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Introduction to Geospatial Semantics and Technology Workshop Handbook

Open-File Report 2012–1109

U.S. Department of the Interior
U.S. Geological Survey

Cover photograph. Meteor Crater, Arizona (*http://en.wikipedia.org/wiki/File:Meteor_Crater_-_Arizona.jpg*).

Introduction to Geospatial Semantics and Technology Workshop Handbook

Edited by Dalia E. Varanka

Open-File Report 2012–1109

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2012

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Introduction to Geospatial Semantics and Technology Workshop Handbook

University Consortium for Geographic Information Science

May 29, 2012

Washington D.C.

The workshop is a tutorial on introductory geospatial semantics with hands-on exercises using standard Web browsers. The workshop is divided into two sections, general semantics on the Web and specific examples of geospatial semantics using data from *The National Map* of the U.S. Geological Survey and the Open Ontology Repository. The general semantics section includes information and access to publicly available semantic archives. The specific session includes information on geospatial semantics with access to semantically enhanced data for hydrography, transportation, boundaries, and names. The Open Ontology Repository offers open-source ontologies for public use.

Dalia E. Varanka, Editor

USGS Center of Excellence for Geospatial Information Science (CEGIS)

http://cegis.usgs.gov/ontology.html

Spatial Ontology Community of Practice (SOCoP)

http://www.socop.org

Workshop Agenda

12:00 – 1:00 pm Introduction to the workshop and to semantic technology concepts
Topics: Semantic Web standards and implementation examples, ontologies, and geospatial Semantic Web adaptations

1:00 – 2:00 pm Hands-on exercise: Accessing Linked Data over the Internet
Using the following URLs:

FOAF-A-MATIC

- *http://ldodds.com/foaf/foaf-a-matic*

Tim Berners-Lee's FOAF page.

- *http://www.w3.org/People/Berners-Lee/*

Start page for the GeoNames map

- *http://www.geonames.org/6295630/*

Download page for GeoNames

- *http://www.geonames.org/ontology/documentation.html*

Start page for the Faceted Search

- *http://dbpedia.neofonie.de/browse*

URL for Virtuoso RDF Browser

- *http://dbpedia.org/fct/*

DBpedia download page

- *http://wiki.dbpedia.org/Downloads37*

2:00 – 3:00 pm USGS Approach to the Geospatial Semantic Web
Topics: Topographic data creation, ontology for *The National Map*, data retrieval, research needs in geospatial semantics

3:00 – 4:00 pm Hands-on exercises: Accessing topographic data triples
Executing queries with SPARQL Protocol and RDF Query Language (SPARQL) and GeoSPARQL, displaying results as URIs, and creating mapped output. URLS to use:
http://usgs-ybother.srv.mst.edu:8890/parliament/
http://usgs-ybother.srv.mst.edu/viz/

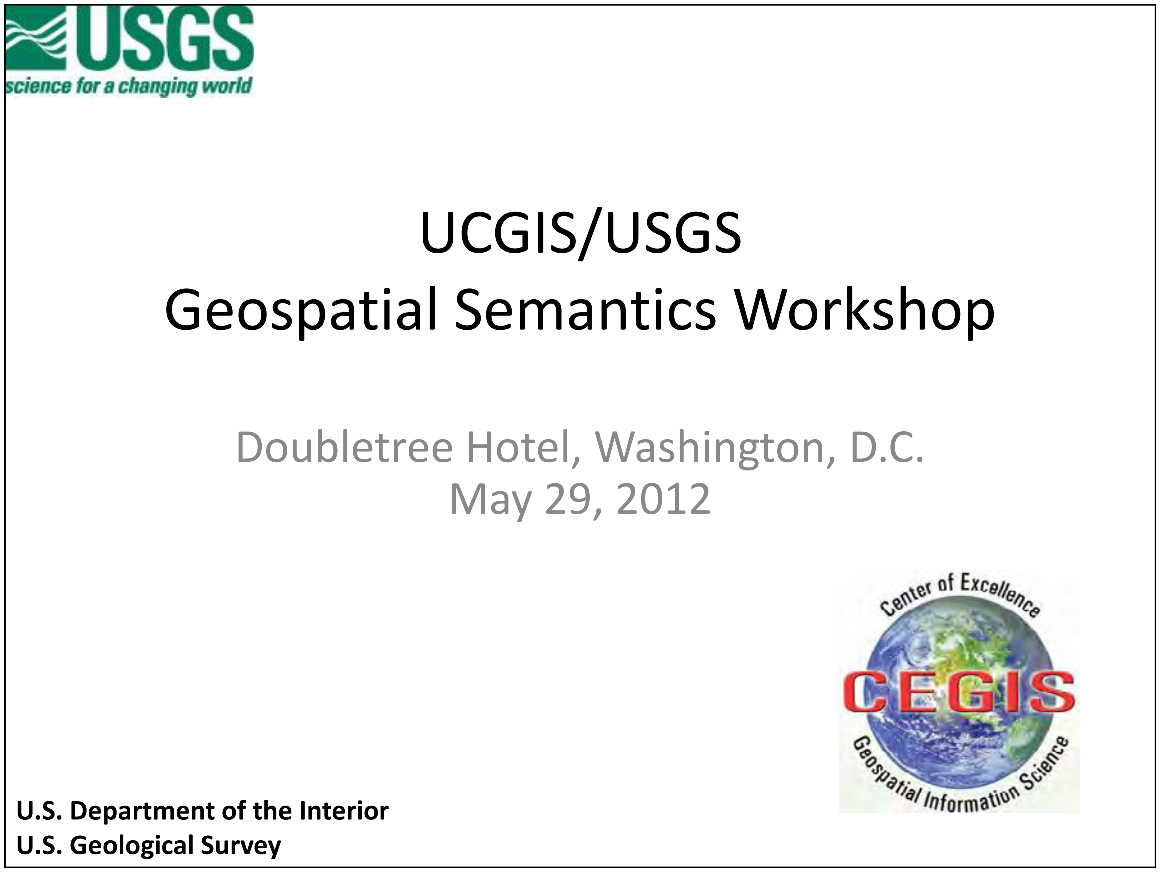
4:00 – 5:00 pm The Spatial Ontology Community of Practice (SOCoP) Open Ontology Repository
http://socop.oor.net/
Summary topics and wrap-up, discussion

Workshop Instructors: E. Lynn Usery, Dalia Varanka, Gary Berg-Cross
Workshop hands-on leads and support: David Mattli, Brian Collinge, Wayne Viers

Breaktimes will be scheduled during the workshop.

Workshop Summary and Slides

Overview



Motivation – Why host a Workshop

Geospatial semantics are future research and operational modes for GIS data

Lack of assimilation of semantics in GIScience community – *e.g.,* Semantic Web appeared in 2001; not many GIScientists use it even now

Potential to expose USGS approach and data to public audience; outreach to gain feedback on USGS efforts

Basic tutorial on semantics is needed in GIScience community

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Introductory Level Tutorial

The Workshop is an introductory tutorial on geospatial semantics

Introduces the Semantic Web and some general applications

Includes specific details of USGS data conversion, availability and access

This workshop assumes little prior knowledge, only an ability to work with computers and Web browsers

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Goals of the Workshop

Introduce semantic data on the Web

Introduce examples of Semantic Web applications

Introduce geospatial semantics

Provide USGS approach to semantics for geospatial data

Provide access to sample geospatial Resource Description Framework (RDF) data

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What you will learn

Basic vocabulary and operation of Semantic Web

How geospatial data are structured as RDF

How to build new RDF data

How to convert existing legacy geospatial data

How to query RDF triplestores with SPARQL and GeoSPARQL

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Some Topics Not Included

Specific software packages

The SPARQL query language and syntax

Reasoning logic used in semantic applications

Specific ontological applications

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Instructors

Dalia Varanka, Research Geographer, USGS

E. Lynn Usery, Research Geographer, USGS

David Mattli, Computer Scientist, USGS

Wayne Viers, Computer Scientist, USGS

Brian Collinge, Geographer, USGS

Gary Berg-Cross, Spatial Ontology Community of Practice

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Workshop Organization

Overview lecture on semantic concepts – Dalia Varanka

Hands-on exercise with Facebook, DBpedia, Geonames – Wayne Viers

Overview of USGS approach and geospatial semantics – E. Lynn Usery

Building ontology with Protégé – Brian Collinge

Hands-on exercises with USGS geospatial semantic data --- David Mattli

Open Ontology Repository – Gary Berg-Cross

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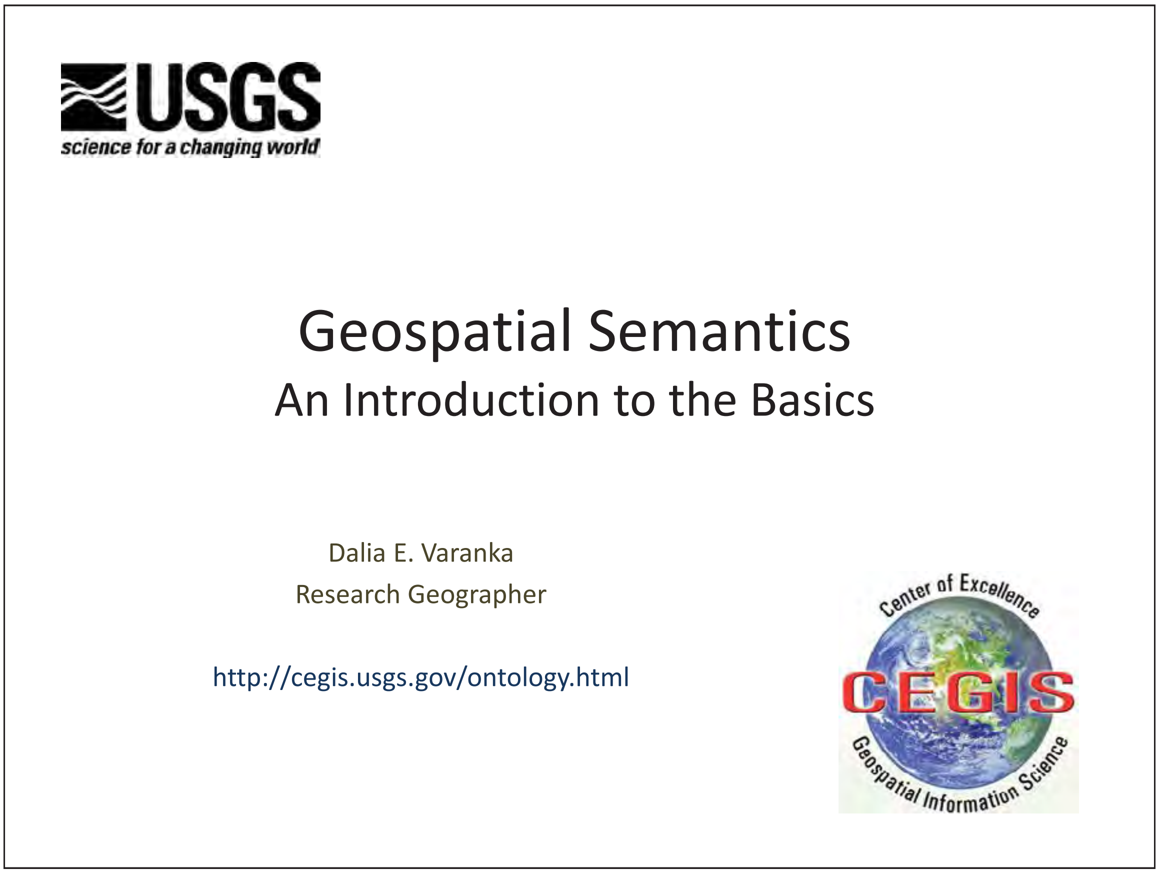
An Introduction to Semantic Web and Technology Concepts

The first section of the workshop introduces background concepts from geospatial semantics and ontology technology, including the triple data model, controlled vocabularies, standards, along with processes such as linking data for federated graphs, logical inference for automated knowledge creation, and information querying using SPARQL and GeoSPARQL protocols.



Why the Semantic Web?

Our world and particularly our cities form complex socio-technical-natural systems, meta-systems, and systems of systems

More intelligence, instrumentation, application, integration

Big Data (volume, variety, velocity, value) driving new paradigms in science

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Semantics

Semantics, the study of how humans derive meaning from representations, is a central approach for the design of new scales of systems and data

Growing area of technical research since 2001

Rooted in artificial intelligence

Ontology: the structural framework for organizing meaningful information

Broadly based research field;

philosophy, linguistics, social science, engineering

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Topics of this Introduction

Semantic Web standards

Semantic technology implementation

Designing ontology patterns

Geosemantic adaptations

- GeoSPARQL standard

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Internet Today

Web page URLs and keywords

- pull out snippets of information; lack context

Linked data using tags

- self-driven interaction with the media

Data scarcity, generalization, and representation can all cause ambiguous information interpretations

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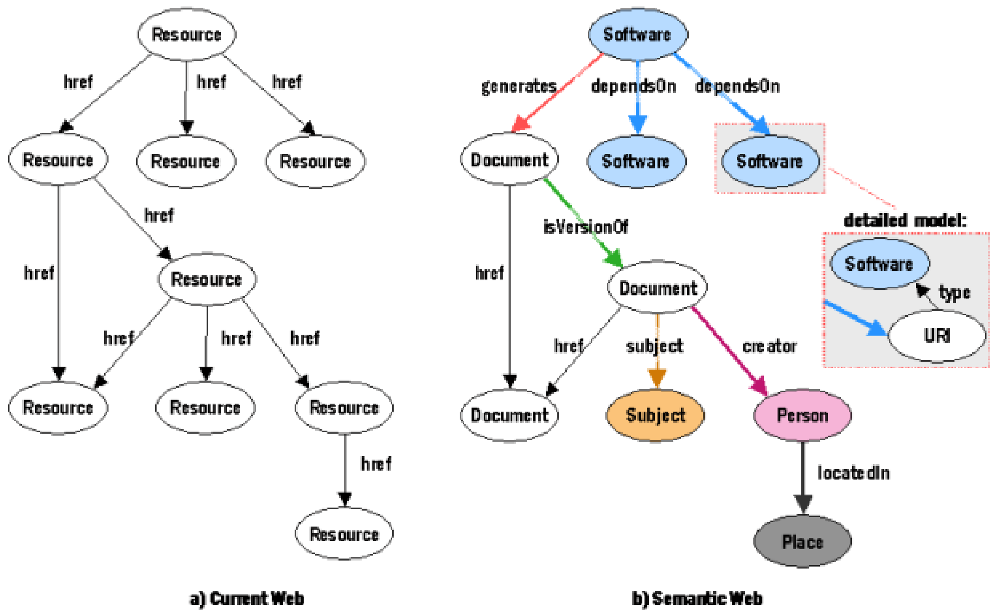

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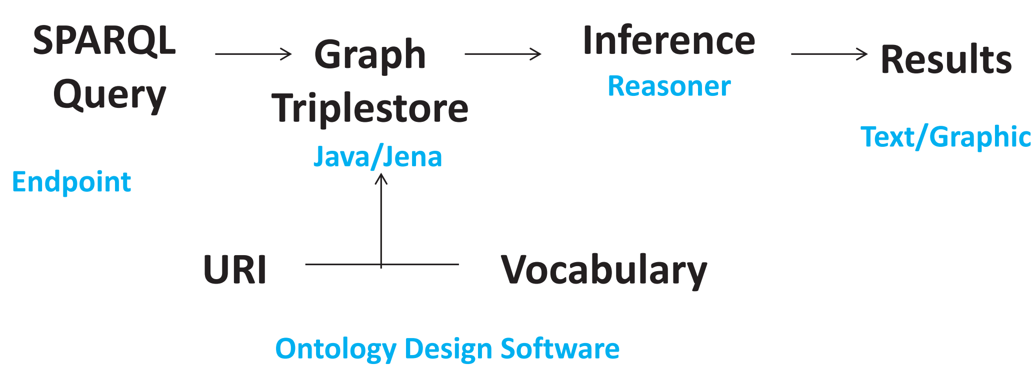
Koivunen, M-R., and Miller, E.
W3C Semantic Web Activity
http://www.w3.org/2001/12/semweb-fin/w3csw

Semantic System



W3C Standards

- **Semantic specification of each datum**
  - **Uniform Resource Identifiers (URI)**
- **Vocabulary**
  - **Simple Knowledge Organization System (SKOS)**
  - **Web Ontology Language (OWL)**
- **Linking data**
  - **Resource Description Framework (RDF)**
  - **Extensible Markup Language (XML)**
- **Query and Reasoning**
  - **SPARQL Protocol And RDF Query Language (SPARQL)**
  - **Rule Interchange Format (RIF)**

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Semantic Specification

Vocabulary subject – predicate – object

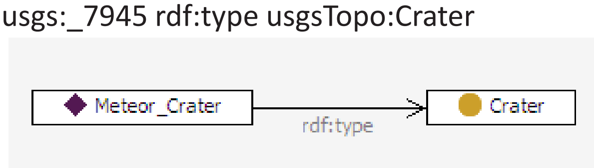
Triple Resources node – edge – node

Uniform Resource Identifier (URI):

http://cegis.usgs.gov/ontology/topovocab/1.0/terrain#

Prefix: usgsTopo

usgs:_7945 rdf:type usgsTopo:Crater



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Identifiers

Uniform Resource Identifier (URI)

- Uniform Resource Locator (URL)
- Uniform Resource Name (URN)

Internationalized Resource Identifier (IRI)

URI can be

- a lexical word
- Random alpha-numeric unique identifier

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Examples of Standard and Controlled Vocabularies

Philosophy terms (DOLCE)

Information content (NASA SWEET)

Metadata (Dublin Core Metadata Initiative)

Web Services (OGC Web Service Common)

Project terms (function, capability, role, purpose, objective, goal, etc.)

Task terms (map, compute, display)

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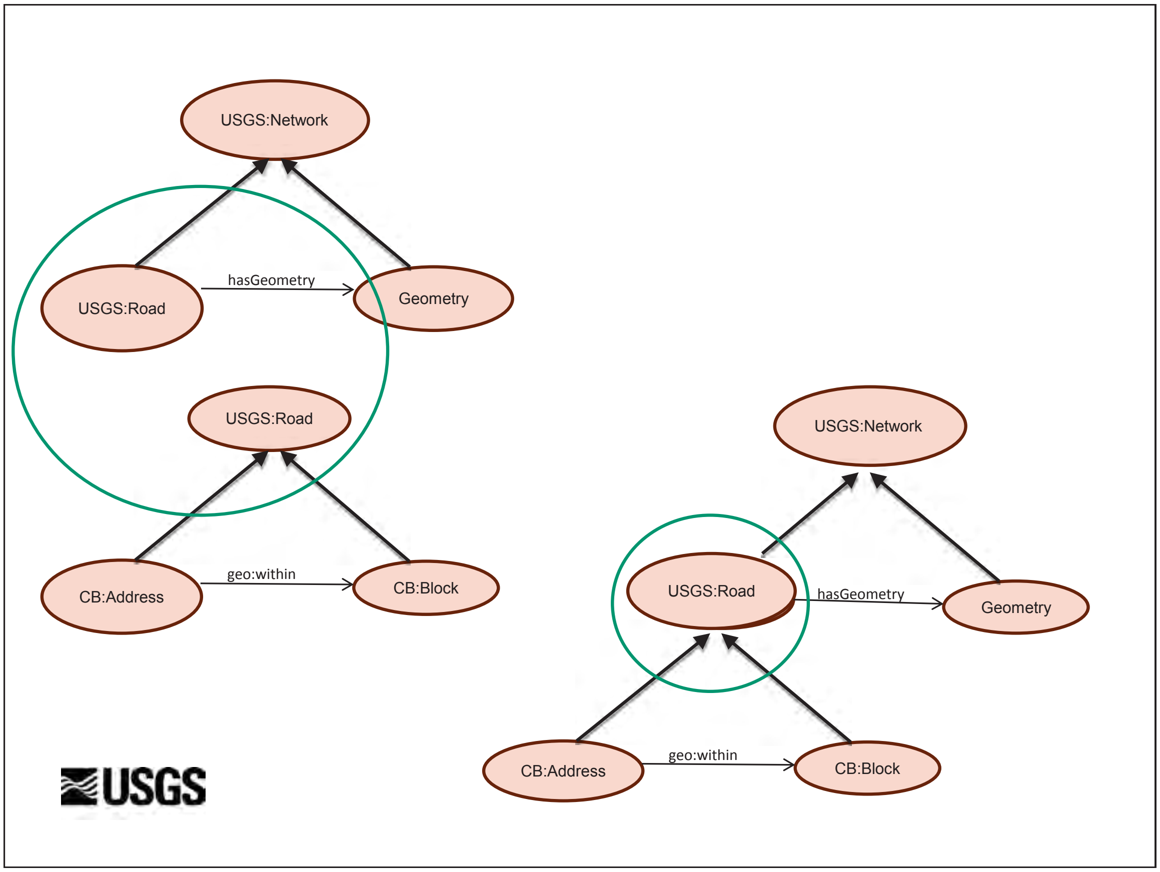
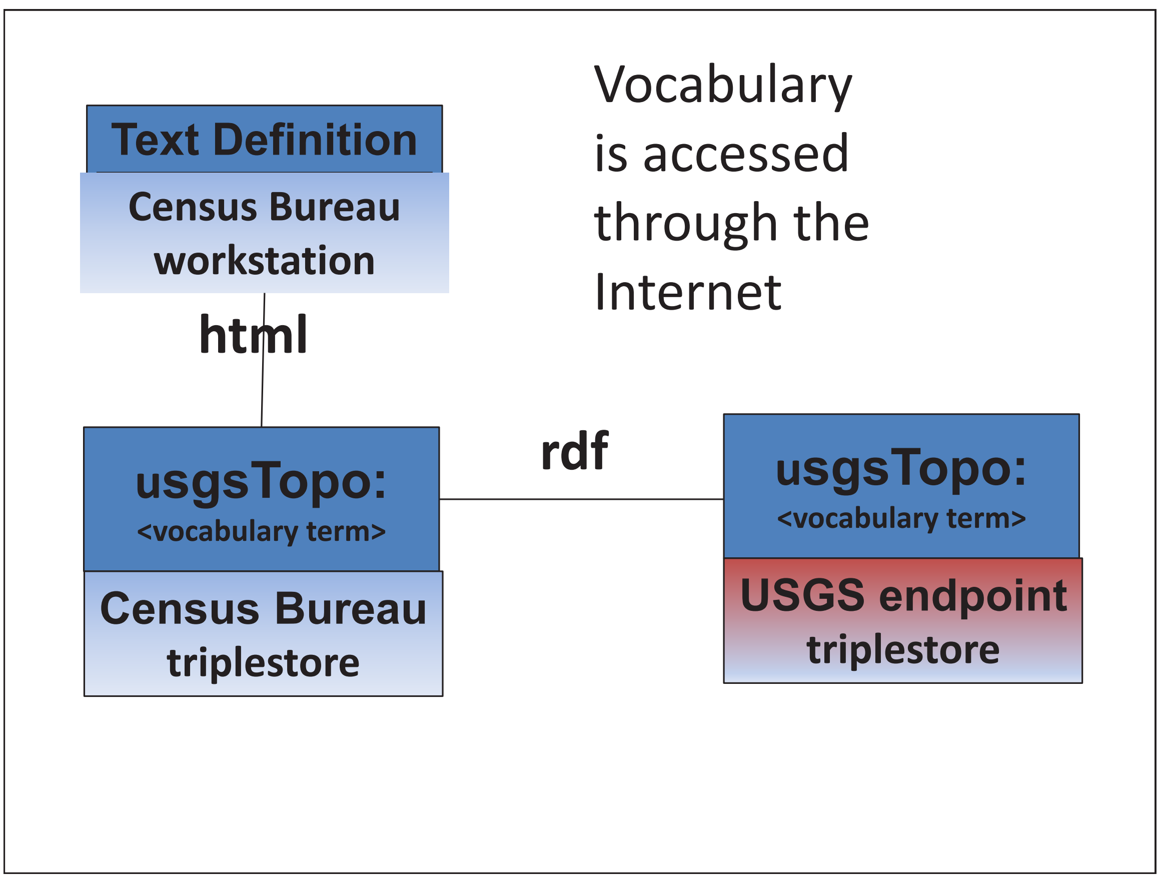

USGS:Network
USGS:Road
hasGeometry
Geometry
USGS:Road
CB:Address
geo:within
CB:Block
USGS:Network
USGS:Road
hasGeometry
Geometry
CB:Address
geo:within
CB:Block
USGS


Text Definition
Census Bureau workstation
html
Vocabulary is accessed through the Internet
usgsTopo:
<vocabulary term>
Census Bureau triplestore
rdf
usgsTopo:
<vocabulary term>
USGS endpoint triplestore

Knowledge Representation and Reasoning (KRR)

Simulates cognition

Language and interpretation

Reasoning forms

- Logical
- Experience and practice
- Signs and semiotics

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Logic Rules as Predicates in OWL

- ogc:intersects rdf:type owl:SymmetricProperty .
  usgsTopo:RoadA ogc:intersects usgsTopo:Road .
- usgs:woodland owl:equivalentClass
  usgsTopo:woodedArea

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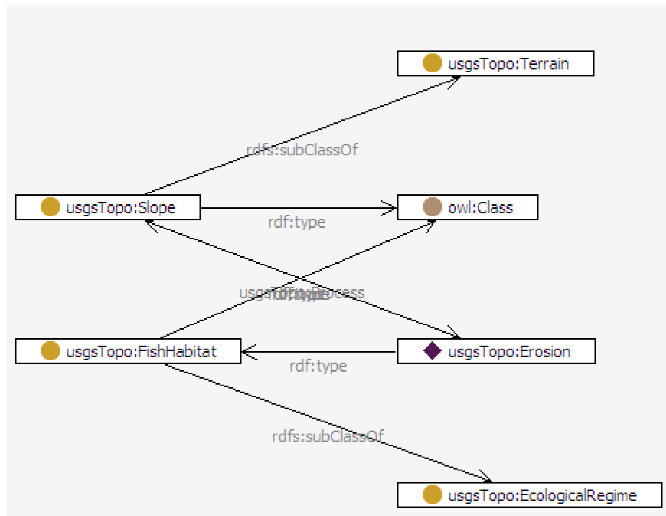
Inference and Logic Rules

Information can be inferred based on logical rules



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Inference Properties

- RDF Schema (RDFS) inference
- Selected elements of OWL
  - equivalent classes and properties
  - inverse properties
  - symmetric properties
  - functional properties
  - inverse functional properties
  - transitive properties

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SPARQL

First part defines prefixes of URI namespaces

SELECT clause identifies the variables to be returned

SELECT ?feature

WHERE clause gives the triple patterns defining a basic graph pattern

WHERE {?feature gnis:name ‘#name#’}

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Solution and Results

Graph pattern given in the WHERE clause is matched against the triple store

An exact match to the pattern is required

Matching variables bind together to form the query solution

The values of the variables are the query results

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Implementations

Converting Table Information to Triples

Rows are subjects, columns are predicates, and cells are objects

Feature	Process
Mountain Range	Tectonics
Delta	Deposition
Peak	Erosion
Volcano	Tectonics
Arch	Erosion

Mountain Range hasProcess Tectonics
Delta hasProcess Deposition
Peak hasProcess Erosion
Volcano hasProcess Tectonics
Arch hasProcess Erosion

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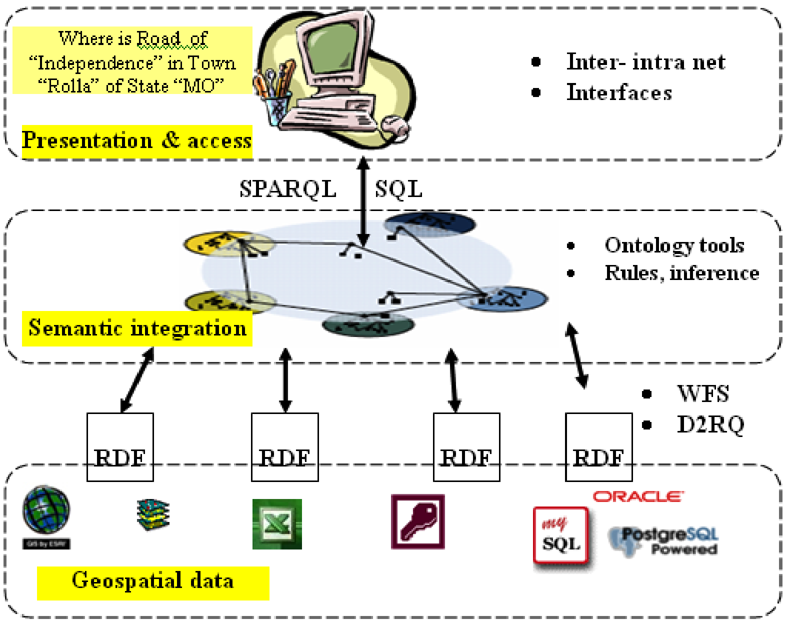
Ontology to Database Interface



Challenges

Legacy resources are ambiguous

Triple stores quickly become volumetrically large

Is scaling up to the entire web possible?

Input data must be formatted -

- Standardization vs. bottom-up information
- Concept commitments vs. multiple perspectives

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Limited Applications

Semantic technology to resolve a specific problem

Metadata indexing for discovery, access, and management

- Oak Ridge National Laboratory MERCURY

Vocabulary sharing

- USGS Integrated Taxonomic Information System (ITIS) resolves Life Science ID (LSID) formats to RDF

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Hybrid Applications

Content management

- Drupal

Social networking data

- Facebook Open Graph

Statistics

- Gene Ontology (GO)

Mathematical functions

- A large body of literature

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Ontology Design Pattern

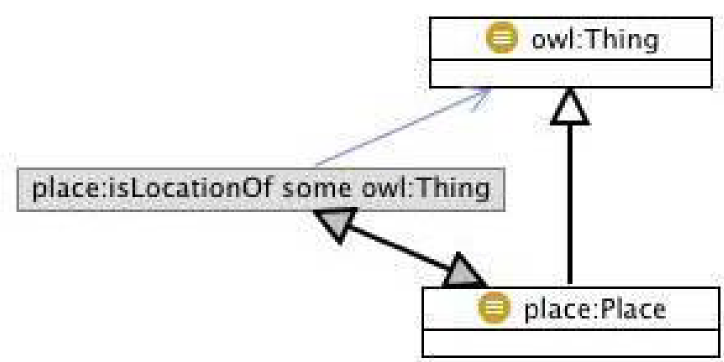
An ontology pattern is

a modeling solution for a recurrent ontology designing problem

a template that represents the necessary and sufficient conditions as a base for specific design solutions

a set of "prototypical" ontology entities that constitute the "abstract form" of a pattern or schema

ODP for Place



http://ontologydesignpatterns.org

Method—Concept Mapping

Narrative and vocabulary are analyzed and converted to logical diagrams and computer applications

Begin With Reuseable Vocabularies

@prefix geonames: <http://www.geonames.org/ontology#> .

@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .

@prefix owl: <http://www.w3.org/2002/07/owl#> .

@prefix dcterms: <http://purl.org/dc/terms/>

@prefix dbpedia: <http://dbpedia.org/ontology/>

@prefix geo: <http://www.opengis.net/ont/OGC-GeoSPARQL/1.0/>

@prefix usgsTopo: <http://cegis.usgs.gov/TopoVocab/1.0/Terrain#> .

@prefix usgs: <http://cegis.usgs.gov/ontology/instances#> .

Construct a Taxonomy

- Semantics of the relation
  - is-a, class inclusion, or subsumption
- Different kinds of relations
  - Generalization, subsets, specialization
- Structural similarities between descriptions
  - Semantic similarity measurement

Geosemantic Adaptations

Topographic Data Semantics

Wide appeal for participatory mapping

Basic categories

- Category theory

A physical 'real world'

- Helps disambiguate cognitive/cultural differences

Geospatial RDF Standards

W3C:

Basic Geo Vocabulary (2003)

- Location points combined with other ontology

GeoRSS (2006)

- Location points with Really Simple Syndication

GeoOWL ontology (2005)

- Expanded the geosemantic vocabulary to include toponyms, spatial relations, coordinate reference systems, metadata, and web services

Geospatial Features as Triples

```
<http://cegis.usgs.gov/ontology/instances> a owl:ontology
usgs:_7945        a usgsTopo:crater;
                  a geo:Feature ;
                  geo:hasGeometry usgs:_7945geo ;
                  geoname:name “Meteor Crater"
                  rdfs:comment "A meteor crater";
                  usgsTopo:hasBenchmark usgs:_5723 ;
                  usgsTopo:hasBenchmark usgs:_e5706 ;
                  dcterms:identifier "7945" ;
                  dcterms:description "Circular-shaped depression on the surface of the land caused by the impact of a meteorite"

usgs:_7945geoa geo:Geometry ;
                  usgsTopo:hasShape "circular" ;
                  usgsTopo:width "0.2km" ;
                  usgsTopo:innerDiameter "833m" ;
                  usgsTopo:outerDiameter "1250m" ;
                  usgsTopo:hasUTM "E 497959.94m  N 3876020.68m Zone 12";
                  usgsTopo:hasPLSS "T 19 N, R 12 1/2 E, Section 13 and 24";
                  usgsTopo:hasMBR "Max E 489536.79m  Min E 497317.62m  Max N 3876632.29m  Min N 3875479.58m";
                  dbpedia:MaximumElevation "5723ft";
                  dbpedia:MinimumElevation "5123ft";
                  dbpedia:MaximumDepth "600ft" .
```

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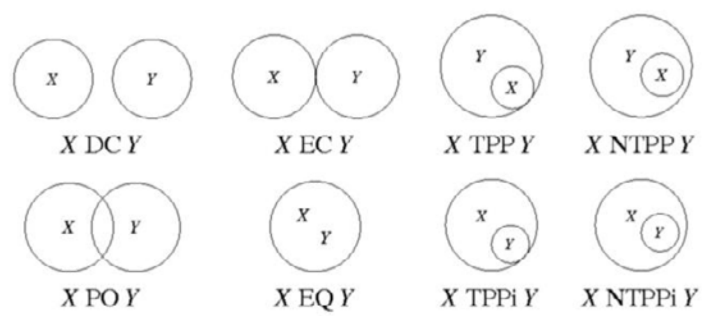
Topological Relations

Relations based on interior, boundary, and exterior contact between two features

OGC Simple Feature Terms

- •Equals
- •Disjoint
- •Intersects
- •Touches
- •Within
- •Contains
- •Overlaps
- •Crosses



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GIS vs. Geosemantic Topology

- **GIS topology is not converted**
- **Topology is calculated with**
  - **Well Known Text (WKT)**
  - **Geography Markup Language (GML)**

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GeoSPARQL Ontology

geo:SpatialObject

geo:Feature geo:hasGeometry geo:Geometry

geo:defaultGeometry

geo:asWKT / sf:wktLiteral for values

geo:asGML / gml:gmlLiteral for values

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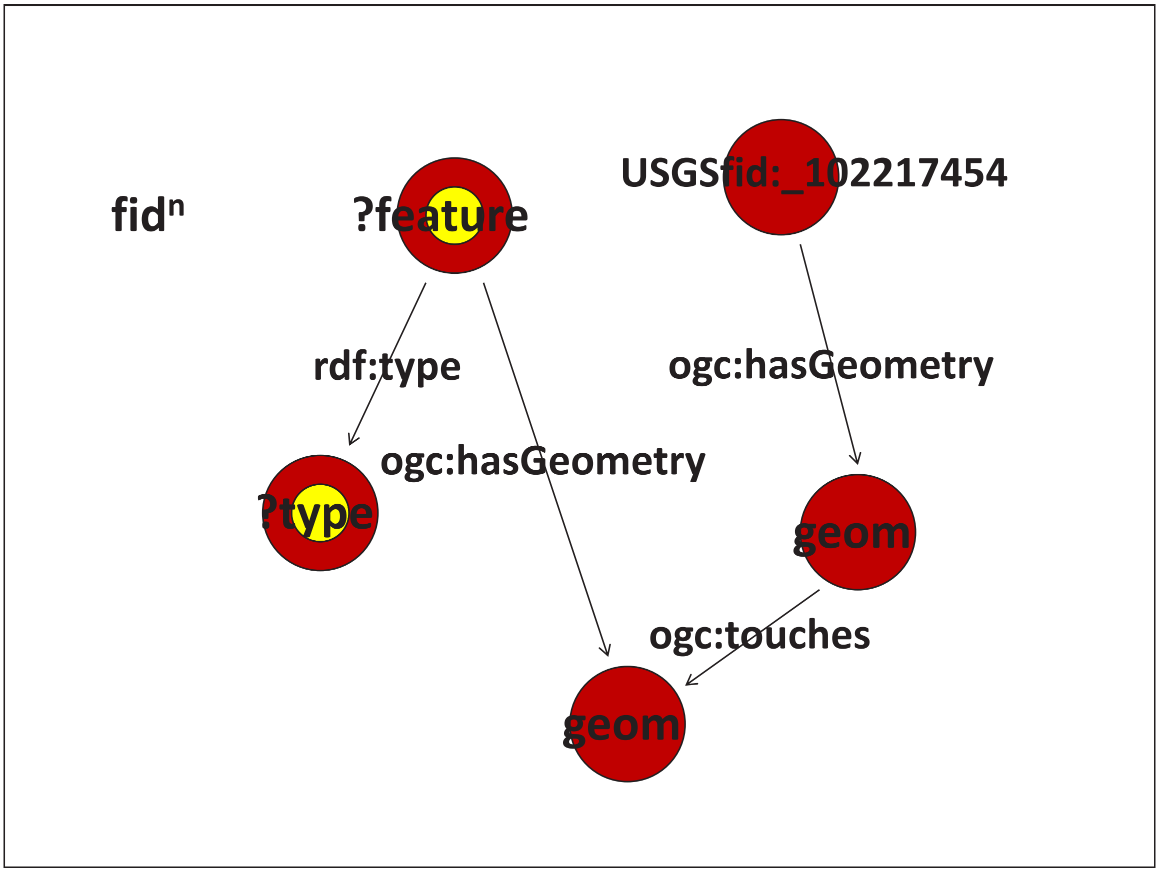

GeoSPARQL Filter Functions

Operator functions take multiple geometries as predicates and produce either a new geometry or another datatype as a result

- ogcf:intersection returns a geometry produced by the spatial intersection of two geometries
- ogcf:distance produces xsd:double

Boolean topological tests of geometries

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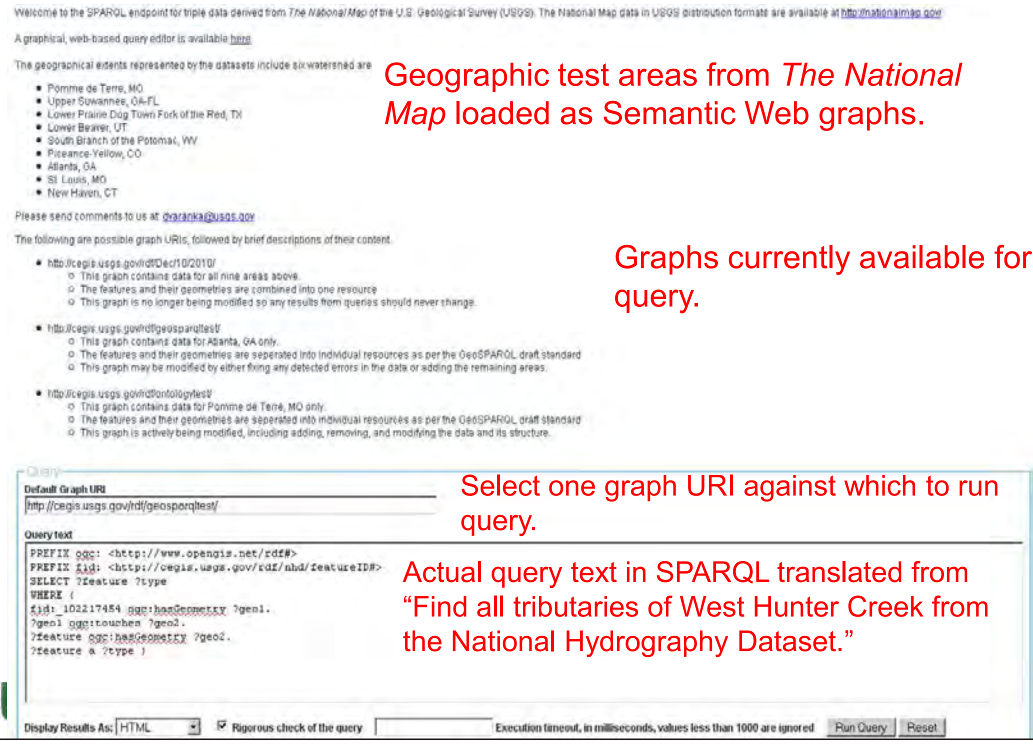
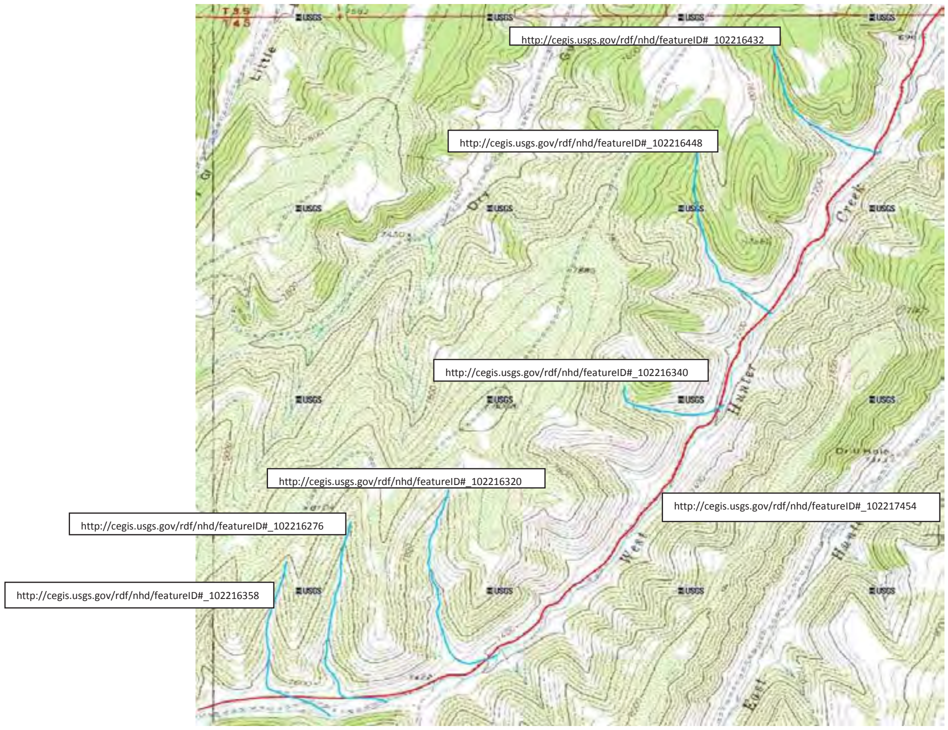
SPARQL Query – Data Converted from *The National Map*



SPARQL Query Results with Uniform Resource Identifiers (URI)

feature	type
http://cegis.usgs.gov/rdf/nhd/featureID#_102216358	http://cegis.usgs.gov/rdf/nhd#Stream_River
http://cegis.usgs.gov/rdf/nhd/featureID#_102216276	http://cegis.usgs.gov/rdf/nhd#Stream_River
http://cegis.usgs.gov/rdf/nhd/featureID#_102216320	http://cegis.usgs.gov/rdf/nhd#Stream_River
http://cegis.usgs.gov/rdf/nhd/featureID#_102216340	http://cegis.usgs.gov/rdf/nhd#Stream_River
http://cegis.usgs.gov/rdf/nhd/featureID#_102216448	http://cegis.usgs.gov/rdf/nhd#Stream_River
http://cegis.usgs.gov/rdf/nhd/featureID#_102216432	http://cegis.usgs.gov/rdf/nhd#Stream_River
http://cegis.usgs.gov/rdf/nhd/featureID#_102216442	http://cegis.usgs.gov/rdf/nhd#Stream_River
http://cegis.usgs.gov/rdf/nhd/featureID#_102216272	http://cegis.usgs.gov/rdf/nhd#Stream_River
http://cegis.usgs.gov/rdf/nhd/featureID#_102216308	http://cegis.usgs.gov/rdf/nhd#Stream_River
http://cegis.usgs.gov/rdf/nhd/featureID#_102216274	http://cegis.usgs.gov/rdf/nhd#Stream_River
http://cegis.usgs.gov/rdf/nhd/featureID#_102216382	http://cegis.usgs.gov/rdf/nhd#Stream_River
http://cegis.usgs.gov/rdf/nhd/featureID#_102216400	http://cegis.usgs.gov/rdf/nhd#Stream_River

Query Result



Summary: Ontology is Expressed at Multiple Levels

- Formalized logical structures of knowledge
  - Cognitive world views
- Narratives and vocabularies of commonly shared words and meanings
  - Discourses about things
- Applied representations based on concepts and their relations to each other
  - A map is an ontology

On-line Demonstrations of Semantic Web sites

- Semantic Web ontology example
  - File formats handle triples in various ways
- Geonames.org toponym ontology
  - Basic Geo point coordinates
- DBpedia
  - At the center of linkeddata.org

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The USGS Project

Data Conversion from *The National Map*

Reuseable ODP for base data

Graphical output for topographic mapping

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Publicly Contributed Approaches

- GeoVoCamp
  - Community-based approaches to controlled vocabulary development
- Communities of Practice
  - Spatial Ontology Community of Practice (SOCoP)
- Open Ontology Repository Initiative

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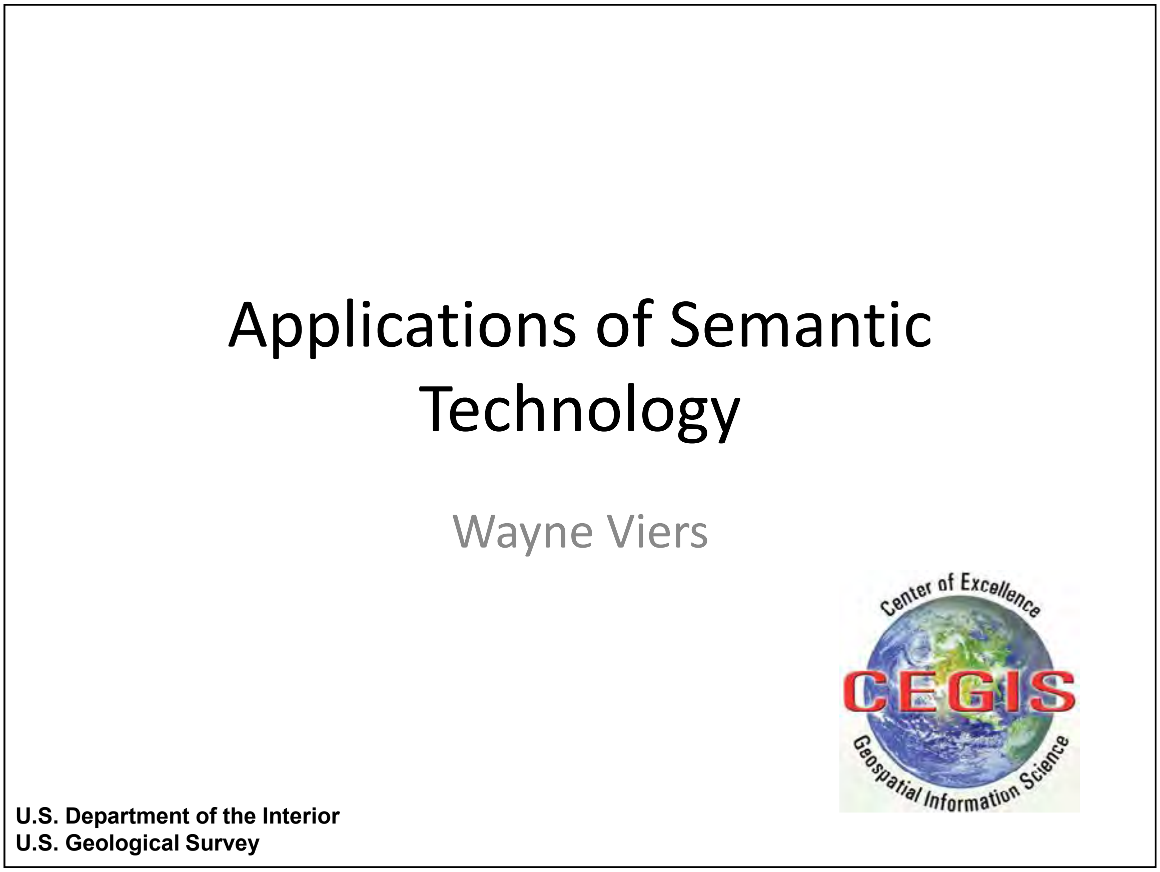
Accessing Linked Data Over the Internet

Concepts introduced in the first hour are illustrated with examples using interactive data search, access, and download sites on the Internet. Sites to be visited are the Friend-of-a-Friend ontology, Geonames.org, and DBpedia, the Semantic Web version of Wikipedia.



Outline

- Three organizations that effectively use RDF
- FOAF: Example of RDF/XML generation
- Geonames: Example of Semantic Web
- DBpedia: Example of semantic querying

Friend of a Friend

Goal: Create a web of machine readable pages describing people and the links between them

An ontology designed to allow portability of information between Web sites

Exercise

- http://www.ldodds.com/foaf/foaf-a-matic
- We will use FOAF-a-Matic to show how one can easily create a FOAF RDF page
- The triples are generated in RDF/XML, which is a syntax for representing RDF in XML
- In this exercise, all triples have a common subject (you!)
- This RDF/XML file can be added to your website to contribute to the Semantic Web

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Example FOAF Page

- A good example of a FOAF page is Tim Berners-Lee's
- Web page as seen in your browser
- http://www.w3.org/People/Berners-Lee/

- Embedded RDF/XML (Can be viewed as XML or using your browser's View Source option.)
- http://www.w3.org/People/Berners-Lee/card.rdf

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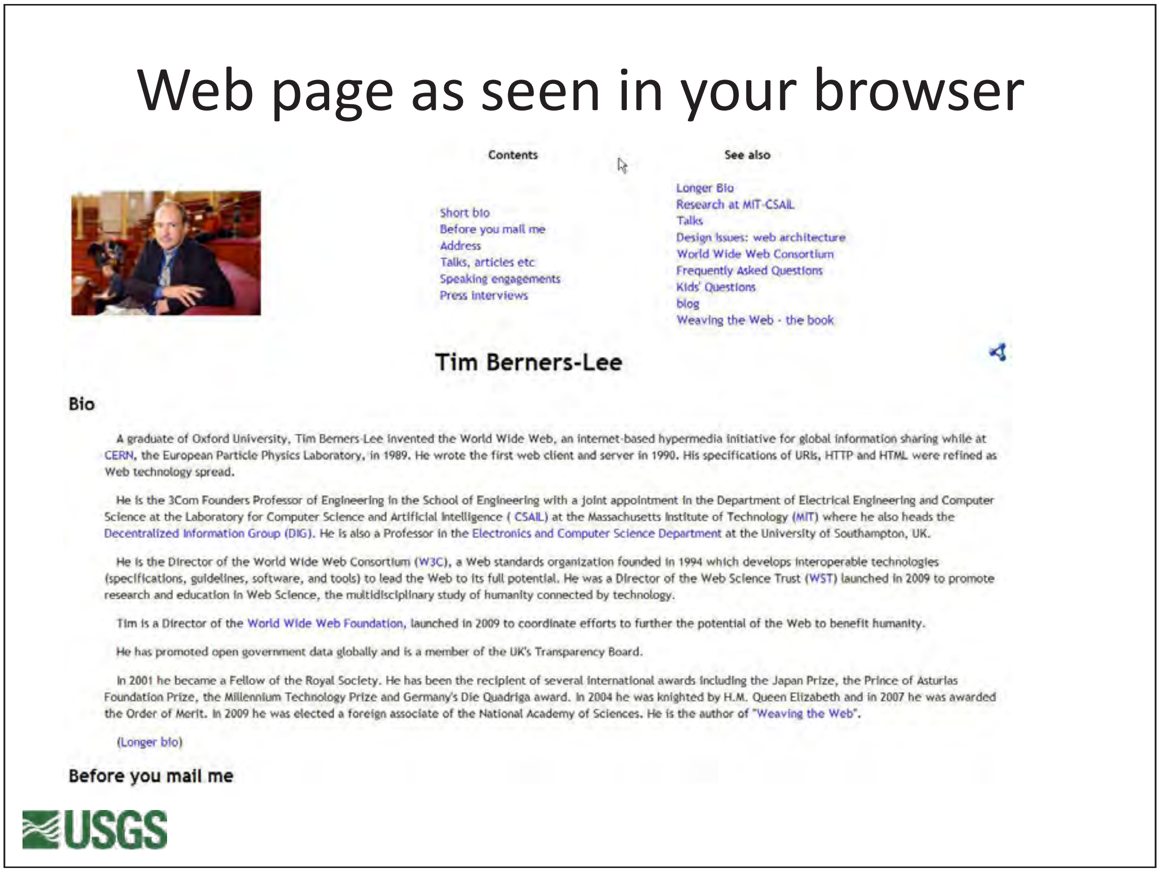
Web page as seen in your browser
Contents
See also
Short bio
Before you mail me
Address
Talks, articles etc
Speaking engagements
Press interviews
Longer Bio
Research at MIT-CSAIL
Talks
Design Issues: web architecture
World Wide Web Consortium
Frequently Asked Questions
Kids' Questions
blog
Weaving the Web - the book
Tim Berners-Lee
Bio
A graduate of Oxford University, Tim Berners-Lee invented the World Wide Web, an internet-based hypermedia initiative for global information sharing while at CERN, the European Particle Physics Laboratory, in 1989. He wrote the first web client and server in 1990. His specifications of URIs, HTTP and HTML were refined as Web technology spread.
He is the 3Com Founders Professor of Engineering in the School of Engineering with a joint appointment in the Department of Electrical Engineering and Computer Science at the Laboratory for Computer Science and Artificial Intelligence (CSAIL) at the Massachusetts Institute of Technology (MIT) where he also heads the Decentralized Information Group (DIG). He is also a Professor in the Electronics and Computer Science Department at the University of Southampton, UK.
He is the Director of the World Wide Web Consortium (W3C), a Web standards organization founded in 1994 which develops interoperable technologies (specifications, guidelines, software, and tools) to lead the Web to its full potential. He was a Director of the Web Science Trust (WST) launched in 2009 to promote research and education in Web Science, the multidisciplinary study of humanity connected by technology.
Tim is a Director of the World Wide Web Foundation, launched in 2009 to coordinate efforts to further the potential of the Web to benefit humanity.
He has promoted open government data globally and is a member of the UK's Transparency Board.
In 2001 he became a Fellow of the Royal Society. He has been the recipient of several international awards including the Japan Prize, the Prince of Asturias Foundation Prize, the Millennium Technology Prize and Germany's Die Quadriga award. In 2004 he was knighted by H.M. Queen Elizabeth and in 2007 he was awarded the Order of Merit. In 2009 he was elected a foreign associate of the National Academy of Sciences. He is the author of "Weaving the Web".
(Longer bio)
Before you mail me
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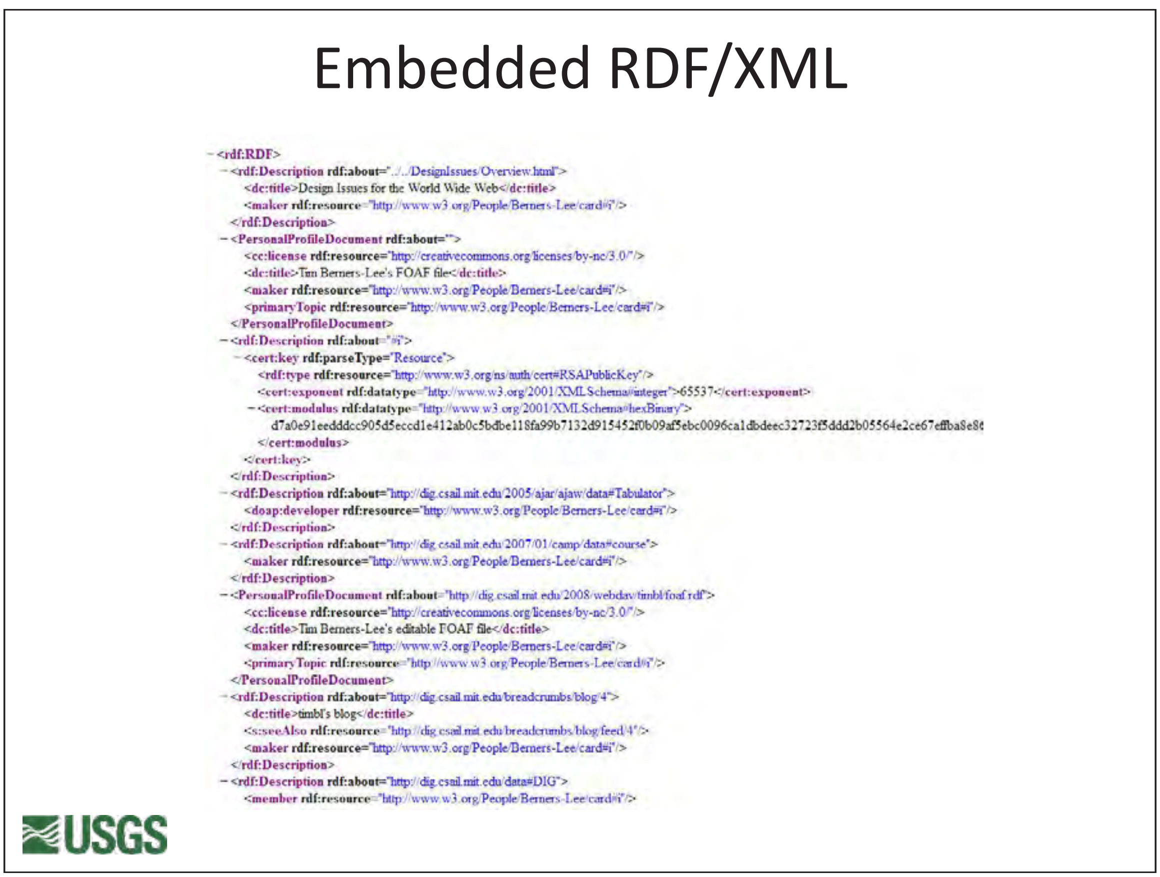
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- <rdf:RDF>
- <rdf:Description rdf:about="../../DesignIssues/Overview.html">
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</rdf:Description>
- <PersonalProfileDocument rdf:about="">
<cc:license rdf:resource="http://creativecommons.org/licenses/by-nc/3.0/"/>
<dc:title>Tim Berners-Lee's FOAF file</dc:title>
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<primaryTopic rdf:resource="http://www.w3.org/People/Berners-Lee/card#i"/>
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- <rdf:Description rdf:about="#i">
- <cert:key rdf:parseType="Resource">
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- <PersonalProfileDocument rdf:about="http://dig.csail.mit.edu/2008/webdav/timbl/foaf.rdf">
<cc:license rdf:resource="http://creativecommons.org/licenses/by-nc/3.0/"/>
<dc:title>Tim Berners-Lee's editable FOAF file</dc:title>
<maker rdf:resource="http://www.w3.org/People/Berners-Lee/card#i"/>
<primaryTopic rdf:resource="http://www.w3.org/People/Berners-Lee/card#i"/>
</PersonalProfileDocument>
- <rdf:Description rdf:about="http://dig.csail.mit.edu/breadcrumbs/blog/4">
<dc:title>timbl's blog</dc:title>
<s:seeAlso rdf:resource="http://dig.csail.mit.edu/breadcrumbs/blog/feed/4"/>
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</rdf:Description>
- <rdf:Description rdf:about="http://dig.csail.mit.edu/data#DIG">
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Geonames

Contains more than 10 million geographical names and more than 8 million unique features

More than 6.2 million Geonames toponyms have a unique URL

Has a map service that can display the semantic information of displayed features

Exercise

- **We will traverse Geonames semantic web to find the Washington Monument's Wikipedia page starting from the National Mall's semantic page.**
- **To do this we will be using an online application called XMLGrid**

xmlgrid.net

http://xmlgrid.net/

We will use the sites XML Viewer to look at RDF/XML embedded in the Geonames map

http://www.w3.org/People/Berners-Lee/card.rdf

Click the "By URL" box

Paste this link into the text box

Click submit, then "TextView"

Geonames Map

- http://www.geonames.org/6295630/
- Search for "National Mall" in the search bar in the top right
- Click the purple "S" symbol next to the National Mall in the list below the map
- Adjust your zoom level so that you have a good view of the National Mall and the Washington Monument.

Solution

- Click the National Mall marker on the map then click "semantic web rdf"
- Copy and paste the "nearbyFeatures" URL's into xmlgrid as shown previously, until you find the Washington Monument's RDF page.
- Finally find the link to the Wikipedia article (making sure you select the one with en.wikipedia for English)

Download Links

http://www.geonames.org/ontology/documentation.html

Can download the entire RDF dataset but the file is very large (2.19 Gigabytes)

DBpedia

- DBpedia is a community effort to extract info from Wikipedia and make sophisticated queries against it.
- Dataset contains 3.64 million "things" and over 1 billion triples
- Triples built from info boxes in Wikipedia

Faceted Search

DBpedia uses the semantic information from Wikipedia pages to perform faceted searches

A facet is an aspect of a feature (elevation for example)

Very useful for finding sets of data with specific qualities

http://dbpedia.neofonie.de/browse

Exercise

We will perform a spatial query using the faceted search to find…

- Cities
- With population between 40,000 and 65,000
- And an elevation of 330 meters to 453 meters

Solution

Since city is not one of the visible facets, type city into the item type field on the left

Type 330 and 453 into the appropriate fields under the elevation facet

Finally enter 40000 and 65000 into the fields under the population total facet

RDF Web Browser

- OpenLink Virtuoso built-in Faceted Browser
- Virtuoso is a database engine made by OpenLink Software
- The Virtuoso data base contains all the triples the browser searches over
- DBpedia's triples can also be displayed in a browser in addition to being queried
- http://dbpedia.org/fct/

Download Links

- http://wiki.dbpedia.org/Downloads37
- Can download the DBpedia ontology in the OWL format (Web Ontology Language)
- Can be viewed in an ontology editor like Protégé.

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science for a changing world

The USGS Approach to the Geospatial Semantic Web

In the second half of the workshop, the motivation for the USGS geospatial applications, including data integration and information retrieval lead to a discussion of approaches for enabling *The National Map* topographic data on the geospatial semantic web. A discussion of raster-based data semantics will be included.

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Geospatial Semantic Technology

A Case Study with USGS Data

Center of Excellence
CEGIS
Geospatial Information Science

U.S. Department of the Interior
U.S. Geological Survey

Outline

- USGS Data Issues and Examples
  - *The National Map*
- Semantics as a Solution
- Building Semantics for Geospatial Data
- Creating New Data with Semantics
- Converting Legacy Data
- Data Archive and Access
  - USGS Sample Data as RDF
  - Ontology for *The National Map*
    - Taxonomy of Domains
    - Topographic Vocabulary
- Querying USGS Sample Data with SPARQL and GeoSPARQL
- Using USGS Data with Other Data Sources
- Linked Open Data
- USGS Research Needs in Geosemantics
- Future of Semantic Data at USGS

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USGS Data Issues

Volume – multiple nationwide datasets at high resolution

Structure – variety of structures, vector and raster, many different formats

Semantics – various attribution and relation schemes, some feature-based, some layers

Integration of multiple datasets – for maximum utility all datasets should be able to be integrated to produce new data and information

Integration with data from users – users require the ability to add their data to USGS base datasets

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Examples of USGS Datasets

Dataset	Geometry/ Format	Attribution/ Scaling	URL
National Hydrography Dataset (NHD)	Vector	Discrete/nominal	http://viewer.nationalmap.gov/viewer/nhd.html?p=nhd
National Transportation Dataset	Vector; tables	Discrete/nominal	http://viewer.nationalmap.gov/viewer/ http://gisdata.usgs.net/website/MRLC/viewer.htm
National Boundaries Dataset	Vector	Discrete/nominal	http://viewer.nationalmap.gov/viewer/
National Structures Dataset	Vector	Discrete/nominal	http://viewer.nationalmap.gov/viewer/
Geographic Names Information System (GNIS)	Vector	Discrete/nominal	http://geonames.usgs.gov/domestic/download_data.htm
National Elevation Dataset (NED)	Raster	Continuous/ratio	http://viewer.nationalmap.gov/viewer/ http://seamless.usgs.gov/website/seamless/viewer.htm
National Digital Orthophotos	Raster	Continuous/ interval	http://www.ndop.gov/data.html; http://viewer.nationalmap.gov/viewer/ http://gisdata.usgs.net/website/MRLC/viewer.htm
National Land Cover Dataset (NLCD)	Raster	Discrete/nominal	http://viewer.nationalmap.gov/viewer/ http://gisdata.usgs.net/website/MRLC/viewer.htm
Global Land Cover Dataset	Raster	Discrete/nominal	http://landcover.usgs.gov/landcoverdata.php
LiDAR	Point	Continuous/ratio	http://viewer.nationalmap.gov/viewer/
Satellite images	Raster	Continuous/interval	http://earthexplorer.usgs.gov//; http://glovis.usgs.gov/
Hazards (Earthquakes, Volcanoes)	Graphics	Multiple forms	http://earthquake.usgs.gov/hazards/; http://volcanoes.usgs.gov/activity/status.php
Minerals	Vector; text	Discrete/nominal	http://mrdata.usgs.gov/; http://tin.er.usgs.gov/mrds/ http://tin.er.usgs.gov/geochem/; http://crustal.usgs.gov/geophysics/index.html
Energy	Vector; databases	Multiple forms	http://energy.usgs.gov/search.html
Landscapes and Coasts	Reports	Discrete/nominal	http://geochange.er.usgs.gov/info/holdings.html
Astrogeology	Databases	Discrete/nominal	http://astrogeology.usgs.gov/DataAndInformation/
Geologic Map Database	Vector; maps; text	Discrete/nominal	http://ngmdb.usgs.gov/
Geologic Data Digital Data Series	Maps; tables	Discrete/nominal	http://pubs.usgs.gov/dds/dds-060/
National Water Information System	Graphics; tables	Continuous/ratio	http://wdr.water.usgs.gov/nwisgmap/
Floods and High Flow	Graphics; tables	Continuous/ratio	http://waterwatch.usgs.gov/new/index.php?id=ww
Drought	Graphics; tables	Continuous/ratio	http://waterwatch.usgs.gov/new/index.php?id=ww
Monthly Stream Flow	Graphics; tables	Continuous/ratio	http://waterwatch.usgs.gov/new/index.php?id=ww
Ground Water	Vector; tables;	Continuous/ratio	http://waterdata.usgs.gov/nwis/gw/; http://groundwaterwatch.usgs.gov/
Water Quality	Graphics	Continuous/ratio	http://waterdata.usgs.gov/nwis/qw/; http://waterwatch.usgs.gov/wqwatch/
Vegetation Characterization	Vector; databases	Multiple forms	http://biology.usgs.gov/npsveg/
Wildlife	Vector; text; video	Multiple forms	http://www.nwhc.usgs.gov/

The National Map – http://nationalmap.gov/

The National Map is a collaborative effort to improve and deliver topographic information for the Nation

The goal of *The National Map* is to become the Nation's source for trusted, nationally consistent, integrated and current topographic information available online for a broad range of uses

The National Map

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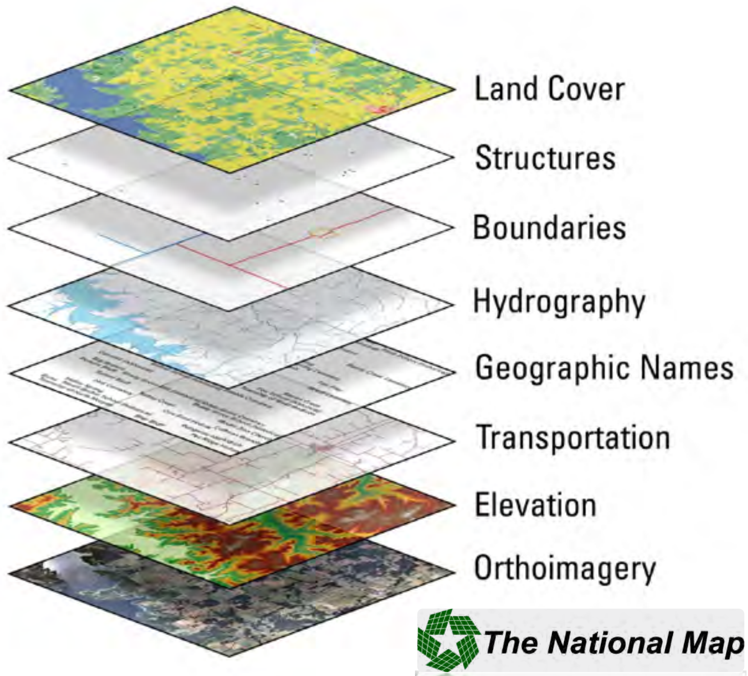
The 8 Layers of *The National Map*



The National Map

Datasets of *The National Map*

- National Land Cover Dataset (1992, 2000, 2006)
- National Elevation Dataset (1,1/3,1/9 arc-sec)
- National Digital Orthophoto Dataset (multiple dates, multiple resolutions, 1 m, 1/3 m urban areas)
- National Hydrography Dataset (NHD) (Medium, High, Local resolution)
- Geographic Names Information System (GNIS)
- National Structures Dataset
- National Boundaries Dataset (US, state, county, minor civil divisions, governmental units)
- National Transportation Dataset (TIGER and others)

Products of *The National Map*

Data display through *The National Map* viewer

http://viewer.nationalmap.gov/viewer/

Palanterra, joint development – National Geospacial-Intelligence Agency, ESRI, USGS

Display user selected *The National Map* data

Data download of eight layers

Mashups with other data using Keyhole Markup Language (KML)

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Products of *The National Map*

US Topo – New 1:24,000-scale topographic maps in GeoPDF; Complete United States coverage 2009-2011; available for free download from USGS Map Store, beginning revision on 3-year cycle – Produce more than 100 maps per day

http://nationalmap.gov/ustopo/index.html

Digital, georeferenced versions of all previous topographic maps for a specified 7.5-minute area; more than 140,000 of the 180,000 total available

http://nationalmap.gov/historical/

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Semantics as a Solution

Allows mapping of vocabularies among datasets

- For example, vocabulary of USGS Digital Line Graph (DLG), DLG-Enhanced, Spatial Data Transfer Standard (SDTS), and others were used in building our semantic vocabulary

Allows data integration for query and mapping without reformatting data from various sources to a common format

Allows data use and applications not supported by GIS and GIS data models

Building Semantics for Geospatial Data

From scratch

- Ontology
- Collect data as RDF according to ontology

From Existing Data

- Ontology
- Convert existing data
- Match data to ontology

Creating New Data with Semantics

- Develop ontology
  - Taxonomy of all features
  - Vocabulary with complete definitions
    - Make compatible with existing systems
    - Use standard vocabularies, if they exist
  - Compilation of all attributes and relations as RDF triples, *i.e.*, attributes and relations become predicates
- Create data instances with geometry and ontology references

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New Data Example using Protégé

- Create Turtle (.ttl) file in text editor including prefixes and OWL geometry and WKT properties (use template)
- Open the .ttl file in Protégé and create classes
- Add individuals (instances) and geometry
- Add coordinates to annotations
- Link feature instances to geometry objects

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Converting Legacy Data

Conversion possibilities and methods depend on content and format of legacy data

Feature-based data are usually converted easily

- Features become subjects and objects, attributes and relations become predicates

Relational data can be used to automatically form RDF triples

- Rows are subjects
- Columns are predicates
- Cell values are objects
- Tables are classes

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Conversion Example – Hydrography

```
## NHD feature

@prefix geo: <http://www.opengis.net/def/geosparql/> .
@prefix gnis: <http://cegis.usgs.gov/rdf/gnis/> .
@prefix nhd: <http://cegis.usgs.gov/rdf/nhd/> .

<http://cegis.usgs.gov/rdf/nhd/Features/flowline/166450429> a nhd:flowline;
   gnis:id <http://cegis.usgs.gov/rdf/gnis/Features/737907>;
   nhd:enabled "1";
   nhd:fCode <http://cegis.usgs.gov/rdf/nhd/fCode/46006>;
   nhd:fDate "Wed Oct 22 21:51:03 CDT 2008";
   nhd:fType <http://cegis.usgs.gov/rdf/nhd/fType/460>;
   nhd:flowDir <http://cegis.usgs.gov/rdf/nhd/flowDir/1>;
   nhd:lengthKM 0.044;
   nhd:reachCode <http://cegis.usgs.gov/rdf/nhd/reachCode/10290107000164>;
   nhd:resolution 2;
   nhd:shapeLength <0>;
   geo:hasGeometry <http://cegis.usgs.gov/rdf/nhd/Geometries/166450429> .

<http://cegis.usgs.gov/rdf/nhd/Geometries/166450429> a geo:Geometry;
   geo:asWKT "LINESTRING (-93.257456099019123 37.784990808016801 0,-
93.257691232352101 37.785210608016428 0,-93.25770129901872
37.785318474682924 0)"^^<http://www.opengis.net/def/sf/wktLiteral> .
```

Define Prefixes

List predicates for nhd:flowline

Assign geometry as WKT

Conversion Example – Transportation

```
## Transportation Feature
@prefix trans: <http://cegis.usgs.gov/rdf/trans/> .
@prefix transf: <http://cegis.usgs.gov/rdf/trans/Features/> .
@prefix transg: <http://cegis.usgs.gov/rdf/trans/Geometries/> .
@prefix geo: <http://www.opengis.net/def/geosparql/> .

<http://cegis.usgs.gov/rdf/trans/Features/22609575> a trans:roadSegment;
   trans:cffcCode "A31";
   trans:countyRoute "2-83";
   trans:dataSecurity "5";
   trans:distributionPolicy "E4";
   trans:fullStreetName "State Hwy N";
   trans:isOneWay false;
   trans:loadDate "Fri Jan 16 10:06:34 CST 2009“, "Sat Mar 28 10:33:21 CDT 2009";
   trans:roadClass <http://cegis.usgs.gov/rdf/trans/roadClass/10002>;
   trans:shapeLength 0.0126977422205;
   trans:sourceDataDesc "Attribute update from 2008 TIGER/Line Shapefiles Release";
   trans:sourceDatasetID "{1B7B3B39-5C38-4115-B429-5B0DD3DE0006}";
   trans:sourceOriginator "US Census Bureau";
   trans:stCoFIPSCode "29015“, "29085";
   trans:stateRoute "82,N";
   geo:hasGeometry <http://cegis.usgs.gov/rdf/trans/Geometries/22609575> .

<http://cegis.usgs.gov/rdf/trans/Geometries/22609575> a geo:Geometry;
   geo:asWKT "LINESTRING (-93.466183999736813 38.071580000280335,-93.478876999717102
38.0719270002798)"^^<http://www.opengis.net/def/sf/wktLiteral> .
```

Define Prefixes

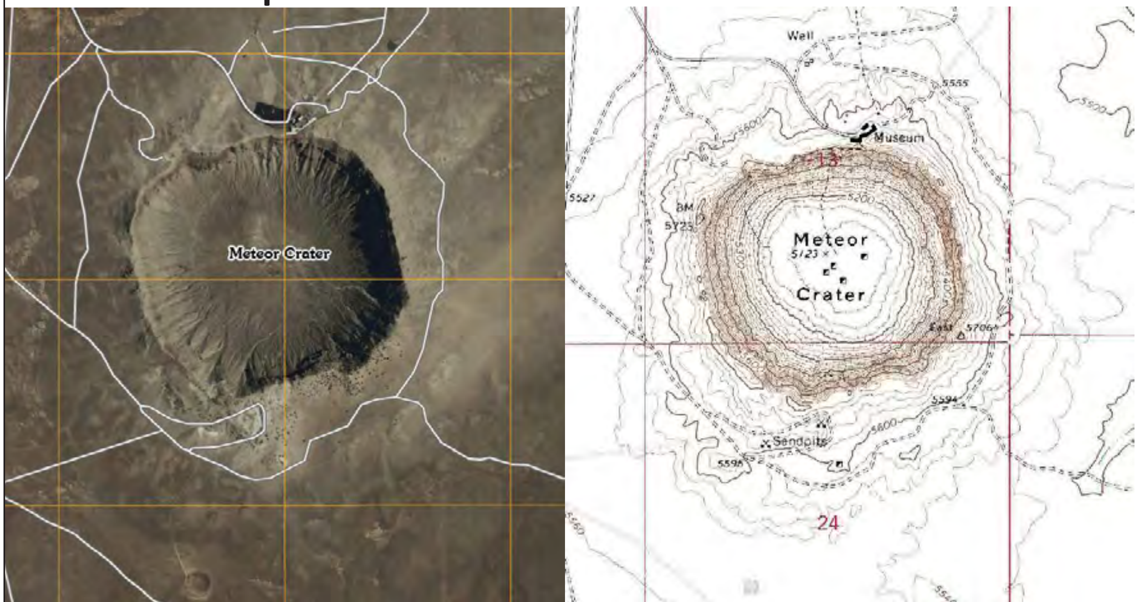
List predicates for trans:roadSegment

Assign geometry as WKT

Conversion Example – Raster Data

- Requires identification of feature, attributes, and relationships in raster dataset
- Create new feature with supporting characteristics in RDF
- Attach geometry from raster image
  - Currently using WKT of minimum bounding rectangle (MBR) since GML only supports full coverage and MBR of raster objects

Meteor Crater
Example Feature from Raster Data



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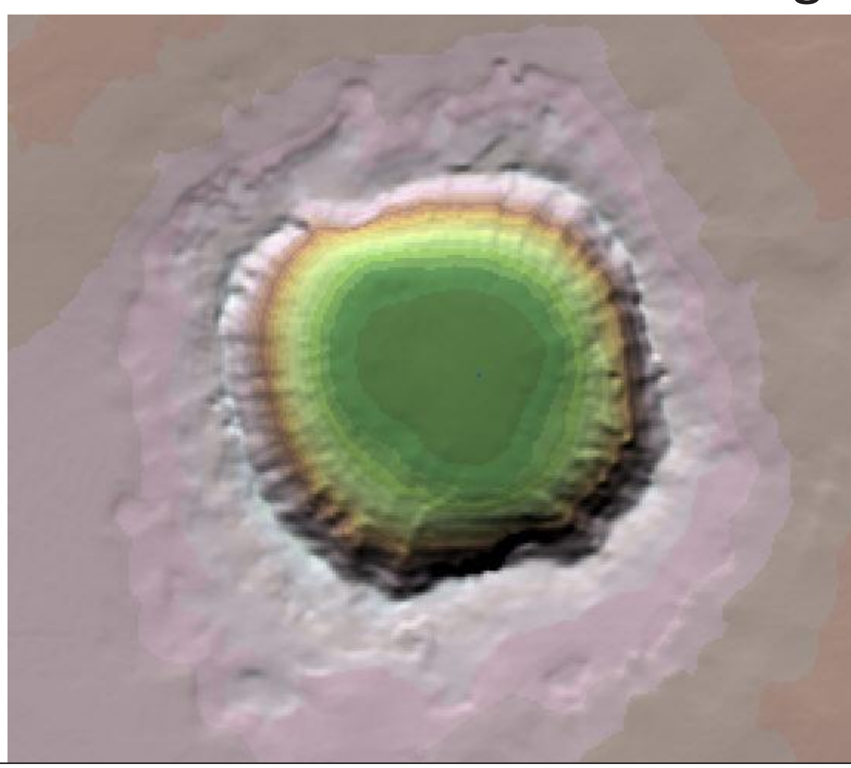
Meteor Crater – Shaded Relief Image



Meteor Crater Attributes and Relationships

Feature Crater

Definition Circular-shaped depression at the summit of a volcanic cone or on the surface of the land caused by the impact of a meteorite; a manmade depression caused by an explosion (caldera, lua).

Instance Meteor Crater

Identifier GNIS ID 7945

Attributes

Location	UTM	E 497,959.94 m	N 3,876,020.68 m	Zone 12
	PLSS	T 19 N, R 12 1/2 E, Section 13 and 24		
	MBR	Max E 498,536.79 m	Min E 497,317.62 m	
		Max N 3,876,632.29 m	Min N 3,875,479.58	
Elevation	High	5,723 ft		
	Low	5,123 ft		
Depth	600 ft			
Shape	Circular			
	Inner Diameter	0.50 mi (0.833 km)		
	Outer Diameter	0.75 mi (1.25 km)		
Rim width	0.125 mi (0.2 km)			
Contour at outer perimeter		5,600 ft		
Contour at inner perimeter		5,180 ft		

Relationships

Surrounded by roads		
Adjacent to Museum	Museum Name:	Meteor Crater Museum
Near sand pits		
Near well		
Benchmarks on crater	BM 5723	BM East 5706

Example of Meteor Crater in RDF/OWL

Data Archive and Access

Data are archived as RDF triplestore
- Usually text-based (ASCII) triples (.ttl, RDF/XML, NTriples, …)
- Generates large data volumes, *e.g.,* for Pomme de Terre 452,577 triples, 43 Mb
- Can be optimized by making binary, *e.g.,* Parliament Triple Store

Data can be accessed by:
- Query of SPARQL Endpoint (using SPARQL or GeoSPARQL)
- Downloaded (remember large data volumes)
- Accessed by URI for mashups with other data
- Application access (concept of Open Linked Data)
  - DBpedia, browsing RDF data but not as queries
  - Access by URI from one dataset to another

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USGS Sample Data as RDF

Availability
- Nine test areas – converted with pre-computed spatial relations
- New conversions of the nine areas with supporting ontology
- Access to Pomme de Terre, MO watershed for this workshop

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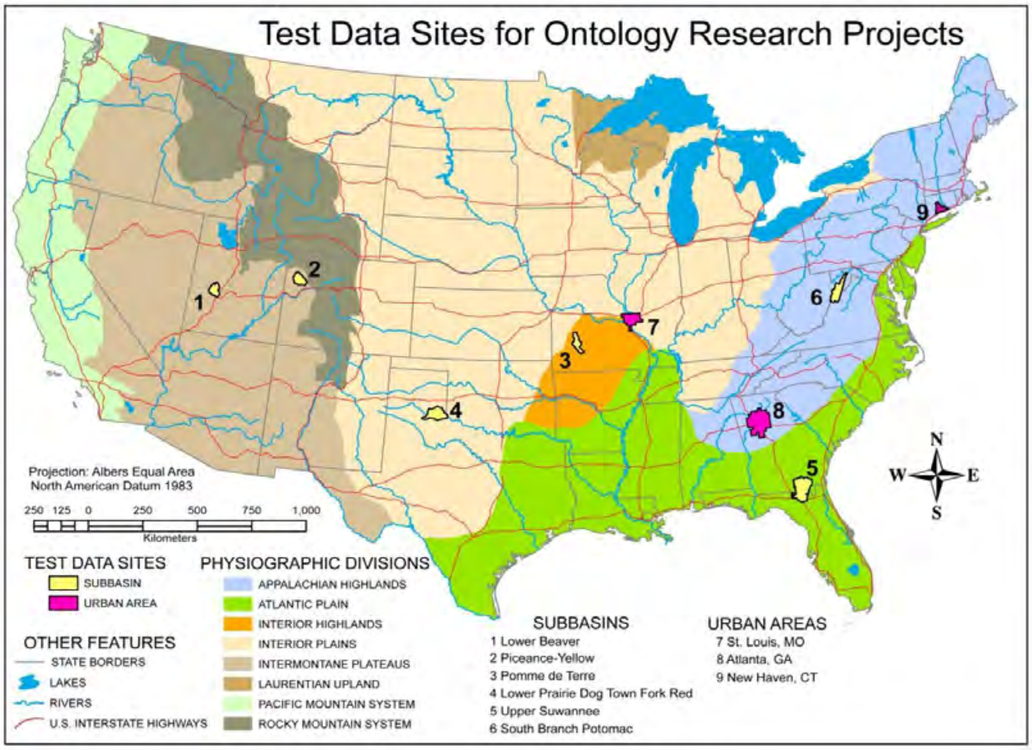

Ontology for *The National Map*

Taxonomy – hierarchy of feature classes

Vocabulary – feature names and definitions

Predicates – attributes and relationships

Instances – actual features with coordinates

All defined as OWL/RDF triples

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Taxonomy of Feature Domains

Events
Divisions
Built-up areas
Ecological regime
Surface water
Terrain

Domains derived from ground surveys incorporated in DLG standards

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Events

Risk		**Legacy**	
Hazard	Hazard zone	Military history	Archeological site
Earthquake	Incident	Historical marker	Cliff dwelling
Flood	Fire	Tree	Ruins
Area to be submerged	Restricted area	Wreck	Pictograph

Divisions

Civil Units		Boundaries
Cadastral	Nation	Fenceline
Parcel	Territory	Hedge
Public Land Survey System	Reservation	Place
Land grant	State	Region
Homestead entry	County	Locale
Survey line	Census	Boundary line
Principle meridian	State	Boundary point
Baseline	County	Hydrologic unit
Survey point	Census county division	
Point monument	Block group	**Shipping**
Survey corner	Block	Lane
Government unit	Tract	Traffic separation scheme area
Municipality	Special use zone	Pilot water
City	Time zone	Roundabout
Town	Nature reserve	Inshore trafic zone
Villiage	Survey line	Exclusive Economic Zone

Built up

Built-up Category	Number of features in Category
Transportation and warehousing	60
Entertainment and recreation	26
Utilities	16
Resource extraction	13
Structure	12
Agriculture and fishing	11
Military	10
Communication	7
Waste management	7
Real estate	6
Place of worship	6
Manufacturing	4
Institutions	3
Burial grounds	3
Disturbed surface	3
Trade	3

Ecological Regime

Tundra
Desert
Grassland
Scrubland
Forest
Pasture
Agricultural land
Transition area
Nature reserve
Wetland

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Natural/Artificial

hasPart: Bottom
Channel
Pond
Basin

Natural

Marine/Estuarine

Cove
Foreshore
Flat
Ice field (regional)

Marine

Ocean
Sea
Gulf
Submerged
Stream
Shore
hasPart: Shingle
Shoreline
Beach
Ice flow (regional)
Polyna (regional)
Breakers
Reef Pool

Estuarine

Estuary
Bay
Inlet

Freshwater

Watercourse
Stream
hasPart: Mouth
hasPart: Source
hasPart: Streambed
hasPart: Streambanks
hasPart: Crossing
hasPart: Ford
River
Creek
Brook
Arroyo
Rapids
Bend
Falls
Cascade
Waterfall
Innundation area
Spring
Mud pot
Geyser
Slope spring
Ice berg (regional)
hasPart: Iceberg tongue
Glacier (regional)
Crevasse (regional)

Wetland

Marsh
Swamp
Bog

Waterbody
Lake
Ice cap (regional)
Snow field (regional)
Sastrugi (regional)
Area of Complex
Channels
Backwater
Headwaters
Ice Mass
Lagoon
Rise
Sink

Artificial

Impounded

Reservoir
Fish ladder

Diked

Levee
Embankment
hasPart: Revetment
Dam
Masonry shore

Channel

Siphon
Aqueduct
Canal
Flume
Turning basin
Crib

Flow Control

Weir
Lock
*hasPart:*Lock chamber
Spillway
Jetty
Breakwater
Pump
Gut

Surface Water

Terrain includes 57 USGS landform features

Arch	Divide	Isthmus	Ridge
Bar	Drainage basin	Karst	Ridge line
Basin	Dunes	Lava	Rock
Beach	Fault	Mineral pile	Salt pan
Bench	Flat	Moraine	Shaft
Cape	Floodplain	Mount	Sink
Catchment	Fracture	Mountain range	Summit
Cave	Fumarole	Peak	Talus
Chimney	Gap	Peneplain	Terrace
Cirque	Glacial	Peninsula	Valley
Cliff	Ground surface	Pinnacle	Volcano
Coast	Hill	Plain	Wash
Continent	Incline	Plateau	
Crater	Island	Quicksand	
Delta	Island cluster	Reef	

Topographic Vocabulary

Examples from:

- Events
- Divisions
- Built up
- Ecological regime
- Surface water
- Terrain

Available from Ontology Project Webpage:
http://cegis.usgs.gov/ontology.html

Ontologies – Reuseable Vocabularies

@prefix geonames: <http://www.geonames.org/ontology#> .

@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .

@prefix owl: <http://www.w3.org/2002/07/owl#> .

@prefix dcterms: <http://purl.org/dc/terms/>

@prefix dbpedia: <http://dbpedia.org/ontology/>

@prefix geo: <http://www.opengis.net/ont/OGC-GeoSPARQL/1.0/>

@prefix usgsTopo: <http://cegis.usgs.gov/TopoVocab/1.0/Terrain#> .

@prefix usgs: <http://cegis.usgs.gov/ontology/instances#> .

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Built-up Vocabulary

Terrain Vocabulary

```
# Filename: Terrain.n3
# Organization: CEGIS, US Geological Survey, US Department of the Interior
# Description:
#          This feature type vocabulary is based on feature definitions from the following standards.
#          The U.S. Geological Survey (USGS) Digital Line Graphs
#          Geographic Names Information System of the U.S. Board of Geographic Names (USBGN)
#          and Spatial Data Transfer Standard (SDTS)

      a     owl:Ontology ;
      owl:versionInfo "Created with TopBraid Composer"^^xsd:string .

:Arch
      a     owl:Class ;
      rdfs:comment "A naturally occurring, freestanding curved structure that spans an opening"^^xsd:string ;
      rdfs:subClassOf :Terrain .

:Bar a     owl:Class ;
      rdfs:comment "A natural accumulation of sand, gravel, or other material forming an underwater or exposed embankment"^^xsd:string ;
      rdfs:subClassOf :Terrain .

:Basin
      a     owl:Class ;
      rdfs:comment "A bowl-shaped depression in the surface of the land or ocean floor"^^xsd:string ;
      rdfs:subClassOf :Terrain .

:Beach
      a     owl:Class ;
      rdfs:comment "The gently sloping shore which is washed by waves, usually composed of sand and pebbles"^^xsd:string ;
      rdfs:subClassOf :Terrain .

:Bench
      a     owl:Class ;
      rdfs:comment "An area of relatively level land on the flank of an elevation such as a hill, ridge, or mountain where the slope of the land rises on one side and descends on the opposite side (level)"^^xsd:string ;
```

Querying USGS Sample Data with SPARQL and GeoSPARQL

SPARQL Endpoint

A URL that allows access to an RDF triplestore

USGS SPARQL Endpoint for Topographic Data

http://usgs-ybother.srv.mst.edu:8890/parliament

USGS

Triplestore of USGS Data

- Collection of RDF triples for our 9 research test areas.
- Data will include names, hydrography, transportation, boundaries, structures, land cover, geomorphic features (from elevation)
- Accessible from SPARQL Endpoint
- SPARQL queries use the ontology

USGS

SPARQL Query Example

```
## SPARQL Query
PREFIX gnis: <http://cegis.usgs.gov/rdf/gnis/> .
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

SELECT ?name ?mapName
WHERE
{
 ?x a gnis:gnisFeature .
 ?x rdfs:label ?name .
 ?x gnis:mapName ?mapName .
}
```

Prefixes defining shorthand notation for URIs

Select clause defining variables (name and mapName in this case)

Match features and bind to variables

GeoSPARQL Query Example

```
## GeoSPARQL Query
   PREFIX gu: <http://cegis.usgs.gov/rdf/gu/>
   PREFIX geo: <http://www.opengis.net/def/geosparql/>
   PREFIX geof: <http://www.opengis.net/def/geosparql/function/>
   PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

   SELECT DISTINCT
   ?feature ?label
   WHERE {
    GRAPH <http://cegis.usgs.gov/rdf/> {

    # Find the WKT of Polk County
    ?polkCounty a gu:countyOrEquivalent ;
          gu:countyName "Polk" .
    ?polkCounty geo:hasGeometry ?polkGeo .
    ?polkGeo geo:asWKT ?polkWKT .

    # Match features that have a label, geo:Geometry and corresponding WKT
    ?feature geo:hasGeometry ?featGeo .
    ?featGeo geo:asWKT ?featWKT .
    ?feature rdfs:label ?label .

    # Find features contained by Polk County
    FILTER (geof:sfContains(?polkWKT, ?featWKT))
    }
   } LIMIT 50
```

Prefixes defining shorthand notation for URIs

Select clause defining variables (feature and label in this case)

Graph to be searched

Item to be searched for as Well Known Text, *i.e.*, coordinates

Match features and bind to variables

Find features in Polk County

Using USGS Data with Other Data

Use of URIs in USGS data and URIs from other data provide access

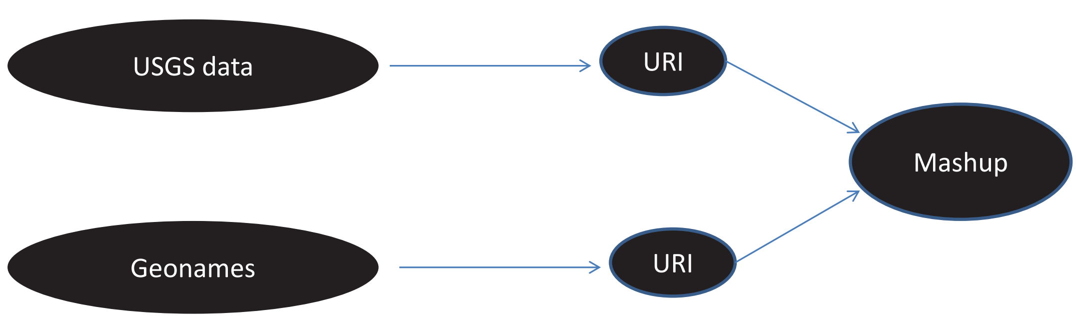
User (computer program that does linking) must determine if data are compatible and make sense

USGS data join the Open Linked Data community

USGS

Linking Data

Data are linked across triplestores by URIs



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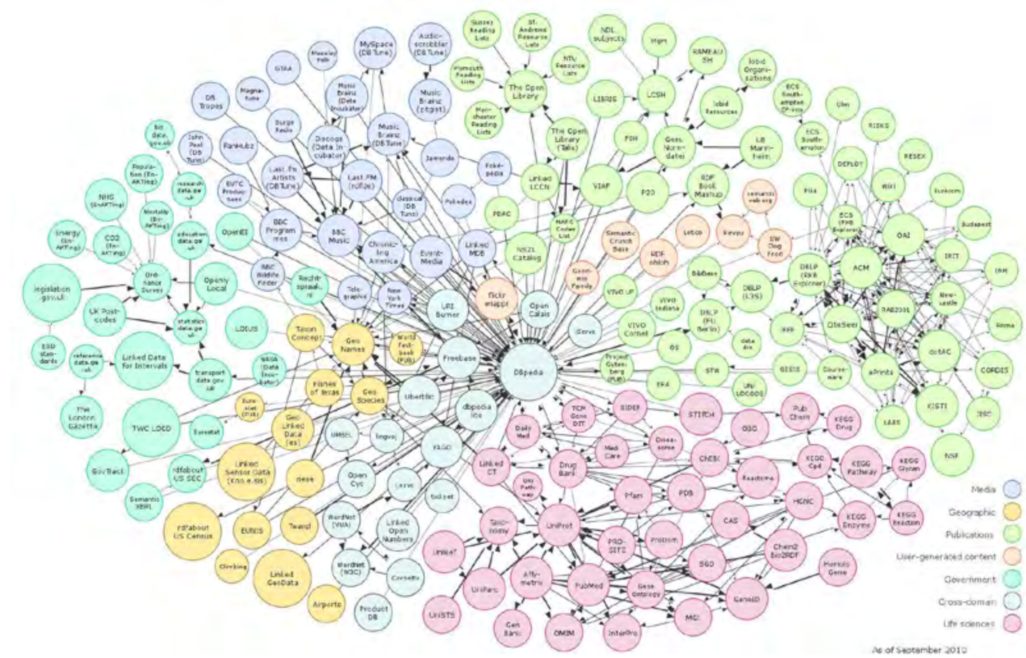
Open Linked Data



With more than 38 billion triples, the Open Linked Data cloud presents difficulties for visualization, use, and analysis. In this visualization, colors distinguish different themes (Dadzie and Rowe, 2011).

USGS Research Needs in Geosemantics

Gazetteer access to geospatial features and data

Geospatial operators and ontology-driven processes that work with RDF

- Direction, distance, overlay, buffer, generalization, mapping and display, geospatial analysis, visualization
- terrain analysis, map algebra

Automated feature identification in raster data including unnamed features, *e.g.*, using ontology design patterns and feature identification software

Future of Semantic Data at USGS

- Convert all data for the nine test areas
- Build raster features, *e.g.*, geomorphic named and unnamed
- Design and build gazetteer interface
- Design and build operators for semantic data
- Convert all data for *The National Map* to semantics

USGS

USGS
science for a changing world

Geospatial Semantic Technology

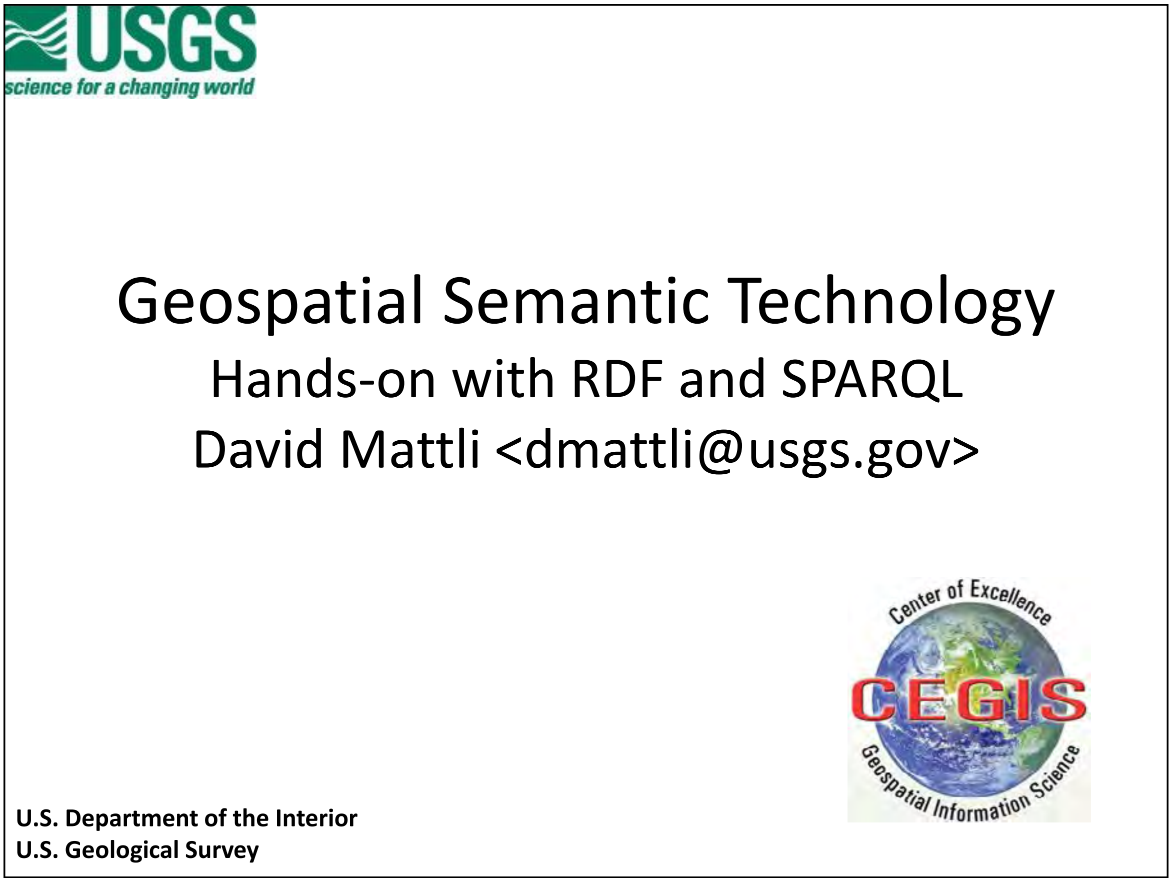
A Case Study with USGS Data

Center of Excellence
CEGIS
Geospatial Information Science

U.S. Department of the Interior
U.S. Geological Survey

Accessing Topographic Data Triples

The building of ontology for *The National Map* topographic data will be reviewed. Demonstrations of data from *The National Map* in triple format, accessible through the triple store endpoint and custom interface, will be shown by designing some commonly used SPARQL and GeoSPARQL types of queries.



Outline

- Resource Description Framework
  - Syntax
  - RDF query examples

David Mattli <dmattli@usgs.gov>

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Resource Description Framework

RDF models data using triples:
Subject-Predicate-Object

The sky is blue.

- If we want to store the idea of a blue sky we choose a subject to represent “the sky”
- We select a predicate to represent “has the color”
- And we choose an object that represents the concept of “blue”

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Triple Example

- “The sky is blue” in triple form might look like this:

```
<http://example.com/sky> <http://example.com/hasColor> <http://example.com/blue> .
```

Subject | Predicate | Object

- Each part is called an “RDF term”
- Each RDF term is separated by (at least) a space
- The triple ends with a period

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URIs vs URLs

- Each of the terms from this example

```
<http://example.com/sky> <http://example.com/hasColor> <http://example.com/blue> .
```

are URIs.

- They look very similar to URLs but the URIs used in RDF triples do not necessarily specify locations on the web
- URIs are used as *unique names*

Another example

```
@prefix gu:   <http://cegis.usgs.gov/rdf/gu/> .
@prefix rdf:  <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdf:type    gu:countyOrEquivalent .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdfs:label  "Polk" .
```

Subjects Predicates Objects

- The first three lines declare “prefixes”
- A prefix is simply a shorthand for specifying URIs

Another example

```
@prefix gu:   <http://cegis.usgs.gov/rdf/gu/> .
@prefix rdf:  <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdf:type    gu:countyOrEquivalent .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdfs:label  "Polk" .
```

Subjects — Predicates — Objects

- Same “Subject Predicate Object” structure
- But now we have two triples
  - The first describes a “type”
  - The second describes the name or label of the feature

Another example

```
@prefix gu:   <http://cegis.usgs.gov/rdf/gu/> .
@prefix rdf:  <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdf:type    gu:countyOrEquivalent .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdfs:label  "Polk" .
```

Subjects — Predicates — Objects

- Subjects are URIs
- URIs are enclosed by '<' and '>'

Another example

```
@prefix gu:   <http://cegis.usgs.gov/rdf/gu/> .
@prefix rdf:  <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdf:type    gu:countyOrEquivalent .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdfs:label  "Polk" .
```

Subjects Predicates Objects

- Predicates are also URIs
- The first three lines declare “prefixes”
- A prefix is simply a shorthand for specifying URIs

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Another example

```
@prefix gu:   <http://cegis.usgs.gov/rdf/gu/> .
@prefix rdf:  <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdf:type    gu:countyOrEquivalent .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdfs:label  "Polk" .
```

- The object of this triple is a URI using a prefix
- This URI is the name attached to the concept of a “county or equivalent”
- The second triple is a little different

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Another example

```
@prefix gu:   <http://cegis.usgs.gov/rdf/gu/> .
@prefix rdf:  <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdf:type    gu:countyOrEquivalent .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdfs:label  "Polk" .
```

- The object of a triple can be either a URI or a literal value
- The object of this triple is a string literal value
  - Literal values can also be numbers, dates, geometries, etc

Another example

```
@prefix gu:   <http://cegis.usgs.gov/rdf/gu/> .
@prefix rdf:  <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdf:type    gu:countyOrEquivalent .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdfs:label  "Polk" .
```

- The object of a triple can be either a URI or a literal value
- The object of this particular triple is a literal string value
  - More literal values: numbers, dates, geometries

Questions?

```
@prefix gu:   <http://cegis.usgs.gov/rdf/gu/> .
@prefix rdf:  <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdf:type    gu:countyOrEquivalent .

<http://cegis.usgs.gov/rdf/gu/Features/758538> rdfs:label  "Polk" .
```

- Any questions about RDF, prefixes, or triples?

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Triplestores

- A collection of triples is called a “graph”
- A program that stores graphs is called a “triplestore”
- Triplestores also execute queries on graphs
- The RDF query language is called SPARQL (sparkle)

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SPARQL

Here is an example query

```
SELECT ?label
WHERE {
  ?feature rdf:type gu:countyOrEquivalent .
  ?feature rdfs:label ?label .
}
```

- The SPARQL query language allows you query a triplestore for RDF terms(subjects, predicates or objects)
- Next we will examine the parts of this query

USGS

SPARQL

```
SELECT ?label
WHERE {
  ?feature rdf:type gu:countyOrEquivalent .
  ?feature rdfs:label ?label .
}
```

- The first part of this query is the “SELECT clause”
- The “SELECT” is followed by a space separated list of “variables”
- A “variable” is a name prefixed by a '?'

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SPARQL - Variables

```
SELECT ?label
WHERE {
  ?feature rdf:type gu:countyOrEquivalent .
  ?feature rdfs:label ?label .
}
```

- SPARQL variables are names that we give to the RDF terms we are querying for
- This query has one variable: ?label
- Variables are arbitrary identifiers

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SPARQL - Graph Patterns

```
SELECT ?label
WHERE {
  ?feature rdf:type gu:countyOrEquivalent .
  ?feature rdfs:label ?label .
}
```

- The second part of a SPARQL query is the "graph pattern"
- The "graph pattern" is a list of "triple patterns"
- In this example there are two triple patterns

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SPARQL - Graph Patterns

```
SELECT ?label
WHERE {
  ?feature rdf:type gu:countyOrEquivalent .
  ?feature rdfs:label ?label .
}
```

- Each “triple pattern” has the now familiar Subject-Predicate-Object structure
- Except now one or more of the RDF terms may be replaced by a variable

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SPARQL - Graph Patterns

```
SELECT ?label
WHERE {
  ?feature rdf:type gu:countyOrEquivalent .
  ?feature rdfs:label ?label .
}
```

- A query is executed by searching a graph in a triplestore for possible substitutions for the variables in a “triple pattern”
- The highlighted pattern would match

```
<http://cegis.usgs.gov/rdf/gu/Features/758538> rdf:type
   gu:countyOrEquivalent .
```

but not

```
<http://cegis.usgs.gov/rdf/gu/Features/766568> rdf:type
   gu:minorCivilDivision .
```

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SPARQL - Graph Patterns

```
SELECT ?label
WHERE {
  ?feature rdf:type gu:countyOrEquivalent .
  ?feature rdfs:label ?label .
}
```

- And this pattern would match any ?feature with an rdfs:label

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SPARQL - Graph Patterns

```
SELECT ?label
WHERE {
  ?feature rdf:type gu:countyOrEquivalent .
  ?feature rdfs:label ?label .
}
```

- Because the same ?feature variable is used in both triple patterns this query searches for the label of a subject that has the type "gu:countyOrEquivalent"

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SPARQL

- Next we will try and execute this SPARQL query.
- Any questions?

```
SELECT ?label
WHERE {
  ?feature rdf:type gu:countyOrEquivalent .
  ?feature rdfs:label ?label .
}
```

SPARQL Query

- Try executing a SPARQL query
- Enter this URL in your web browser:

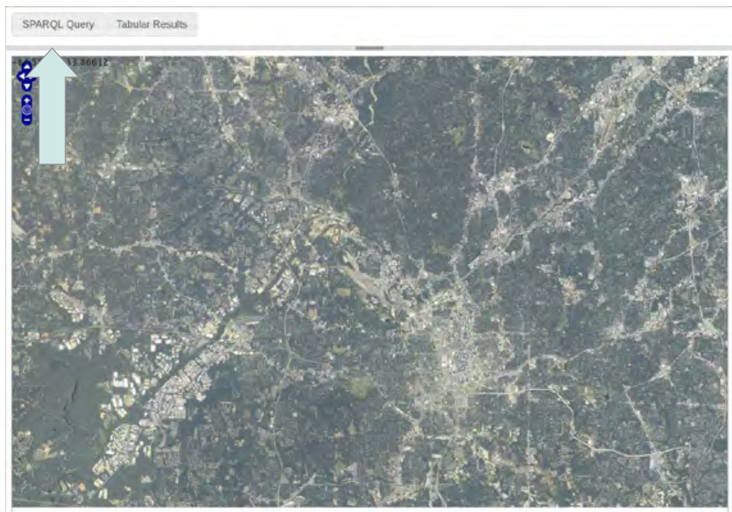
http://usgs-ybother.srv.mst.edu/viz/

You should see something like this:

SPARQL Query

http://usgs-ybother.srv.mst.edu/viz/

- Click on the "SPARQL Query" button



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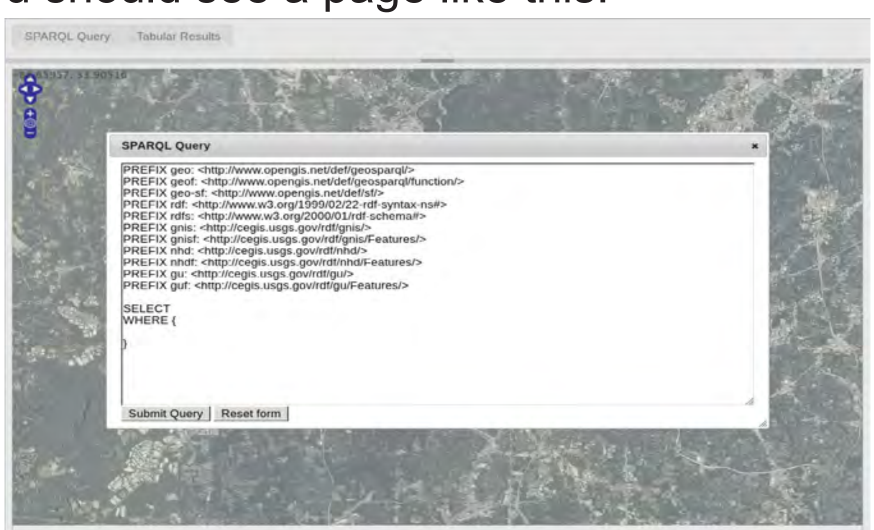
SPARQL Query

http://usgs-ybother.srv.mst.edu/viz/

- You should see a page like this:



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SPARQL Query

http://usgs-ybother.srv.mst.edu/viz/

- Now enter the query we saw earlier

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SPARQL Query

http://usgs-ybother.srv.mst.edu/viz/

- And click “Submit Query” when it is all entered

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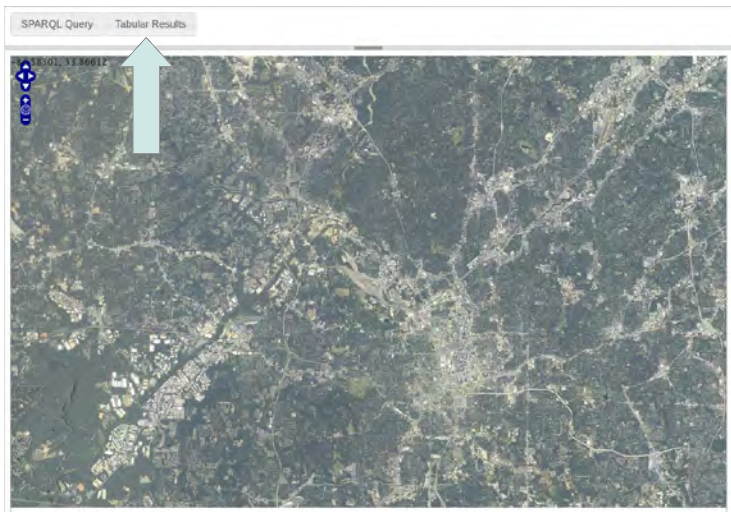
SPARQL Query

http://usgs-ybother.srv.mst.edu/viz/

- Once the dialog closes, click on “Tabular Results”



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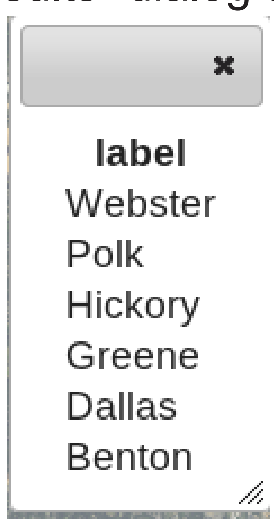
SPARQL Query

http://usgs-ybother.srv.mst.edu/viz/

- The “Tabular Results” dialog should look like:



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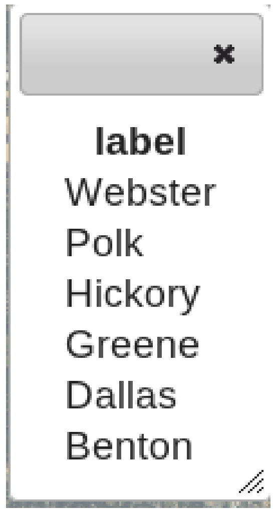
Any Questions?

http://usgs-ybother.srv.mst.edu/viz/

- The “Tabular Results” dialog should look like:



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GeoSPARQL

- GeoSPARQL is an extension of SPARQL
- Associates a Geometry with a feature using geo:hasGeometry

```
<http://cegis.usgs.gov/rdf/nhd/Features/102204610> rdf:type nhd:flowline .

<http://cegis.usgs.gov/rdf/nhd/Features/102204610> geo:hasGeometry
<http://cegis.usgs.gov/rdf/nhd/Geometries/102204610> .

<http://cegis.usgs.gov/rdf/nhd/Geometries/102204610> rdf:type geo:Geometry .
<http://cegis.usgs.gov/rdf/nhd/Geometries/102204610>  geo:asWKT
"LINESTRING (-93.387722032150236 38.166983407423857 0,-93.387682298816969
38.167539207422976 0,-93.388619432148857 38.168476474088209 0,-93.391319032144679
38.169734874086259 0,-93.396768432136241 38.171924274082869 0,-93.398635898799967
38.172490274081952 0,-93.398990298799447 38.17260060741512 0,-93.399145698799202
38.172711207414977 0,-93.399287298798981 38.172574207415153 0,-93.399409832132108
38.172571607415193 0)"^^<http://www.opengis.net/def/sf/wktLiteral> .
```

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GeoSPARQL

- Now we will query for the geometries of the counties from the last SPARQL Query

```
SELECT ?label ?wkt
WHERE {
  ?feature rdf:type      gu:countyOrEquivalent .
  ?feature rdfs:label    ?label .
  ?feature geo:hasGeometry ?g .
  ?g       geo:asWKT     ?wkt .
}
```

GeoSPARQL

- Here we have added a new SELECT variable called ?wkt

```
SELECT ?label ?wkt
WHERE {
  ?feature rdf:type      gu:countyOrEquivalent .
  ?feature rdfs:label    ?label .
  ?feature geo:hasGeometry ?g .
  ?g       geo:asWKT     ?wkt .
}
```

- And we have added two triple patterns

GeoSPARQL

- The first triple pattern searches for a geo:Geometry using the geo:hasGeometry predicate

```
SELECT ?label ?wkt
WHERE {
  ?feature rdf:type      gu:countyOrEquivalent .
  ?feature rdfs:label    ?label .
  ?feature geo:hasGeometry ?g .
  ?g       geo:asWKT     ?wkt .
}
```

- This geo:Geometry is bound to the variable: ?g

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GeoSPARQL

- The last triple pattern searches for the WKT(a geometry serialization) of the geo:Geometry

```
SELECT ?label ?wkt
WHERE {
  ?feature rdf:type      gu:countyOrEquivalent .
  ?feature rdfs:label    ?label .
  ?feature geo:hasGeometry ?g .
  ?g       geo:asWKT     ?wkt .
}
```

- The WKT is bound to the variable ?wkt

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GeoSPARQL example

- Open your web browser to the page:

http://usgs-ybother.srv.mst.edu/viz/

And click on the “SPARQL Query” button

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GeoSPARQL example

- http://usgs-ybother.srv.mst.edu/viz/
- Enter the query:

```
SELECT
?label ?wkt
WHERE {
   ?feature rdf:type gu:countyOrEquivalent .
   ?feature rdfs:label ?label .
   ?feature geo:hasGeometry ?g .
   ?g       geo:asWKT       ?wkt .
}
```

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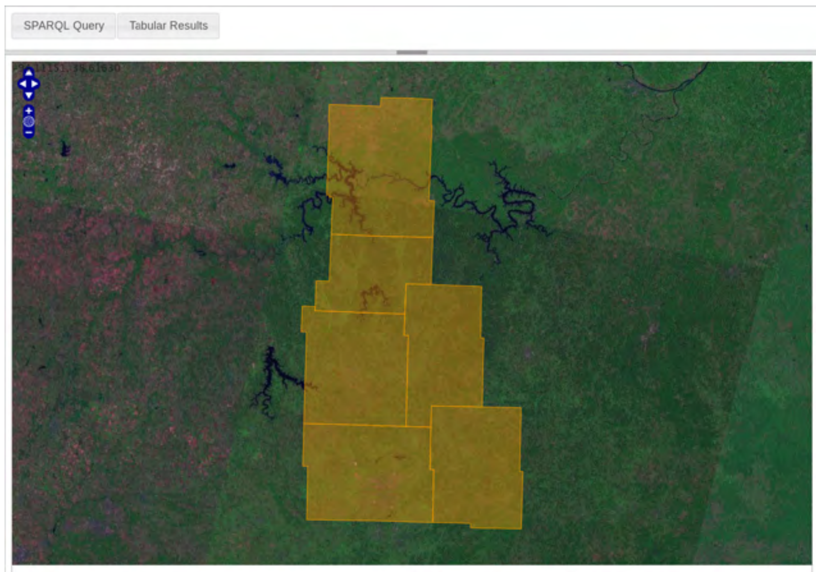
GeoSPARQL Result



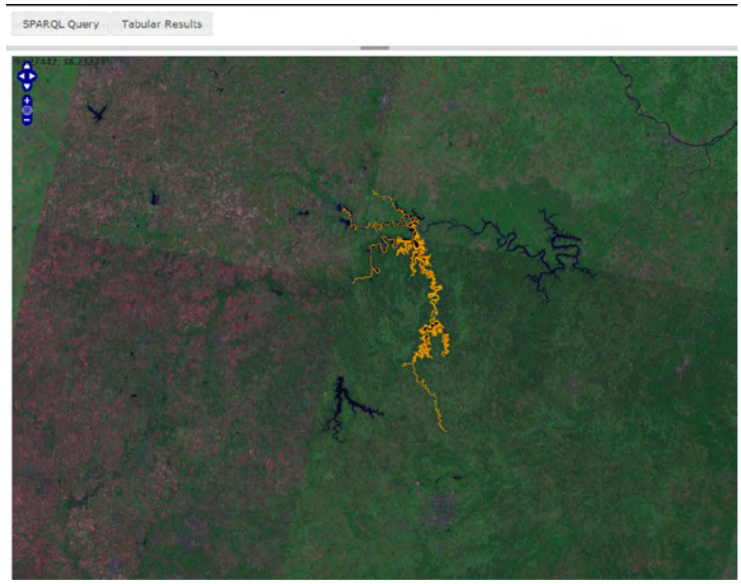
Questions?

FILTER Statements

- Graph patterns allow us to match RDF terms
- But can we remove matches from the results?
- http://usgs-ybother.srv.mst.edu/viz/

```
SELECT ?subject ?wkt
WHERE {
  ?subject rdf:type             nhd:area .
  ?subject nhd:areaSqKM ?a .
  ?subject geo:hasGeometry ?geo .
  ?geo       geo:asWKT ?wkt .
   FILTER(?a > 1.0)
}
```

- The FILTER statement restricts matches to those that satisfy the enclosed expression.




```
SELECT ?subject ?wkt
WHERE {
  ?subject rdf:type nhd:area .
  ?subject nhd:areaSqKM ?a .
  ?subject geo:hasGeometry ?geo .
  ?geo       geo:asWKT ?wkt .
   FILTER(?a > 1.0)
}
```

Try the same query with FILTER(?a > 10.0)

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FILTER statements

The GeoSPARQL standard defines vocabulary for topographical relations.

http://usgs-ybother.srv.mst.edu/viz/

```
SELECT ?wkt
WHERE {
  ?feature rdf:type     gu:countyOrEquivalent .
  ?feature rdfs:label   "Polk" .
  ?feature geo:hasGeometry ?g .
  ?g       geo:asWKT     ?county_wkt .

  ?flowline rdf:type nhd:flowline .
  ?flowline  geo:hasGeometry ?g2 .
  ?g2       geo:asWKT       ?wkt .
  FILTER(geof:sfContains(?county_wkt, ?wkt))
}
```

USGS

Federated Queries

With RDF you are not limited to querying the data in your own triplestore

Federated SPARQL queries tell a triplestore to query other servers over a network

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Federated Query

- http://usgs-ybother.srv.mst.edu/viz

```
SELECT ?picture ?wkt
WHERE {
  ?feature rdfs:label "Pomme de Terre Lake" .
  ?feature geo:hasGeometry ?g .
  ?g geo:asWKT ?wkt .

  SERVICE <http://dbpedia.org/sparql> {
  GRAPH <http://dbpedia.org> {
   ?dbfeature rdfs:label "Pomme de Terre Lake"@en .
   ?dbfeature rdf:type category:ReservoirsInMissouri .
   ?dbfeature foaf:depiction ?picture .
  }
  }
}
```

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Federated Query

```
SELECT ?picture ?wkt
WHERE {
  ?feature rdfs:label “Pomme de Terre Lake” .
  ?feature geo:hasGeometry ?g .
  ?g geo:asWKT ?wkt .

  SERVICE <http://dbpedia.org/sparql> {
  GRAPH <http://dbpedia.org> {
   ?dbfeature rdfs:label “Pomme de Terre
Lake”@en .
   ?dbfeature rdf:type
category:ReservoirsInMissouri .
   ?dbfeature foaf:depiction ?picture .
  }
  }
}
```

USGS

Questions?

USGS

The SOCoP Open Ontology Repository (OOR)

In this session we will demonstrate the use of a geospatial open ontology repository (OOR). The OOR was developed by the Spatial Ontology Community of Practice (SOCoP, *www.socop.org*) to help interdisciplinary conversations and collaboration between geoscientists and ontologists. We will illustrate searching and browsing geospatial ontologies (such as GeoSPARQL), how to map terms in different ontologies, how to visualize stored ontologies, and how to add an ontology to the repository. We will discuss plans for federation with other repositories and its interoperation with SPARQL endpoints.

Meteor Crater Ontology

```
@prefix :        <http://cegis.usgs.gov/Ontology/Instances#>.
@prefix geo:     <http://www.opengis.net/def/geosparql/>.
@prefix ogc:     <http://www.opengis.net/>.
@prefix owl:     <http://www.w3.org/2002/07/owl#>.
@prefix rdf:     <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix xml:     <http://www.w3.org/XML/1998/namespace>.
@prefix xsd:     <http://www.w3.org/2001/XMLSchema#>.
@prefix rdfs:    <http://www.w3.org/2000/01/rdf-schema#>.
@prefix usgs:    <http://cegis.usgs.gov/Ontology/>.
@prefix dbpedia: <http://dbpedia.org/ontology/>.
@prefix dcterms: <http://purl.org/dc/terms/>.
@prefix gn:      <http://www.geonames.org/ontology#>.
@prefix usgsgeo: <http://cegis.usgs.gov.Ontology/geometry/>.

<http://cegis.usgs.gov/Ontology/Instances>
      rdf:type owl:Ontology.

#################################################################
#
#    Annotation properties
#
#################################################################

dcterms:description
      rdf:type owl:AnnotationProperty.

dcterms:identifier
      rdf:type owl:AnnotationProperty.

geo:asWKT
      rdf:type owl:AnnotationProperty.

geo:hasGeometry
      rdf:type owl:AnnotationProperty.

#################################################################
#
#    Data Properties
#
#################################################################

usgsgeo:hasUTM
      rdf:type owl:DatatypeProperty.
```

```
dbpedia:MaximumElevation
      rdf:type owl:DatatypeProperty.

dbpedia:MaximumDepth
      rdf:type owl:DatatypeProperty.

usgsgeo:hasInnerDiameter
      rdf:type owl:DatatypeProperty.

dbpedia:MinimumElevation
      rdf:type owl:DatatypeProperty.

usgsgeo:hasPLSS
      rdf:type owl:DatatypeProperty.

usgsgeo:hasMBR
      rdf:type owl:DatatypeProperty.

usgsgeo:hasWidth
      rdf:type owl:DatatypeProperty.

usgsgeo:hasOuterDiameter
      rdf:type owl:DatatypeProperty.

usgs:hasElevation
      rdf:type owl:DatatypeProperty.

#################################################################
#
#    Object Properties
#
#################################################################

usgs:hasVerticalControlAccuracy
      rdf:type owl:ObjectProperty.

usgs:hasHorizontalControlAccuracy
      rdf:type owl:ObjectProperty.

usgs:hasMonument
      rdf:type owl:ObjectProperty.

usgs:hasName
      rdf:type owl:ObjectProperty.

usgs:hasRelationshipToSurface
      rdf:type owl:ObjectProperty.

usgsgeo:hasShape
      rdf:type owl:ObjectProperty.

usgs:hasOperationalStatus
      rdf:type owl:ObjectProperty.

usgs:hasProduct
      rdf:type owl:ObjectProperty.
```

```
gn:nearbyFeatures
      rdf:type owl:ObjectProperty.

gn:locatedIn
      rdf:type owl:ObjectProperty.

#################################################################
#
#    Classes
#
#################################################################

usgs:Building
      rdf:type owl:Class.

usgs:ControlStation
      rdf:type owl:Class.

usgs:MeteoricCrater
      rdf:type owl:Class.

usgs:Road
      rdf:type owl:Class.

usgs:Well
      rdf:type owl:Class.

usgs:Quarry
      rdf:type owl:Class.

geo:Geometry
      rdf:type owl:Class.

usgs:MineShaft
      rdf:type owl:Class.

#################################################################
#
#    Individuals
#
#################################################################

:7945
      rdf:type usgs:MeteoricCrater,
               owl:NamedIndividual;
      dcterms:identifier “7945”^^xsd:string;
      rdfs:comment “A meteor crater”^^xsd:string;
      dcterms:description “Circular-shaped depression on the surface of the
land caused by the impact of a meteorite”^^xsd:string;
      rdfs:label “Meteor Crater”^^xsd:string;
      usgs:hasName usgs:CharacterIdentifier;
      gn:nearbyFeatures :8763,
                        :5723,
                        :5123,
                        :e5706,
                        :1649,
```

```
                    :1652,
                    :3876,
                    :9763,
                    :1552;
      geo:hasGeometry :7945geo.

:3876
      rdf:type usgs:Road,
                owl:NamedIndividual;
      usgs:hasName usgs:CharacterIdentifier;
      rdfs:label “Crater Road”^^xsd:string;
      geo:hasGeometry :3876geo.

:8763
      rdf:type usgs:Building,
      owl:NamedIndividual;
      usgs:hasName usgs:CharacterIdentifier;
      rdfs:label “Meteor Crater Museum”^^xsd:string;
      geo:hasGeometry :8763geo.

:1649
      rdf:type usgs:Quarry,
               owl:NamedIndividual;
      usgs:hasProduct usgs:Sand;
      usgs:hasName usgs:unknown;
      usgs:hasOperationalStatus usgs:unknown;
      geo:hasGeometry :1649geo.

:1652
      rdf:type usgs:Quarry,
               owl:NamedIndividual;
      usgs:hasProduct usgs:Sand;
      usgs:hasOperationalStatus usgs:unknown;
      usgs:hasName usgs:unknown;
      geo:hasGeometry :1652geo.

:9763
      rdf:type usgs:Well,
               owl:NamedIndividual;
      usgs:hasProduct usgs:water;
      usgs:hasOperationalStatus usgs:Operational;
      usgs:hasName usgs:unknown;
      geo:hasGeometry :9863geo.

:5123
      rdf:type usgs:ControlStation,
               owl:NamedIndividual;
      gn:locatedIn :7945;
      usgs:hasElevation “5123 ft.”;
      usgs:hasName usgs:CharacterIdentifier;
      rdfs:label “USGS Benchmark 5123”^^xsd:string;
      usgs:hasVerticalControlAccuracy usgs:3rdOrderOrBetter;
      usgs:hasRelationshipToSurface usgs:ExposedAtSurface;
      usgs:hasMonument usgs:Tablet;
      geo:hasGeometry :5123geo.
```

```
:5723
      rdf:type usgs:ControlStation,
               owl:NamedIndividual;
      usgs:hasElevation “5723 ft.”;
      usgs:hasName usgs:CharacterIdentifier;
      rdfs:label “USGS Benchamrk BM5723”^^xsd:string;
      usgs:hasHorizontalControlAccuracy usgs:3rdOrderOrBetter;
      usgs:hasRelationshipToSurface usgs:ExposedAtSurface;
      usgs:hasMonument usgs:NoTablet;
      geo:hasGeometry :5723geo.

:e5706
      rdf:type usgs:ControlStation,
               owl:NamedIndividual;
      usgs:hasElevation “5706 ft.”;
      usgs:hasName usgs:CharacterIdentifier;
      rdfs:label “USGS Benchmark BM East 5706”^^xsd:string;
      usgs:hasHorizontalControlAccuracy usgs:3rdOrderOrBetter;
      usgs:hasRelationshipToSurface usgs:ExposedAtSurface;
      usgs:hasMonument usgs:NoTablet;
      geo:hasGeometry :e5706geo.

:1497
      rdf:type usgs:MineShaft,
               owl:NamedIndividual;
      gn:locatedIn :7945;
      usgs:hasOperationalStatus usgs:Abandoned;
      usgs:hasName usgs:unknown;
      geo:hasGeometry :1497geo.

:1523
      rdf:type usgs:MineShaft,
               owl:NamedIndividual;
      gn:locatedIn :7945;
      usgs:hasOperationalStatus usgs:Abandoned;
      usgs:hasName usgs:unknown;
      geo:hasGeometry :1523geo.

:1529
      rdf:type usgs:MineShaft,
               owl:NamedIndividual;
      gn:locatedIn :7945;
      usgs:hasOperationalStatus usgs:Abandoned;
      usgs:hasName usgs:unknown;
      geo:hasGeometry :1529geo.

:1546
      rdf:type usgs:MineShaft,
               owl:NamedIndividual;
      gn:locatedIn :7945;
      usgs:hasOperationalStatus usgs:Abandoned;
      usgs:hasName usgs:unknown;
      geo:hasGeometry :1546geo.

:1552
      rdf:type usgs:MineShaft,
```

```
                owl:NamedIndividual;
        usgs:hasOperationalStatus usgs:Abandoned;
        usgs:hasName usgs:unknown;
        geo:hasGeometry :1552geo.

   :7945geo
        rdf:type geo:Geometry,
                owl:NamedIndividual;
        usgsgeo:hasWidth “0.2Km”;
        usgsgeo:hasOuterDiameter “1250 m”;
        dbpedia:MinimumElevation “5123 ft.”;
        dbpedia:MaximumElevation “5723 ft.”;
        dbpedia:MaximumDepth “600 ft.”;
        usgsgeo:hasInnerDiameter “833 m”;
        usgsgeo:hasShape usgsgeo:Circular;
        usgsgeo:hasUTM “E 497959.94m N 3876020.68m Zone12”;
        usgsgeo:hasMBR “Max E 489536.79m Min E 497317.62m Max N 3876632.29m Min
N 3875479.58m”;
        usgsgeo:hasPLSS “T 19 N, R 12 1/2 E, Section 13 and 24”;
        geo:asWKT “POINT -111.02236372362403 35.02684835590344”.

   :1649geo
        rdf:type geo:Geometry,
                owl:NamedIndividual;
        geo:asWKT “POINT -111.02334 35.02136”.

   :1652geo
        rdf:type geo:Geometry,
                owl:NamedIndividual;
        geo:asWKT “POINT -111.02600 35.02056”.

   :3876geo
        rdf:type geo:Geometry,
                owl:NamedIndividual;
        geo:asWKT “”.

   :5123geo
        rdf:type geo:Geometry,
                owl:NamedIndividual;
        geo:asWKT “POINT -111.02314 35.02808”.


   :5723geo
        rdf:type geo:Geometry,
                owl:NamedIndividual;
        geo:asWKT “POINT -111.02913 35.02945”.

   :8763geo
        rdf:type geo:Geometry,
                owl:NamedIndividual;
        geo:asWKT “POINT -111.02149 35.03270”.

   :9863geo
        rdf:type geo:Geometry,
                owl:NamedIndividual;
        geo:asWKT “POINT -111.02328 35.03655”.
```

```
:e5706geo
      rdf:type geo:Geometry,
               owl:NamedIndividual;
      geo:asWKT "POINT -111.01656 35.02470".

:1497geo
      rdf:type geo:Geometry,
               owl:NamedIndividual;
      geo:asWKT "POINT (-111.02309 35.02726)".

:1523geo
      rdf:type geo:Geometry,
               owl:NamedIndividual;
      geo:asWKT "POINT (-111.02271 35.02750)".

:1529geo
      rdf:type geo:Geometry,
               owl:NamedIndividual;
      geo:asWKT "POINT (-111.02122 35.02787)".

:1546geo
      rdf:type geo:Geometry,
               owl:NamedIndividual;
      geo:asWKT "POINT (-111.02225 35.02692)".

:1552geo
      rdf:type geo:Geometry,
               owl:NamedIndividual;
      geo:asWKT "POINT (-111.02242 35.01962)".

usgs:3rdOrderOrBetter
      rdf:type owl:NamedIndividual.

usgs:CharacterIdentifier
      rdf:type owl:NamedIndividual.

usgs:ExposedAtSurface
      rdf:type owl:NamedIndividual.

usgs:Tablet
      rdf:type owl:NamedIndividual.

usgs:Sand
      rdf:type owl:NamedIndividual.

usgs:Abandoned
      rdf:type owl:NamedIndividual.

usgs:Water
      rdf:type owl:NamedIndividual.

usgs:Unknown
      rdf:type owl:NamedIndividual.

usgs:NoTablet
      rdf:type owl:NamedIndividual.
```

Internet Resources

Semantic Web. World Wide Web Consortium (W3C).
http://www.w3.org/standards/semanticweb/

Standards and Shared Vocabularies

Basic Geo (WGS84 lat/long) Vocabulary
http://www.w3.org/2003/01/geo/.

CIDOC—Conceptual Reference Model
http://www.cidoc-crm.org/index.html

DOLCE—Descriptive Ontology for Linguistic and Cognitive Engineering
http://www.loa.istc.cnr.it/DOLCE.html

GeoSPARQL Users Guide 2012
http://ontolog.cim3.net/cgi-bin/wiki.pl?InteropProject/Geosparql_USER_GUIDE_2012

Glossary of Semantic Web Terms
https://wiki.base22.com/display/btg/Glossary+of+Semantic+Web+Terms#GlossaryofSemanticWebTerms-T

Publishing Vocabularies
http://www.w3.org/TR/swbp-vocab-pub/

Resource Description Framework (RDF) Primer
http://www.w3.org/TR/2004/REC-rdf-primer-20040210/

SPARQL Protocol and RDF Query Language (SPARQL)
http://www.w3.org/TR/rdf-sparql-query/.

Turtle—Terse RDF Triple Language
http://www.w3.org/TR/2011/WD-turtle-20110809/

WordNet—WordNet, A lexical database for English. Princeton University.
http://wordnet.princeton.edu/.

Software and Technology Products

AllegroGraph RDFStore
http://www.franz.com/agraph/

Jena
http://openjena.org/wiki/TDB

Oracle
http://www.oracle.com/technetwork/database/options/semantic-tech/index.html

Parliament
http://parliament.semwebcentral.org/

Protégé Ontology Editor
http://protege.stanford.edu/

Semantic Web Development Tools
http://www.w3.org/2001/sw/wiki/Tools

SemWebCentral
http://www.semwebcentral.org/

TopBraid Composer
http://www.topquadrant.com/products/TB_Composer.html

Ontologies and Linked Data

OpenCyc
http://sw.opencyc.org/

DBpedia
http://dbpedia.org/About

e-Government
http://oegov.org/

Freebase
http://www.freebase.com/

Linked Open Data Initiative
http://linkeddata.org/

LinkedGeoData
http://linkedgeodata.org/About

NeoGeo Vocabulary
http://geovocab.org/doc/survey.html

OntologyDesignPatterns.org
http://ontologydesignpatterns.org/wiki/Main_Page.

Open Ontology Repository Initiative
http://OpenOntologyRepository.org

Semantic MediaWiki
http://mapping.referata.com/wiki/Semantic_Maps

Semantic Web
http://semanticweb.org/wiki/Main_Page

Semantic Web for Earth and Environmental Terminology (SWEET) Ontologies
http://sweet.jpl.nasa.gov/

U.S. Geological Survey Triple Data
http://usgs-ybother.srv.mst.edu:8890/parliament

Online Tutorials

Information Semantics 101: Semantics, Semantic Models, Ontologies, Knowledge Representation, and the Semantic Web
http://c4i.gmu.edu/OIC09/workshop.php

Introduction to Ontologies and Semantic Web [On-line]
http://www.obitko.com/tutorials/ontologies-semantic-web/

Introduction to Ontologies and Semantic Technologies
http://stids.c4i.gmu.edu/STIDS2011/agenda2011.php

SPARQL By Example, A Tutorial
http://www.cambridgesemantics.com/semantic-university/sparql-by-example

Ontology Communities, Professional Organizations, and Workshop Events

International Association for Ontology and its Applications (IOAO)
http://www.iaoa.org/

The 11th International Semantic Web Conference
http://iswc2012.semanticweb.org/

Terra Cognita 2011 Workshop
http://asio.bbn.com/terracognita2011

Semantic Technology for Intelligence, Defense, and Security (STIDS)
http://stids.c4i.gmu.edu/

Federation of Earth Science Information Partners (ESIP) Semantic Web Cluster
http://wiki.esipfed.org/index.php/Semantic_Web

Spatial Ontology Community of Practice (SOCoP)
http://www.socop.org/

Ontolog collaborative work environment
http://ontolog.cim3.net/

Research Groups and Programs of Study

GeoLinkedData.es, Ontology Engineering Group
http://geo.linkeddata.es/web/guest

Laboratory for Applied Ontology
http://www.loa.istc.cnr.it/

Tetherless World Constellation
http://tw.rpi.edu/web/TWC

Muenster Semantic Interoperability Lab
http://musil.uni-muenster.de/

Blogs

Data.gov/semantic
http://www.data.gov/communities/node/116/blogs

John Goodwin
http://www.johngoodwin.me.uk/

Suggested Literature

Semantic and Geospatial Semantic Web

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