Linked Spatiotemporal Data and Interoperability*

*1. Introduce Linked data
2. Outline New Frontiers
3. Relate to SeCoGIS 2012 papers
4. Focus on Examples

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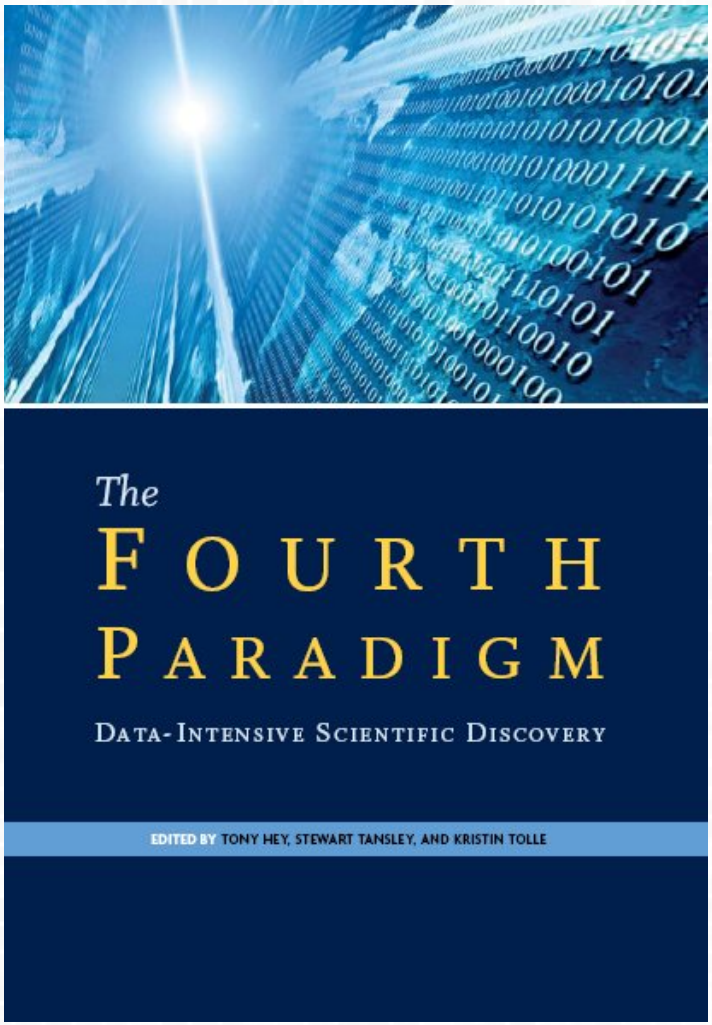
SeCoGIS 2012

The 4th Paradigm and the Semantic Web



http://research.microsoft.com/en-us/collaboration/fourthparadigm/

1. **Empirical**
2. **Theoretical**
3. **Computational**
4. **Explorational**

Value Proposition of the Semantic Web

- Publishing and **Retrieving**
- **Interacting** and Accessing
- Reusing and **Integrating**

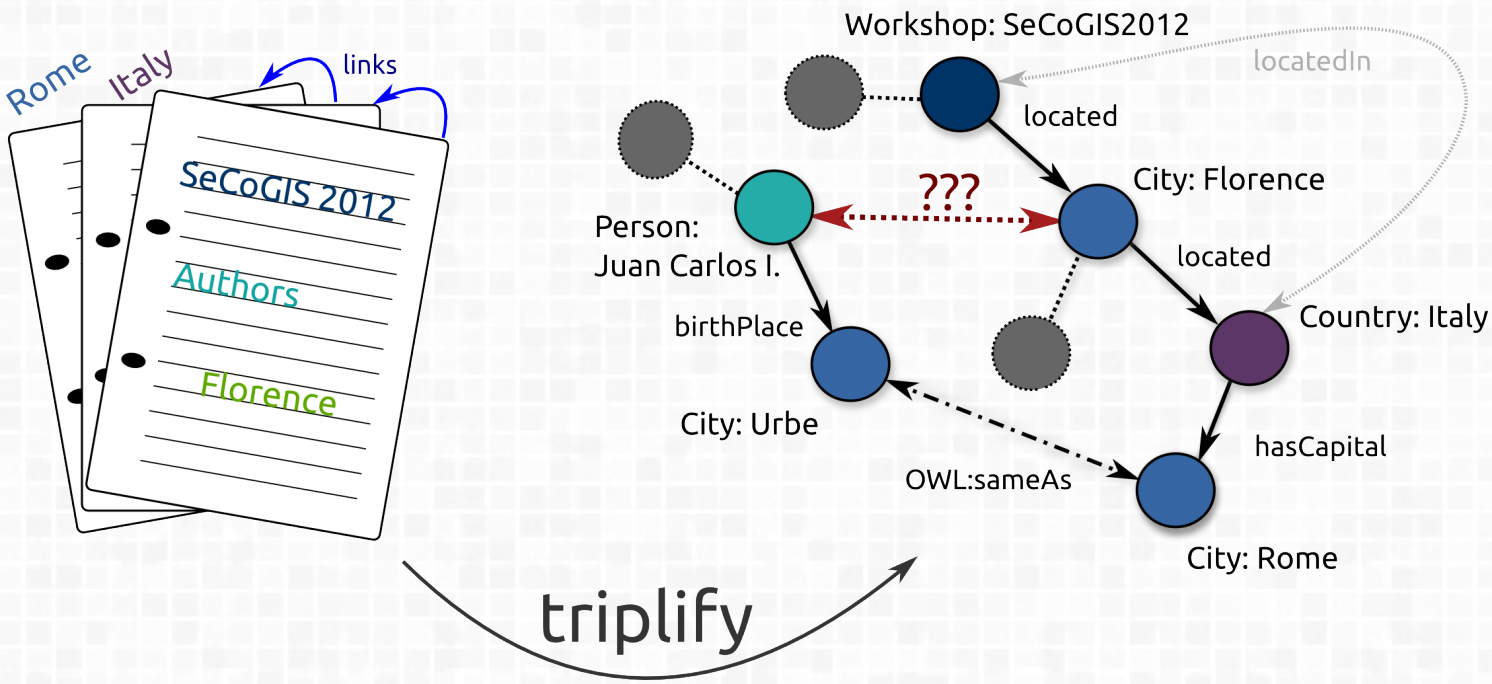
Linking Data as Next-Generation Infrastructure

Data Silos

- Web services
- Databases
- Web pages

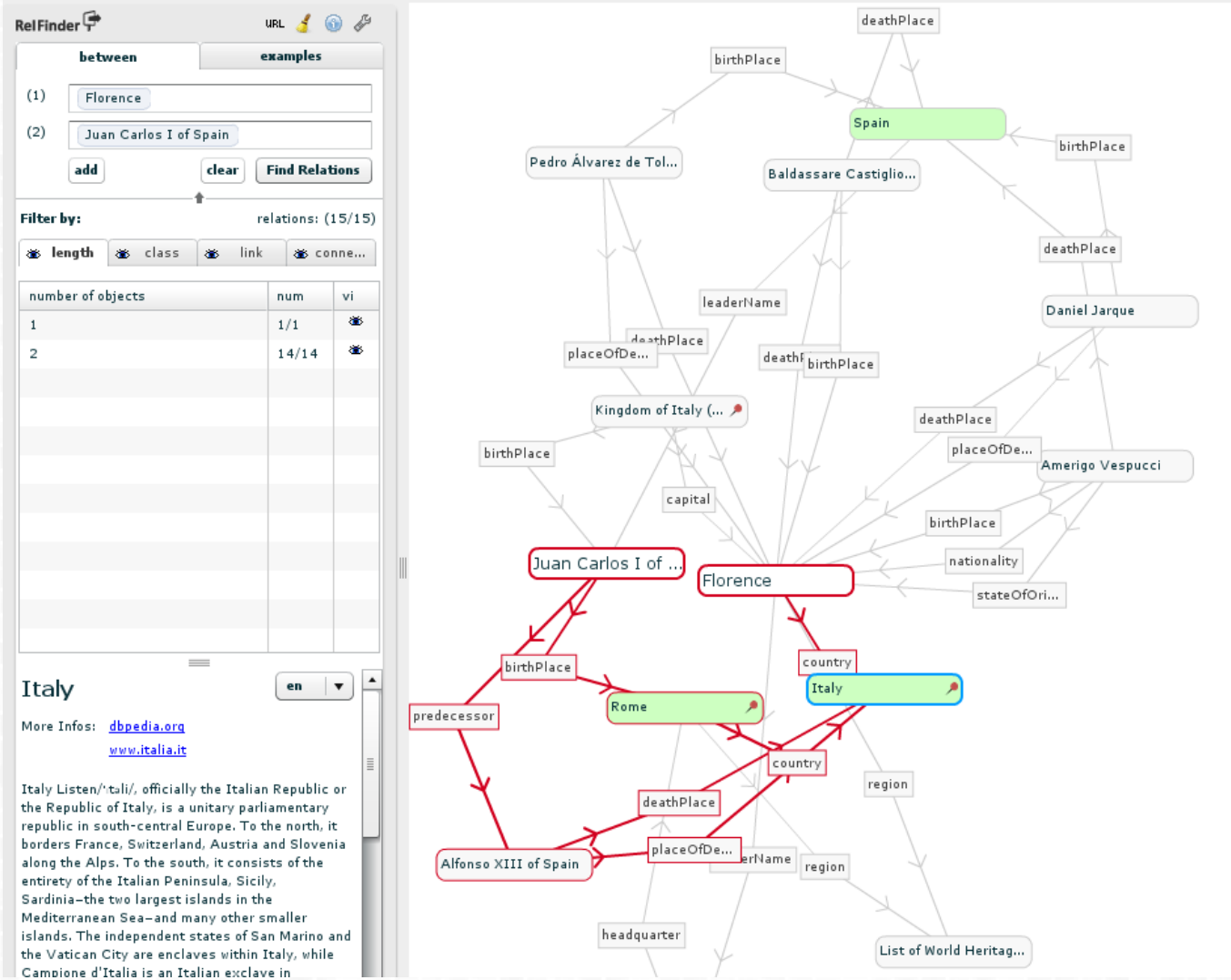
- hinder ad-hoc combination
- enforce data models
- limit re-usability

From Linked Documents to Linked Data



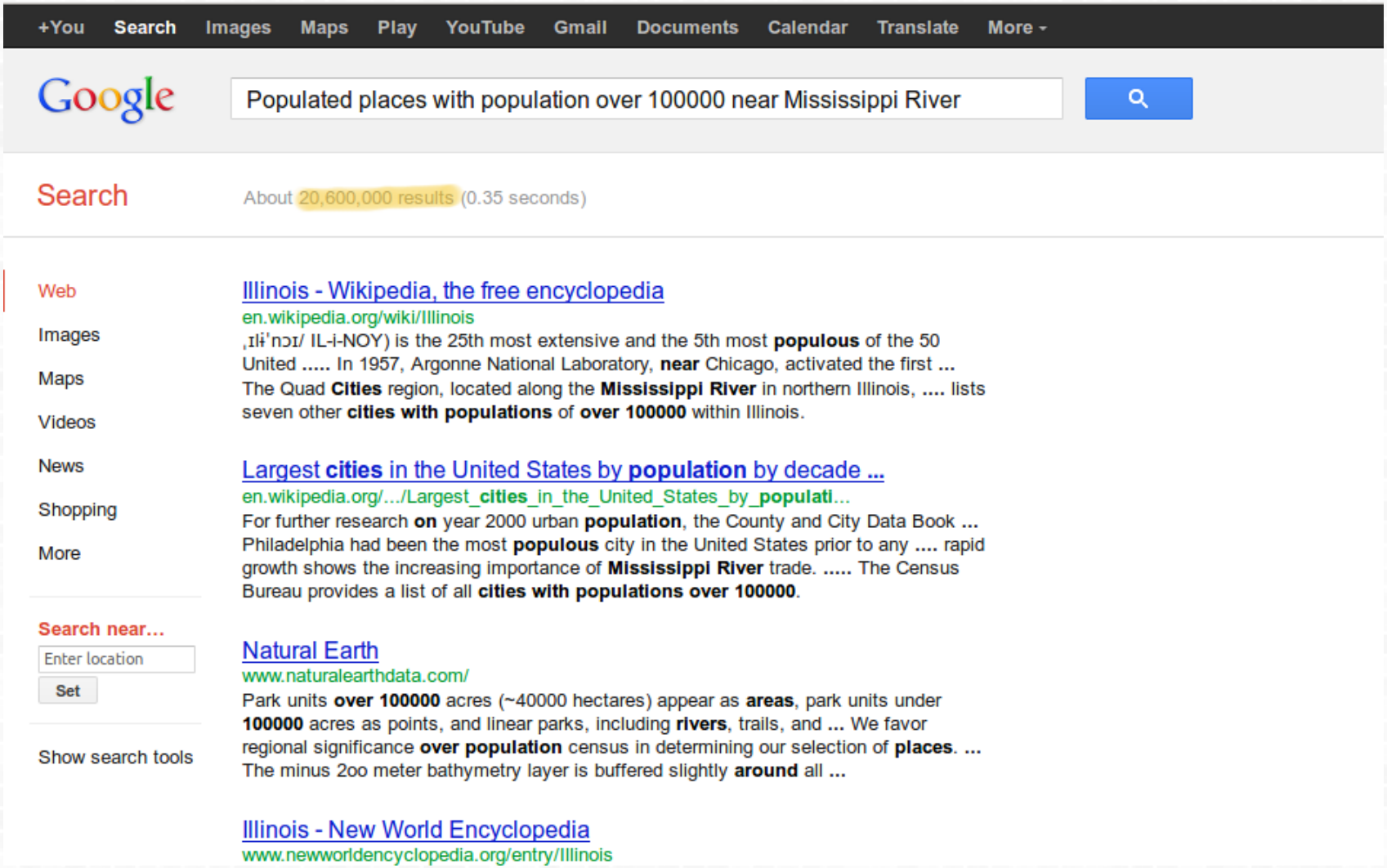
Use Uniform Resource Identifiers (**URI**) to identify **entities**, **link** them to other entities, encode information about these entities using the **machine-understandable RDF**, and make them available on the **Web**.

Exploring Linked Data Related to Florence, Italy

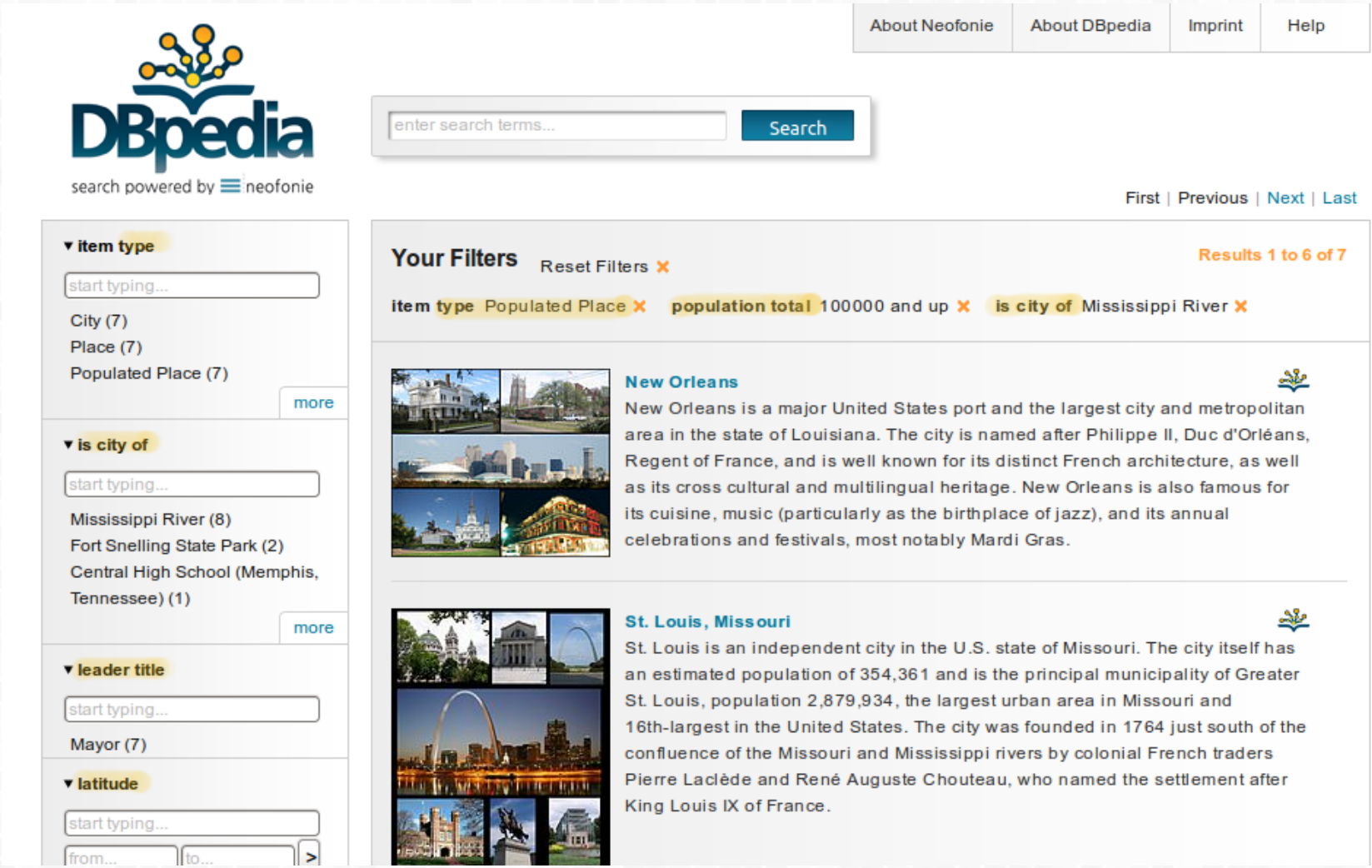


Explore information related to Florence using the **Linked Data (DBpedia)**.

Searching the Web of Documents

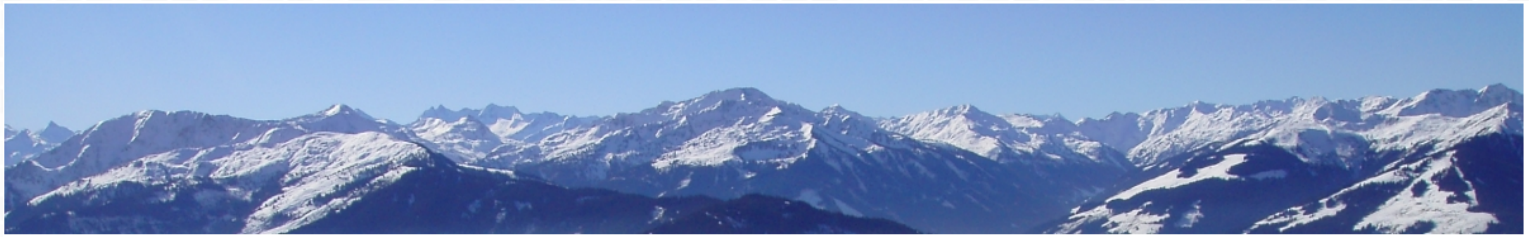


Searching the Web of Data



- **Populated places** have a population, are located, occupy a certain area,...

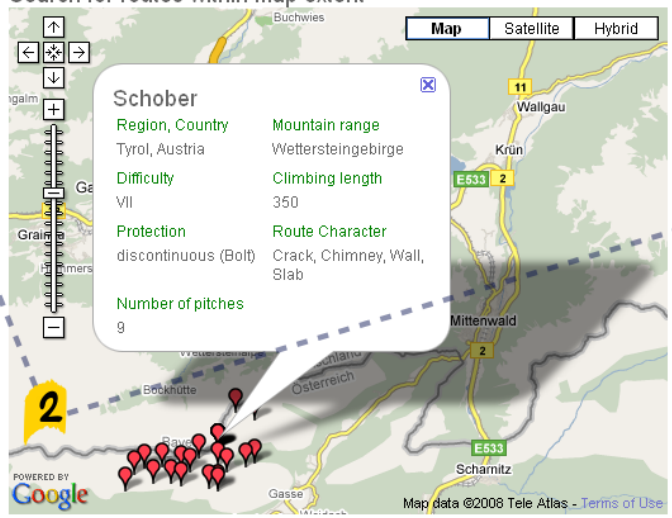
Semantics-enabled Geo-Information Retrieval



Reference routes
Suedkante
Bellissima
Nordostpfeiler
Suedkurve

1

Search for routes within map extent



2

<< back next >>

3

Route recommendations

Overall Ranking
Erdenkaeufer Sigl
Mon Cheri
Bayerischer Traum
Schober
Pfeilerrisse
Siemens Wolf Variante 1
Siemens Wolf Variante 2
Siemens Wolf
Aquaplaning
Peters Haringer

Length Ranking show ranking
Difficulty Ranking hide ranking
Schober
M
Compared to reference routes

4

Bayerischer Traum
Erdenkaeufer Sigl
Pfeilerrisse
Peters Haringer
Aquaplaning
Siemens Wolf Variante 1
Siemens Wolf Variante 2
Siemens Wolf

Rock Ranking show ranking

- **Query-by-example**, exploratory search & browsing, **analogy-based search**

  E.g., 'Deepwater Horizon oil spill of the 1980s?', 'Riviera of the United States?', etc.

Google's Knowledge Graph

Google

Amerigo Vespucci born

Search

About 1,050,000 results (0.12 seconds)

Web
Images
Maps
Videos
News
Shopping
More

Show search tools

March 9, 1454, Florence
Amerigo Vespucci, Born

In 1512 **Amerigo Vespucci** died of malaria. - Library
library.thinkquest.org/J002678F/**vespucci**.htm
Hello my name is **Amerigo Vespucci**. I was **born** March 18, 1454 in **Florence**, Italy. When I was a boy I was interested in astronomy and the study of the universe.

Amerigo Vespucci - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/**Amerigo_Vespucci**
Amerigo Vespucci was **born** and raised in **Florence**, Italy. He was the third son of Ser Nastagio (Anastasio), a Florentine notary, and Lisabetta Mini. Amerigo ...

Amerigo Vespucci - Biography of **Amerigo Vespucci**
geography.about.com › ... › Geography › History of Geography
Learn all about the explorer for whom America is named - **Amerigo Vespucci**, from your ... Vespucci was **born** in 1454 to a prominent family in **Florence**, Italy.

Amerigo Vespucci - NNDB
www.nndb.com/people/438/000085183/
... who gave his name of **Amerigo** to the new world as America, was **born** at **Florence** on the 9th of March 1451. His father, Nastagio (Anastasio) **Vespucci**, was a ...

Amerigo Vespucci

liberapedia.wikia.com

Amerigo Vespucci was an Italian explorer, financier, navigator and cartographer who first demonstrated that Brazil and the West Indies did not represent Asia's eastern outskirts as initially conjectured ...
Wikipedia

Born: March 9, 1454, Florence
Died: February 22, 1512, Seville

People also search for


Christopher Columbus


Ferdinand Magellan

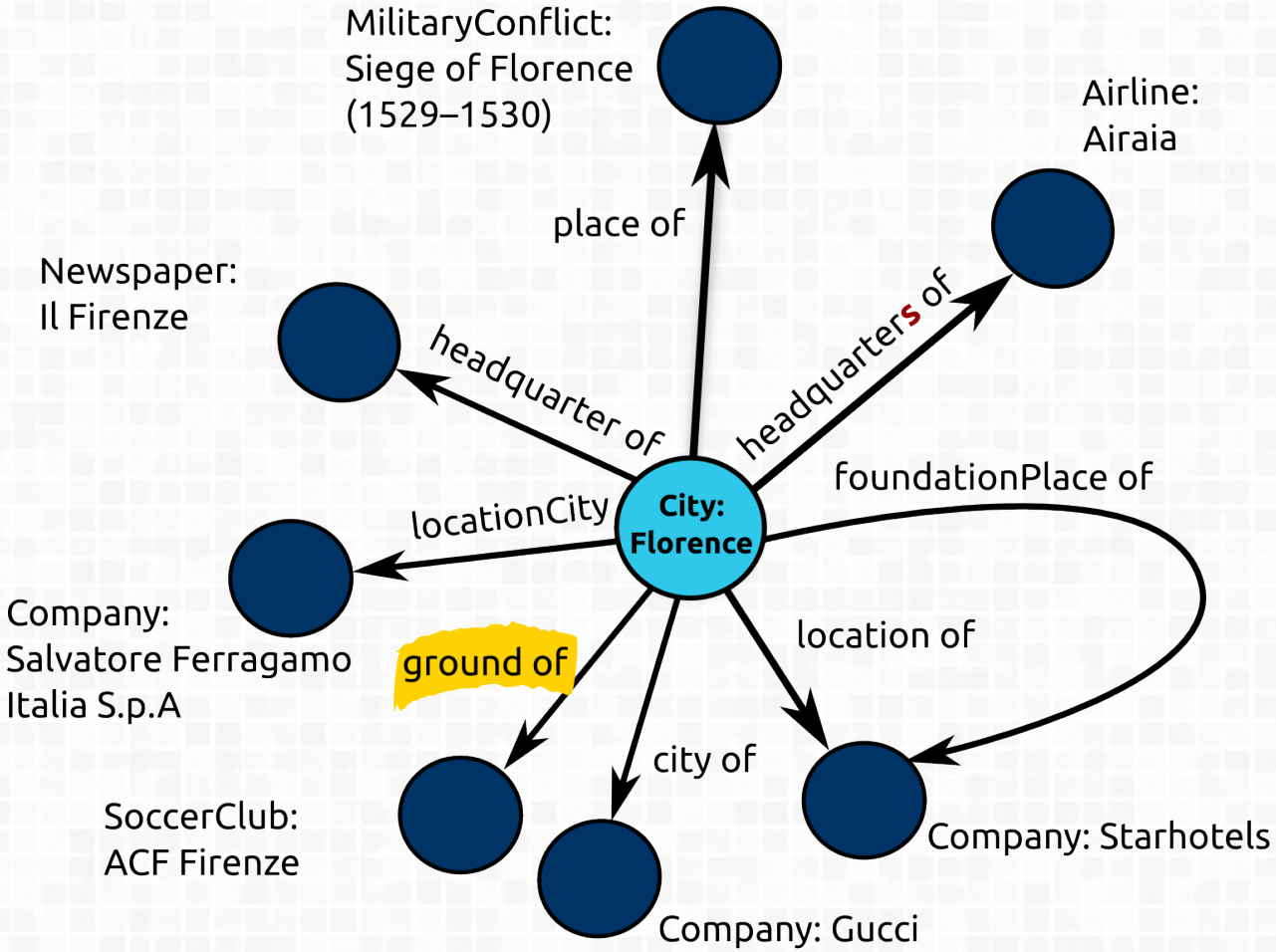

John Cabot


Martin Waldsee...


Vasco da Gama

Feedback

Some DBpedia Facts About Florence, Italy



A GLIMPSE AT THE DBPEDIA ONTOLOGY

About: ground

An Entity of Type : ObjectProperty, from Named Graph : http://dbpedia/classes#, within Data Space : dbpedia.org

Property	Value
rdf:type	owl:ObjectProperty
rdfs:domain	dbpedia-owl:SoccerClub
rdfs:isDefinedBy	http://dbpedia.org/ontology/
rdfs:label	ground
rdfs:range	dbpedia-owl:Place

About: soccer club

An Entity of Type : Class, from Named Graph : http://dbpedia.org/resource/
Data Space : dbpedia.org

Property	Value
rdf:type	owl:Class
rdfs:isDefinedBy	http://dbpedia.org/ontology/
rdfs:label	club de football soccer club
rdfs:subClassOf	dbpedia-owl:SportsTeam
is rdfs:domain of	dbpedia-owl:chairmanTitle dbpedia-owl:clubsRecordGoalscorer dbpedia-owl:managerTitle dbpedia-owl:firstGame dbpedia-owl:fansgroup dbpedia-owl:largestWin dbpedia-owl:worstDefeat dbpedia-owl:dissolved dbpedia-owl:ground dbpedia-owl:capacity dbpedia-owl:manager dbpedia-owl:season dbpedia-owl:honours
is rdfs:range of	dbpedia-owl:soccerTournamentMostSteady dbpedia-owl:soccerTournamentLastChampion dbpedia-owl:soccerTournamentMostSuccesfull
is rdfs:subClassOf of	dbpedia-owl:NationalSoccerClub

A GLIMPSE AT THE SCHEMA.ORG

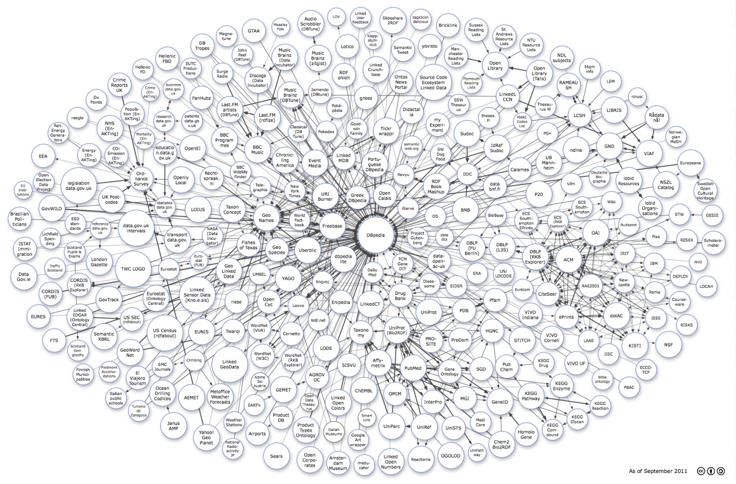
Thing > Place > Landform > Mountain

A mountain, like Mount Whitney or Mount Everest

Property	Expected Type	Description
Properties from Thing		
additionalType	URL	An additional type for the item, typically used for adding more specific types from external vocabularies in microdata syntax. This is a relationship between something and a class that the thing is in. In RDFa syntax, it is better to use the native RDFa syntax - the 'typeof' attribute - for multiple types. Schema.org tools may have only weaker understanding of extra types, in particular those defined externally.
description	Text	A short description of the item.
image	URL	URL of an image of the item.
name	Text	The name of the item.
url	URL	URL of the item.
Properties from Place		
address	PostalAddress	Physical address of the item.
aggregateRating	AggregateRating	The overall rating, based on a collection of reviews or ratings, of the item.
containedIn	Place	The basic containment relation between places.
event	Event	Upcoming or past event associated with this place or organization.
events	Event	Upcoming or past events associated with this place or organization (legacy spelling; see singular form, event).
faxNumber	Text	The fax number.
geo	GeoCoordinates or GeoShape	The geo coordinates of the place.

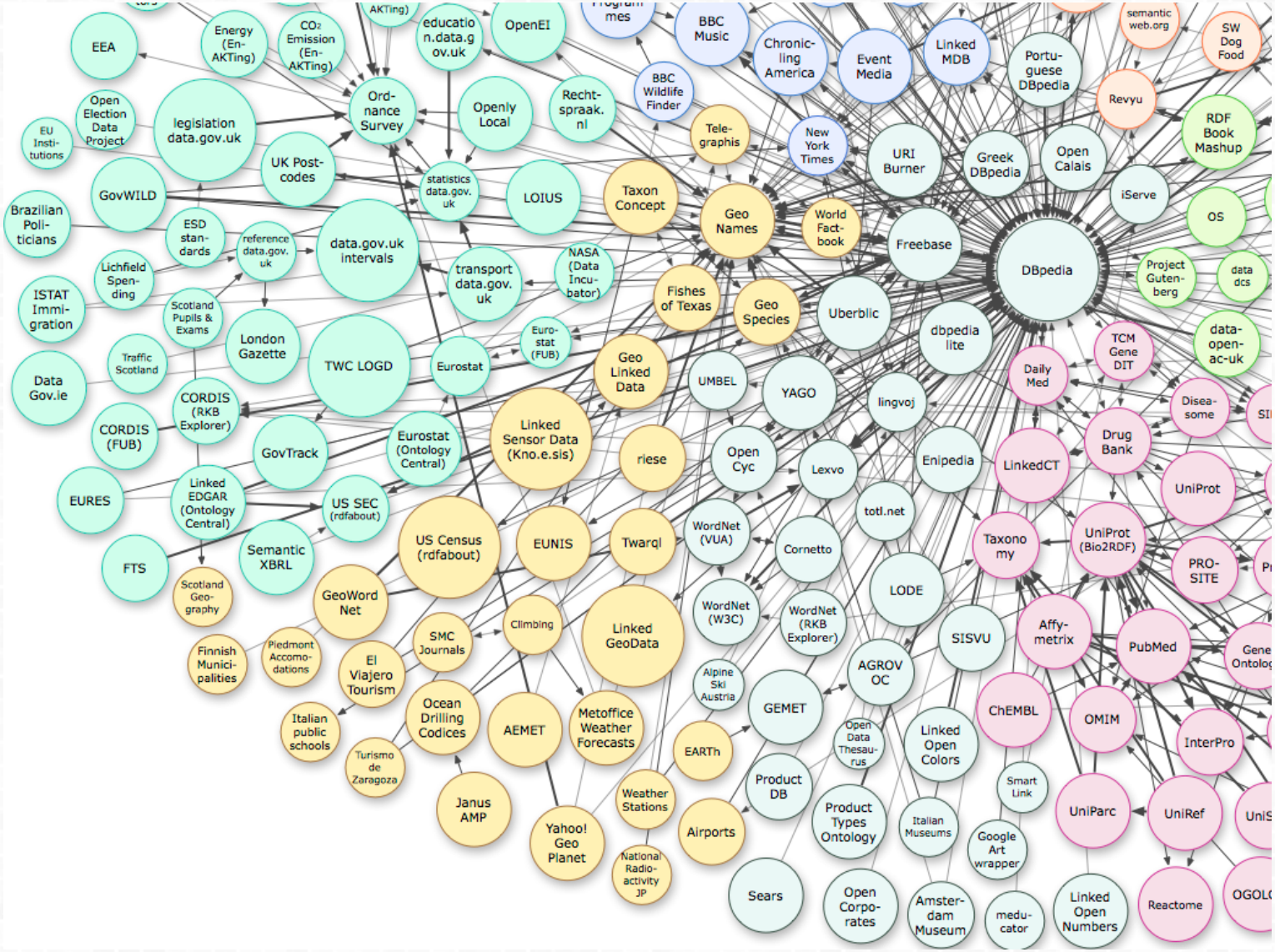
Most of the ontologies/vocabularies used to annotate popular Linked Data sets are **too lightweight**; they fail to restrict the interpretation of terms towards their intended **meaning**.

THE GLOBAL GRAPH OF LINKED DATA

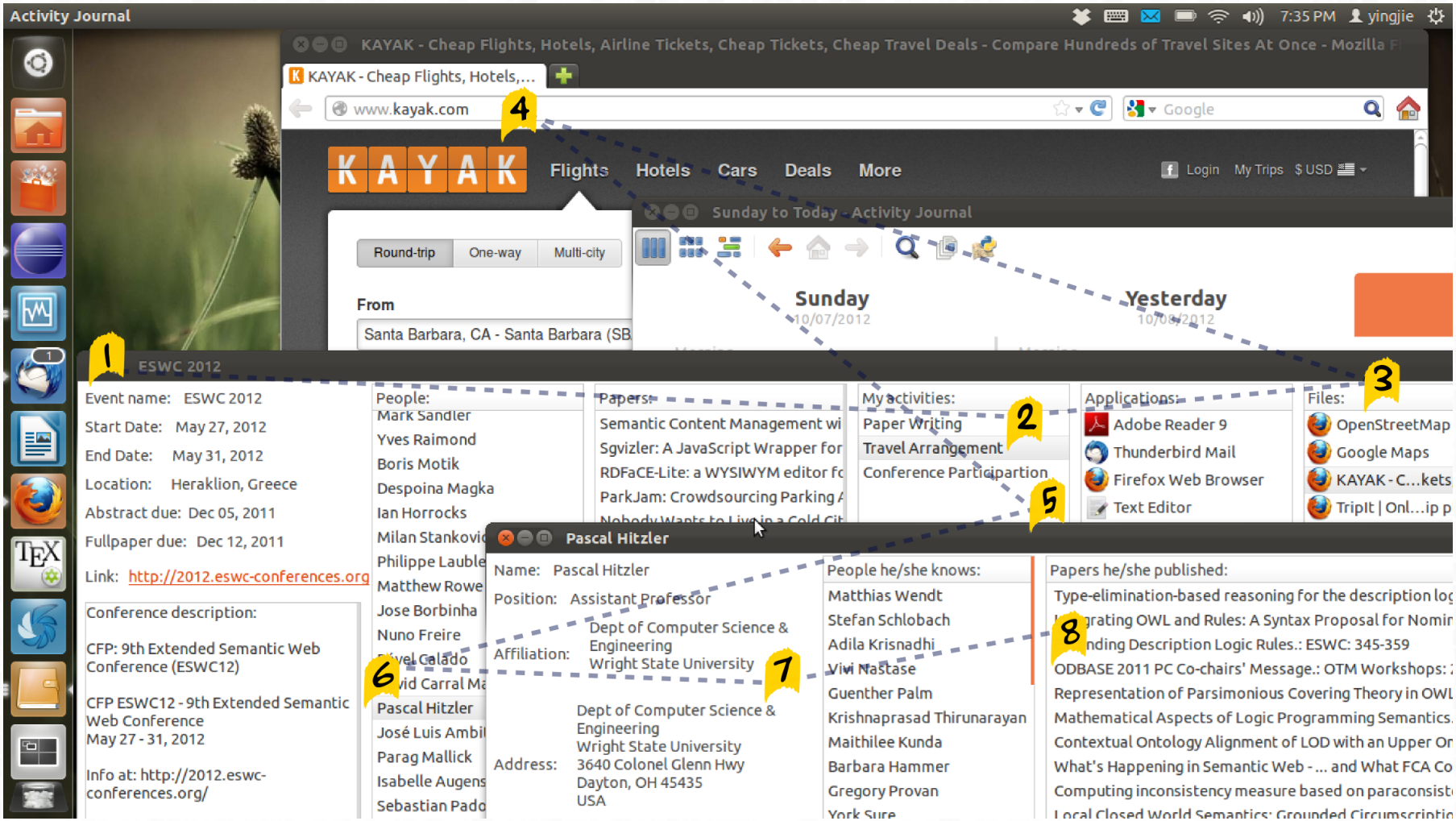


The examples before involved only **one data set**, but there is much more to explore.

The Global Graph of Linked Data

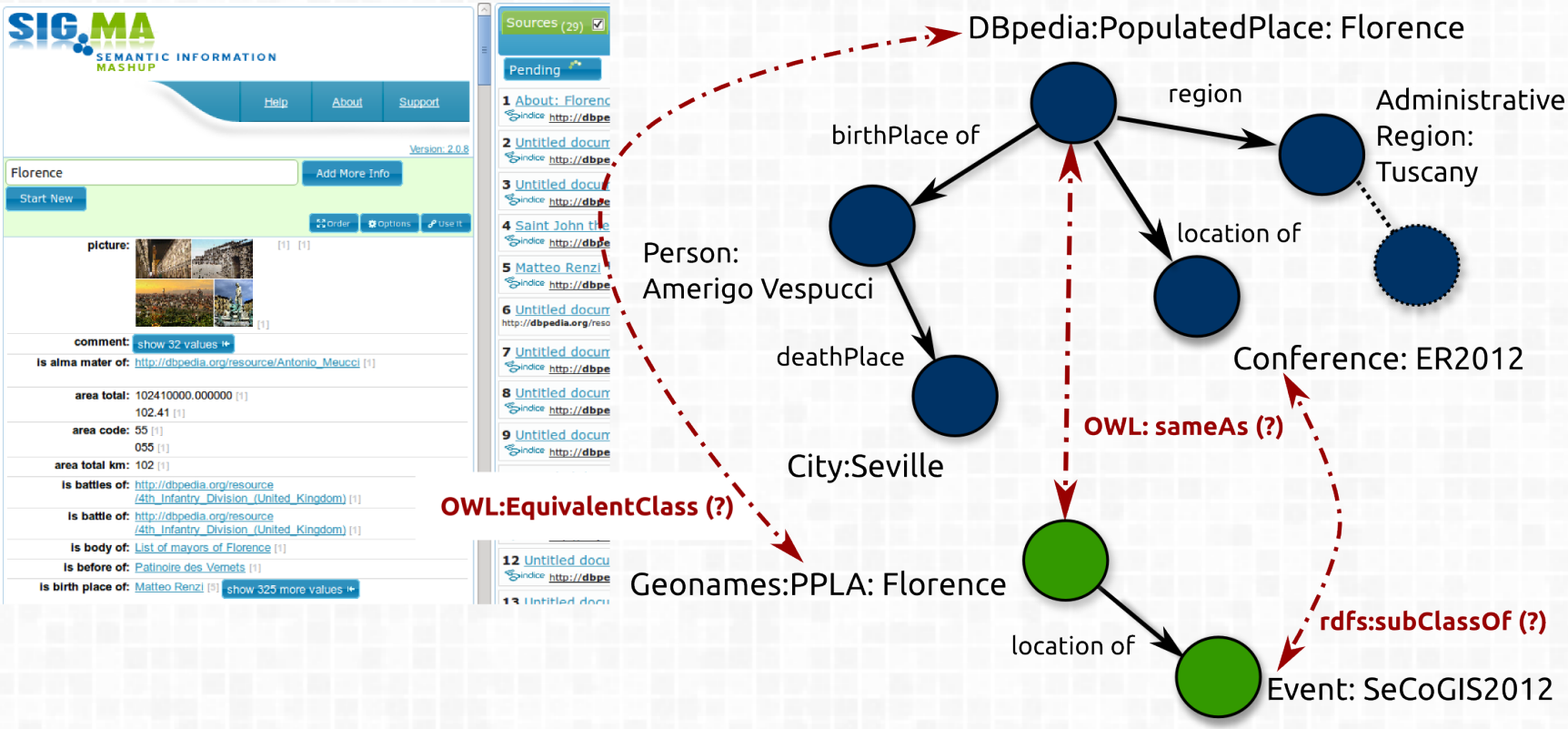


SEMANTICS-ENABLED PERSONAL INFORMATION MANAGEMENT



Queries and integrates Linked Data from Freebase, Semantic Web Dog Food, CFPWiki, Arnetminer, Bibsonomy, and Delicious.

INTEGRATION AND QUERY FEDERATION



Integration by searching **equivalent classes** or/and **same features** in data sets. This requires **ontology** matching and **alignment**.

Why Not Just Standardize Meaning?

Why Not Just Standardize Meaning?

- **California**:
  $City \equiv Town$
- **Utah**:
  $Town \equiv <(population, 1000)$
- **Pennsylvania**:
  $Town \equiv \{Bloomsburg\}$

Semantic Interoperability – Meaningful Links

- Unfortunately, our data sources use exactly the **same terminology** (e.g., *connection*) to talk about totally different and **contradicting facts** (*e.g., separation*)
- While we can still **syntactically integrate** and reuse information, the results may be misleading or even **meaningless**

- We need **heterogeneity preserving** semantic interoperability methods

Semantic Interoperability – Meaningful Links

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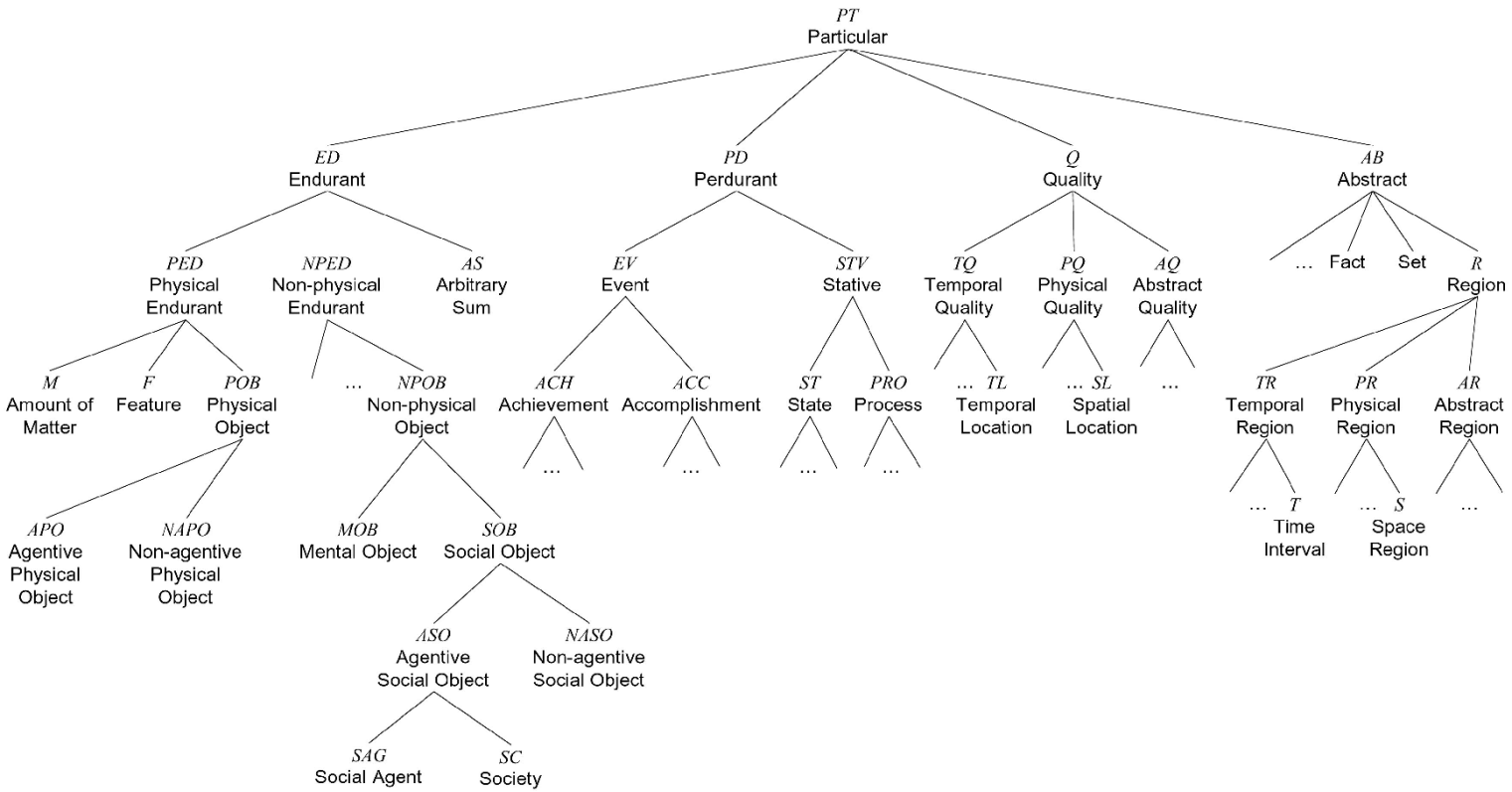
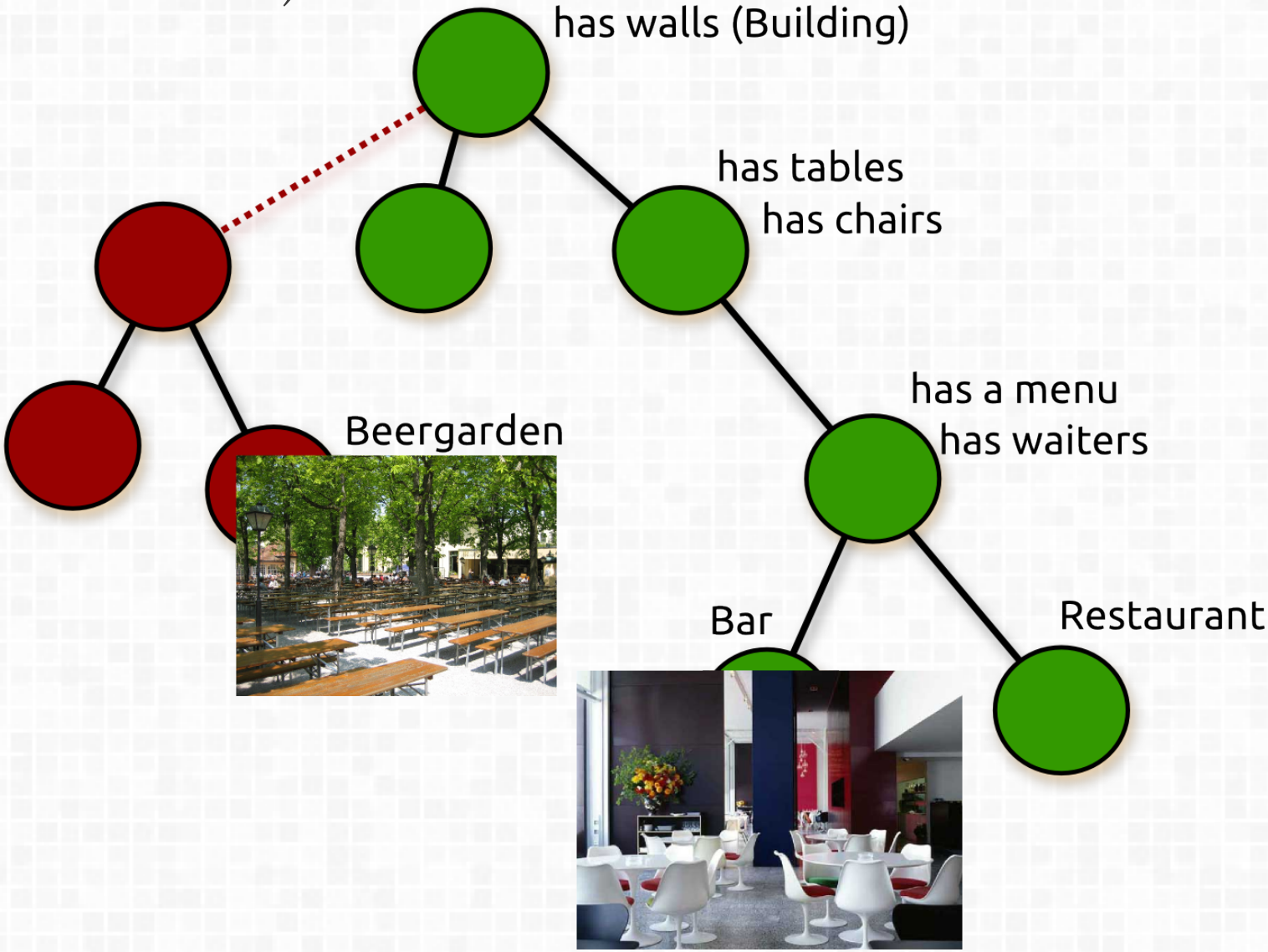
Restricting Meaning Via Foundational Ontologies

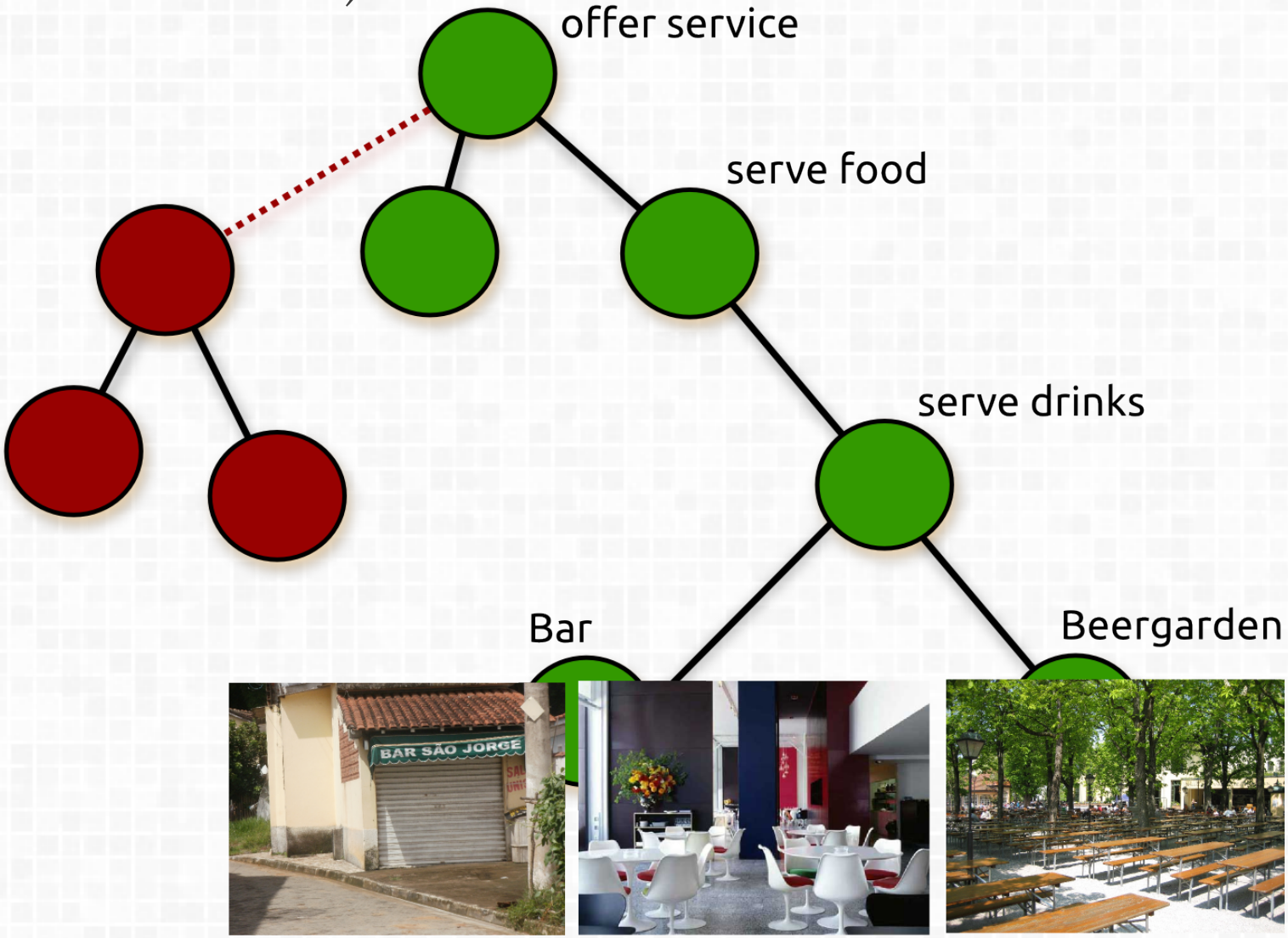


- Arrive at a **common agreement** on how to **partition** the world and define it in a **machine readable** way
- The **Semantic Web** offers formal **languages** and **reasoning** support

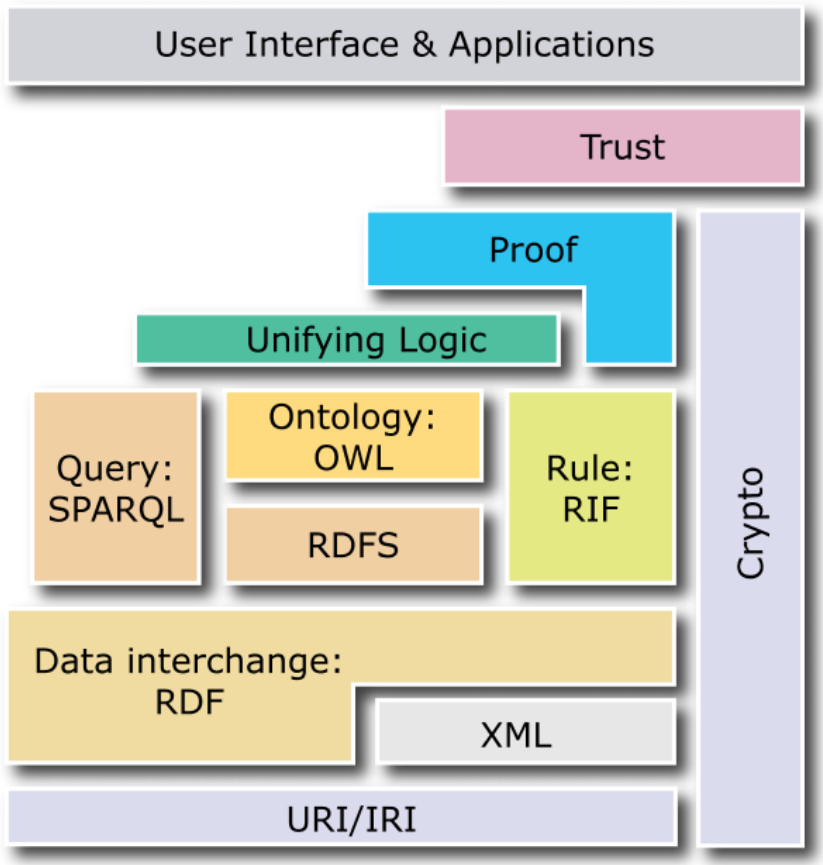
Difficulties with Global Top-Down Ontologies (Attribute View)



Difficulties with Global Top-Down Ontologies (Functional View)

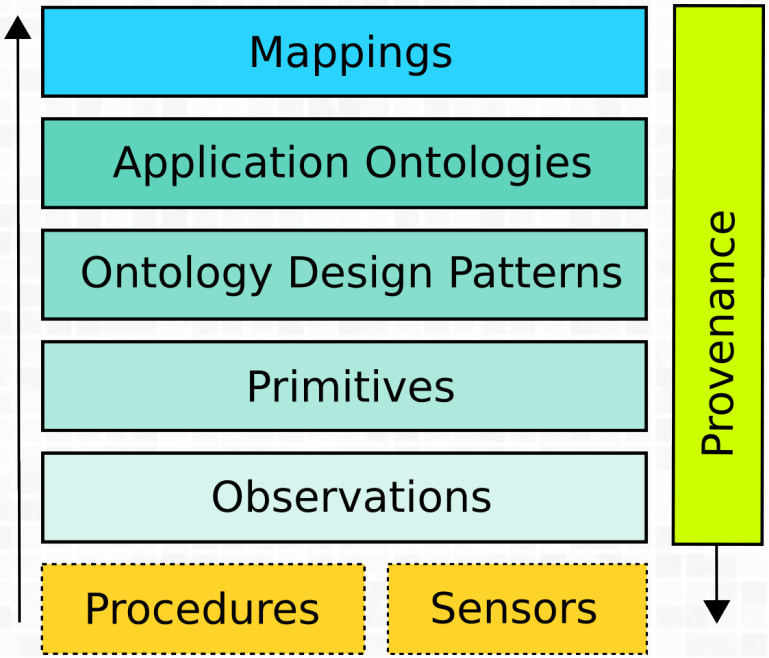


The Semantic Web is a Technology Stack



- Almost all Semantic Web layer cakes are **technology stacks**
- They tell us which languages to use, not **how to model**

Observation-Driven Ontology Engineering



- Local and crisp **microtheories** instead of global ontologies
- Mine ontological primitives out of real **observation data**
- Assist domain experts in becoming knowledge engineers by developing reusable **patterns**
- **Defer** the introduction of classes that are heavy on ontological **commitments** (e.g., forest)

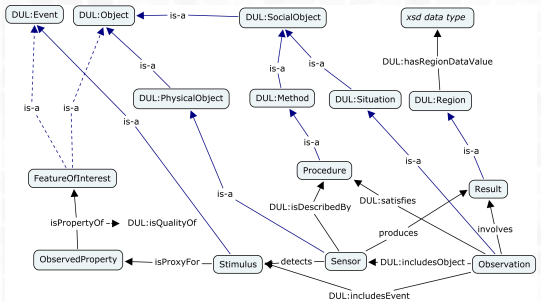
- Ontologies should be about **communication** not about replacing **numerical models**. We should **not** try to develop an **universal ontology** for rivers, mountains, forests, and so forth, but work on the **alignment** and translation between local ontologies.

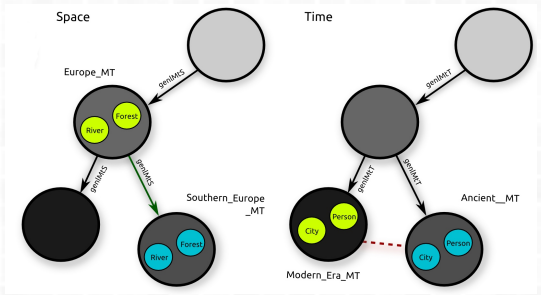
A Roadmap for Semantic Interoperability in GIScience

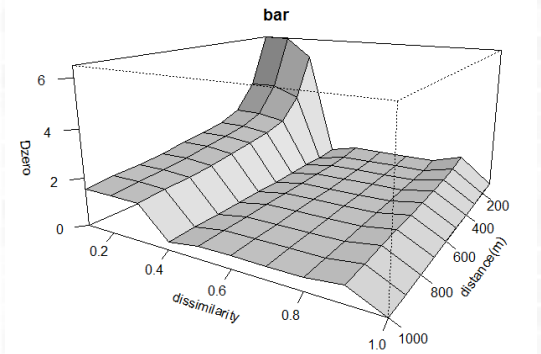
1. Develop building blocks and strategies to assist users in becoming knowledge engineers
   → **E.g., Ontology Design Patterns**

2. Sustain Semantic Heterogeneity via anetwork of local, aligned ontologies
   → **E.g., Microtheories**

3. Learn and mine ontological primitives bottom-up out of real data
   → **E.g., Semantic Signatures**







Aligning, Matching, and Translating Ontologies

$$\text{a:flowsInto} \sqsubseteq \text{a:IsConnected} \quad (1)$$
$$\text{a:IrrigationCanal} \sqsubseteq \text{a:Canal} \quad (2)$$
$$\exists \text{a:flowsInto}.\text{a:AgriculturalField} \sqsubseteq \text{a:IrrigationCanal} \quad (3)$$
$$\text{a:Waterbody} \sqcap \text{a:Land} \sqsubseteq \bot \quad (4)$$
$$\text{a:AgriculturalField} \sqsubseteq \text{a:Land} \quad (5)$$

$$\text{b:flowsInto} \sqsubseteq \text{b:IsConnected} \quad (6)$$
$$\text{b:Canal} \sqsubseteq (\geq 2\ \text{b:IsConnected}.\text{b:Waterbody}) \quad (7)$$
$$\text{b:IrrigationCanal} \equiv (=1\ \text{b:isConnected}.\text{b:Waterbody}) \sqcap (=1\ \text{b:flowsInto}.\text{b:AgriculturalField}) \quad (8)$$

Aligning, Matching, and Translating Ontologies

a:Canal ≡ b:Canal [...]

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a:AgriculturalField≡b:AgriculturalField

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b:IrrigationCanal ⊑ a:IrrigationCanal

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b:IrrigationCanal ⊑ a:IrrigationCanal

AgriculturalField≡Waterbody

Aligning, Matching, and Translating Ontologies

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a:AgriculturalField≡b:AgriculturalField

b:IrrigationCanal ⊑ a:IrrigationCanal

AgriculturalField≡Waterbody

a:Canal(x) ∧ ¬a:IrrigationCanal(x) → b:Canal(x)

Aligning, Matching, and Translating Ontologies

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a:AgriculturalField≡b:AgriculturalField

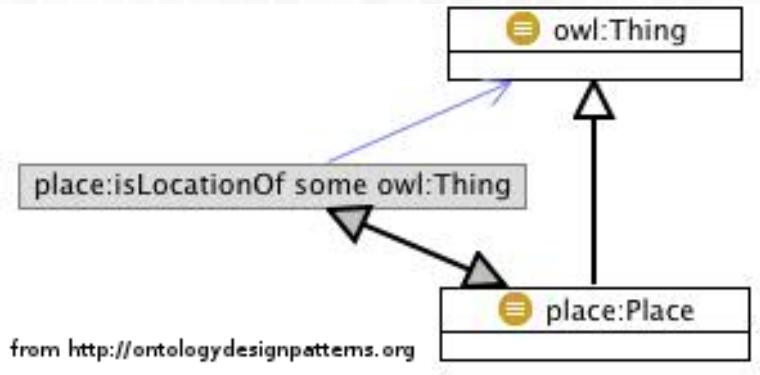
b:IrrigationCanal ⊑ a:IrrigationCanal

AgriculturalField≡Waterbody

a:Canal(x) ∧ ¬a:IrrigationCanal(x) → b:Canal(x)

a:Canal(x) ∧ a:Vessel(y) ∧ builtIn:navigable(x, y) → c:NavigableCanal(x)

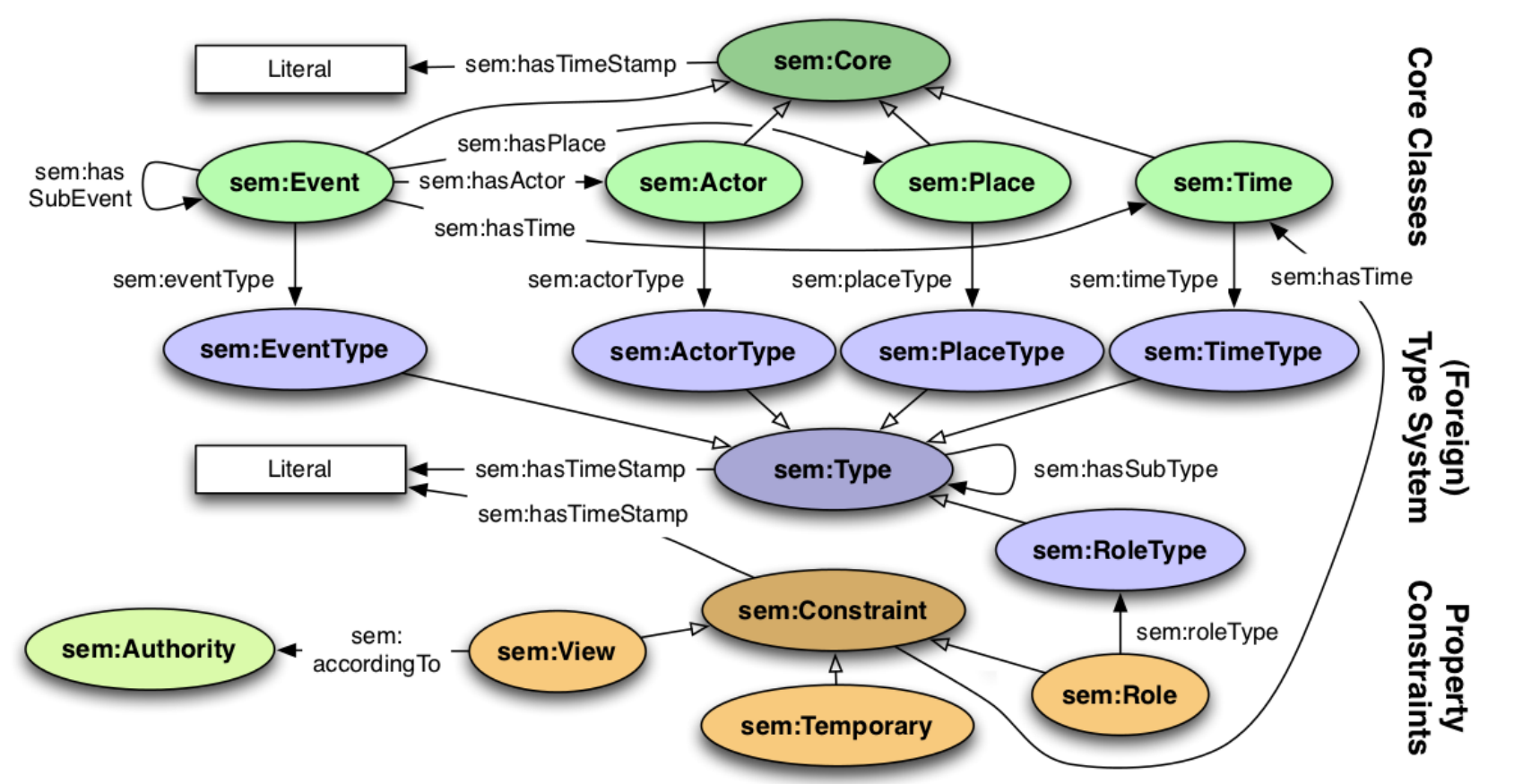
ONTOLOGY DESIGN PATTERN



- **Modular** but **self-contained** building blocks/strategies
- **Reusable** and **extendible**
- Even huge ontologies can be modularized using ODP (for example **DOLCE**)
- **No need** to import **full** ontology and **all** *ontological* ***commitments***
- Different **types** of patterns, e.g. **content** vs. **logical**

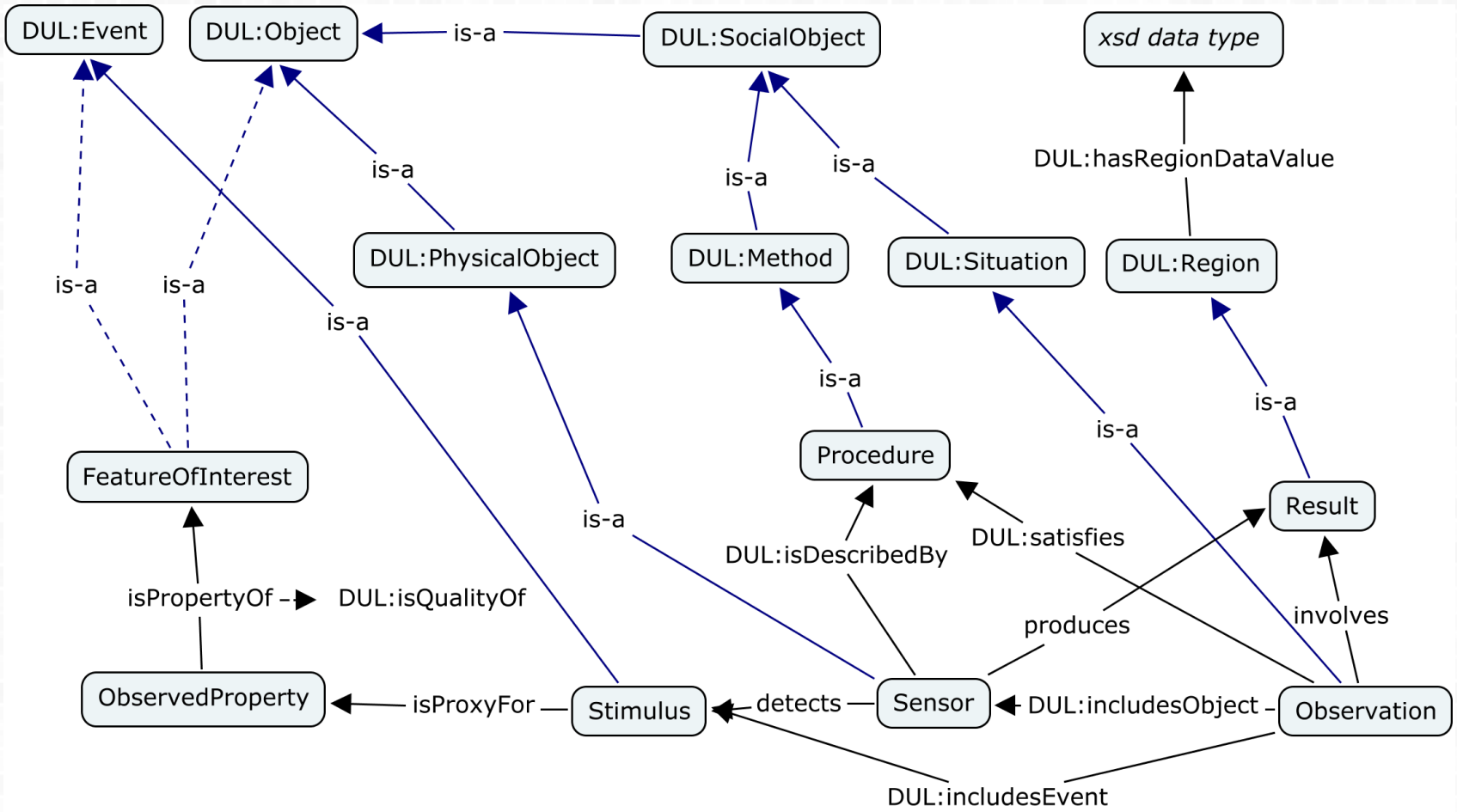
- What are the major **geo-ontology** design patterns?

Anatomy of (Complex) Patterns



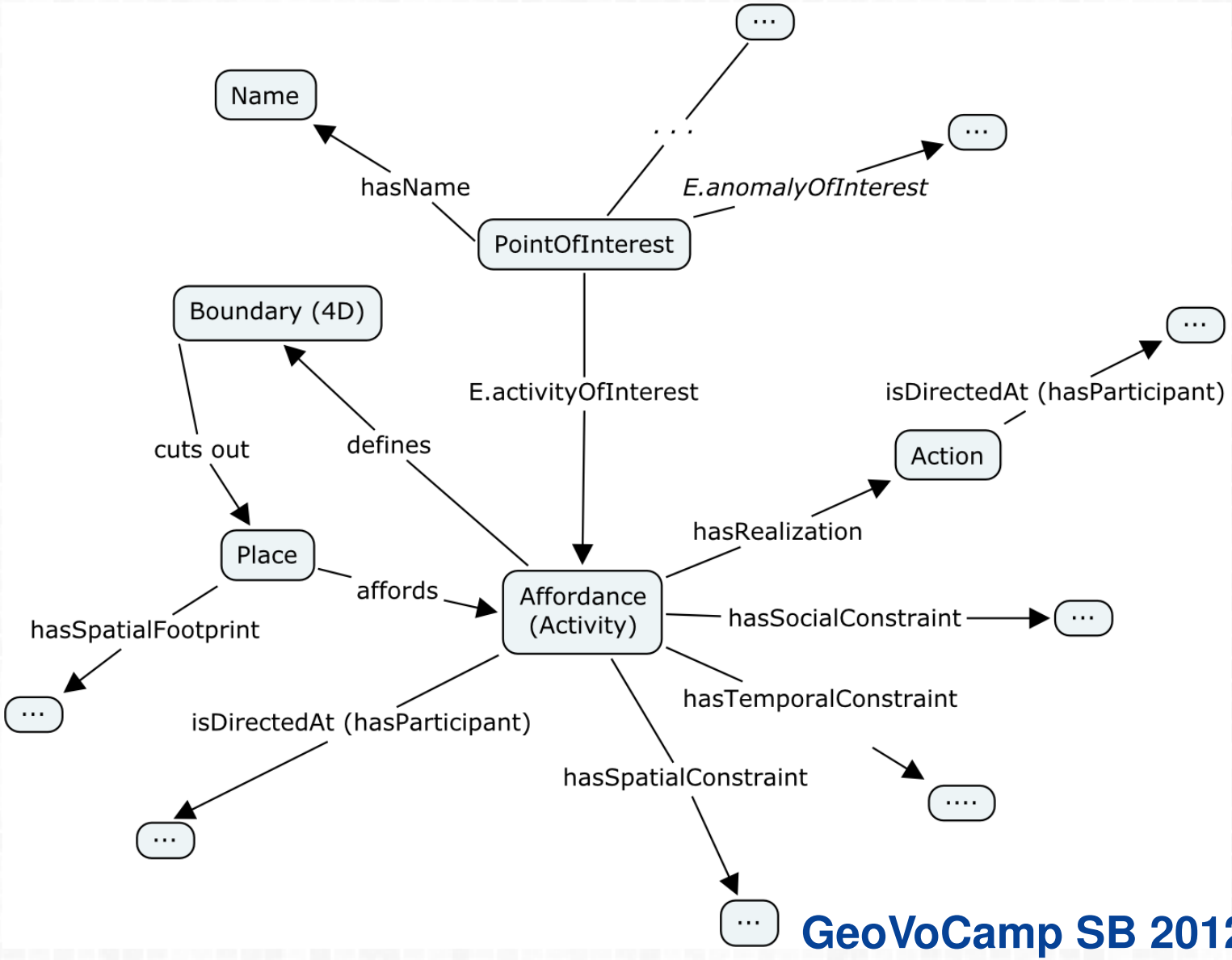
Simple Event Model

STIMULUS SENSOR OBSERVATION PATTERN



W3C XG SSN Pattern + DOLCE alignment

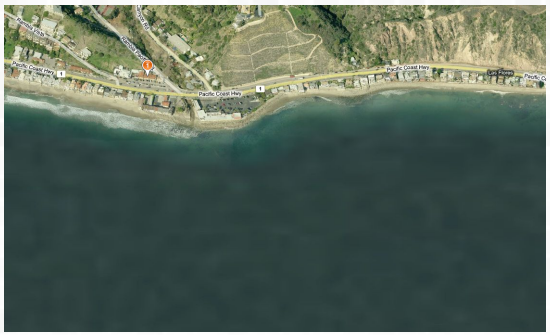
POINTS OF INTEREST PATTERN

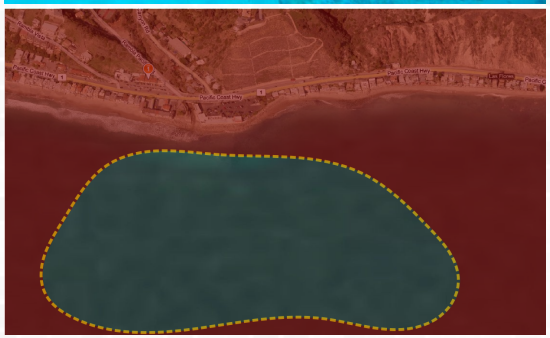


GeoVoCamp SB 2012

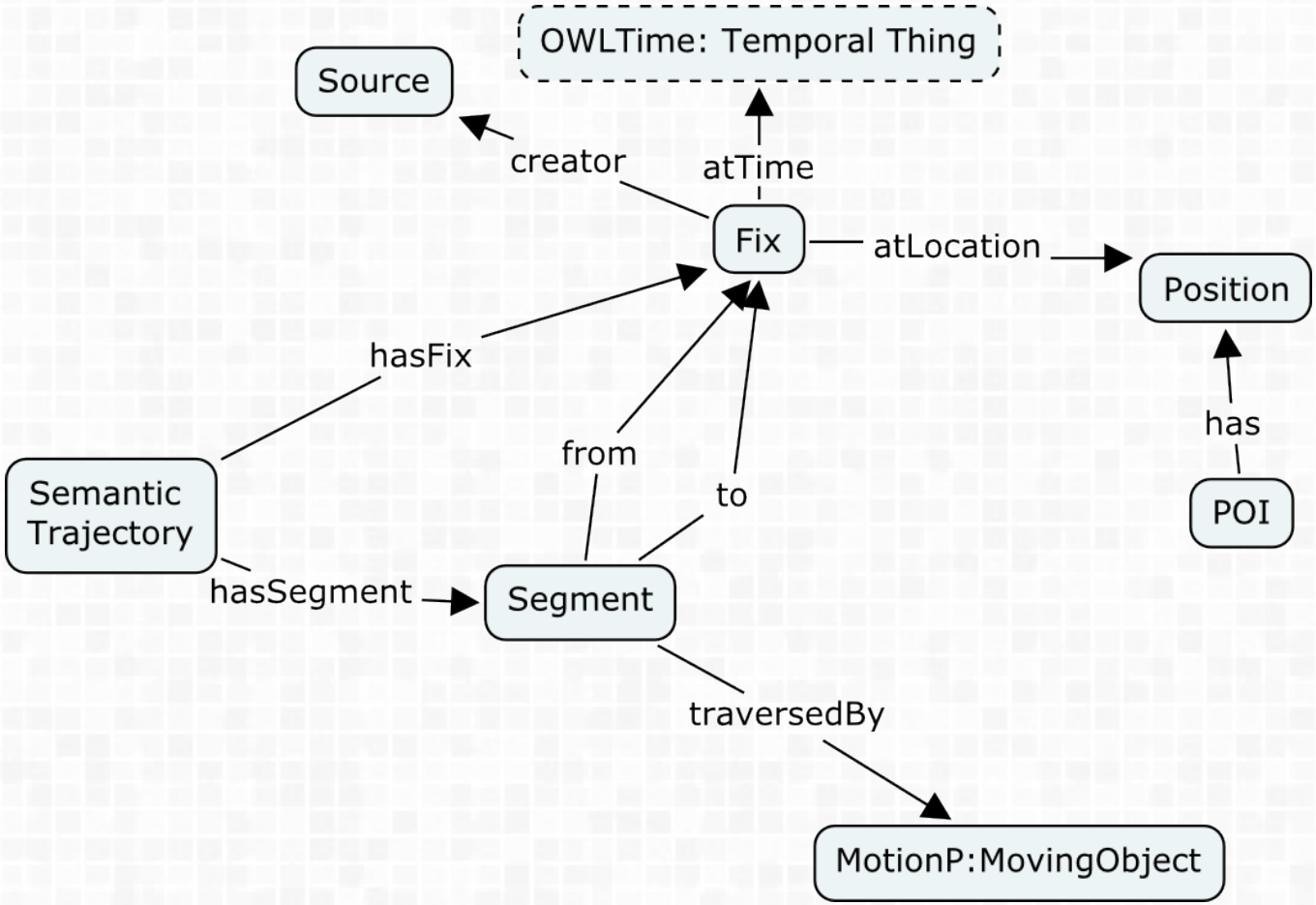
Scuba Diving Place(s) Example

- **Field**/surface of water depth **observation**
- ScubaDiving**Activity**
  - **Constraints** (> 3m water depth)
  - ...
- **Boundary** (**GIS** clip operation)
- bounded **region(s)** on the surface of the Earth
- **named** places (for those of **interest**).





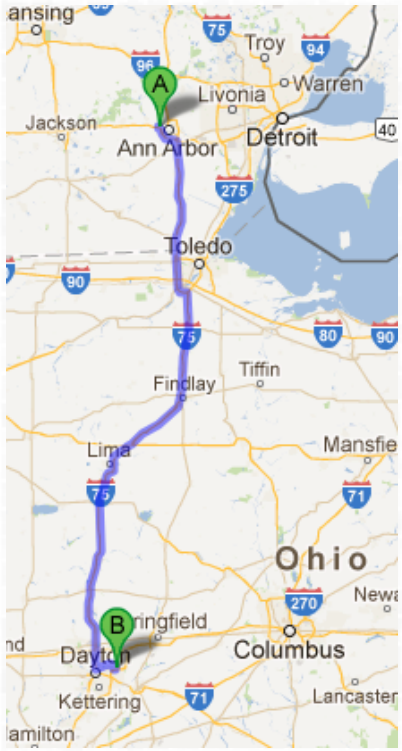
(Semantic) Trajectory Pattern



GeoVoCamp Dayton 2012

Mike's Trip to the GeoVoCamp Dayton 2012

```
:mikestrip a :SemanticTrajectory;
  :hasSegment
    [a :Segment;
      :from :fix1;   // mikeshome
      :to :fix2;     // rest stop
      :traversedBy :fordFocus],
  [...]
    [a :Segment;
      :from :fixn;   // WrightStateUniversity
      :to :fixm],    // Knoesis
      :traversedBy :mike],
  [...]
:time1 a time:Instant;
  :inXSDDateTime "2012-09-15T11:26:22Z".
:pos1 a :Position;
  :geo:astWKT "Point(-83.XYZ45348 42.XYZ53678)";
:mikesHome a :POI;
  :has :pos1;
  [...]
```



Geo-Vocabulary Camps

Krzysztof Janowicz

page | discussion | edit | history | move | unwatch

GeoVoCampSB2012

Contents [hide]

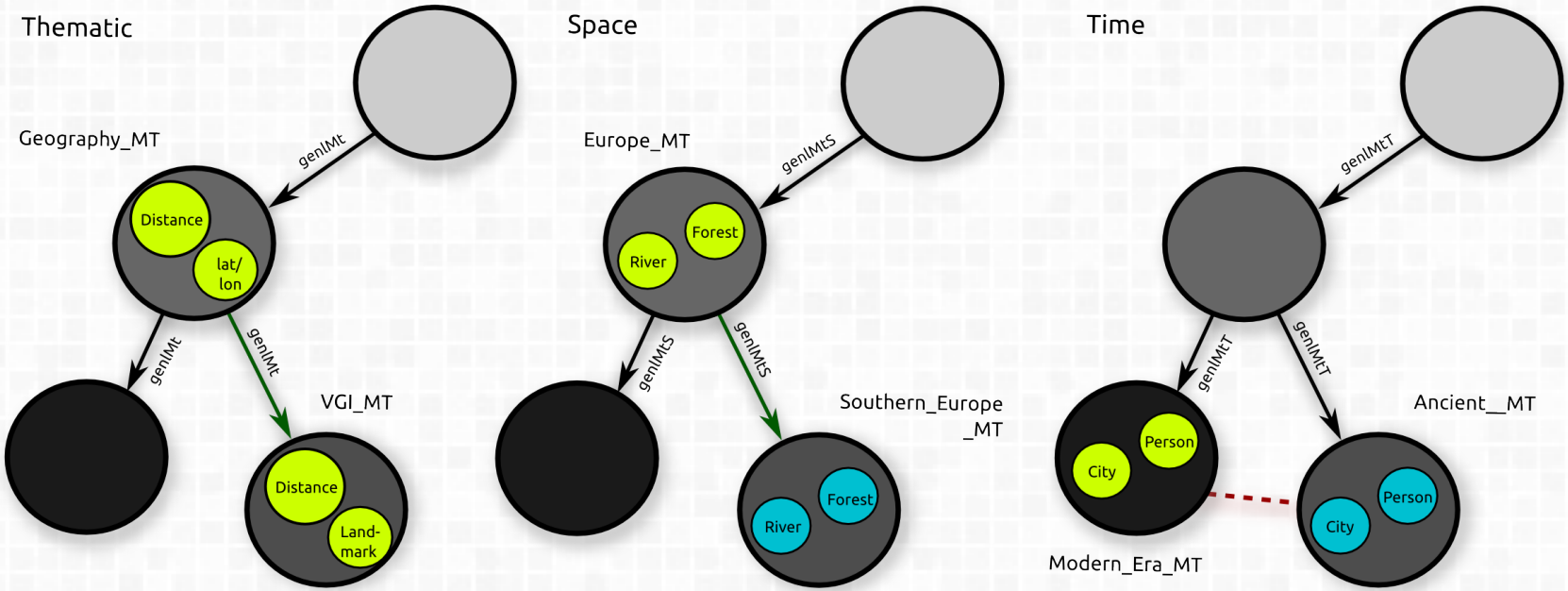
General

We are currently planning a GeoVoCamp as follow-up to the 2009 and 2011 Vocamps in Washington D.C. and the 2011 GeoVoCamp in Southam **Santa Barbara, California** to bring the events to the West Coast as well.

NEW: There will be a follow-up event in Dayton, OH in September 2012.

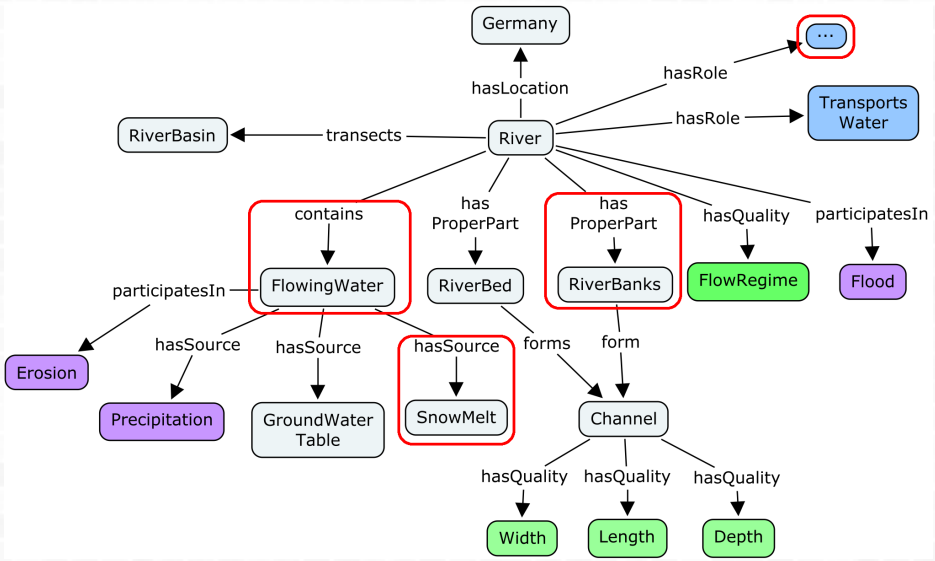
What

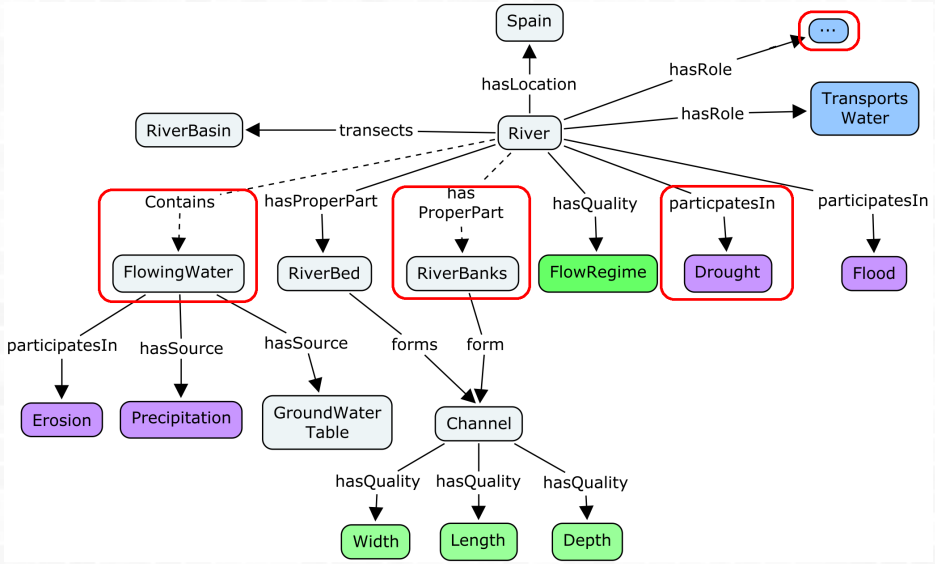
Handling Semantic Heterogeneity by Microtheories



- Employ **space** and **time** as fundamental **structuring principles** for the development of **ontologies**.

INSPIRE EXAMPLE– COMPUTING A COMMON GROUND



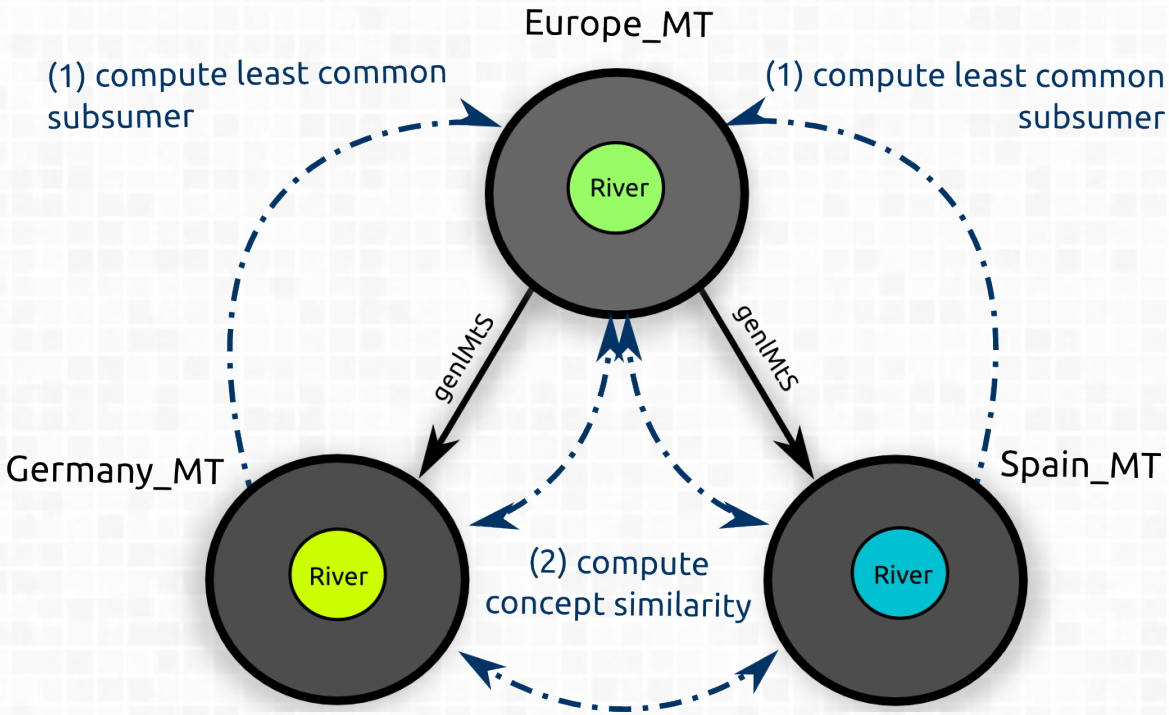


- INSPIRE **Watercourse**: 'A natural or man-made **flowing water** course or stream.'
- **Instead** of a **top-down ontology** for the EU that violates local definitions, **compute** a top-level based on **local definitions** of the member states.

*)INSPIRE: Infrastructure for Spatial Information in the European Community

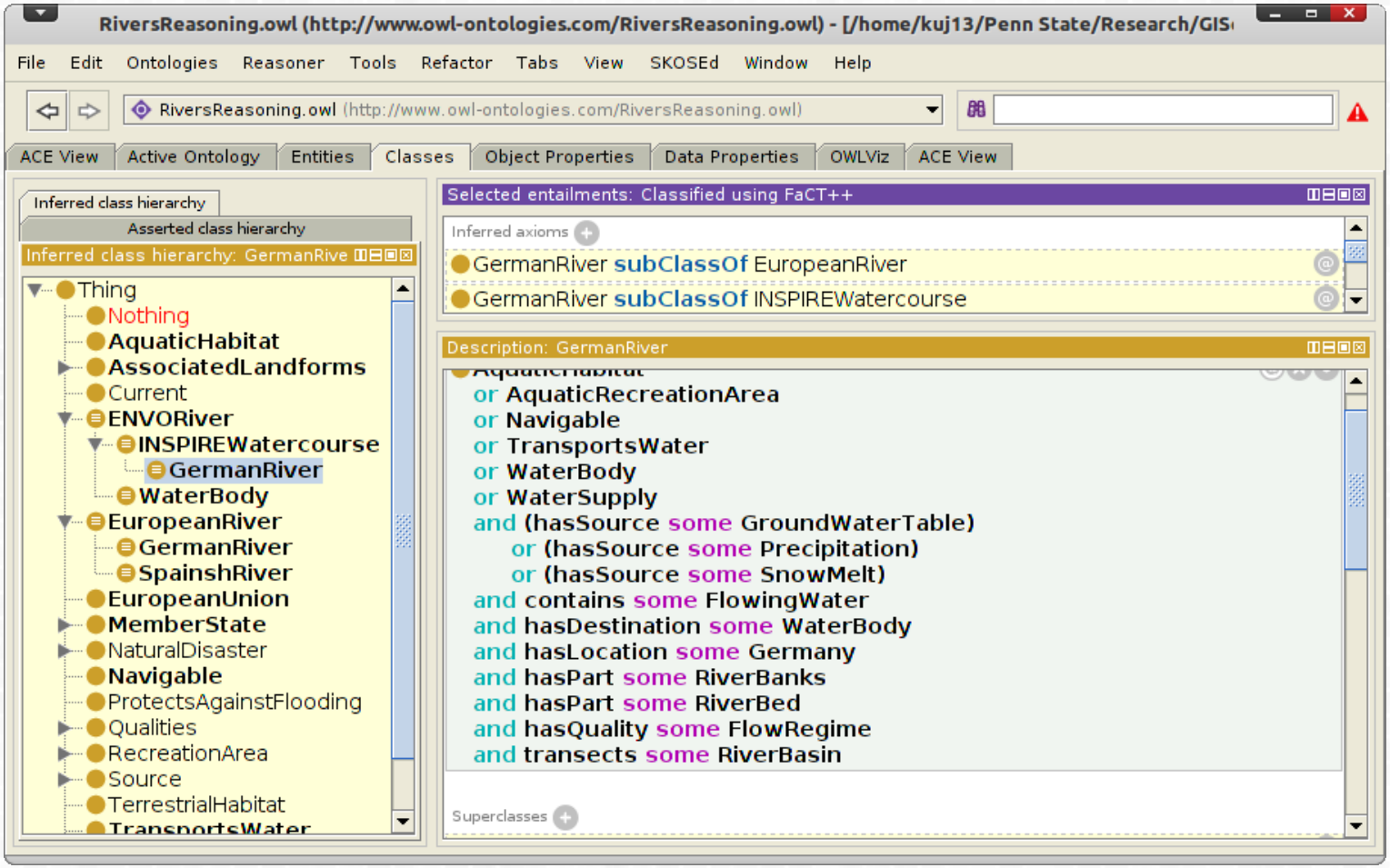
INSPIRE EXAMPLE– LCS AND SIMILARITY

- Germany and Spain are administratively **contained** in Europe. Hence, the European definition has to **satisfy** the **local** definitions.



  - Least Common Subsumer (LCS) reasoning to **compute** a **common** EU definition. Similarity reasoning to ensure that the result does not end up as the **compromise of nobody**.

Preserving Local Conceptualizations



The INSPIRE definition is **too restrictive**

A Final Thought...

We assume that **ontology standardization** is less difficult and more persistent than **aligning** and translating local application-centric ontologies.

What if standardization is the more difficult task?

Special Issue on Linked Spatiotemporal Data