Ontologies for Big Systems: Aspects of Semantic Interoperability
Track 1&2 Ontology for Big Systems & Systems Engineering II

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Semantic Integration Implies Semantic Composition

Simple Procedure Integration & Composition
Concatenation, alignment of calling Procedure with called procedure:

- Caller: Do_this (integer: 5, string: “sales”)  
- Called: Do_this (integer: X, string: Y)

Simple Syntactic Object Integration & Composition
Alignment of embedded interface definition language statements mapping two CORBA, Javabean objects

Simple Semantic Model, Knowledge Integration & Composition
Unification of tree or graph structures, with reasoning, simple ontologies:

Complex Semantic Model, Knowledge, System Integration & Composition
Unification of complex networks of graph Structures, with complex reasoning, complex ontologies:

- signifies the composition operation

Timeline:
- 1960
- 1998
- 2005
- 2020
Dimensions of Interoperability & Integration

6 Levels of Interoperability

3 Kinds of Integration

Our interest lies here

Data
Object
Component
Application
System
Enterprise
Community

Interoperability Scale

0% 100%
Semantic Interoperability, Integration Definition

- To *interoperate* is to participate in a *common purpose*
  - Operation sets the context
  - Purpose is the intention, the end to which activity is directed
- **Semantics is fundamentally *interpretation***
  - Within a particular context
  - From a particular point of view
- **Semantic Interoperability/Integration is fundamentally driven by *communication of purpose***
  - Participants determined by interpreting capacity to meet operational objectives
  - Service obligations and responsibilities explicitly contracted
Enabling Semantic Interoperability

- Semantic Interoperability is enabled through:
  - Establishing base semantic representation via ontologies (class level) and their knowledge bases (instance level)
  - Defining semantic mappings & transformations among ontologies (and treating these mappings as individual theories just like ontologies)
  - Defining algorithms that can determine semantic similarity and employing their output in a semantic mapping facility that uses ontologies

- The use of ontologies & semantic mapping software can reduce the loss of semantics (meaning) in information exchange among heterogeneous applications, such as:
  - Web Services
  - E-Commerce, E-Business
  - Enterprise architectures, infrastructures, and applications
  - Complex systems-of-systems
  - Integrated collective intelligence
Semantic Interoperability, Integration: Multiple Semantics

- Multiple contexts, views, application & user perspectives
- Multiple levels of precision, specification, definiteness required
- Multiple levels of semantic model verisimilitude, fidelity, granularity, dynamicity
- Multiple kinds of semantic mappings, transformations needed:
  - Entities, Relations, Properties, Ontologies, Model Modules, Namespaces, Meta-Levels, Facets (i.e., properties of properties), Units of Measure, Conversions, Theories, Interpretations, etc.
- Upper & Middle Ontologies are important
  - To be able to interrelate domain ontologies
Electronic Commerce Example: One Company, Many Systems

- **Products**
  - Metal
  - Electronic
  - Health
  - Chemical

- **Support**
  - Applications
  - RFI/RFQ

- **Distributor**
  - TransWorld
  - iMicro
  - EndRun

- **Manufacturer**
  - 3Initial

- **Wholesaler**
  - Retailer

- **Shipping Methods**
  - Air
  - Ground
  - Truck
  - Sea

- **Regional Carrier**
  - Local Carrier

- **Trading Hub**

- **Trading Partners**
  - TradingHub
  - RFI/RFQ

- **Applications**
  - Sell

- **Location**
  - Africa
  - Europe
  - Asia
  - Spain
  - Portugal

- **Coordinate System**
  - UTM
  - Geographic

- **Point**
  - Time
  - Interval

- **Unit of Measure**
  - Distance
  - Mass
  - Liquid
  - Solid
Now assume each company has separate enterprise semantics, multiply by the number of companies, & have them interoperate and preserve semantics: Many systems!

Try doing this without Ontologies! You can, but it's a nightmare, and it COSTS: Now & Later!
Mainstream Systems Engineering and Information Technology cannot adequately address these issues

- Service-Oriented Architecture, database technology (including Big Data), programming technology (including OO, genetic programming, “swarm” agents), parallel distributed technologies (Cloud, Grid) cannot address

- Ontology can address these issues:
  - Formal ontological analysis
  - Theory of Parts and Wholes
  - Theory of Essence and Identity
  - Theory of Dependence
  - Theory of Qualities
  - Theory of Composition and Constitution
  - Theory of Function (teleology)
  - Formal Pragmatic Intent and Use
  - Theory of Social/Organizational Roles
  - Relations between Semantics and Ontology for Systems
  - Theory of Dynamics: Change and Time
Conclusion

- Ontology can contribute much to Systems Engineering and Engineered Systems
- Semantic complexity will only increase: Ontology is the lever

The image is from: http://en.wikipedia.org/wiki/File:Archimedes_lever_%28Small%29.jpg