Semantic Web Technologies for Military Modeling and Simulation

MOVES Open House
Curtis Blais
24 August 2004
Outline

- Motivation/Problem Statement
- Thesis: Assumptions and Research Questions
- Application to Military M&S
- Initial Approach
Motivation / Problem Statement

- Training Capabilities Analysis of Alternatives (February 2004):
  - Scenario generation for training and mission planning is difficult and time-consuming
  - No automated scenario generation tools exist

- CAPT Jeff Kline, USN NPS Systems Engineering (August 2004):
  - “The greatest barrier to the use of modeling and simulation in the 72-hour planning cycle is the time to generate scenarios.”
Scenario Information (RD3*)

*Rapid Distributed Database Development
Automated Scenario Generation

- Scenario Description (Operations Order) to Populated Scenario Data

Forms of Expression
- C2 Information Exchange Data Model
- Battle Management Language
- Military Scenario Definition Language

Semantic Discovery and Composition

Maps
Terrain
Weather
Intelligence
Forces
Behaviors
Distributed Resources
Elements of the Problem (1)

- Description
  - Scenario (orders, plans, problem specification, requirements)
  - Resources (inferred from scenario description)
  - Services (data sources)

  → Ontologies: “specification of a conceptualization”
  - Classes in the domains of interest
  - Instances
  - Relationships
  - Properties (and property values)
  - Functions and processes
  - Constraints and rules
Ontology Spectrum

Weak semantics

Is subclassification of

Is subcategory of

Has narrower meaning than

Local Domain Theory

Description Logic

DAML+OIL, OWL

Unified Modeling Language

RDF/S

XTM

Extended ER

Thesaurus

Conceptual Model

RDF/S

Unified Modeling Language

Extended ER

Thesaurus

ER

Schema

Rules & Logic

Inference Engines

Modal Logic

First Order Logic

Semantic Levels

Semantic Levels

Rules & Logic

Inference Engines

Weak semantics

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Levels of Conceptual Interoperability Model (LCIM)

<table>
<thead>
<tr>
<th>Level 0, No Connection</th>
<th>No interoperability intended</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCIM Level 1, Technical</td>
<td>Physical connectivity established</td>
</tr>
<tr>
<td>LCIM Level 2, Syntactic</td>
<td>Data exchangeable in standard formats</td>
</tr>
<tr>
<td>LCIM Level 3, Semantic</td>
<td>Data in context (information) is exchanged</td>
</tr>
<tr>
<td>LCIM Level 4, Pragmatic/Dynamic</td>
<td>Information and its use and applicability are exchanged</td>
</tr>
<tr>
<td>LCIM Level 5, Conceptual</td>
<td>Common world-view established</td>
</tr>
</tbody>
</table>

Elements of the Problem (2)

- Dynamic, distributed resources
  - Web-based
  - New sources, new products

⇒ Web Technologies
  - Open standards
  - Universal Resource Identifier (URI) for identification
  - Extensible Markup Language (XML) for description
  - Web services for communications and distributed processes
  - Beyond Web services, strong semantics: logical assertions, classification, formal class models, rules, trust
Semantic Web Stack

Web Services

How a client talks to a Service provider depends on the WSDL

Web services registry

WSDL

UDDI: Universal Description, Discovery and Integration
WSDL: Web Services Description Language
SOAP: Simple Object Access Protocol
FTP: File Transfer Protocol
HTTP: Hyper Text Transfer Protocol
SMTP: Simple Mail Transfer Protocol

UDDI: Green pages
White pages
Yellow pages

XML/ SOAP

Web

From: Coyle, F. P., XML, Web Services and the Data Revolution, Addison-Wesley, 2002
Web Services Stack

Processes
- Discovery, Aggregation, Choreography, ...

Descriptions
- Web Services Descriptions (WSDL)

Messages
- SOAP Extensions
  - Reliability, Correlation, Transactions, ...

SOAP

Communications
- HTTP, SMTP, FTP, JMS, IIOP, ...

Base Technologies: XML, DTD, Schema
Semantic Web Services Stack

<table>
<thead>
<tr>
<th>OWL, OWL-S, OWL-Rules</th>
<th>Service Entities, Relations, Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDF/S</td>
<td>Service Instances</td>
</tr>
<tr>
<td>BPEL4WS (Business Process Execution Language for Web Services)</td>
<td>Service Flow &amp; Composition</td>
</tr>
<tr>
<td>Trading Partner Agreement</td>
<td>Service Agreement</td>
</tr>
<tr>
<td>UDDI/WS Inspection</td>
<td>Service Discovery (focused &amp; unfocused)</td>
</tr>
<tr>
<td>UDDI</td>
<td>Service Publication</td>
</tr>
<tr>
<td>WSDL</td>
<td>Service Description</td>
</tr>
<tr>
<td>WS Security</td>
<td>Secure Messaging</td>
</tr>
<tr>
<td>SOAP</td>
<td>XML Messaging</td>
</tr>
<tr>
<td>HTTP, FTP, SMTP, MQ, RMI over IIOP</td>
<td>Transport</td>
</tr>
</tbody>
</table>
Thesis

Semantic Web Services enable software agents to auto-generate large-scale virtual environments.
Definitions

- **Semantic Web Services**: software components distributed over a network that are deployed, discoverable, and accessible through standardized message protocols implemented through software-understandable logical formalisms.

- **Software agents**: software components able to sense their local operating environment and operate autonomously (on a single processor or mobile over a network) with the ability to adapt to changing conditions over time.
Definitions

- **Auto-generate**: working from a specification of a final product, perform necessary operations to achieve the desired end product without further guidance from a human.

- **Large-Scale Virtual Environments**: distributed, loosely coupled software components able to interoperate to represent a simulated place and time with dynamic, interacting actors.

- **Scenario**: a particular place in time having particular physical properties and a collection of situated and non-situated actors initialized with behaviors, capabilities, goals, and missions.
Research Questions

- What is a workable ontology (or layers of ontologies) for scenario descriptions that will infer necessary resources?
- How to describe the data sources and services for discovery and access?
- How to map military ontologies to foundational ontologies? (e.g., C2IEDM to Suggested Upper Merged Ontology (SUMO))
  - “Conceptualizations that contain specifications of domain independent concepts and relations based on formal principles derived from linguistics, philosophy, and mathematics”
- What technologies, standards, guidelines, policies are required to enable an automated scenario generation capability?
Assumptions

- Assumes continuing efforts to encode scenario data sources in XML for Web-based storage and retrieval
  - Force structures
  - Maps/imagery
  - Terrain/bathymetry
  - Environment
  - Parametric data
  - Behaviors/cognitive models
Extensible Modeling and Simulation Framework (XMSF)

- A composable set of standards, profiles and recommended practices for Web-based modeling and simulation.

- Exploiting industry investment in Web technologies for military M&S
  - Open standards
  - XML-based markup languages → strong semantics
  - Internet technologies
  - Cross-platform Web services
Application to Military M&S

- XMSF Profiles
- Raising Levels of Conceptual Interoperability
- Semantic Mapping for Data Interchange
  - Common Maneuver Network
  - Flexible Asymmetric Simulation Technologies
- Composition of Services (Global Information Grid Enterprise Services)
- Rapid Scenario Generation
Initial Approach

- C2IEDM to XML Schema: vocabulary and structure for data interchange (NPS, IDA, NUWC)
- C2IEDM to Resource Description Framework (RDF) and RDF-Schema: foundation for richer semantic representations
  - Web Ontology Language (OWL): scenario descriptions and scenario resources
  - OWL-S: semantic web services (data sources)
- Mapping to foundational ontologies (e.g., SUMO)

Demonstrate implications of the richer semantics
Questions?

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Backup Slides
RD3 Production Process and Strong Semantics
OOTW FAST Toolbox Data Interchange

- Flexible Asymmetric Simulation Technologies (FAST) Operations Other Than War (OOTW) Toolbox
- Thesis work by Capt Glenn Hodges USA (graduation: September 2004)
- Goal: Create data interchange mechanism between Unit Order of Battle (UOB) and C2IEDM
FAST OOTW Toolbox

Access Tool to Task
Organize & Produce
TOs In Standard Format
Extending Unit Data Interchange

- JCATS
  - xslt
  - xsd

- SAI-FAST-DIF
  - xslt
  - xsd
  - exports
  - UOB.xml
  - xsd

- DIAMOND
  - xslt
  - xsd

- UOB Data Access Tool
  - exports

- C2IEDM
  - xsd

- US and Coalition C4ISR
Common Maneuver Network

- Common data representations across C4I systems and M&S (embedded M&S in FCS)
  - Battlespace Terrain Reasoning and Assessment (BTRA) decision support tool
  - OneSAF Objective System (OOS)
- Survey maneuver network representations across a number of systems and standards
  - BTRA, OOS, C2IEDM, Geographic Markup Language (GML), others
- Assess alternatives and make recommendation
  - New representation scheme
  - Identification/adaptation of existing representation scheme (C2IEDM extension?)
  - Proof-of-concept interchange transformations
Common Maneuver Network

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Composition of Services

- GIG Enterprise Services
- Capability for software agents to reason about software components and composite goals (problem-solving, goal-seeking)
OPNAV N81 World-Class Modeling

- Model interoperation through Web services
- Composition of model components
- Semantics of discrete event simulation
Operations Order Data Interchange


- Primary focus areas
  - XML representation of tactical message formats
  - Common data model (C2IEdM)
  - Web-based 3D graphics standard (X3D)

- Laid conceptual foundation and motivation for birth of the Extensible Modeling and Simulation Framework (XMSF) program
Operations Order Data Interchange

Generic Hub Design Methodology for Battlespace Visualization + Semantics: DoD-wide Autoconversion Of Operation Orders into 3D Virtual Environments

Generic Hub version d (GH4) Information Exchange Data Model

X3D/VRML World: Amphibious Operation Order Displayed as Networked, Animated 3D Scene!