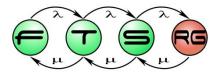
Ontologies and Semantic Technologies

Bergmann Gábor





Budapesti Műszaki és Gazdaságtudományi Egyetem Méréstechnika és Információs Rendszerek Tanszék

Agenda

- Ontologies
- RDF and Semantic Web
- Semantic Technologies and Resources
- Semantic Integration







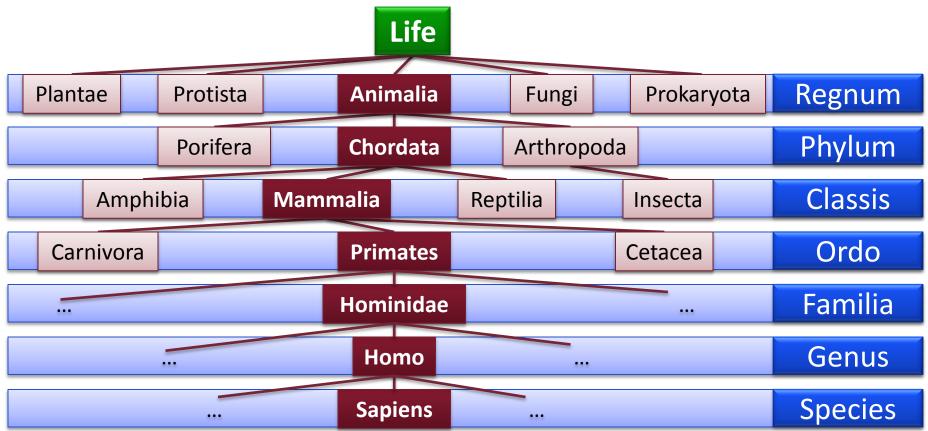


Ontologies and semantic reasoning



Taxonomy

Taxonomy = hierarchy of domain concepts



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Ontology

- Ontology = "the study of existence"
- Computer representation of domain knowledge
 - Identifying concepts to categorize individuals
 - Relationships that can hold between individuals
 - Axioms on concepts and their relationships
 - Including taxonomy of domain concepts (supertypes)
- Created by
 - domain experts
 - o knowledge engineers
- Intended for automatic processing, reasoning



Domain Ontologies

- Domain Ontologies for expert systems

 Reasoning based on axioms and formal logic
 Ontology-based search
- Sample Ontologies
 - Open Biological and Biomedical Ontologies (OBO)
 - Chemical information
 - Cells, cell types, proteins, etc.
 - Anatomy (Upper/Human/...)
 - General Medical Science, disease ontologies
 - Medical software, imaging methods, spectrometry etc.
 - Food Ontologies, Wines, Air Traffic, Legal, etc.



Example Ontology

- Concepts/classes: Animal, Person, Male, Female, Man, Woman, SingleChild, etc.
- Attributes: name, weight, etc.
- Relationships: mate, child, parent, etc.
- Axioms and definitions
 - child = parent⁻¹, mate = mate⁻¹
 - \circ Person \subseteq Animal
 - \circ Male \cap Female = Ø, Male \cup Female = Animal
 - \circ Woman = Female \cap Person
 - \circ SingleChild = Animal \cap ∀parent.∃₌₁child



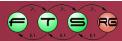
No strict

distinction

Formal Background

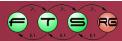
- Description Logics (DL)
 - Individuals, concepts, roles (properties)
 - \circ Axioms \approx set operations and role tree navigation
 - A-Box: axioms about individuals
 - T-Box: axioms about concepts and roles
 - Reasoning with tableau calculi
- Dialects: SHOIQ(D), SHIQ, SHIN, ALCN, etc.
 - Varying expressive power
 - Usually weaker than FOL (first-order logic)
 - Expressivity vs. reasoning complexity





Open World Semantics

- Can we enumerate all diseases?
 - Traditional databases have Closed World Semantics
 - E.g. if not explicitly listed as a disease, then not a disease
- Most ontologies: Open World Semantics
 - \circ Not proven true/false \rightarrow not treated as false or true
 - Why? Ontologies can never be complete
 - Examples
 - E.g. if not listed / implied as a viral disease, still can be one
 - Patient 42 has lepers. Does Patient 42 have a flu? Unknown!
 - Patient 2501 died of lepers. Did she die of flu? No! (by multiplicity 1 of cause of death)



Unique Name Assumption

- Can two identifiers correspond to the same thing?
 Patient 42 carries a skin disease.
 - A disease of patient 42 was found to be of viral nature.
 Are they two different diseases?
- Usually NO Unique Name Assumption
- Two things can be the same, unless contradicted

 disjoint classes (Patient 2501 has a hereditary disease)
 explicit control: owl:sameAs, owl:differentFrom
- Why? Distributed knowledge gathering





OWL

- W3C: Web Ontology Language (OWL)
 - \circ owl:Class (\approx concept) = set of individuals
 - \circ rdf:Property (\approx role) = link to data or other individuals
 - \circ Individual (≈ A-box), nominal (*O* in *SHOIQ*), enum
 - Datatype, axioms, etc.
 - Uses URIs, builds on RDF+XML syntax (see later)
- Subsets for scalability
 - DL-compatible subset: OWL DL = SHOIN(D)
 - OWL Full is stronger, has multi-level metamodeling
 - OWL 2 has further subsets (profiles)







Ontologies and semantic reasoning



Metadata

- Metadata: description of data,
 - For people
 - For machines
- Example: image metadata
 - Generated partly automatically
 - o "on this picture: John Doe, Jean-Baptiste Grenouille"
- Example: text document metadata
 - Author, literary category, year of publishing, etc.
- Metadata-based search

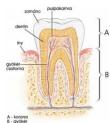




Syntactic Interpretation

- Can machines understand what we mean?
 Textual / syntactic services can not
- Example: show me pictures depicting "fog"!







- Example: show me poems by female authors!
- Semantic solution
 - Machines should process the meaning, not the form
 - Use standardized concepts "fog", "female", "author"...
 - Refer to it in metadata and queries

Resource Description Framework

- W3C: Resource Description Framework (RDF)
 - \circ rdf:Resource \rightarrow something we talk about
 - a document (e.g. this photo)
 - a standardized meaning (e.g. tooth, Hungary)
 - identified by a URI
 - \circ rdf:Property \rightarrow relation type between resources
 - e.g depicts, taken_in etc.
 - also identified by a URI
 - \circ Triplets \rightarrow statements about properties of resources
- Open world, no unique names
- RDFS: RDF Schema

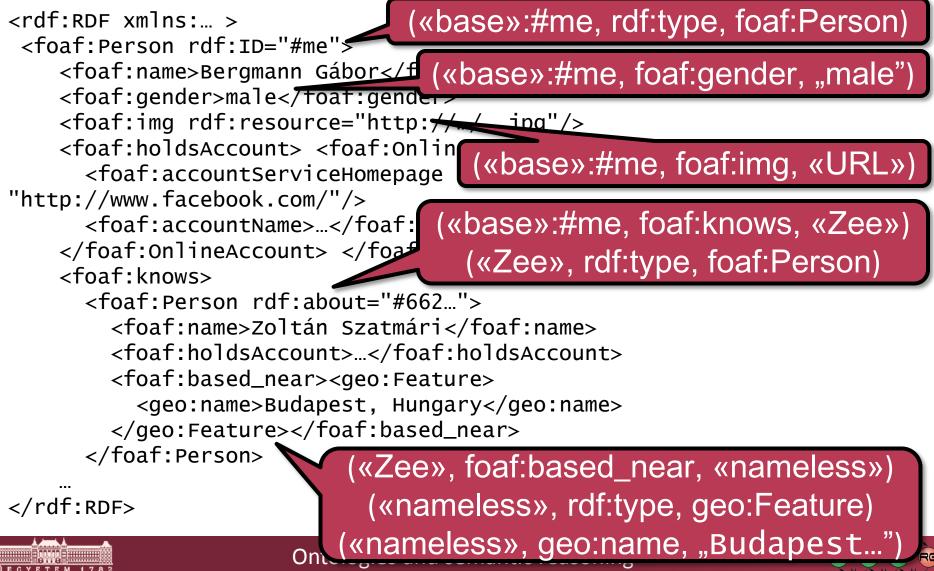
RDF Statements

- RDF statement = triplet
 - (resource, property, value)
 - resource, property are URIs
 - value: URI of other resource or raw data
- Example triplets
 - o (this_photo, taken_in, Hungary)
 - o (this_photo, file_name, "DSC00001.JPG")
 - (this_photo, depicts, John Doe)
 - o (this_photo, rdf:type, Photo)
 - o (rdf:type, rdf:type, rdf:Property)



RDF Concrete Syntax

Concrete syntaxes: RDF+XML, RDFa, N3, etc.



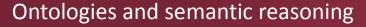
RDF Application

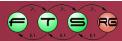
- RDF Site Summary (RSS)
 - Items with title, description, link, creator, date, ...
 - RSS 2.0 abandons RDF, backronym
- OWL itself is an RDF document

Classes, properties identifiable by URIs

Semantic Web

- o Is a photo of my Porsche a photo of a car?
- Need standard URIs for RDF resource/property types
- Use OWL ontologies to provide type URIs
- Local metadata + ontologies = semantic web





SEMANTIC TECHNOLOGIES AND RESOURCES



Ontologies and semantic reasoning



Semantic Web Technologies

- Swoogle
 - Indexes RDF, OWL files
 - PageRank-like ranking



- Descriptions collected from referencing documents
- SPARQL RDF query language
 - SQL-like syntax
- Programming frameworks (e.g. Jena, Sesame)
 O APIs for RDF and OWL
 - In-memory and persistent storage + remote access
 - Manipulation, query and inference



Protégé Ontology Editor

pizza.owl (http://www.co-ode.org/ontolo	gies/pizza/pizza.owl) - [http://www.co-ode.org/ontologies/pizza/pizza.owl]
File Edit Ontologies Reasoner Tools Refactor Tabs View V	Vindow Help
pizza.owi (http://www.co-ode.org/ontologies/pizza/pizza.	owl)
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Ontologies and semantic reasoning

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RACER reasoner

- RacerPro: DL reasoner engine
- RacerPorter GUI

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Ontologies and semantic reasoning



Semantic Web Ontologies

- Friend-of-a-Friend (FOAF) ontology
 - Classes: Person, Image, Document, OnlineAccount, etc.
 - Attributes: surname, birthday, title, etc.
 - Relationships: knows, made, depicts, weblog, topic, logo, openID, page, interest, etc.
 - Used / usable in Facebook, flickr, LauchPad...
- Dublin Core (DC) ontology
 - Librarian metadata for documents
 - Title, publisher, language, format, date, creator, etc.
 - Widespread usage (e.g. as an RSS Module)





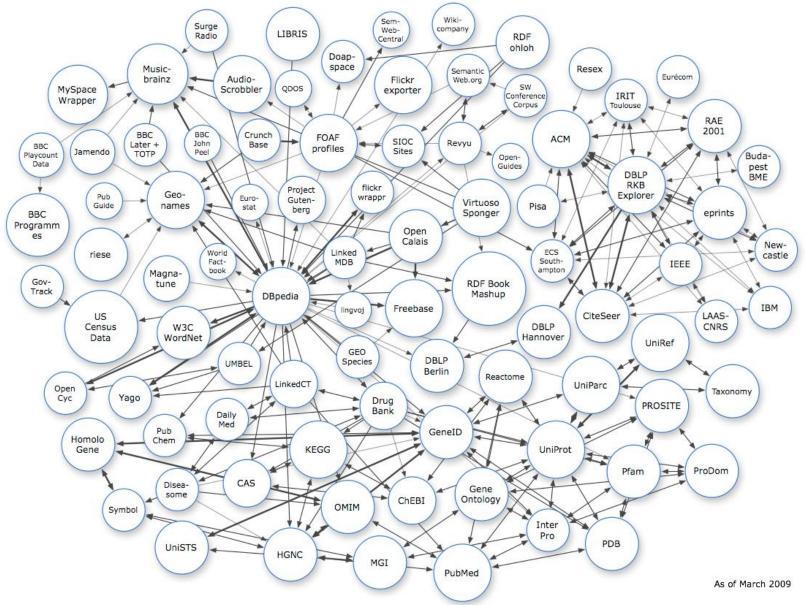
Encyclopedic Knowledge Bases

- WordNet: lexical knowledge base of english words
 - Synonym sets (synsets)
 - Semantic relations, including
 - Antonym (opposite)
 - Hypernym, hyponym (super/subtype)
- DBpedia Knowledge Base
 - RDF information
 - Automatically extracted from Wikipedia
 - Manual annotation, links to WordNet etc.
 - SPARQL interface





Linking Open Data (LOD)



Ontologies and semantic reasoning

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SEMANTIC INTEGRATION



Ontologies and semantic reasoning



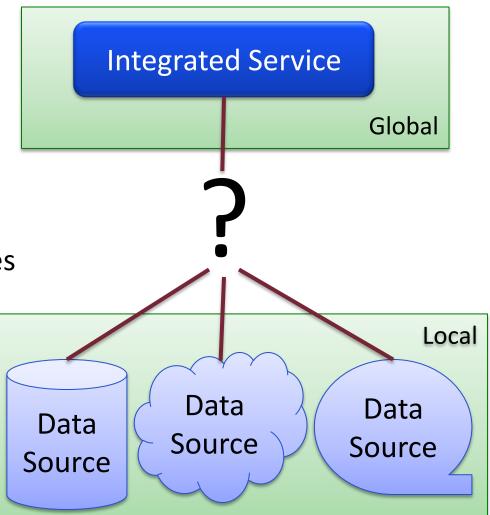
Data Integration

Distributed, heterogenous sources

- Relational DB
- Web Service
- Ad-hoc interfaces
- Unified global service
 - Usually query-only
 - Global query vs. local sources

Terminology

- Data Integration
- Information Integration
- Data Fusion





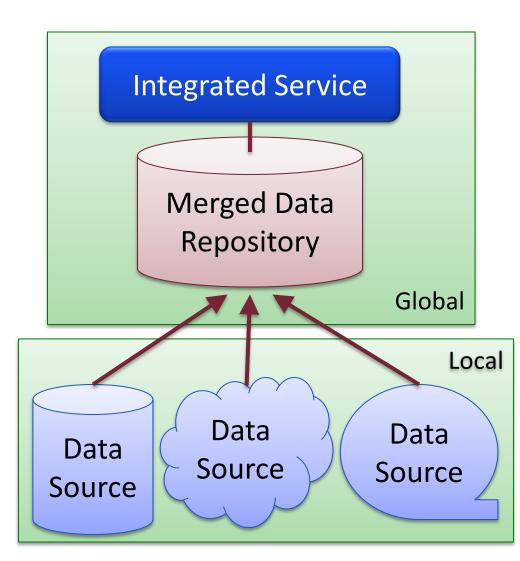


Merging (Data Warehousing)

Solutions

- Merging (warehousing)
- Mediation (federated DB)
- Single central repository

 Contains all merged data
- Straightforward
- Drawbacks
 - Merge cost
 - Outdated
 - Unless regularly refreshed
 - Maintainability issues

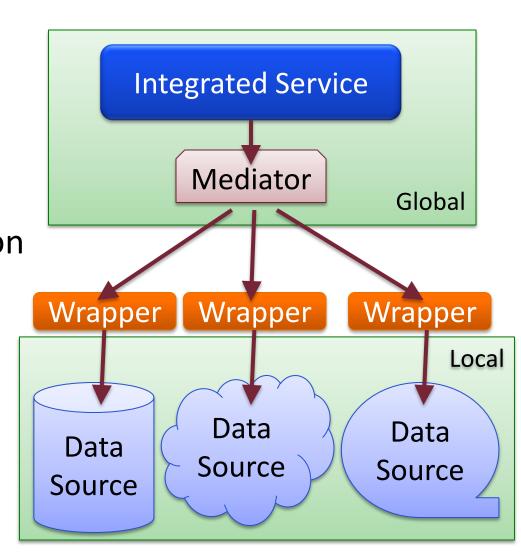




Mediation (Database Federation)

Solutions

- Merging (warehousing)
- Mediation (federated DB)
- Query propagation
 Result composition
- Problem: query translation
 - o GaV
 - o LaV
- Advantages
 - Always up-to-date
 - Lightweight





Mediation: Global as View

- Problem: query translation
 - GaV (Global as View)
 - o LaV
- The global schema expressed as a view on locals
 Transformations, projections, unions, joins
 - \circ E.g. 'ACME'×($\pi_{Name,Price}$ AcmeProducts)∪...
- Query execution: simple view evaluation
- The same basic design as in the merging case
 Onmaintainable with too many sources





Mediation: Local as View

- Problem: query translation
 - o GaV
 - LaV (Local as View)
- Each local schema as a view of the global
 OProjections, selections
 - E.g. only product data, only for ACME boxes
- Easier to add new sources
- Query execution
 - theory of federated databases
 - o "answering queries using views"



Semantic Integration

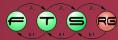
Heterogeneity

- Non-relational sources
- Different vocabulary and semantics
- Different structure
- Different representations
- Ontology-based Semantic Data Integration
 - Local scheme explained with linked ontologies
 - Semantic mapping between schemes
 - Query formulation based on ontology
 - Execution: automatic reasoning?



Semantic Service Integration

- Standards such as WSDL define the syntax • Currency? Unit of measurement? **OWL-S** • The identifier of *what*? **Process Model DL-based Types** o Preconditions? Semantic Web Services **Inputs / Outputs** Atomic Process OWL-S Operation Message Process Model, DL types Binding to SOAP, HTTP, etc. \circ WSMO **WSDI**
 - Goals of clients, mediators, etc.
- Dream: Semantic Service Discovery







Ontologies and semantic reasoning



Summary

- Semantic technologies
 - Metadata (RDF)
 - Ontologies (OWL)
 - Formal logic based reasoning
- Applications
 - Domain ontologies in expert systems
 - Semantic Web
 - Ontology-based semantic data integration
 - Semantic Service Discovery



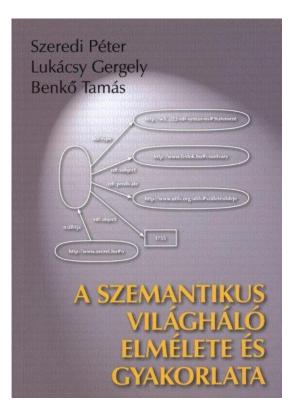


Recommended reading

Benkő-Szeredi-Lukácsy: *A szemantikus világháló elmélete és gyakorlata*. Typotex, 2005.

BMEVIMIM222 Információ- és tudásintegrálás

(MSc intelligens rendszerek szakirány)





Ontologies and semantic reasoning

