Ontologies and Semantic Technologies

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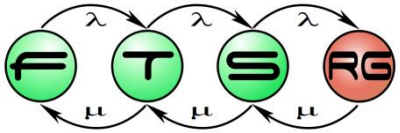
Bergmann Gábor



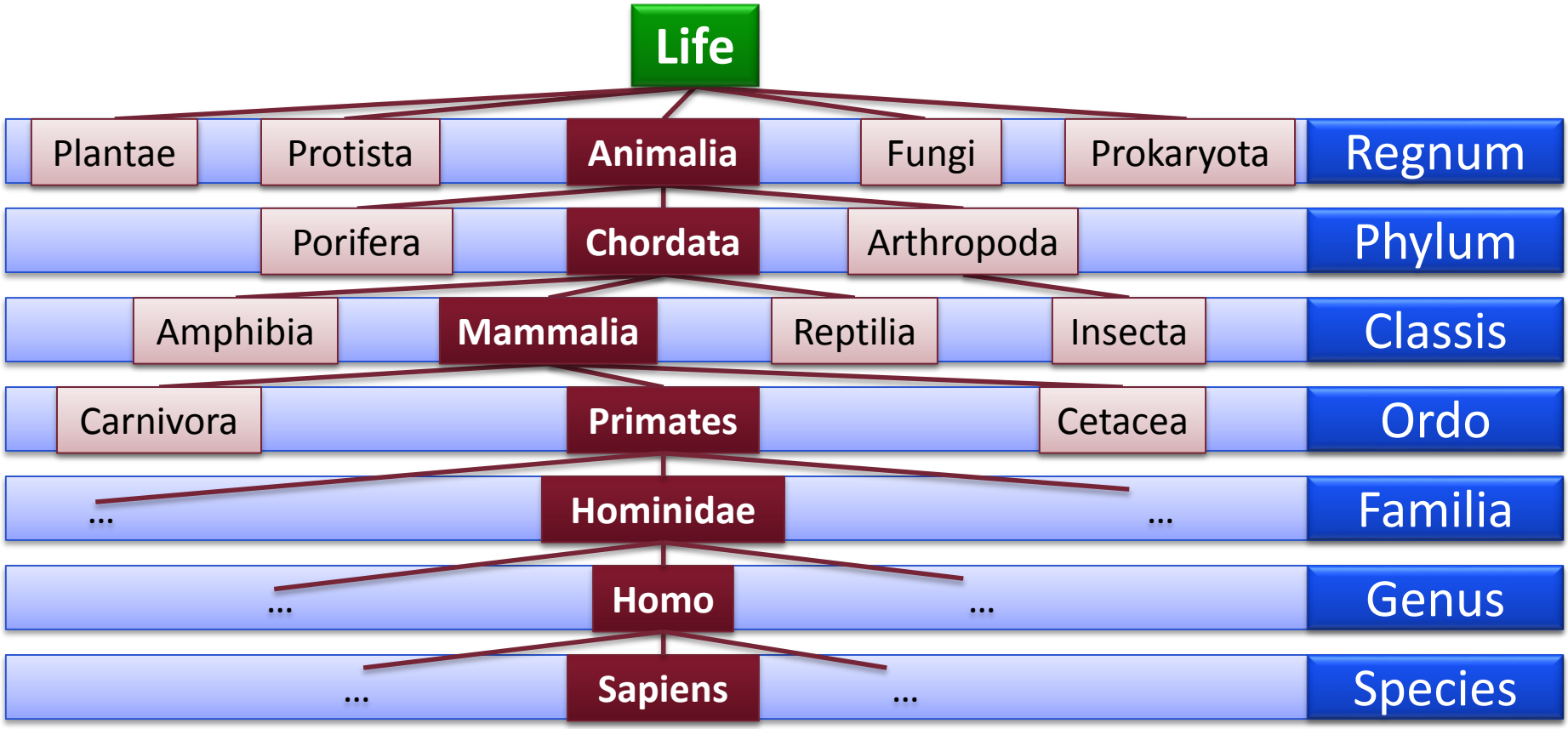
Agenda

- Ontologies
  - Resource Description Framework (RDF)
  - Web Ontology Language (OWL)
- Semantic Technologies and Resources
- Modeling approaches
- Semantic Integration

ONTOLOGIES

Taxonomy

- **Taxonomy** = hierarchy of domain concepts



- Ontology ≅ taxonomy + relationships + definitions

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, knowledge engineers**
  - People using annotation tools
  - Natural language text analysis tools

Domain Ontologies

- Open Biological and Biomedical Ontologies (OBO)
  - Chemical information
  - Cells, cell types, proteins, etc.
  - Anatomy (Upper/Human/…)
  - Medical software, imaging methods, spectrometry etc.
- National Center for Biomedical Ontology (NCBO)
  - National Drug File
  - International Classification of Deseases
  - SNOMED Clinical Terms
- data.gov (public access to US government data)
  - Documents categorized in an ontology

Open World Assumption

Can we enumerate all diseases?

- Traditional databases have Closed World Assumption
  - E.g. if not explicitly listed as a disease, then not a disease
- Most ontologies: **Open World Assumption** (OWA)
  - Not proven true/false → 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 skin disease31.
  - Disease5 of patient 42 was found to be of viral nature.
  - Are they two different diseases? (→ unknown)
- Two things can be the same, unless contradicted
  - disjoint classes (hereditary and viral disease)
    - Patient 42 has a hereditary disease
  - explicit control: owl:sameAs, owl:differentFrom
- Usually NO **Unique Name Assumption**
- Why? Distributed knowledge gathering

Unique Name Assumption

- Can two identifiers correspond to the same thing?
  - Patient 42 carries skin disease31.
  - Disease5 of patient 42 was found to be of viral nature.
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- Two things can be the same, unless contradicted
  - disjoint classes
    - Patient 42 has
  - explicit cont
- Usually NO **Unique Name Assumption**
- Why? Distributed knowledge gathering

John works at KeyWest.

Jill phoned Johnny.

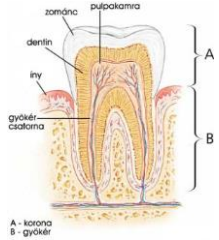
RESOURCE DESCRIPTION FRAMEWORK (RDF)

Metadata

- **Metadata**: description of data,
  - For people
  - For machines
- Example: image metadata
  - Generated partly automatically
  - „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

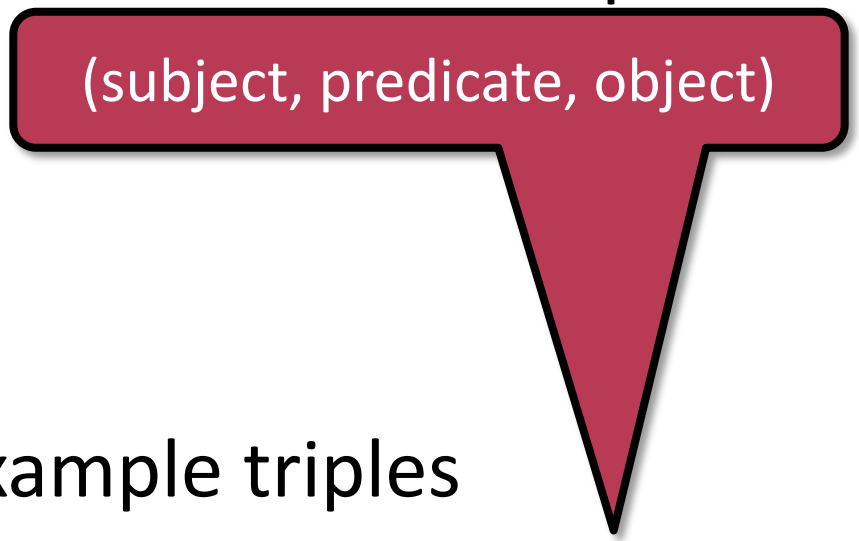
- W3C: Resource Description Framework (**RDF**)
- *Graph based* structure
  - Node: **rdf:Resource** → something we talk about
    - e.g. a document, this photo, a table or “something”
  - Edge: **rdf:Property** → relation type between resources
    - e.g depicts, taken_in, type etc.
- Node name and relation type name: **IRI** (Internationalized Resource Identifier)
- **Literal** nodes: 5^^xsd:integer, „John”

Resource Description Framework

- Basic modeling concepts
  - RDF: rdf:type, graph based description
  - RDFS (RDF Schema): rdfs:subClassOf, rdfs:domain, rdfs:range
- Properties
  - Open World Assumption
  - No Unique Name Assumption (by default)

RDF Statements

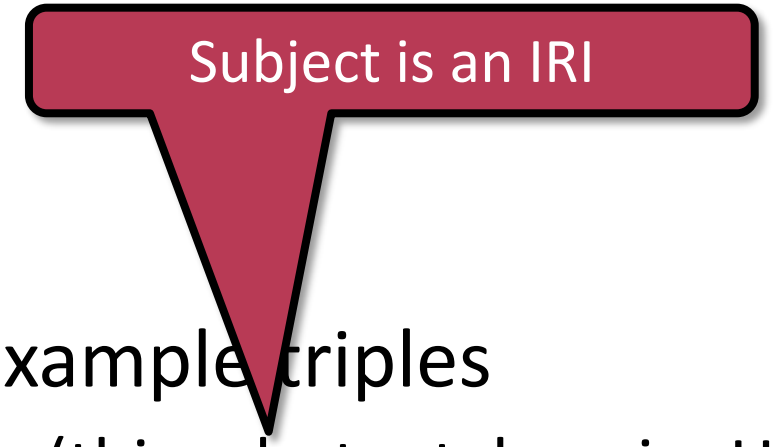
- RDF statement = triple:



- Example triples
  - (this_photo, taken_in, Hungary)

RDF Statements

- RDF statement = triple:
  - (subject, predicate, object)



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RDF Statements

- RDF statement = triple:
  - (subject, predicate, object)

- Example triples
  - (this_photo, taken_in, Hungary)

RDF Statements

- RDF statement = triple:
  - (subject, predicate, object)
  - subject is an IRI
  - predicate is an IRI
- Example triples
  - (this_photo, taken_in, Hungary)
  - (this_photo, file_name, „DSC0001.JPG”)

Object is an IRI or

Object is an rdf:Literal

RDF Statements

- RDF statement = triple:
  - (subject, predicate, object)
  - subject is an IRI
  - predicate is an IRI
  - object: can be an IRI or a Literal
- Example triples
  - (this_photo, taken_in, Hungary)
  - (this_photo, file_name, „DSC0001.JPG”)
  - (this_photo, depicts, John Doe)
  - (this_photo, has_type, Photo)
  - (rdf:type, rdf:type, rdf:Property)

RDF Statements

- RDF statement = triple:
  - (subject, predicate, object)
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  - predicate is an IRI
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  - (this_photo, taken_in, Hungary)
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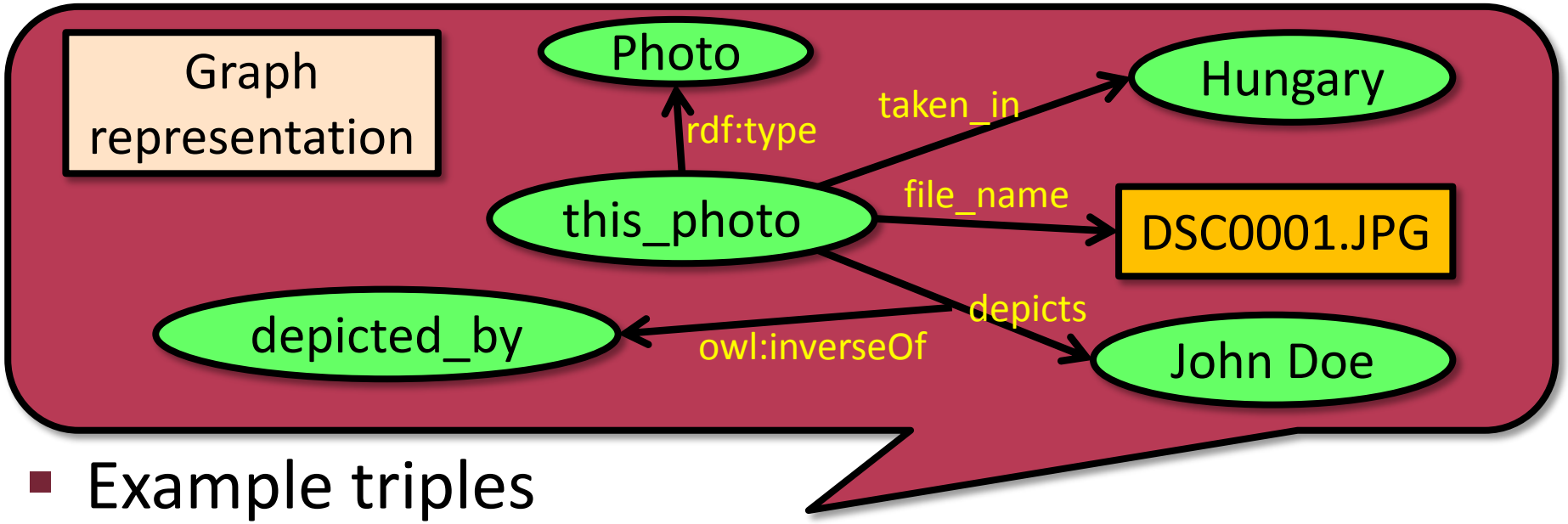
  - (this_photo, depicts, John Doe)
  - (this_photo, rdf:type, Photo)
  - (rdf:type, rdf:type, rdf:Property)

rdf:type is defined in the RDF standard

RDF Statements



- Example triples
  - (this_photo, taken_in, Hungary)
  - (this_photo, file_name, „DSC0001.JPG”)
  - (this_photo, depicts, John Doe)
  - (this_photo, rdf:type, Photo)
  - (rdf:type, rdf:type, rdf:Property)

RDF Concrete Syntaxes

- **RDF+XML**

```
<rdf:RDF xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
     xmlns:geo="http://www.geonames.org/ontology#"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
     xmlns:foaf="http://xmlns.com/foaf/0.1/">

<foaf:Person rdf:about="https://www.inf.mit.bme.hu/members/izso">
 <foaf:firstName>Benedek</foaf:firstName>
 <foaf:surname>Izso</foaf:surname>
 <foaf:homepage rdf:resource="https://www.inf.mit.bme.hu/members/izso"/>
 <foaf:depiction rdf:resource="https://www.inf.mit.bme.hu/.../photos/picture-578.png"/>

 <foaf:based_near>
  <geo:Feature>
   <geo:name>Hungary</geo:name>
  </geo:Feature>
 </foaf:based_near>

 <foaf:knows>
  <foaf:Person rdf:about="http://www.okkam.org/ens/idb89852b2-2b8d-43ac-ac5a-e2d00b65d0df">
   <foaf:surname>Herman</foaf:surname>
   <foaf:firstName>Ivan</foaf:firstName>
   <foaf:homepage rdf:resource="http://www.w3.org/People/Ivan/"/>
  </foaf:Person>
 </foaf:knows>
</foaf:Person>

</rdf:RDF>
```

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<foaf:Person rd          ut="https://www.inf.mit.bme.hu/members/izso">
 <foaf:firstName          k</foaf:firstName>
 <foaf:surname>Iz          rname>
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 <foaf:depiction rd          ://www.inf.mit.bme.hu/.../photos/picture-578.png"/>

 <foaf
  <geo
   <ge
  </ge
 </foa

 <foaf
  <foa                                                          ">
   <fo
   <foa
   <foaf:homepage rdf:resource="http://www.w3.org/People/Ivan/"/>
  </foaf:Person>
 </foaf:knows>
</foaf:Person>

</rdf:RDF>
```

xmlns:foaf=http://xmlns.com/foaf/0.1/

Organize concepts and relation types into namespaces

RDF Concrete Syntaxes

- **RDF+XML**

```
<rdf:RDF xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
     xmlns:geo="http://www.geonames.org/ontology#"
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     xmlns:foaf="http://xmlns.com/foaf/0.1/">

<foaf:Person rdf:about="https:/
 <foaf:firstName>Benedek</foaf
 <foaf:surname>Izso</foaf:surn
 <foaf:homepage rdf:resource="
 <foaf:depiction rdf:resource=

 <foaf:based_near>
  <geo:Feature>
   <geo:name>Hungary</geo:
  </geo:Feature>
 </foaf:based_near>

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  <foaf:Person rdf:about="http://www.okkam.org/ens/idb89852b2-2b8d-43ac-ac5a-e2d00b65d0df">
   <foaf:surname>Herman</foaf:surname>
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   <foaf:homepage rdf:resource="http://www.w3.org/People/Ivan/"/>
  </foaf:Person>
 </foaf:knows>
</foaf:Person>

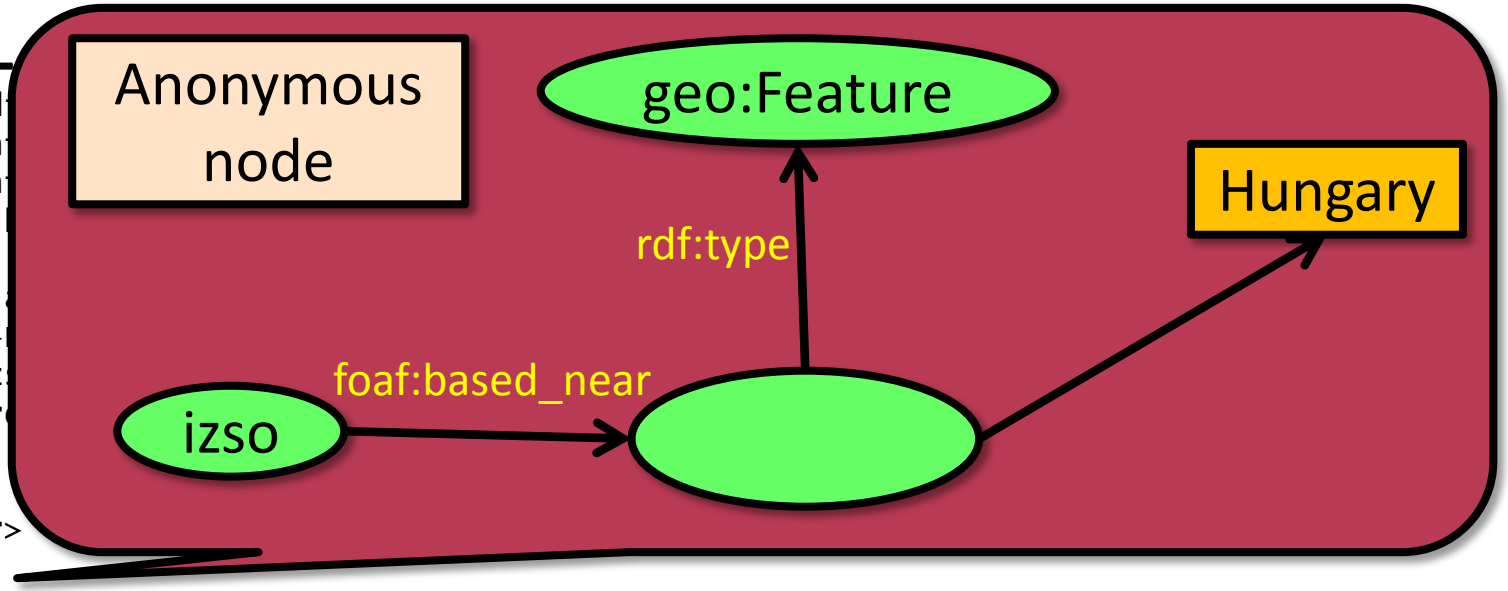
</rdf:RDF>
```

(e2d00b65d0df, ***rdf:type***, foaf:Person)
(e2d00b65d0df, ***foaf:firstname***, “Ivan”)

The semantics of these concepts and relations are well understood, these means the same for everyone.

RDF Concrete Syntaxes

- **RDF+XML**




```
<rdf:RDF xmlns:rd
      xmlns:geo="h
      xmlns:rdf="h
      xmlns:foaf="

<foaf:Person rdf:
 <foaf:firstName>
 <foaf:surname>Iz
 <foaf:homepage r
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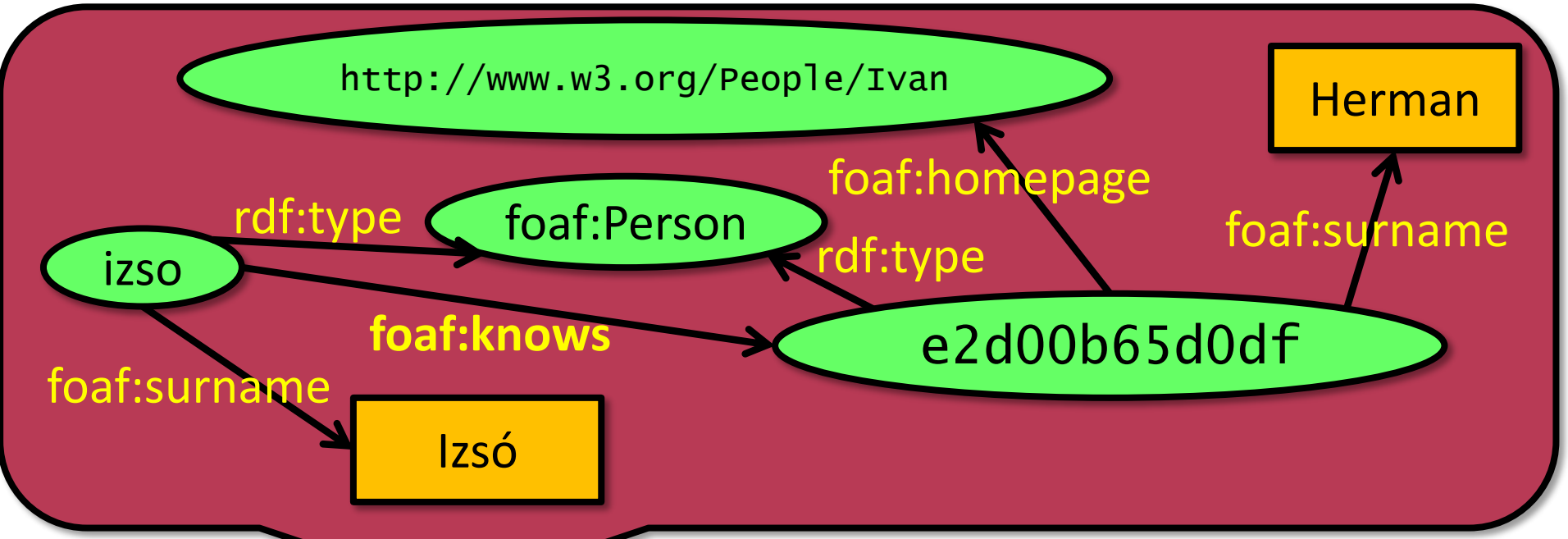
RDF Concrete Syntaxes

- **RDF+XML**

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 </foaf:knows>
</foaf:Person>

</rdf:RDF>
```

RDF Concrete Syntaxes

- RDF+XML
- **Turtle** (Terse RDF Triple Language)

```
1. <ftsrg:izso> rdf:type          owl:NamedIndividual ,
2.                                foaf:Person ;
3.              foaf:firstName    "Benedek" ;
4.              foaf:homepage     <https://inf.mit.bme.hu/members/izso> .
```

- **RDFa:** tag a HTML webpage with RDF attributes

```
<div xmlns:v="http://rdf.data-vocabulary.org/#"
typeof="v:Person">
  My name is <span property="v:name">Bob Smith</span>,
  but people call me <span property="v:nickname">Smithy</span>.
  Here is my homepage:
  <a href="http://www.example.com"
rel="v:url">www.example.com</a>.
</div>
```

RDF Tools

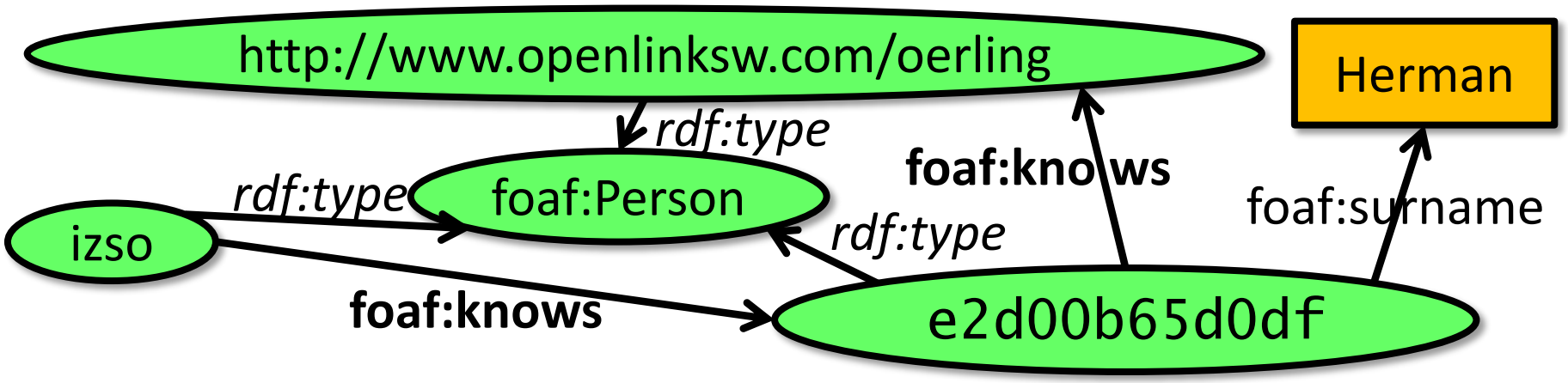
- RDF API: Sesame, Jena
- RDF engine for inference and query:
  OpenLink Virtuoso, Allegro Graph, 4store, Stardog

RDF Query

- SPARQL: Graph Pattern based RDF Query Language

```
SELECT ?persA ?persB
WHERE {
   ?persA rdf:type foaf:Person .
   ?persB rdf:type foaf:Person .
   ?persA foaf:knows ?persB .
}
```

**Give me pairs,
where
the first entry is a Person
as well as the second one,
and the first knows the second.**



RDF Query

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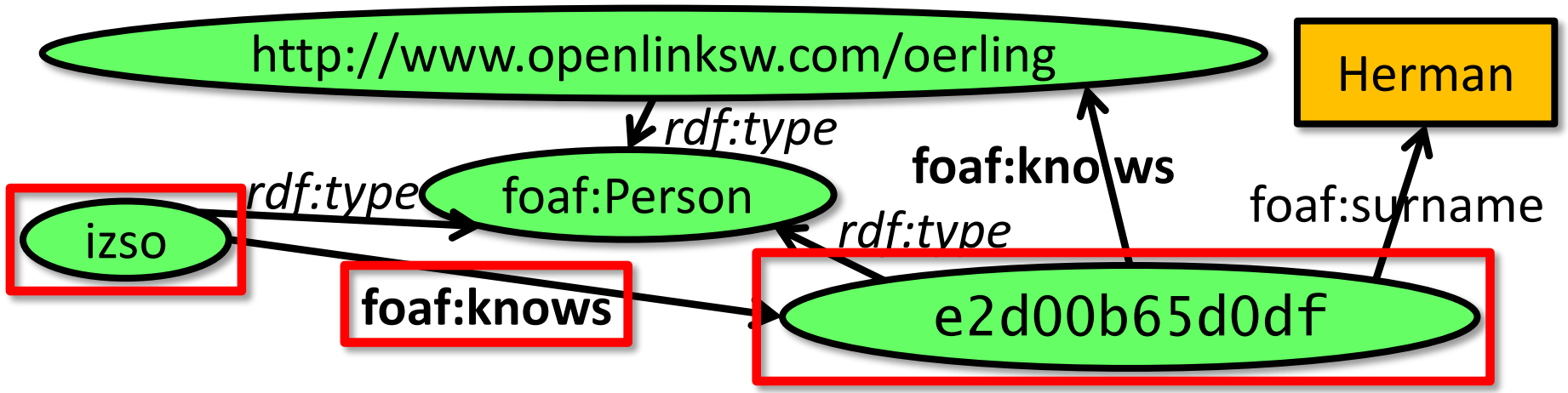
?persA	?persB
izso	e2d00b65d0df
e2d00b65d0df	oerling

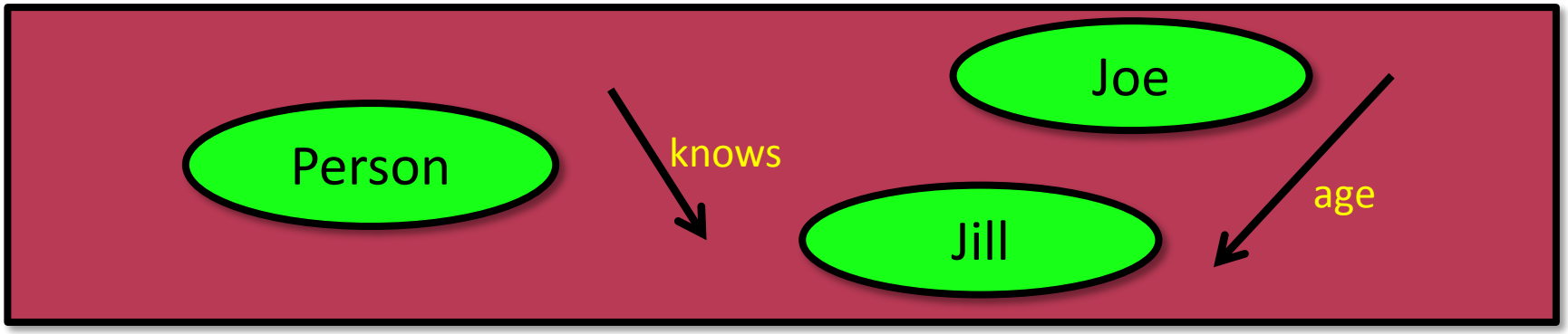


WEB ONTOLOGY LANGUAGE (OWL 2)

Formal Background

- Axiomatic language
  - Declaration (for tools): concepts, roles, individuals

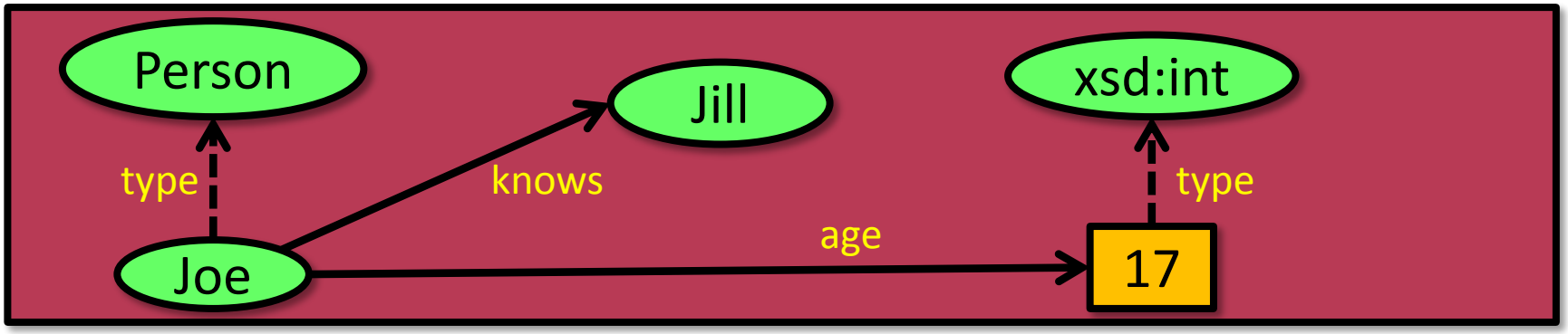
Class: Person
ObjectProperty: knows
DatatypeProperty: age
Individual: Joe, Jill



Formal Background

- Axiomatic language
  - Declaration (for tools): concepts, roles, individuals
  - A-Box (instance model level): typify individuals, data and object role assertions

```
Individual: Joe
    Types: Person
    Facts:
        knows Jill,
        age  "17"^^xsd:int
```



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- Axiomatic language
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  - T-Box (metamodel level): subsumption between class expressions, which use role navigations and bool operators

Every person is an animal:

$\text{Male} \sqsubseteq \text{Person}$

The intersection of males and females is the empty set:

$\text{Male} \sqcap \text{Female} \equiv \bot$ // $\bot$ sign means: empty set

Single child is a person, whose all parents have only one child:

$\text{SingleChild} \equiv \text{Person} \sqcap \forall \text{parent}.=1\text{child}.\text{Person}$

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OWL defines the semantics of some new relation types, e.g. owl:intersectionOf or owl:cardinality

Every person is an animal:
Male ⊑ Person
The intersection of males and fe… …s the empty set:
Male ⊓ Female ≡ ⊥ // ⊥ sig… …eans: empty set
Single child is a person, whose all …arents have only one child:
SingleChild ≡ Person ⊓ ∀parent.=1child.Person

Formal Background

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  - A-Box (instance model level): typify individuals, data and object role assertions
  - T-Box (metamodel level): subsumption between class expressions, which use role navigations and bool operators
- OWL Dialects:
  - OWL 2 RDF-Based Semantics: supports multi-level metamodeling, not decidable
  - OWL 2 Direct Semantics: $\mathcal{SROIQ}(\mathcal{D})$ description logic (DL)
    - decidable **reasoning** and **consistency checking**

Formal Background

- Axiomatic language
  - $\mathcal{S}$: Mother ≡ ∃child.Person // have child who is a person
  - $\mathcal{R}$: ObjectProperty knows // everybody knows oneself
    Characteristics: Reflexive
  - $\mathcal{O}$: Visibility ≡ {private, public} // enumeration
  - $\mathcal{I}$: child ≡ parent^{-1} // Inverse
  - $\mathcal{Q}$: FootballCoach ⊑ ≥11 knows.FootballPlayer
    // a football coach knows at least 11 football player
  - $(\mathcal{D})$: Individual: Joe
    Facts: age "17"^^xsd:int // data assertion
  - OWL 2 Direct Semantics: $\mathcal{SROIQ}(\mathcal{D})$ description logic (DL)
    - decidable **reasoning** and **consistency checking**

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  - OWL 2 Direct S
    - decidable **reasoning** **consistency checking**
  - OWL 2 profiles: ($\mathcal{EL}$, $\mathcal{QL}$, $\mathcal{RL}$)
    - reduced expressivity → more efficient algorithms

OWL2 EL profile:
- useful for ontologies that contain very large number of classes and relations
- only existential quantification is enabled
- polinomial reasoning algorithms can be used w.r.t. size of the ontology

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    - reduced expressivity → more efficient algorithms

Concrete Syntaxes

- OWL is compatible with RDF, hence RDF tools can be used (at RDF semantics level)
  - RDF/XML is obligatory for OWL 2 tools
  - For data change, not human readable

```
<owl:Class rdf:about="Young">
    <owl:equivalentClass>
      <owl:Restriction>
        <owl:onProperty rdf:resource="age"/>
        <owl:someValuesFrom>
          <rdfs:Datatype>
            <owl:onDatatype rdf:resource="&xsd;int"/>
            <owl:withRestrictions rdf:parseType="Collection">
              <rdf:Description>
                <xsd:maxExclusive rdf:datatype="&xsd;integer">18</xsd:maxExclusive>
              </rdf:Description>
            </owl:withRestrictions>
          </rdfs:Datatype>
        </owl:someValuesFrom>
      </owl:Restriction>
    </owl:equivalentClass>
  </owl:Class>
```

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- Functional Syntax: close to AST, readable

```
EquivalentClasses(:Young
DataSomeValuesFrom(:age DatatypeRestriction(xsd:int xsd:maxExclusive "18"^^xsd:integer)))
```

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- Functional Syntax: close to AST, readable
- OWL/XML: more compact than RDF/XML, but not used widely

```
<EquivalentClasses>
    <Class IRI="#Young"/>
    <DataSomeValuesFrom>
        <DataProperty IRI="#age"/>
        <DatatypeRestriction>
            <Datatype abbreviatedIRI="xsd:int"/>
            <FacetRestriction facet="&xsd;maxExclusive">
                <Literal datatypeIRI="&xsd;integer">18</Literal>
            </FacetRestriction>
        </DatatypeRestriction>
    </DataSomeValuesFrom>
</EquivalentClasses>
```

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  - RDF/XML is obligatory for OWL 2 tools
  - For data change, not human readable
- Functional Syntax: close to AST, readable
- OWL/XML: more compact than RDF/XML, but not used widely
- Manchester: readable, used in ontology editors

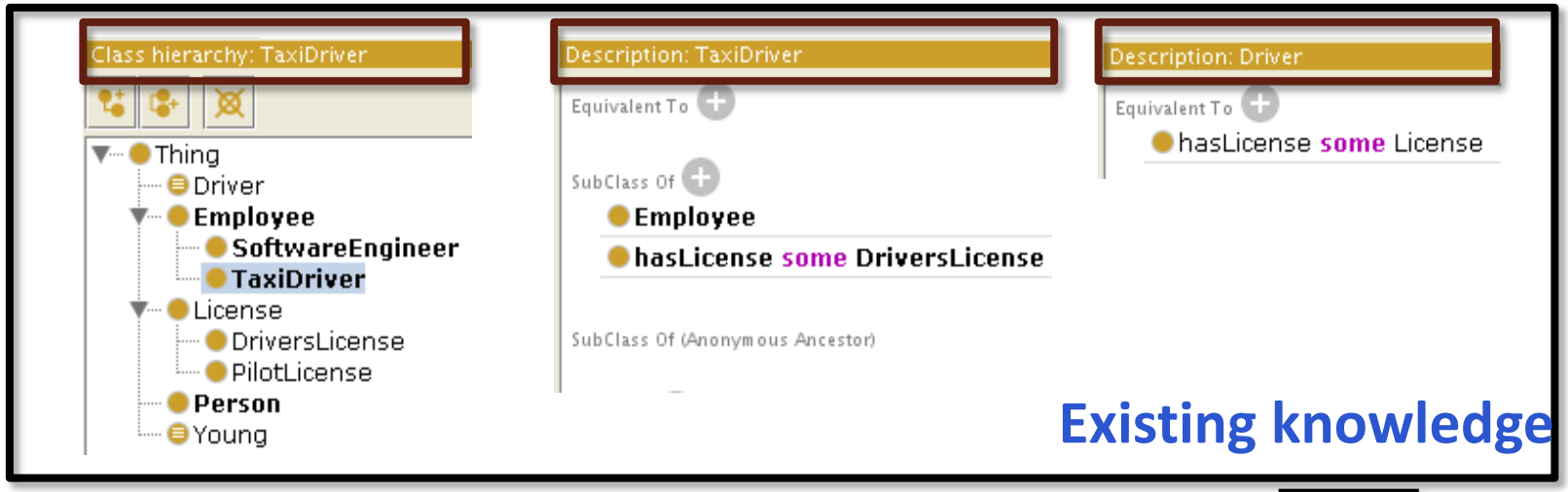
```
Class: Young
    EquivalentTo:
        age some xsd:int[< 18]
```

Tools

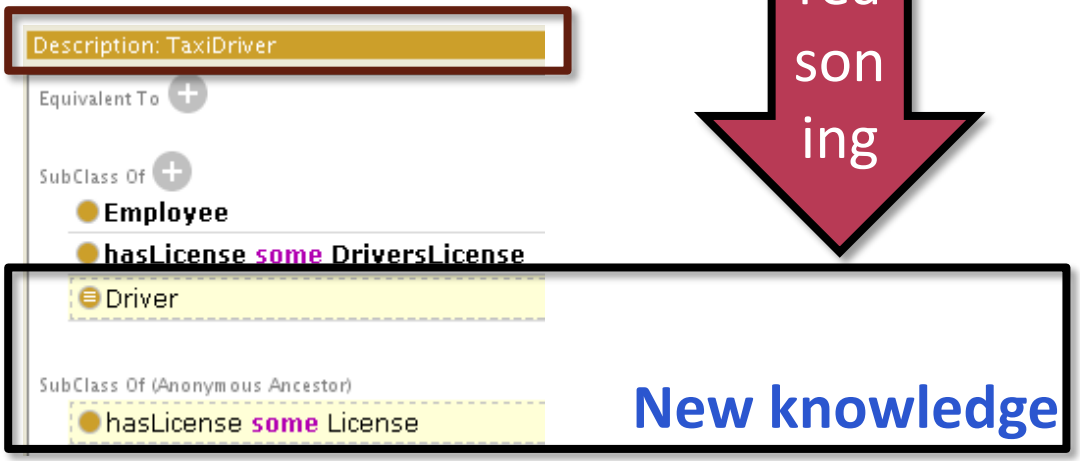
- Editors: Protégé
- Most usable part: DL subset for **reasoning** and **consistency checking**
  - Reasoning: infer new knowledge from existing ones
  - Reasoning algorithms: tableau calculi
  - Open World Assumption
  - Unique Name Assumption: not applied for OWL by default, but reasoners can be configured to use
- Reasoners: Pellet, RacerPro, HermiT
- API: OWL API (owlapi.sf.net), Java based

Ontology editing and reasoning demo

T-Box reasoning: new knowledge at meta level



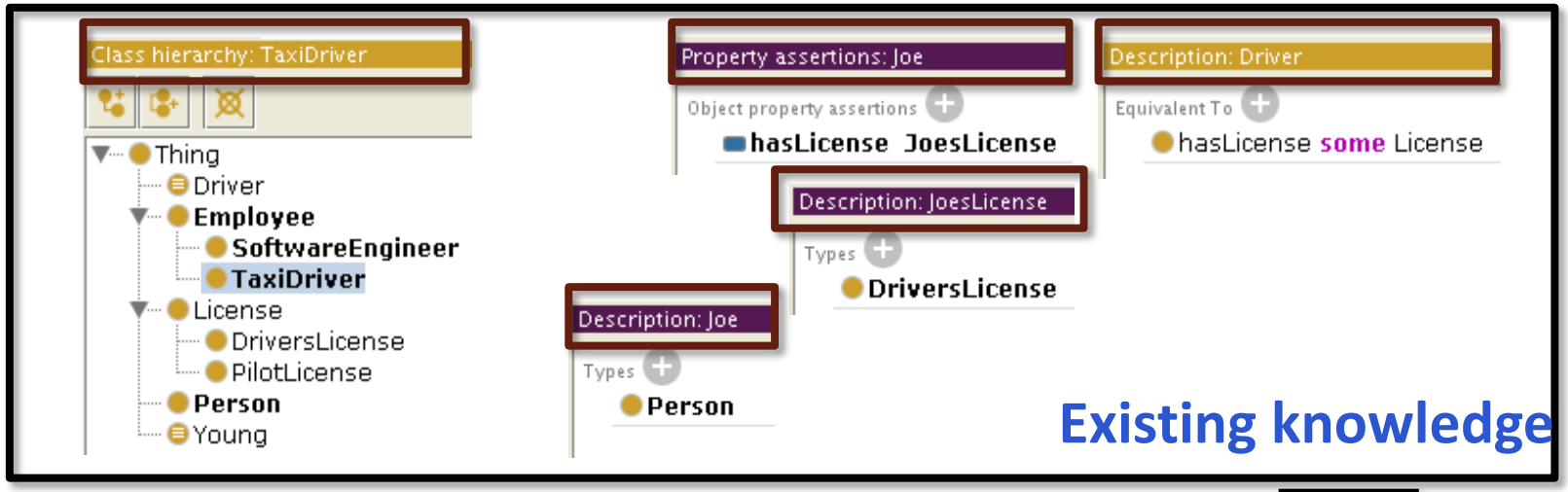
rea
son
ing



Reasoned:
Every TaxiDriver is a Driver.

Ontology editing and reasoning demo

A-Box reasoning: new assertion at instance level

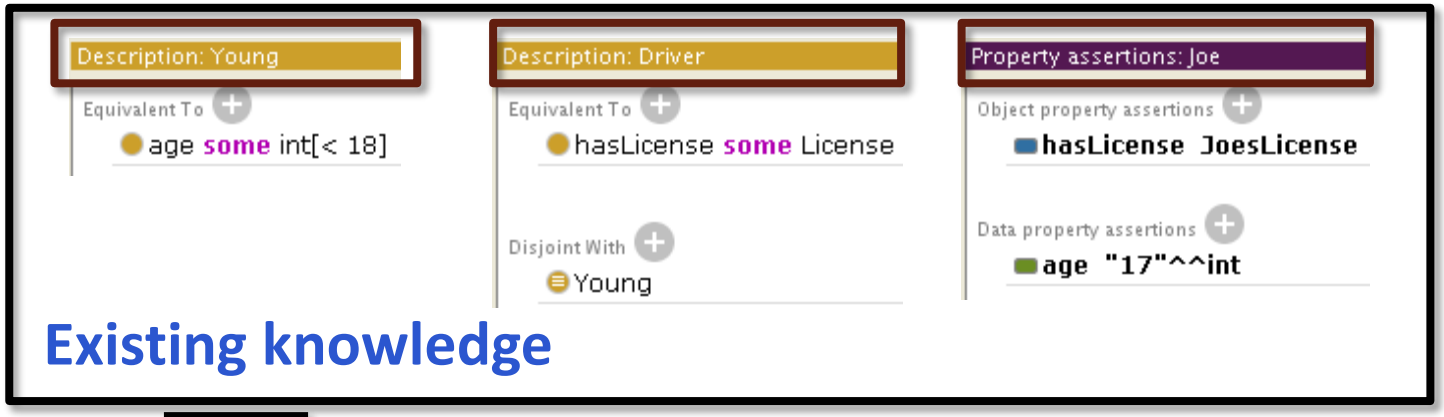


rea
son
ing

Reasoned:
Joe is a Driver.

Ontology editing and reasoning demo

Consistency checking: detect conflicting axioms



rea son ing

Reasoned:
Inconsistent ontology

$ pellet explain –inconsistent profession.owl
Axiom: Thing subClassOf Nothing

Explanation(s):
1) JoesLicense type DriversLicense
Young equivalentTo age some int[< 18]
Driver equivalentTo hasLicense some License
Joe hasLicense JoesLicense
DriversLicense subClassOf License
Joe age "17"^^int
Driver disjointWith Young

SEMANTIC TECHNOLOGIES AND RESOURCES

RDF Application

- **Semantic Web**
  - Is a photo of my Porsche a photo of a car?
  - Need standard IRIs for RDF resource/property types
  - Local metadata + ontologies = semantic web

RDF Application

- RDF Site Summary (**RSS**) 
  - Items with title, description, link, creator, date, …
  - RSS 2.0 abandons RDF, backronym

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  - Items with title, description, link, creator, date, …
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```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns="http://purl.org/rss/1.0/"
         xmlns:slash="http://purl.org/rss/1.0/modules/slash/"
         xmlns:dc="http://purl.org/dc/elements/1.1/" >
<title>Wikipedia Mobile Apps Switch To OpenStreetMap</title>
<link>http://rss.slashdot.org/~r/Slashdot/slashdot/~3/fQXcTk0g-aY/
      wikipedia-mobile-apps-switch-to-openstreetmap</link>
<dc:creator>timothy</dc:creator>
<dc:date>2012-04-08T14:31:00+00:00</dc:date>
<dc:subject>google</dc:subject>
<slash:department>location-aware</slash:department>
<slash:section>mobile</slash:section>
<slash:comments>125</slash:comments>
<slash:hit_parade>125,124,96,79,35,22,14</slash:hit_parade>
```

RDF Application

- RDF Site Summary (**RSS**) 
  - Items with title, description, link, creator, date, …
  - RSS 2.0 abandons RDF, backronym

Standard IRIs

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns="http://purl.org/rss/1.0/"
         xmlns:slash="http://purl.org/rss/1.0/modules/slash/"
         xmlns:dc="http://purl.org/dc/elements/1.1/" >
<title>Wikipedia Mobile Apps Switch To OpenStreetMap</title>
<link>http://rss.slashdot.org/~r/Slashdot/slashdot/~3/fQXcTk0g-aY/
      wikipedia-mobile-apps-switch-to-openstreetmap</link>
<dc:creator>timothy</dc:creator>
<dc:date>2012-04-08T14:31:00+00:00</dc:date>
<dc:subject>google</dc:subject>
<slash:department>location-aware</slash:department>
<slash:section>mobile</slash:section>
<slash:comments>125</slash:comments>
<slash:hit_parade>125,124,96,79,35,22,14</slash:hit_parade>
```

Defined vocabulary used to describe data

Semantic Web Vocabularies

- Dublin Core (DC) ontology
  - Librarian metadata for documents
  - Title, publisher, language, format, date, creator, etc.
  - Widespread usage (e.g. as an RSS Module)
- 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…

Semantic Web Vocabularies

- **Opengraph Protocol (Facebook)**

A Like button on a movie page on imdb.co

* More info: The Open Graph Protocol: Understanding the design decisions

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Me:
- I like The Rocks

Computer:
- What?? This HTML tag, or CSS?

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Me:
- I like The Rocks

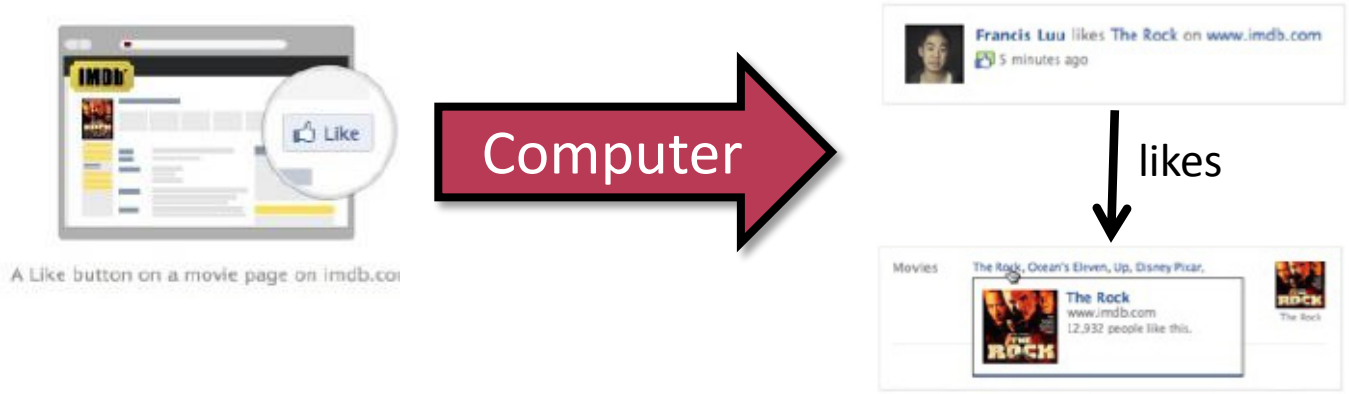
Computer:
- What?? This HTML tag, or CSS?

```
<html xmlns="http://www.w3.org/1999/xhtml"
xmlns:og="http://opengraphprotocol.org/schema/" >
<head>
<meta property="og:title" content="The Rock (1996)"/>
<meta property="og:type" content="video.movie"/>
<meta property="og:image" content="http://media-imdb.com/images/the_rocks.jpg"/>
<meta property="og:site_name" content="IMDb"/>
<meta property="fb:app_id" content="115109575169727"/>
</head>
```

* More info: The Open Graph Protocol: Understanding the design decisions

Semantic Web Vocabularies

- **Opengraph Protocol (Facebook)**

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Semantic Web Vocabularies

- **Microformat**

Wednesday 10 April 2013

Nordic Nexus of Nemesis Tour 2013
Stratovarius, Amaranthe

Alcatraz
Milano, Milan, Italy

Thursday 11 April 2013

Stratovarius & Amaranthe & Special Guest
Stratovarius, Amaranthe

Rockfabrik
Ludwigsburg, Germany

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Stratovarius, Amaranthe

Rockfabrik
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Last.fm:
We collected the events for the band Amaranthe. How can we make data more searchable?

Semantic Web Vocabularies

- **Microformat**

Wednesday 10 April 2013

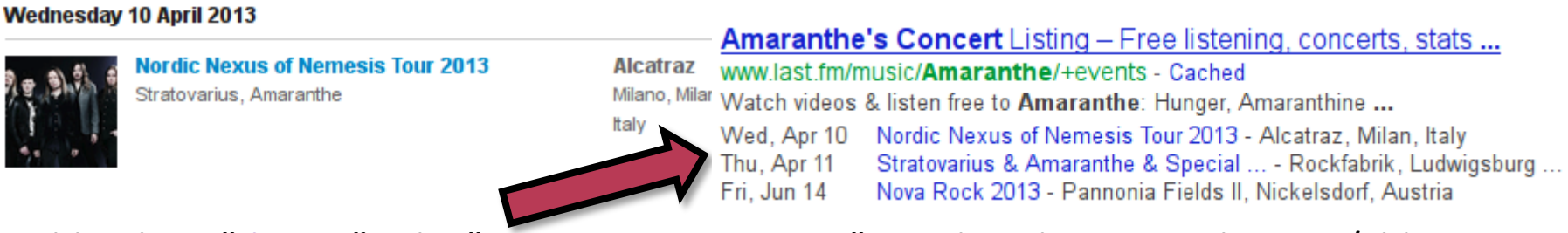
Nordic Nexus of Nemesis Tour 2013
Stratovarius, Amaranthe

Alcatraz
Milano, Milan,
Italy

```
<abbr class="dtstart" title="2013-04-10T12:53:00">Wednesday 10 April 2013</abbr>
<td class="location vcard">
 <span class="fn org"><a href="/venue/8778527+Alcatraz">Alcatraz</a></span>
 <span class="adr"><br />Milano,
   <span class="locality">Milan</span>,
   <span class="country-name">Italy</span>
 </span>
 <div class="geo">
    <span class="latitude">45.494282</span>
    <span class="longitude">9.182612</span>
 </div>
</td>
```

Semantic Web Vocabularies

- **Microformat**

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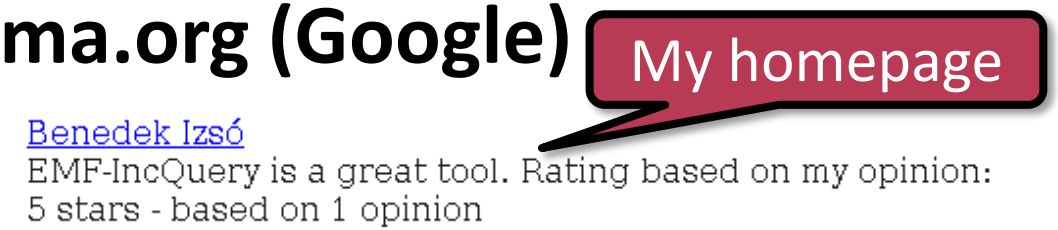

Semantic Web Vocabularies

- **Microdata: schema.org (Google)**

Benedek Izsó
EMF-IncQuery is a great tool. Rating based on my opinion:
5 stars - based on 1 opinion

```
<body>
<div itemscope itemtype="http://schema.org/People">
  <span itemprop="name">
    <a href="https://plus.google.com/111902568077770766904?rel=author">
      Benedek Izsó</a>
</span>
</div>
<div itemscope itemtype="http://schema.org/Product">
  <span itemprop="name">EMF-IncQuery</span> is a great tool. Rating based on my opinion:
  <div itemprop="aggregateRating" itemscope itemtype="http://schema.org/AggregateRating">
    <span itemprop="ratingValue">5</span> stars -
    based on <span itemprop="reviewCount">1</span> review
  </div>
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```

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```

Only a product can be rated (online shops)

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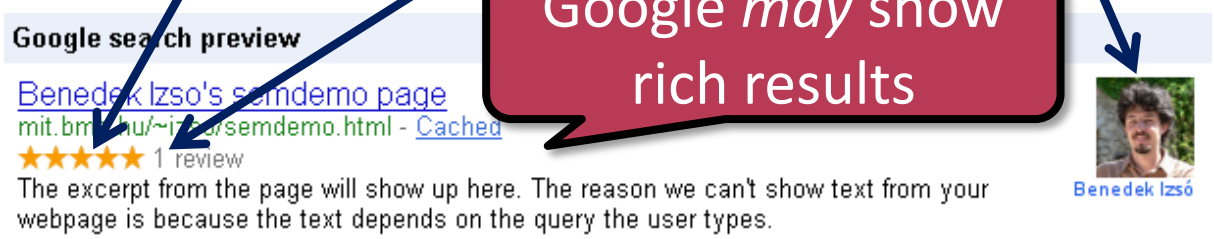

Google *may* show rich results

Semantic Web Vocabularies

- Common vocabularies: schema.org (G), Open Graph Protocol (FB), Microformats
- Data searching and connecting services **needs data** and not the graphical look
  - A website will not upload its database
  - But may annotate their website content
- One easily usable, unified vocabulary
  - not reused existing ones which can be a big mess
  - Concepts can be the most popular ones, based on site statistics
- Data is more structured with annotations than natural language, but less structured than a DB.
  - E.g.: not every Product must have a rating in semweb
  - But in an object oriented datamodel every Product have a rating reference

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 endpoint

Knowledge Bases

- DBpedia SPARQL Query example with Sesame

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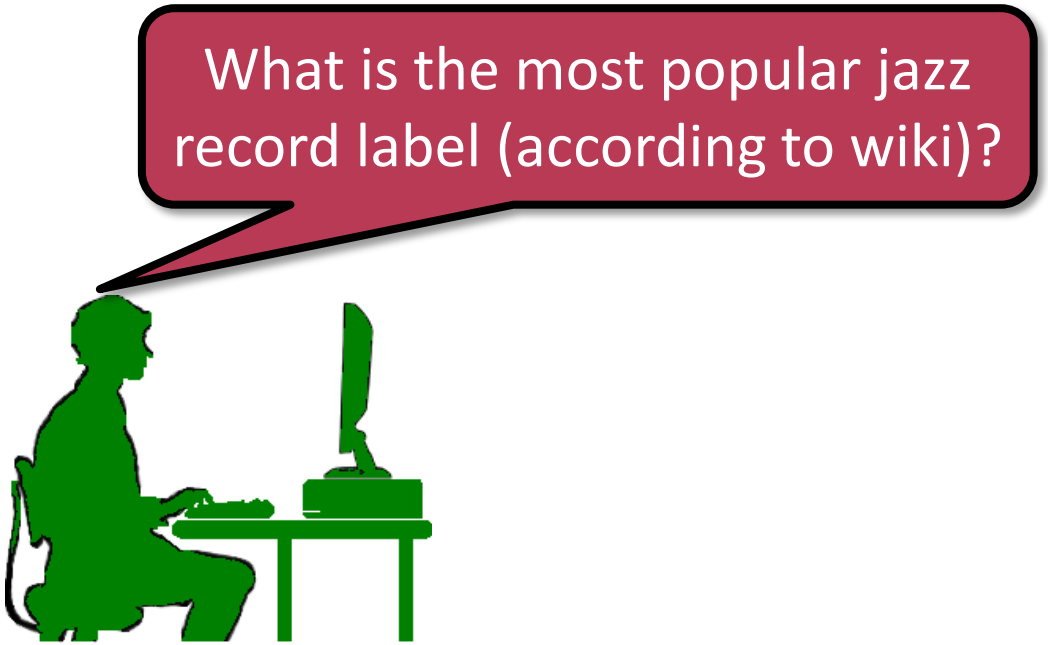
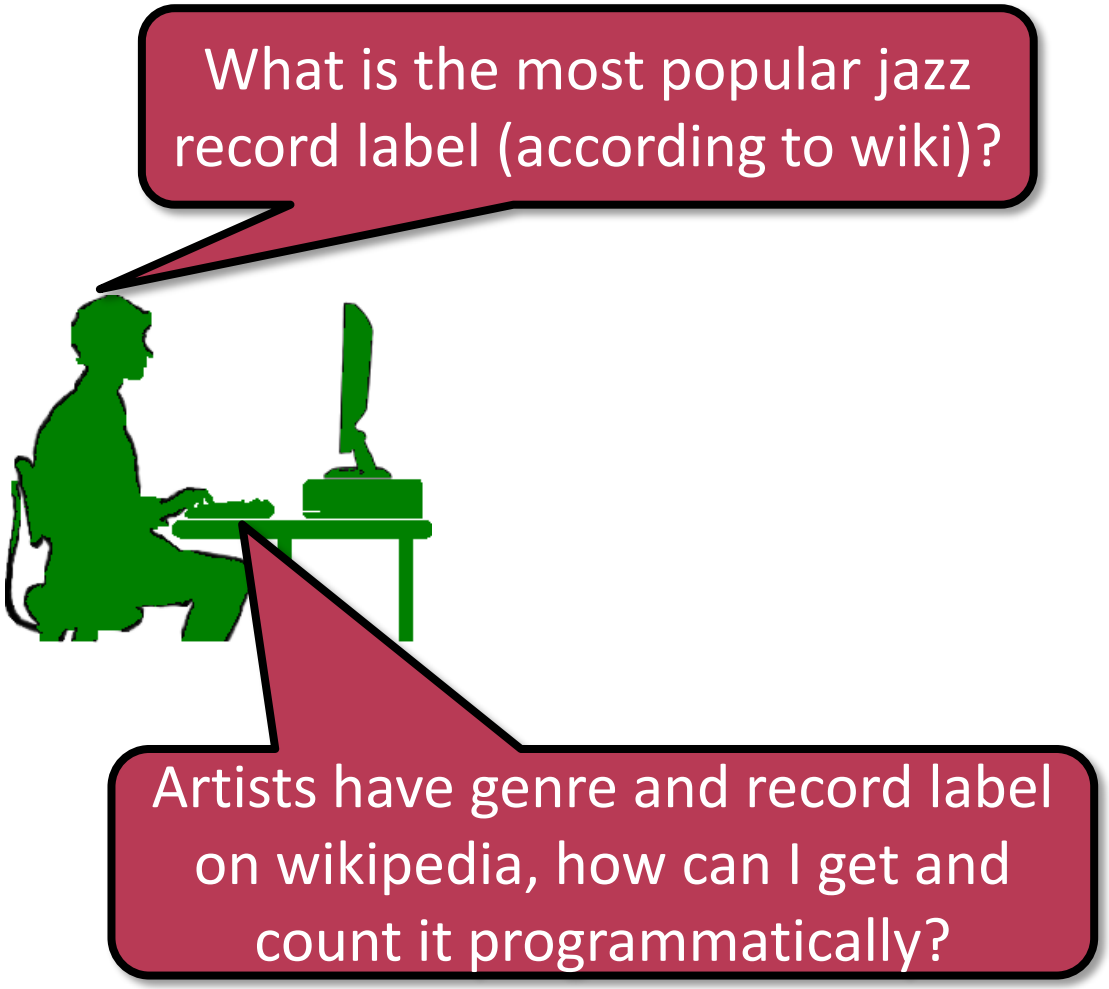


Knowledge Bases

- DBpedia SPARQL Query example with Sesame



Knowledge Bases

- DBpedia SPARQL Query example with Sesame

```
SELECT ?label (count(?label) AS ?labelCount)
WHERE {
  ?person dbp:genre dbr:Jazz .
  ?person dbp:label ?label .
  ?label rdf:type dbo:RecordLabel .
 } ORDER BY DESC(?labelCount)
```

Knowledge Bases

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```
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WHERE {
  ?person dbp:genre dbr:Jazz .
  ?person dbp:label ?label .
  ?label rdf:type dbo:RecordLabel .
 } ORDER BY DESC(?labelCount)
```

Record Label	Count
Blue_Note_Records	739
ECM_Records	507
Columbia_Records	386
Verve_Records	374

Knowledge Bases

- DBpedia SPARQL Query example with Sesame

```
HTTPRepository sparqlEndpoint = new HTTPRepository("http://live.dbpedia.org/sparql", "");
sparqlEndpoint.initialize(); conn = sparqlEndpoint.getConnection();
String sparqlQuery = " SELECT ?label (count(?label) AS ?labelCount) WHERE { " +
                     "   ?person dbp:genre dbr:Jazz . " +
                     "   ?person dbp:label ?label . " +
                     "   ?label rdf:type dbo:RecordLabel . " +
                     " } ORDER BY DESC(?labelCount) ";
TupleQuery query = conn.prepareTupleQuery(QueryLanguage.SPARQL, sparqlQuery);
TupleQueryResult result = query.evaluate();
while (result.hasNext()) {  // print answers
        BindingSet triple = result.next();
        System.out.println(triple.getBinding("label").getValue());
        Literal labelCount = (Literal) triple.getBinding("labelCount").getValue();
        System.out.println(labelCount.intValue());
} conn.close();
```

Knowledge Bases

- Linked GeoData: OpenStreetMap in RDF format
  - SPARQL endpoint
  - or downloadable RDF (10GB)

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```
prefix lgdo: <http://linkedgeodata.org/ontology/>
select * from <http://linkedgeodata.org>
{
   ?s a                  lgdo:Cafe .
   ?s rdfs:label         ?l .
   ?s geo:geometry ?g .
   filter(bif:st_intersects (?g,
          bif:st_point (19.061667, 47.489722), 0.4)) .
};
```

Knowledge Bases

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  - SPARQL endpoint
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   filter(bif:st_intersects (?g,
          bif:st_point (19.061667, 47.489722), 0.4)) .
};
```

Filter near places: Intersect function not in SPARQL, LGD extension

Coordinate of Calvin Square

0.4 km

Knowledge Bases

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  - SPARQL endpoint
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```
prefix lgdo: <http://linkedgeodata.org/ontology/>
select * from <http://linkedgeodata.org>
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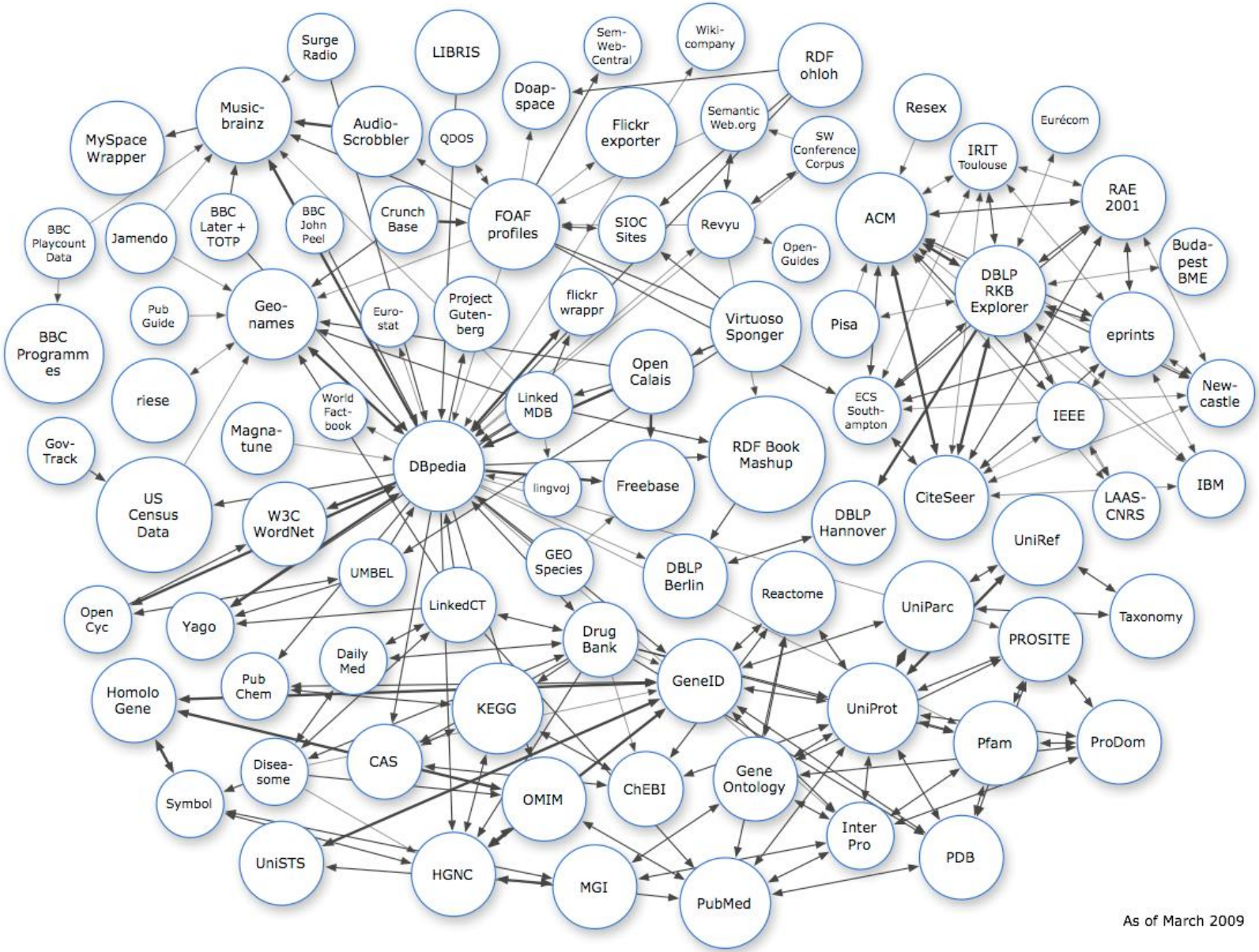
   ?s geo:geometry ?g .
   filter(bif:st_intersects (?g,
          bif:st_point (19.061667, 47.489722), 0.4)) .
};
```

Cafes near Calvin Square (?l)
Frank Zappa
LUMEN
California Coffee Bean

Linking Open Data (LOD)



MODELING APPROACHES

DSM and Ontology languages - Similarities

	Domain Specific Models	Ontology (DL)
Language	UML, **EMF**	RDF, OWL
1-ary predicate	EClass	Concept
2-ary predicate	EReference/EAttribute	Object/Datatype property
Model element	EObject	Instance
Enumeration	EEnum	Nominals
Cardinality	Role cardinality	Cardinality restriction
Inverse	EOpposite	owl:inverseOf
Type of	EType	rdf:type
Subsumption	Generalizaton	rdfs:subClassOf

DSM and Ontology languages - Differences

	Domain Specific Models	Ontology (DL)
Classifying instances	Enum, multiple inheritance	Multi domain metamodeling
Constraint description	Other auxiliary language (e.g.: OCL)	Built into the language
Types	One instance has 1 type	One instance can belong to multiple classes
Unique Name Assumption	Yes	No (by default)
Open World Assumption	No	Yes

DSM and Ontology based modeling - Usage

	Domain Specific Models	Ontology (DL)
Metamodel description	Practical description -for engineers	Precise definitions - for mathematicians
Instance model	Complete data	Continuously evolving data
Strengths	• Code generation • Model transformation • Existing tools • Fast instance model query	• Reasoning • Consistency checking • Common vocabularies • Prototyping (OWA, UNA)
Modeling	Efficient instance model editing and querying	Efficient metamodel designing and reasoning
Language elements	Common OO terms	Mathematical constraints (e.g.: existential and universal quantification)
Structuredness	Highly structured	Usually not structured

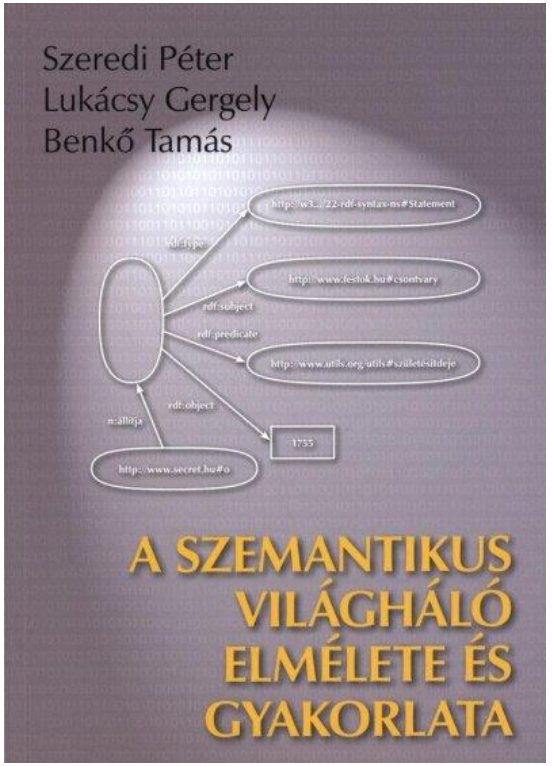
SUMMARY

Summary

- Semantic technologies
  - Metadata (RDF)
  - Ontologies (OWL)
  - Formal logic based reasoning
  - Querying with SPARQL
- Applications
  - Domain ontologies in expert systems
  - Semantic Web

Recommended reading

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



BMEVIMIM222
Információ- és tudásintegrálás
(MSc intelligens rendszerek szakirány)