Ontology

- A specification of a conceptualization or a set of knowledge terms for a particular domain, including
  - The vocabulary: concepts and relationships
  - The semantic interconnections: relationships among concepts and relationships
  - Some simple rules of inference and logic
- Some representation languages for ontologies:
  - Unified Modeling Language (UML) Class Diagrams
  - Resource Description Framework Language Schema (RDFS)
  - Web Ontology Language (OWL)
- Some ontology editors: Protégé, Eddy (OBDA Systems)

Common Ontology

A shared representation between interoperating parties

- Analogy with humans: shared physical, biological, and social worlds
- Who builds a common ontology?
- Standardization efforts, e.g., by IEEE
  - *Upper-level* ontologies include concepts (of space, time, personhood), which apply across domains
  - Domain-level ontologies
- Language-based efforts
  - WordNet (Princeton)
  - Longman's Dictionary of Contemporary English
- Bottom-up approaches build consensus incrementally

Dimensions of Description for Interoperation

- Descriptions of services that have a bearing on interoperation
- Constraints that we must discover, represent, and reason about

The Data Dimension

Assumptions about a service's data inputs and outputs

- Domain specifications
- Value ranges, e.g., Price ≥ 0
- Allow or disallow null values

The Structure Dimension

Conceptual model of the information processed by a service

- Specializations and generalizations of domain concepts
  - Taxonomic representations and relationships such as in schemas and views, e.g., securities are stocks
- Semantics of data
  - Some stock price databases consider daily averages; others closing prices
  - Value maps, e.g., S&P A+ rating corresponds to Moody's A rating
- Integrity constraints
  - Each stock must have a unique SEC identifier
  - Cardinality constraints

The Process Dimension

Model of operational interactions of a service

- Procedures, i.e., how to process information, e.g., how to decide what stock to recommend
  - Flow, e.g., where to forward requests or results
  - Temporal constraints, e.g., report tax data every quarter
- Preferences for accessing and updating information
  - Dealing with data replication (recency or accuracy)
  - Updating views
- Contingency strategies (failure recovery), e.g., whether to ignore, redo, or compensate
  - Contingency procedures, i.e., how to compensate transactions

The Governance Dimension

Model of organizational interactions of a service

- Privileges, i.e., who has rights to what service
  - Owners can access all of their accounts, except blind trusts
- Authentication, i.e., how to establish identity
  - Passwords, retinal scans, or smart cards
- Bookkeeping
  - Logging all accesses

Value Maps

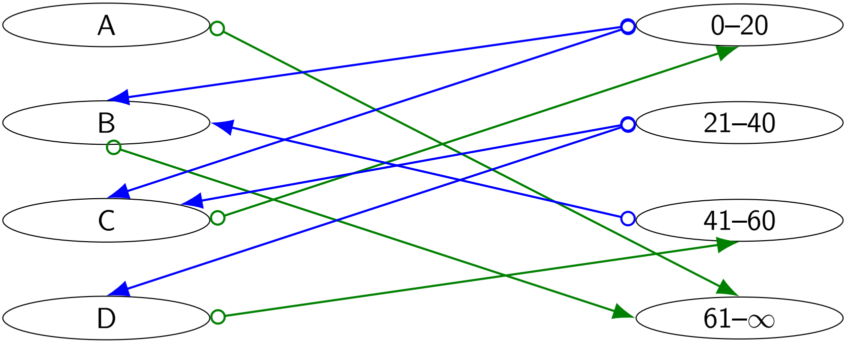
A value map relates the values expressed by different services

- Two sets of values
- A function in each direction
- Important properties satisfied by a "reasonable" value map
  - Totality or coverage: each function is total
  - Consistent inversion (à la triple negation): the two functions are adjoint
- Often each set is ordered in some domain-dependent way; then add
  - Order preservation or monotonicity: each function preserves order

Example Value Map

Birthday gift selection services

- User rankings (best to worst): A, B, C, D
- Prices (in \$): 0–20, 21–40, 41–60, 61–∞



Procedural versus Declarative Knowledge Representation

How versus What

- Declarative pros: enables standardization, optimization, improved productivity of developers
- Declarative cons: nontrivial to achieve and causes short-term loss of performance
- Trade-offs shifted by Web to favor declarative modeling
  - Because of heterogeneity

Frames versus Descriptions

How to marry intuitive ease and rigor

- Frame-based approaches are intuitive
  - Like object-oriented modeling
  - Rely on names of classes and properties to indicate meaning
- Description logics provide a computationally rigorous means to represent meaning; difficult for people

Evaluating a Knowledge Representation Language

Expressive power

- Is unambiguous
- Supports legitimate inferences
- Avoids unjustified inferences
- Reduces reliance on names for meaning
- Supports representing partial knowledge
- Supports inserting knowledge incrementally

Compare for Expressiveness and Flexibility

Think of a database in which you store such facts

- awg22SolidBlueWire(ID5)
- blueWire(ID5, AWG22, Solid)
- solidWire(ID5, AWG22, Blue)
- wire(ID5, AWG22, Solid, Blue)
- wire(ID5) $\wedge$ size(ID5, AWG22) $\wedge$ type(ID5, solid) $\wedge$ color(ID5, Blue)

Summary

- Based on shared ontologies or conceptualizations
  - Shared models are essential for interoperation
  - Declarative representations facilitate reasoning about and managing models
  - Formalization enables ensuring correctness of models and using them for interoperation
- Good models must accommodate several important considerations
- Modeling requires several subtle considerations