Exploration of Semantic Web Technologies as an Enabler of Model-based Systems Engineering (MBSE) and Digital Engineering (DE)

Hyun June Ferrabolli
System Engineer
CCDC-Armaments Center, Picatinny Arsenal
• Name: Hyun June Ferrabolli  
• Title: System Engineer  
• Education:  
  » Stevens Institute of Technology  
  » M.Eng. in Systems Engineering (concentration in Decision making and Risk mitigation)  
  » B.Eng. Mechanical Engineering

• I research and develop system engineering infrastructure for the System Engineering Directorate at the Combat Capabilities Development Center Armaments Center, Picatinny Arsenal, NJ.

• My current work has focused on exploring integration and interoperability frameworks that connect engineering workflows.
WHAT ARE SEMANTIC WEB TECHNOLOGIES?

- Semantic = machine readable data and information
- Web = interconnected data and information

- Made up of tools and standards
  - Standards
    - RDF: Simple class hierarchies
    - OWL: RDF vocabulary for formal logic
    - SPARQL: Powerful language for querying RDF/OWL databases
    - Ontologies: formal naming and definition of the categories, properties and relations between the concepts
  - Tools
    - Ontology editors: Protégé, Composer
    - Knowledge repositories: Sesame (rdf4j, Oracle Semantic Database, Mulgara)
    - Application frameworks: Sesame, Jena

- Enables building relationships between data from various sources in various formats, allowing for domain knowledge capture, standardization, and reuse

- Technology provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries.
EXTRACT TRANSFORM LOAD (ETL)

EXTRACT
- SysML Architectures
- Requirements
- SE Plans, analysis reports, field reports, ...

TRANSFORM
- ETL SERVER

LOAD
- DATA WAREHOUSE SERVER
- SEMANTIC LAYER
- SQL
- Mongo
- File System
• Focused on workflows using projectile data and lethality model
• Created ontologies from these two areas and linked them together
• Demonstrated use of SWT tools and standards in practice across these two domains
PHASE 2 OVERVIEW

- Focused on decision analysis resolution (DAR) workflow
- More proper development of ontology (inheritance from upper level ontologies)
- Close collaboration with academic partners (Systems Engineering Research Center)
- Byproduct: Python toolkit for decision analysis (AAMODAT) equipped with embedded MongoDB utility
PHASE 2 OVERVIEW

- Detailed view of ontology hierarchy

[Diagram showing ontology hierarchy with BFO, Common Core, Information Entities, Extended Relations, Events, Artifacts, Agents, Technical Models, Decision Core, Decision Methods, Decision Process, Application-level decision ontology, and layers of decisions and common core.]
RESEARCH EXAMPLE: TRADE STUDY
LOADING ONTOLOGIES

In [2]:

conn = rdf.Connection()

conn.repository = 'decisions'

leif_file = ['permanence/rdf4j/artifacts/leif.owl']

bfo_files = ['permanence/rdf4j/artifacts/ontologies/top/bfo.owl']

mid_files = ['permanence/rdf4j/artifacts/ontologies/mid/GeospatialOntology.owl',
              'permanence/rdf4j/artifacts/ontologies/mid/InformationEntityOntology.owl',
              'permanence/rdf4j/artifacts/ontologies/mid/model.owl',
              'permanence/rdf4j/artifacts/ontologies/mid/ExtendedRelationOntology.owl',
              'permanence/rdf4j/artifacts/ontologies/mid/UnitsOfMeasureOntology.owl',
              'permanence/rdf4j/artifacts/ontologies/mid/TimeOntology.owl',
              'permanence/rdf4j/artifacts/ontologies/mid/Math.owl',
]

decision_files = ['permanence/rdf4j/artifacts/decision_core.owl',
                  'permanence/rdf4j/artifacts/decision_method.owl',
                  'permanence/rdf4j/artifacts/decision_process.owl',
                  'permanence/rdf4j/artifacts/DecisionToolOntology.owl',
]

all_files = bfo_files + mid_files + decision_files

c.conn.reset_repo('decisions', decision_files + leif_file)

In [3]:

t = rdf.Translator(conn)
LOADING AND SEARCHING THE TRADESTUDY RESULTS

In [7]: t.to_rdf_entity(tradestudy)

Out [7]: Entity(5d84f40ec0404ed05e270b84a-Instance-TradeStudy,

In [8]: t.commit()

In [24]: # TradeStudy results (alternative information )

u_id = str(alt[0].id)
populate_sparsql_prefix(conn)

query = """
    SELECT ?name ?cost ?rdtime ?valuation
    WHERE {{
        ?x rdfs:label ?name .
        ?x dec:hasCost ?cost .
        ?x dec:hasRDTIME ?rdtime .
        ?x dec:hasValuation ?valuation
    }}""

response = conn.query(query, debug=0)
response
Semantic Web Technologies have a future in Systems Engineering tooling

- There is still a gap that needs to be traversed between academic research (i.e. the “art of the possible”), and polished, user friendly vendor tools.

Has a lot of potential for vendors to begin to include these technologies in their future versions of their tools

- Looking forward to using tools that are built with the mindset of being more accessible, and more integration focused
Questions, comments?
THE POWER OF INFERENCE AND REASONING

• Formal and explicit definitions of a system’s concepts enables inferencing and reasoning on those concepts—characteristics lacking in most current MBSE implementations.

• The user is able to impose axioms to construct a self-governing model.

(I) The sum of two real numbers is a real number.
(II) $\alpha$ and $\beta$ are real numbers.
(III) $\mu = \alpha + \beta$
(IV) [$Inferred$] $\mu$ is a real number.

(I) A system has a requirement “the system needs a bearing that withstands a static load of 50000 Mpa”.
(II) A viable system alternative satisfies all requirements.
(III) Alternative ABC uses a bearing with a static load capacity of 41000 MPa.
(IV) [$Inferred$] Alternative ABC is not a viable system alternative.
ONTOLOGY & SEMANTIC WEB TECHNOLOGY

• An ontology is a controlled vocabulary for representing the types of entities in a given domain\(^{(1)}\). It describes entities/concepts and relationships between them in an object-oriented, machine-readable manner.

• formal: machine-readable, utilize first-order logic (FOL).
• explicit: structural components are clearly defined
• shared: knowledge captured is consensual by group

• Semantic web technology (SWT) is a collection of tools and internet standards that help enable linked-data capabilities across the web. In conjunction with SWT, ontological models can be utilized to attain higher levels of integration.

\(^{(1)}\) Smith, Barry. Building Ontologies with Basic Formal Ontology
Ontologies are constructed of triple statement axioms.

To the left is a view of an ontology from an ontology editing software named Protégé
- The nodes are subjects/objects
- The edges are predicates