishes an assessment of their progress in Afghanistan in their Canadian Quarterly Report [25]. They use quantitative and qualitative indicators tied to specific benchmarks.

4. Ontology Design and Development Approach

The approach used to conduct this effort is summarized in the IDEF0 activity diagram in Figure 3 and in the following sections.

Plan and Manage Project

As part of the project management effort, a detailed project plan was developed with specific subplans for each major activity. A Requirements Traceability Matrix (RTM) helped track requirements throughout the effort.

Develop Ontology Overview

Researchers developed an ontology overview briefing to help communicate a common understanding of the problem and the use of ontologies to support a solution. The briefing provides background on related prior efforts, defines key concepts for the research effort, and provides educational materials on ontology development.

Harvest and Distill Information

The section on related prior efforts above describes several valuable sources of the raw materials for ontology creation in addition to historical information on what has been done before. An ontology requires a set of terms that are relevant to the domain at hand. These terms may represent elements in a taxonomy, names of variables, names of indicators or metrics, or names of actions and participants in various IW operations. In addition, an ontology requires information about the relationships among the terms. The reference materials cited above (and others) were collected to support the researchers and the workshop participants in harvesting and understanding this information.

As the information was harvested from the material, the researchers began organizing and distilling it. The distillation was required to allow meaningful contributions in the workshops, as the workshop environment does not support analysis of great quantities of data.

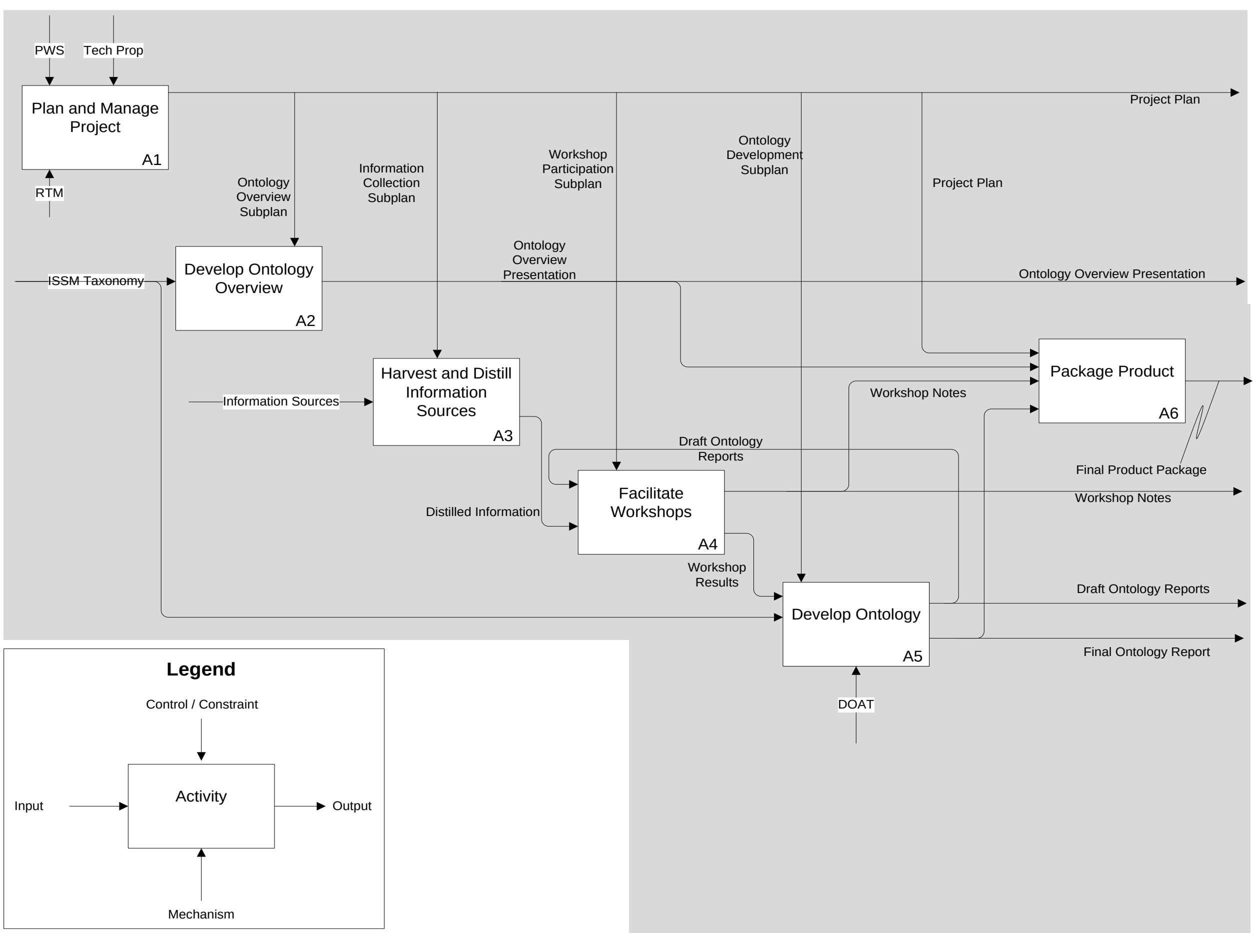

Figure 3. Activity Diagram for Ontology Development Effort

A SharePoint site is used to support collaboration. The site reposes reference documents and data files. The site is also used to maintain the project lexicon. Wiki pages are also included on the site to help organize references to the reposed contents and support final report generation.

Facilitate Workshops
A key element of the approach was to prepare strawman materials for consideration by participants. These products include a conceptual diagram and high level ontology design diagrams using UML notation.

The workshops provide consensus perspectives on the strawman products drafted by the research team. Participants set the foundation for the research artifacts by refining the problem statement and associated objectives and validating the authoritativeness of reference materials and the project lexicon. Participants are provided with the ontology overview briefing to establish common ground. The participants update strawman products including metrics categories, action categories, high level environment descriptors, actor categories, and individual metrics. The workshop results are documented in notes that are shared with participants.

Develop Ontology
The results of the workshops are used to develop OWL ontologies. Ontological classes and properties are entered into the DRC Ontology Authoring Tool (DOAT). DOAT is a relational database tool that can generate reports and contains code to create OWL files with correct syntax that describe the ontological concepts entered using forms.

Package Product
The various artifacts of the research effort will be packaged for delivery to TRAC. TRAC may make some product available to other researchers.

6. Summary

Simulations should be developed using conceptual models that explicitly document abstractions in detail. Conceptual models support HSCB simulations as part of IW MMT development. Formalizing conceptual models with ontologies allows for unambiguous descriptions and potential inferencing.

TRAC is performing research to develop ontological representations of operational environment state variables.

Prior efforts have generated reusable metrics sets that are being leveraged as part of the research.

Workshops are being used to collaboratively develop the ontology or operational environment state variable ontology. Collaborative approach involving academics and military experts helps ensure multiple perspectives contribute to the effort and lowers the risk of missing something.

The resulting ontology creates a reusable source for TRAC and for other HSCB M&S efforts.

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