



Semantic Web and Big Data – Opportunities and Challenges

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- **Big Data**, Linked Data, Semantic Web
- The Big Data Added Value Pipeline
- Fragments



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Gartner: Big Data Will Generate 6 Million U.S. Jobs by 2015



[Susan Hall](#) | [CHARTING YOUR IT CAREER](#) | 23 OCT, 2012

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Gartner predicts that 4.4 million IT **jobs will be created to support Big Data** by 2015, with 1.9 million of them to be in the United States.

In addition, every Big Data-related role in the United States will create employment for three people outside of IT, pushing the total to 6 million U.S. jobs, Peter Sondergaard, senior vice president at Gartner and global head of research, told those attending the Gartner Symposium/ITxpo. He said:

But there is a challenge. There is **not enough talent** in the industry. Our public and private education systems are failing us. Therefore, only one-third of the IT jobs will be filled. Data experts will be a scarce, valuable commodity," he said. "IT leaders will need immediate focus on how their organization develops and attracts the skills required. These jobs will be needed to grow your business. These jobs are the future of the new information economy.

Though I don't follow Sondergaard's math, we know there's a **shortage of analytics talent for Big Data and for engineering talent as well.**



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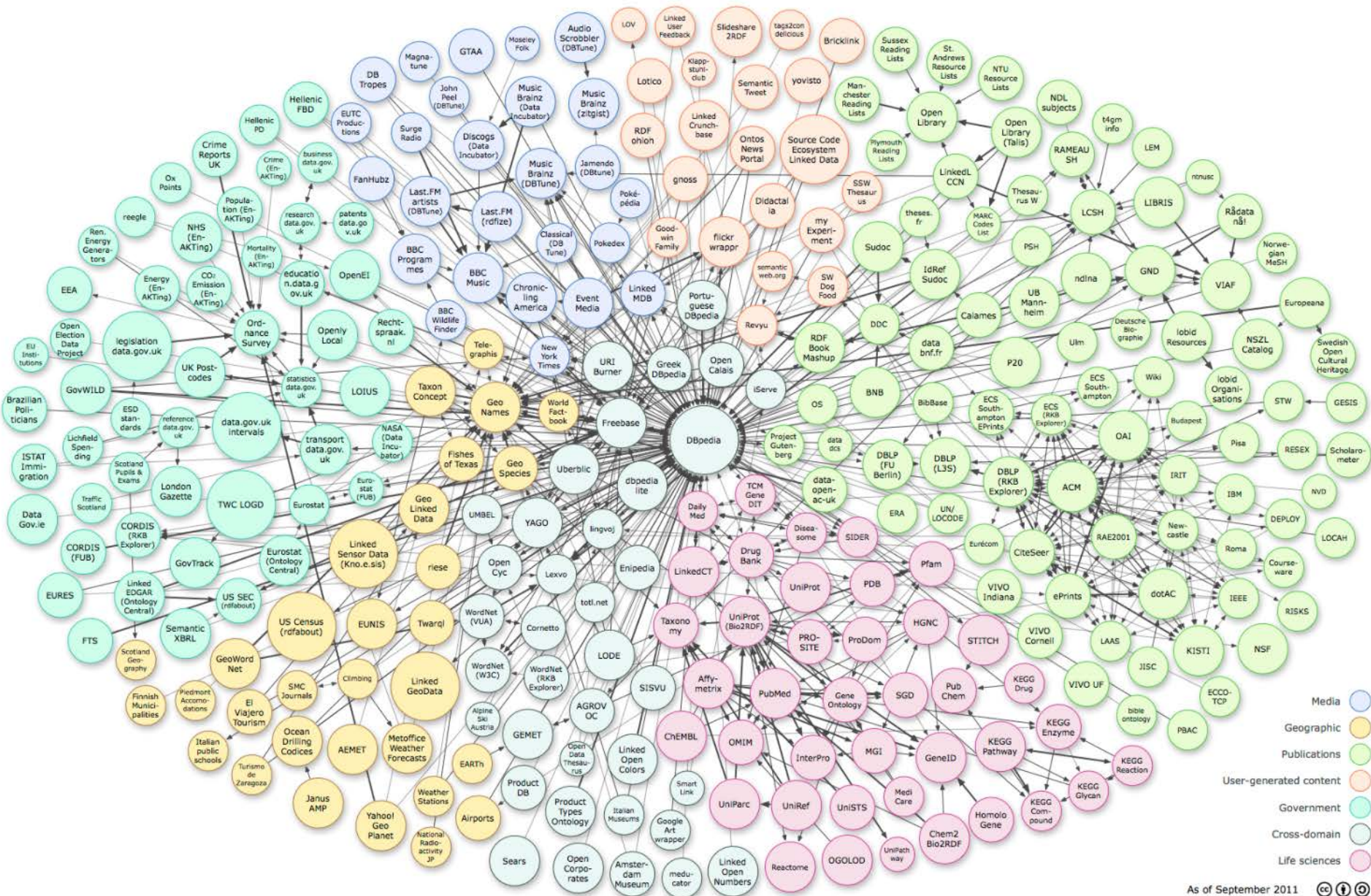
Big Data is characterized not only by the enormous volume or the velocity of its generation but also by the heterogeneity, diversity and complexity of the data.

Suzi Iacono, source: <http://community.topcoder.com/coeci/nitrd/>

- **volume**: the sheer size of the data
- **velocity**: new data is added at breathtaking speed
- **variety**: different formats and different perspectives
- (**value**: how useful is the data?)
- (**veracity**: how good/reliable is the data?)

- Big Data, **Linked Data**, Semantic Web
- The Big Data Added Value Pipeline
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Linked Data 2011



dbpedia-owl:thumbnail	<ul style="list-style-type: none">▪ http://upload.wikimedia.org/wikipedia/commons/thumb/6/62/Jrrt_lotr_cover_design.jpg/200px-Jrrt_lotr_cover_design.jpg
dbpedia-owl:wikiPageExternalLink	<ul style="list-style-type: none">▪ http://lotr.wikia.com▪ http://www.glyphweb.com/arda/▪ http://www.tolkienlibrary.com/▪ http://www.tolkien.co.uk/▪ http://www.houghtonmifflinbooks.com/features/lordoftheringstrilogy/
dbpprop:author	<ul style="list-style-type: none">▪ dbpedia:J._R._R._Tolkien
dbpprop:books	<ul style="list-style-type: none">▪ dbpedia:The_Two_Towers▪ dbpedia:The_Return_of_the_King▪ dbpedia:The_Fellowship_of_the_Ring▪ "Volumes:"
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dbpprop:expiry	<ul style="list-style-type: none">▪ 20 (xsd:integer)
dbpprop:genre	<ul style="list-style-type: none">▪ dbpedia:Adventure_novel▪ dbpedia:High_fantasy
dbpprop:hasPhotoCollection	<ul style="list-style-type: none">▪ http://www4.wiwiss.fu-berlin.de/flickwrappr/photos/The_Lord_of_the_Rings
dbpprop:imageCaption	<ul style="list-style-type: none">▪ Tolkien's own cover designs for the three volumes
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dbpprop:mediaType	<ul style="list-style-type: none">▪ Print
dbpprop:name	<ul style="list-style-type: none">▪ The Lord of the Rings
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dbpprop:wikiPageUsesTemplate	<ul style="list-style-type: none">▪ dbpedia:Template:Infobox_book_series▪ dbpedia:Template:Pp-vandalism
dcterms:subject	<ul style="list-style-type: none">▪ category:Monomyths▪ category:High_fantasy_novels▪ category:Middle-earth_books▪ category:British_fantasy_novels▪ category:Fantasy_books_by_series▪ category:1950s_fantasy_novels▪ category:Sequel_novels▪ category:The_Lord_of_the_Rings▪ category:English_novels

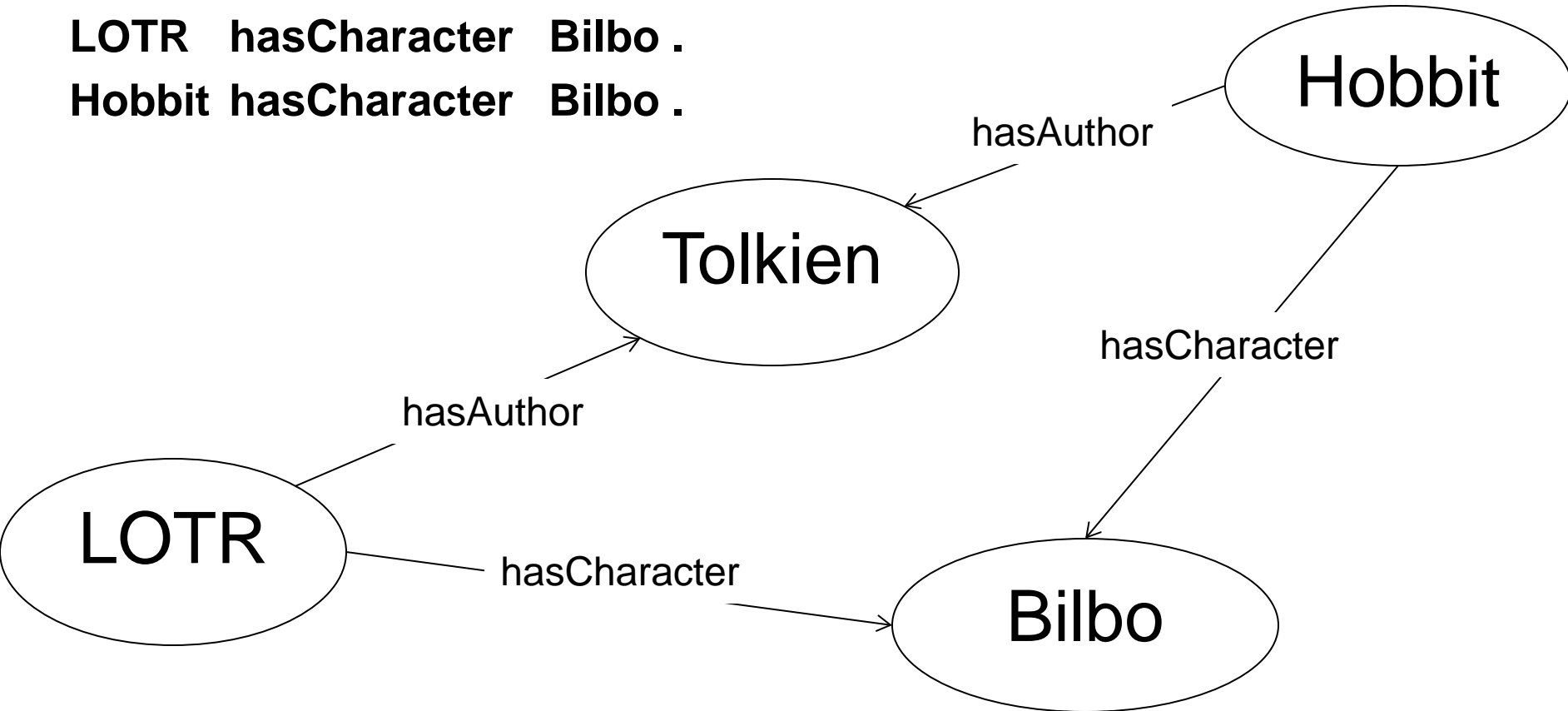
Information as RDF triples / graph

LOTR hasAuthor Tolkien .

Hobbit hasAuthor Tolkien .

LOTR hasCharacter Bilbo .

Hobbit hasCharacter Bilbo .



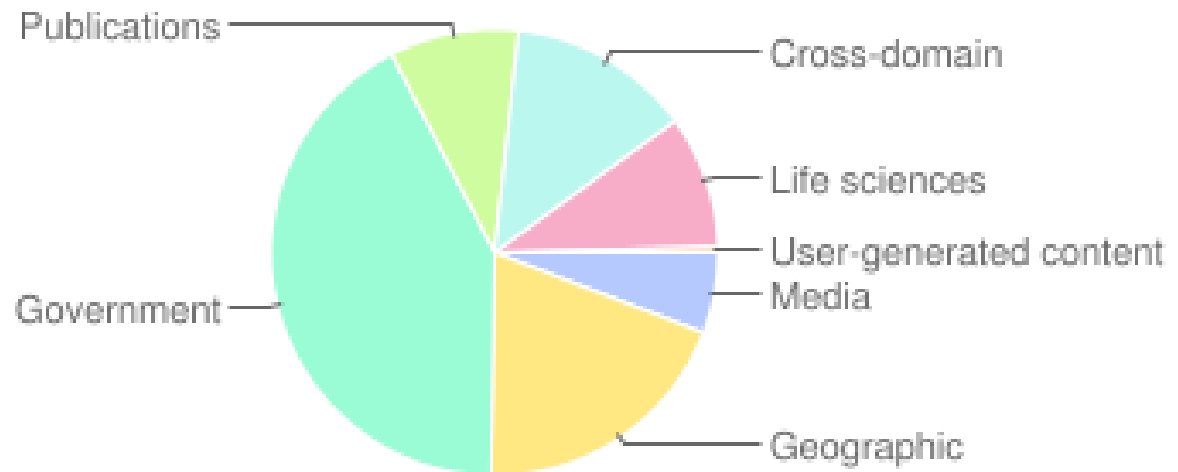
Number of Datasets

2011-09-19	295
2010-09-22	203
2009-07-14	95
2008-09-18	45
2007-10-08	25
2007-05-01	12

Number of triples (Sept 2011)

31,634,213,770

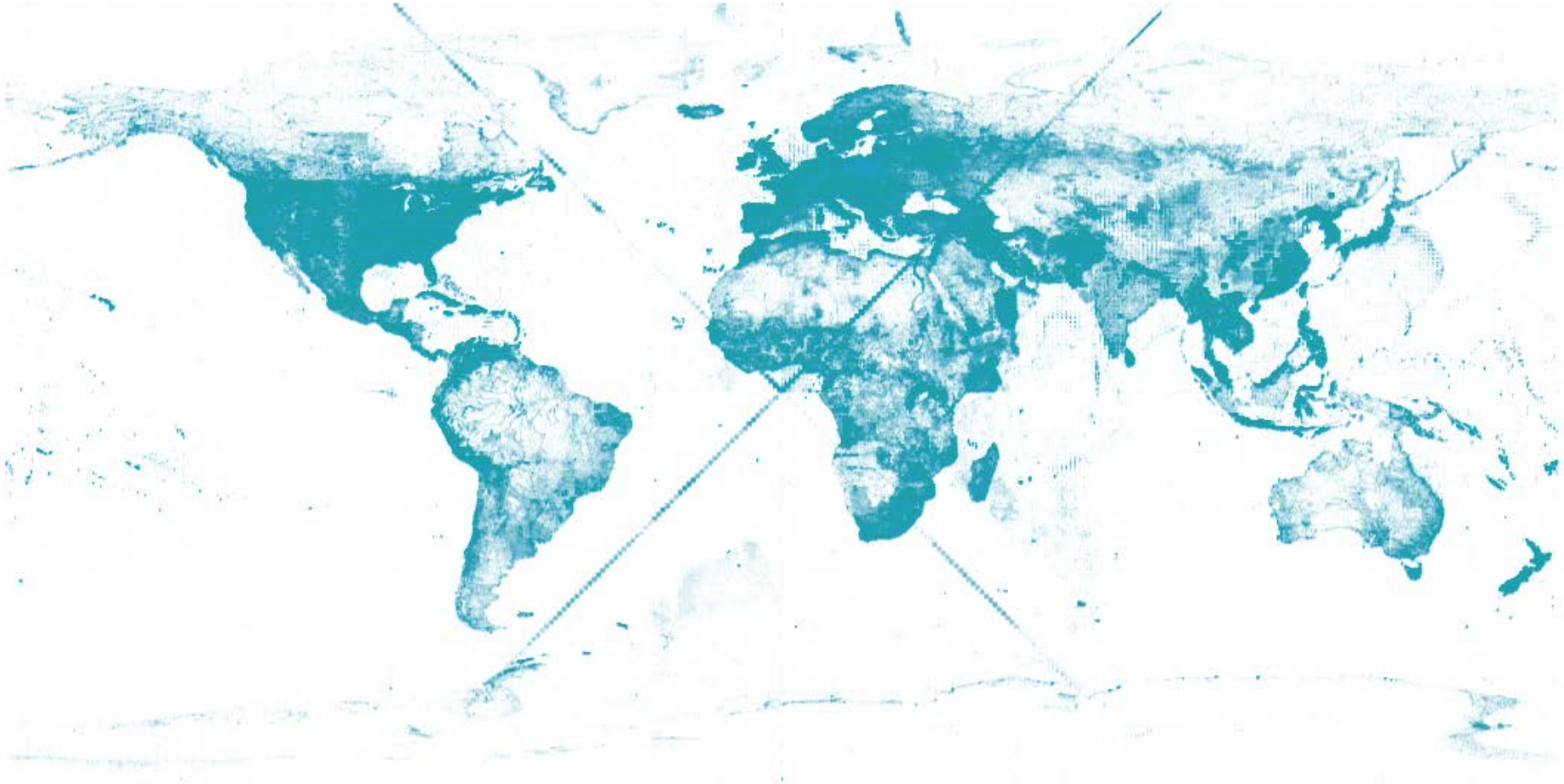
with 503,998,829 out-links



From <http://www4.wiwiss.fu-berlin.de/lodcloud/state/>

Geoindexed Linked Data – courtesy of Krzysztof Janowicz

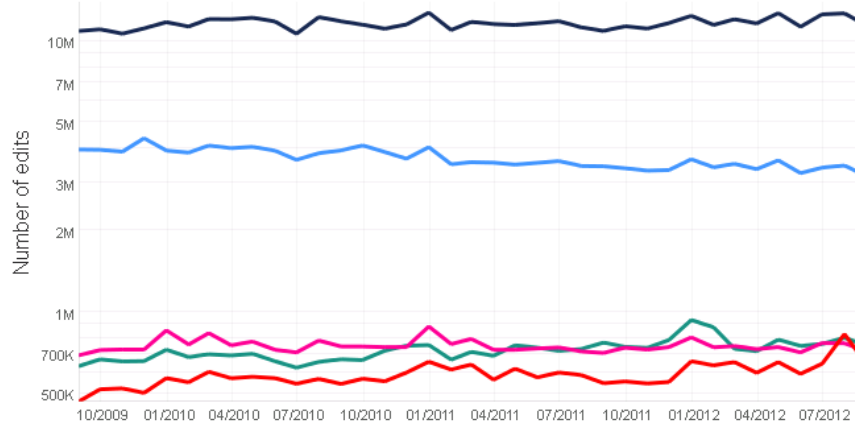
http://stko.geog.ucsb.edu/location_linked_data



11.39 Million

Sep 11 — Sep 12 4.64%
 Aug 12 — Sep 12 -9.85%

Wikipedia Edits per Month

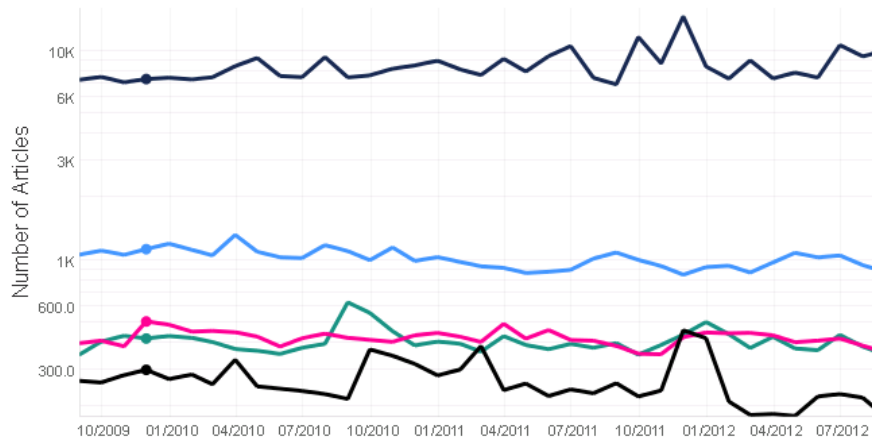


- Weather sensors
- Tweets
- Satellite images
- ...

10,028.00

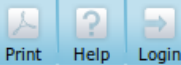
Sep 11 — Sep 12 45.19%
 Aug 12 — Sep 12 6.68%

New Wikipedia Articles per Day



Dec 2009:	
Total:	7.3K
English:	1.1K
French:	422.0
German:	509.0
Polish:	299.0

Copernicus lunar crater located on earth – courtesy of Krzysztof Janowicz http://stko.geog.ucsb.edu/location_linked_data (missing reference coordinate system)



Copernicus (lunar crater)

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[View](#) [Revisions](#)

Copernicus is a [lunar impact crater](#) named after the astronomer [Nicolaus Copernicus](#), located in eastern [Oceanus Procellarum](#). It is estimated to be about 800 million years old, and typifies craters that formed during the [Copernican period](#) in that it has a prominent [ray system](#).

Contents

- [Characteristics](#)
- [Names](#)
- [Satellite craters](#)
- [See also](#)
- [References](#)
- [External links](#)

Characteristics

Copernicus is visible using [binoculars](#), and is located slightly northwest of the center of the Moon's Earth-facing hemisphere. South of the crater is the [Mare Insularum](#), and to the south-south west is the crater [Reinhold](#). North of Copernicus are the [Montes Carpatus](#), which lie at the south edge of [Mare Imbrium](#). West of Copernicus is a group of dispersed lunar hills. Due to its relative youth, the crater has remained in a relatively pristine shape since it formed.

The circular rim has a discernible hexagonal form, with a [terraced](#) inner wall and a 30 km wide, sloping [rampart](#) that descends nearly a kilometer to the surrounding [mare](#). There are three distinct terraces visible, and arc-shaped [landslides](#) due to slumping of the inner wall as the crater debris subsided.

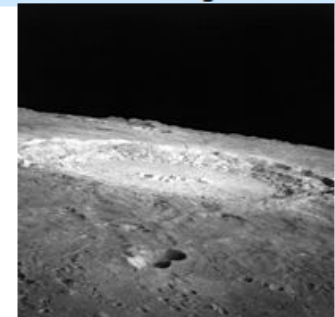
Most likely due to its recent formation, the crater floor has not been flooded

Location of Copernicus.

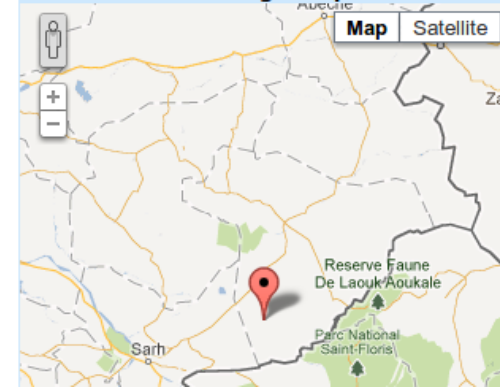


Location of Copernicus.

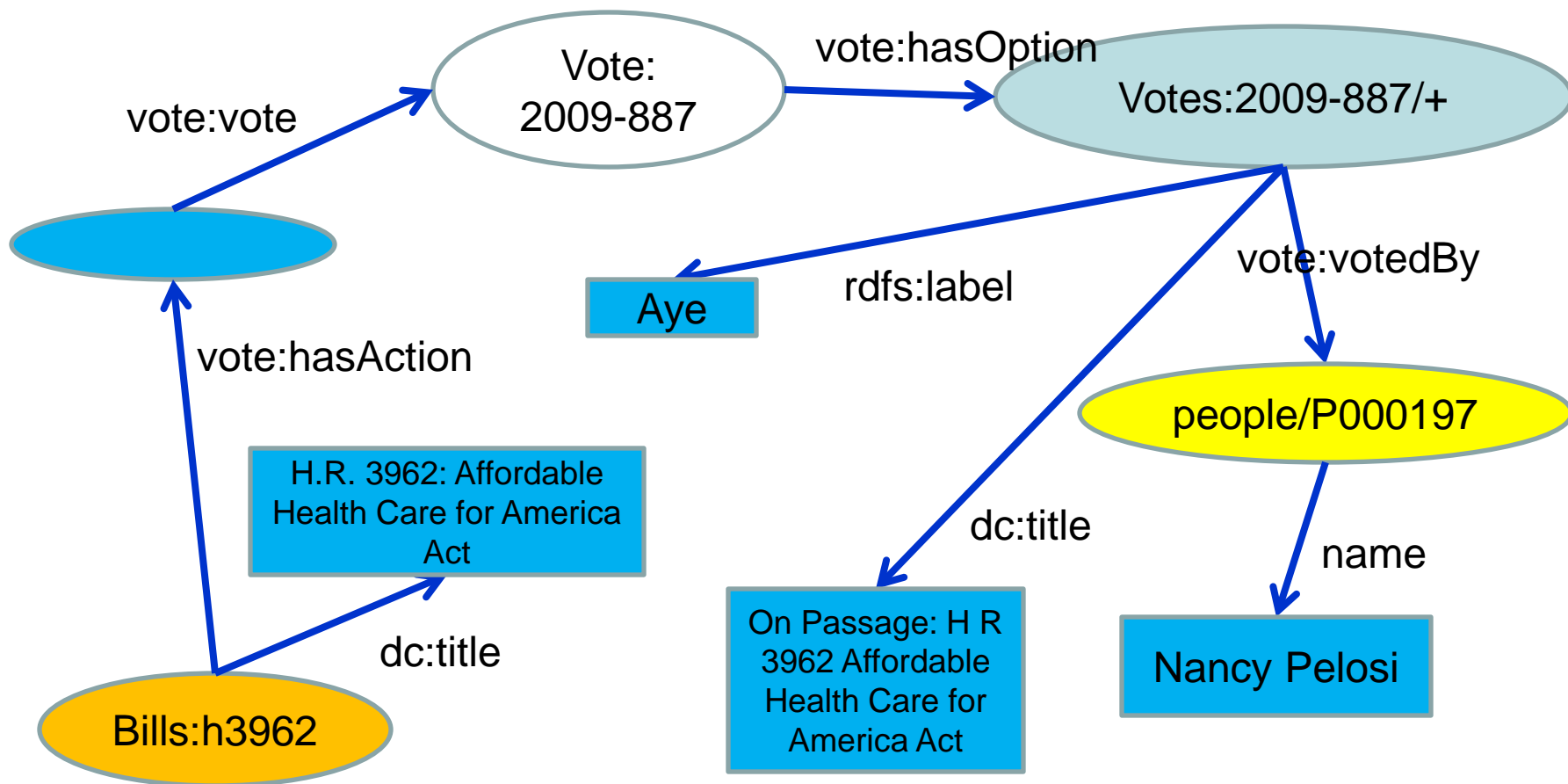
Image



Google Map

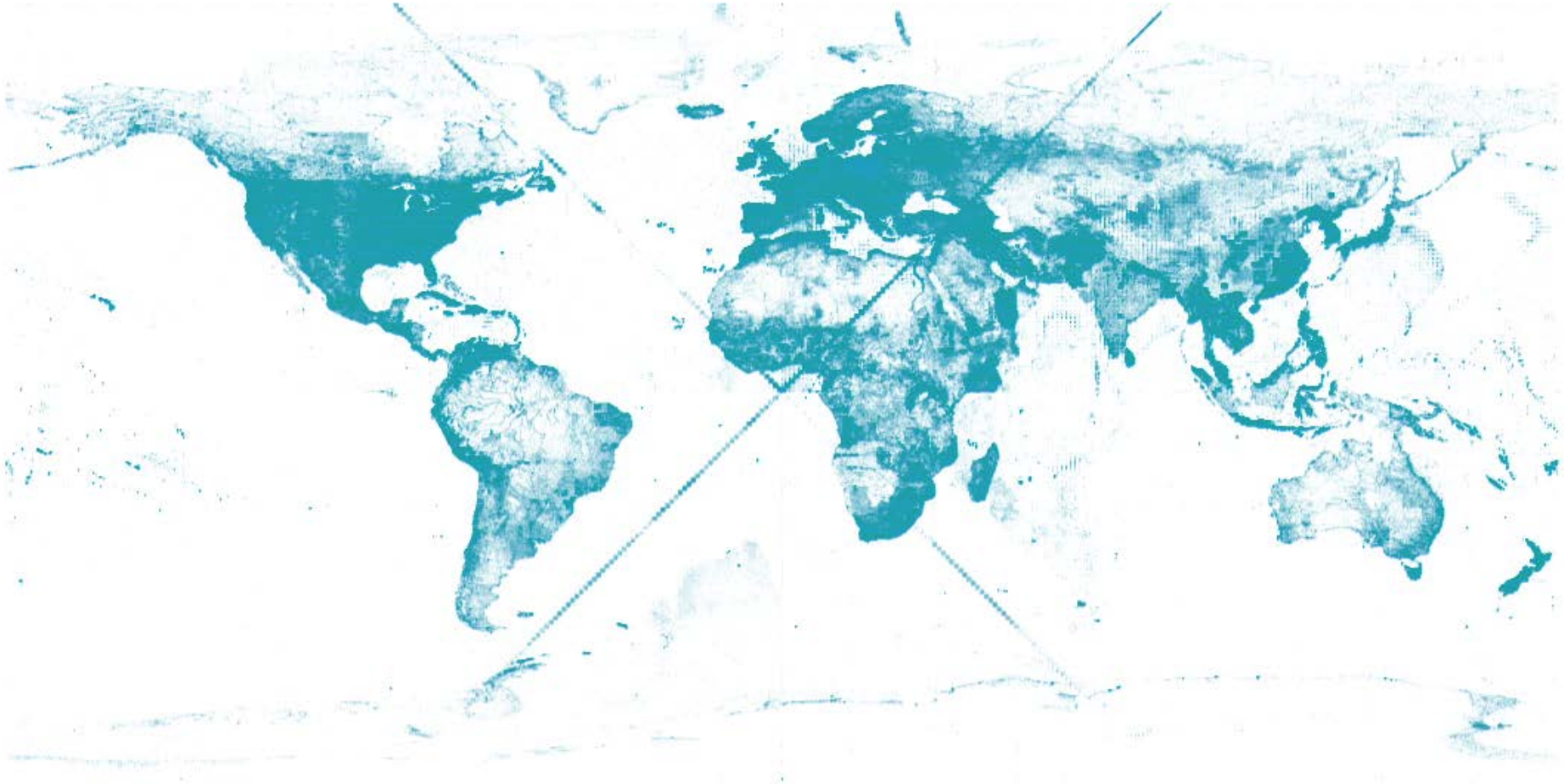


“Nancy Pelosi voted in favor of the Health Care Bill.”



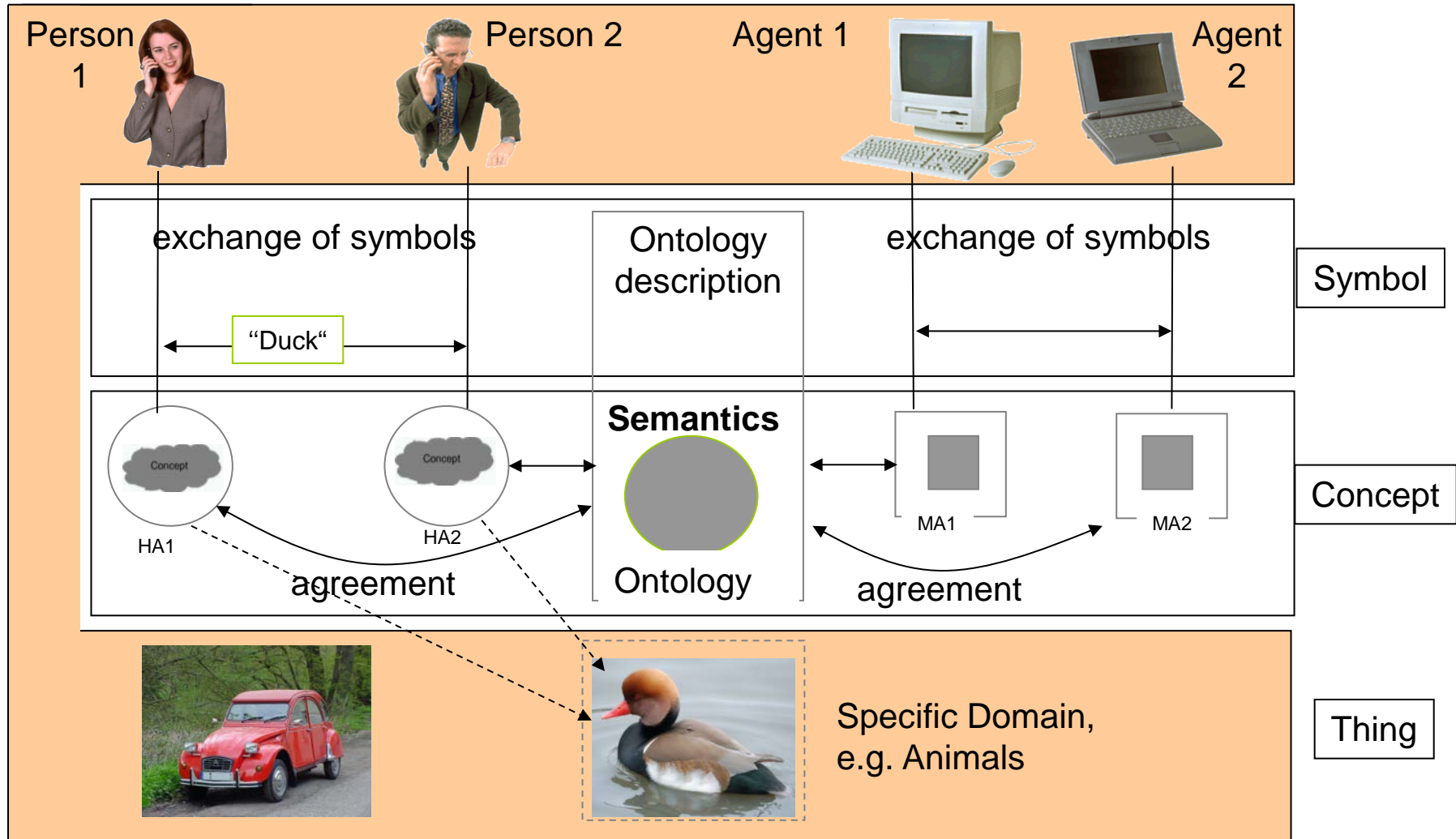
Geoindexed Linked Data – courtesy of Krzysztof Janowicz

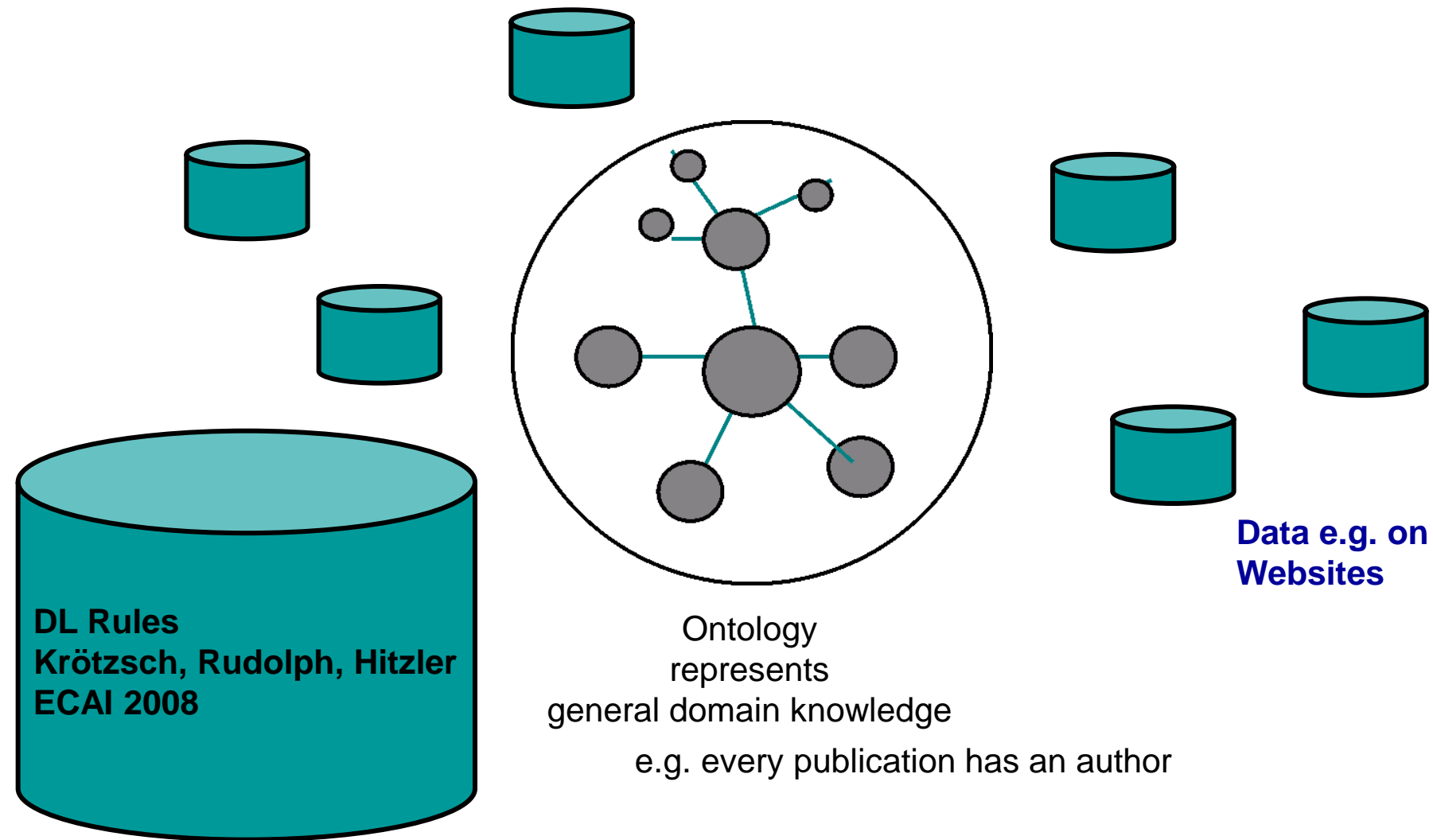
http://stko.geog.ucsb.edu/location_linked_data

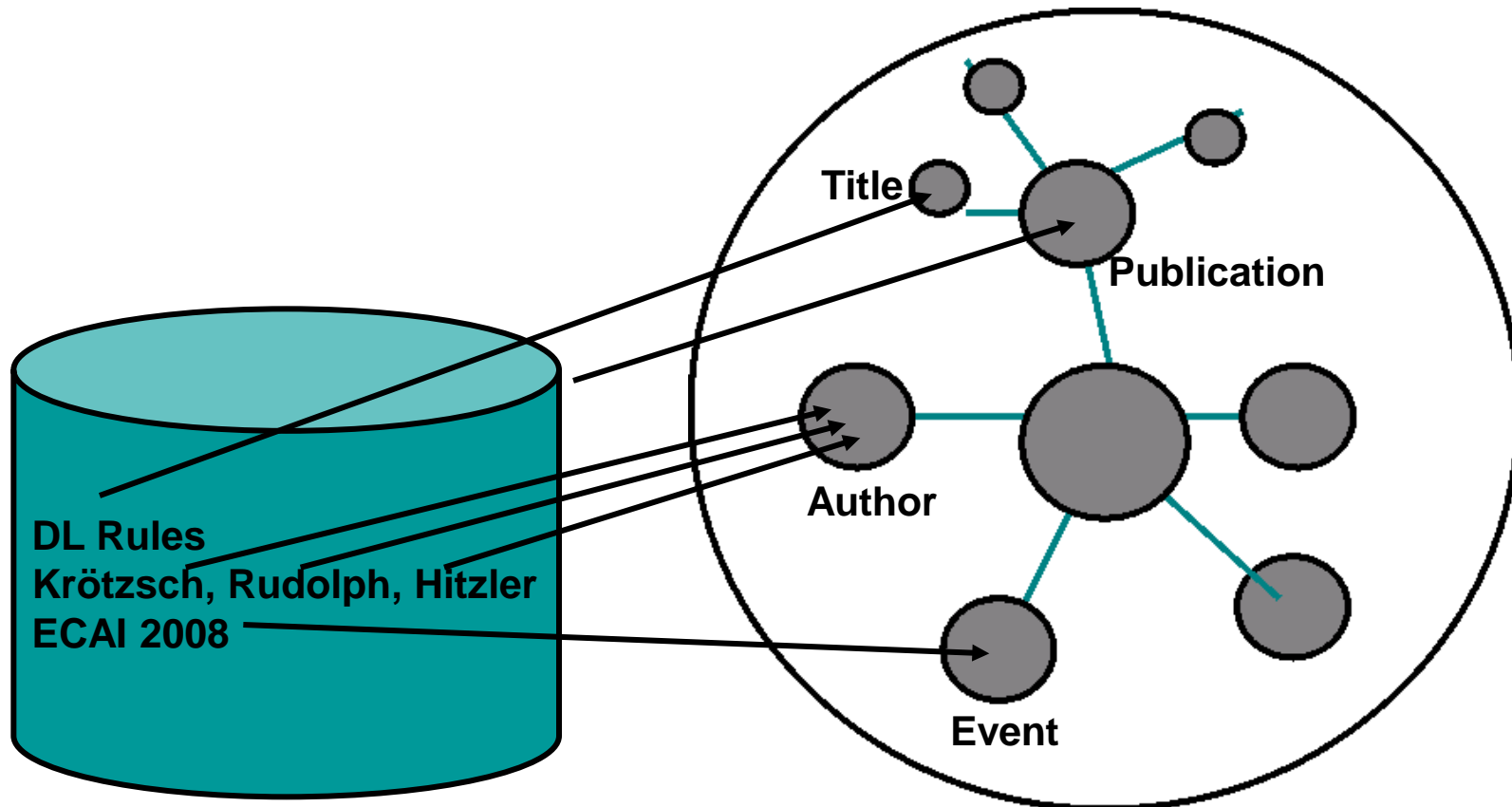


- **Big Data, Linked Data, **Semantic Web****
- **The Big Data Added Value Pipeline**
- **Fragments**

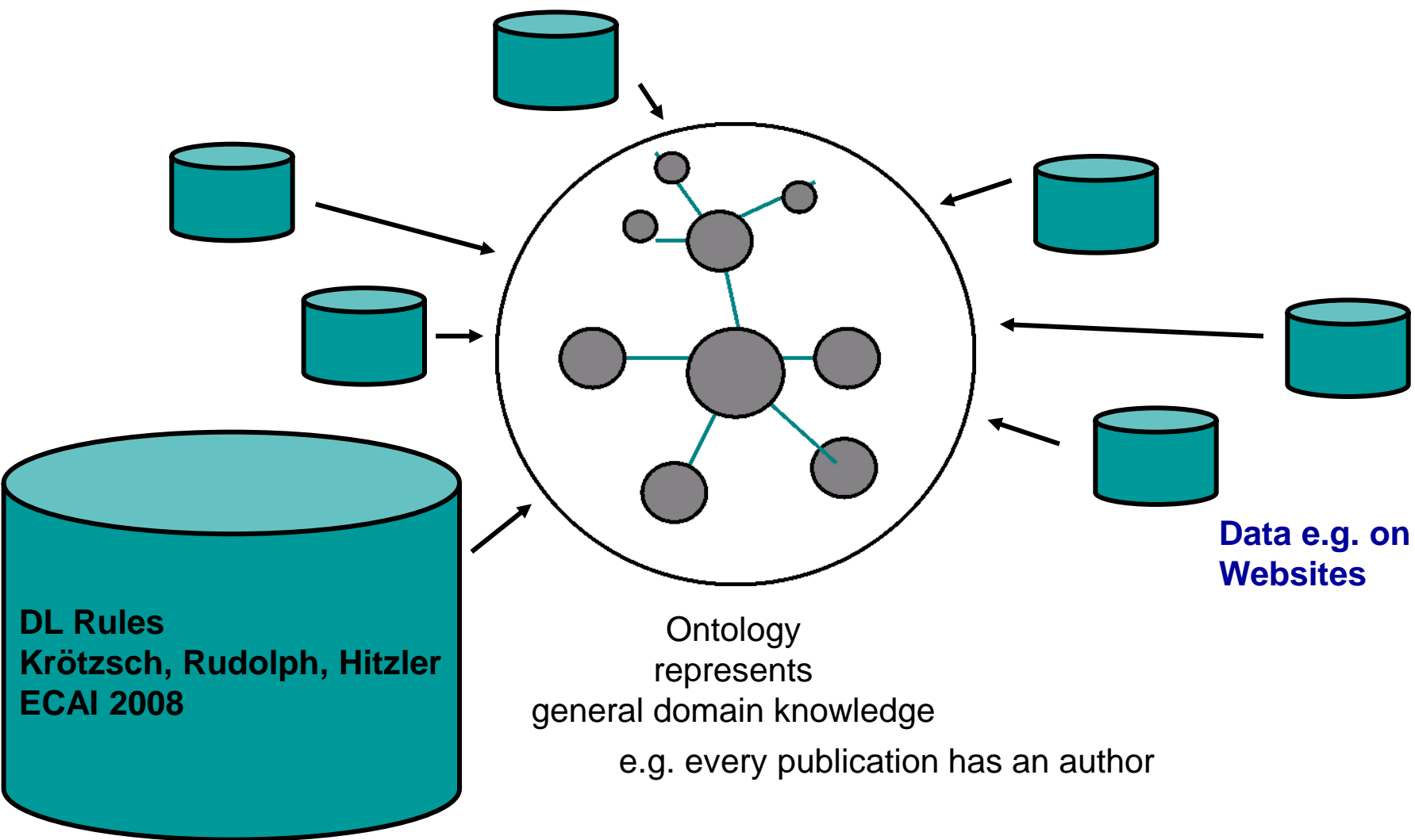
Basic Idea of the Semantic Web







e.g. every publication has an author



DL Rules
Krötzsch, Rudolph, Hitzler
ECAI 2008

Ontology
represents
general domain knowledge
e.g. every publication has an author

Data e.g. on
Websites

The Science Behind an Answer

Watson performs so fast that it can rival the greatest human contestants in understanding a Jeopardy! clue and arriving at a single, precise answer. The significance of this accomplishment can be difficult to comprehend.

[Watch the video](#) to see how the computing system designed to play Jeopardy! works.

- Possible Answers
- bake
 - balance
 - ban
 - bang
 - bare
 - bat
 - bathe
 - battle
 - be
 - beam
 - bear



The **first person mentioned by name** in 'The Man in the Iron Mask' is this **hero** of a French play by the **same author**.

The DeepQA hypothesis is that by complementing classic knowledge-based approaches with recent advances in NLP, Information Retrieval, and Machine Learning to interpret and reason over huge volumes of widely accessible naturally encoded knowledge (or "unstructured knowledge") we can build effective and adaptable open-domain QA systems. While they may not be able to formally prove an answer is correct in purely logical terms, they can build confidence based on a combination of reasoning methods that operate directly on a combination of the raw natural language, automatically extracted entities, relations and available structured and semi-structured knowledge available from for example the **Semantic Web**.

What is Watson?

Implications for analytics, system design and industry transformation >

Watson for a Smarter Planet™

- Join the conversation on IBM Watson Connect
- Watson - A System Designed for Answers
- Optimize Your Growing



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iPhone

iPad

iTunes

Support



iPhone

Features

Built-in Apps

From the App Store

iOS

iCloud

Tech Specs

Buy iPhone



Siri. Beta

Your wish is its command.

Siri on iPhone 4S lets you use your voice to send messages, schedule meetings, place phone calls, and more. Ask Siri to do things just the way you talk. Siri



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SEMANTIC TECH & BUSINESS CONFERENCE June 3-7, 2012 San Francisco
 presented by SemanticWeb.com and WebMediaBrands

Apple Buys Siri: Once Again The Back Story Is About Semantic Web

by Bernard Lunn on April 26, 2010 2:35 PM

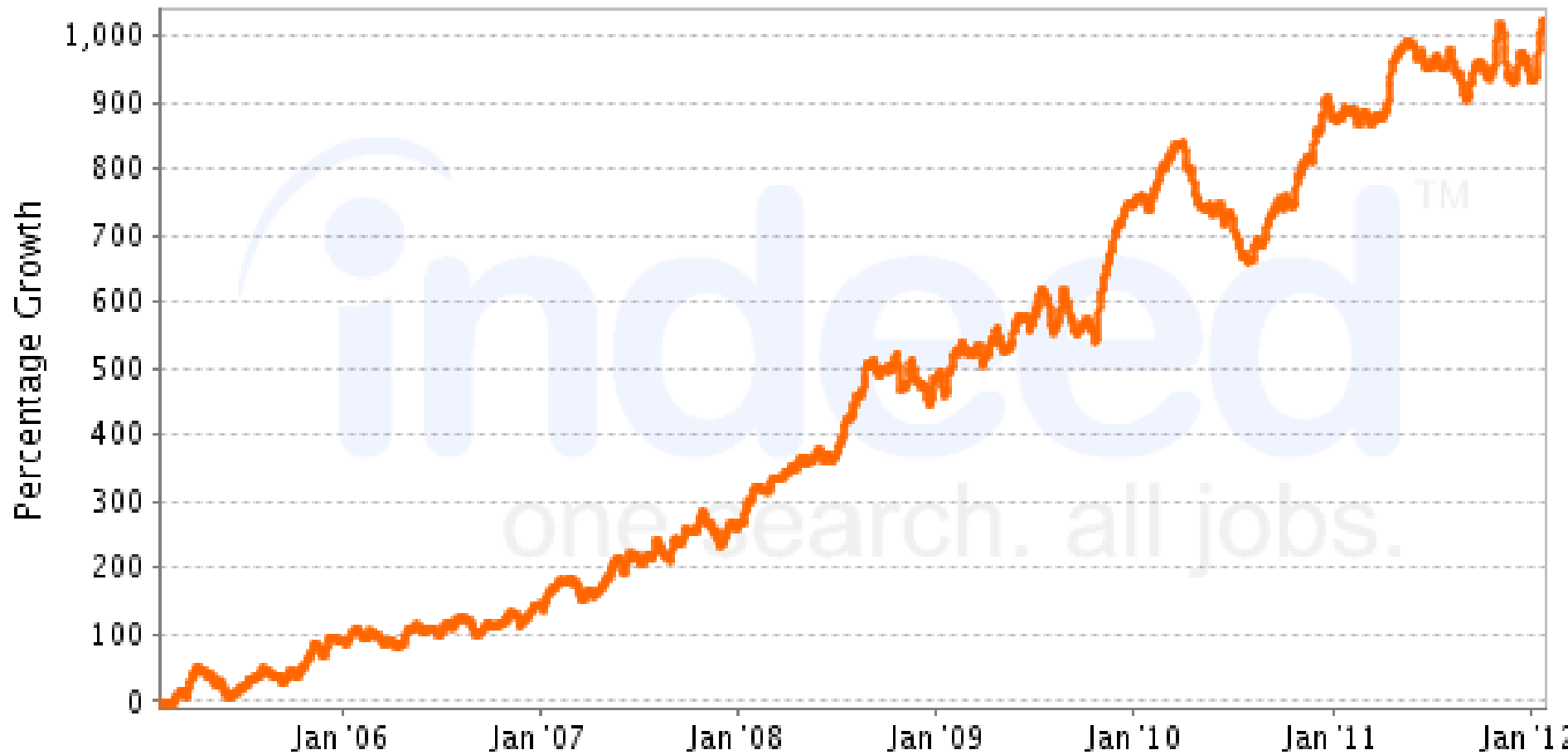
According to Robert Sooble who got it from tracking FTC, [Apple is buying Siri](#). (This has yet to be confirmed by Siri or Apple). The front story is mobile, specifically a bruising battle between Apple and Google. But once again the back story is semantic technology. Siri is not some cute iPhone app banged together in a garage over a Red Bull fueled long weekend. Siri has hard core semantic tech that originated from Darpa (just like that little system called the Internet).

Like the Facebook OpenGraph story, this is another example of semantic web going mainstream. The Open Graph front story was all about social media, but the back story was their adoption of RDFa. That has been a big boost to the semantic web community.

Siri looks like a good exit for investors and will give them confidence to invest more in companies

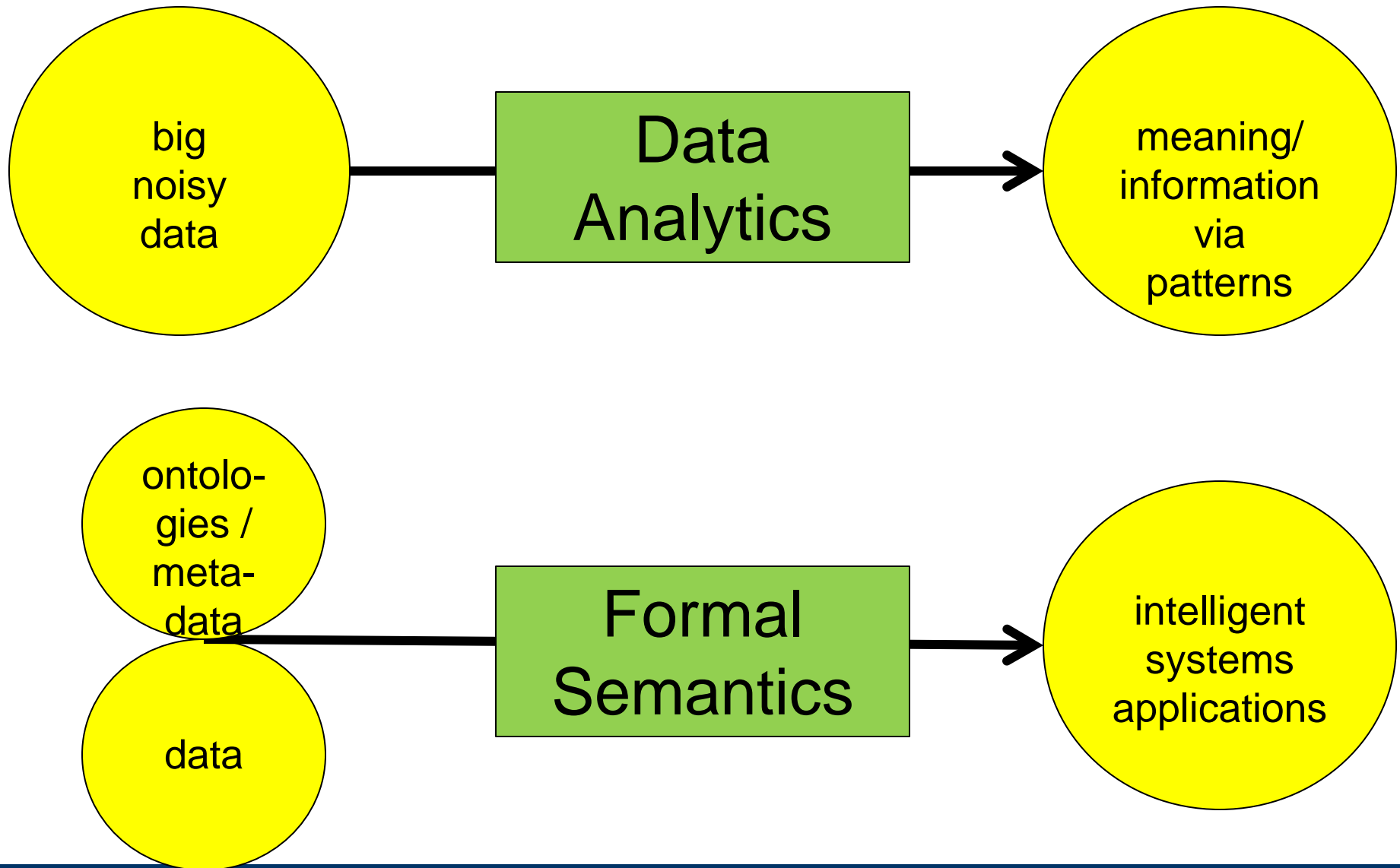
Job Trends from Indeed.com

— semantic web

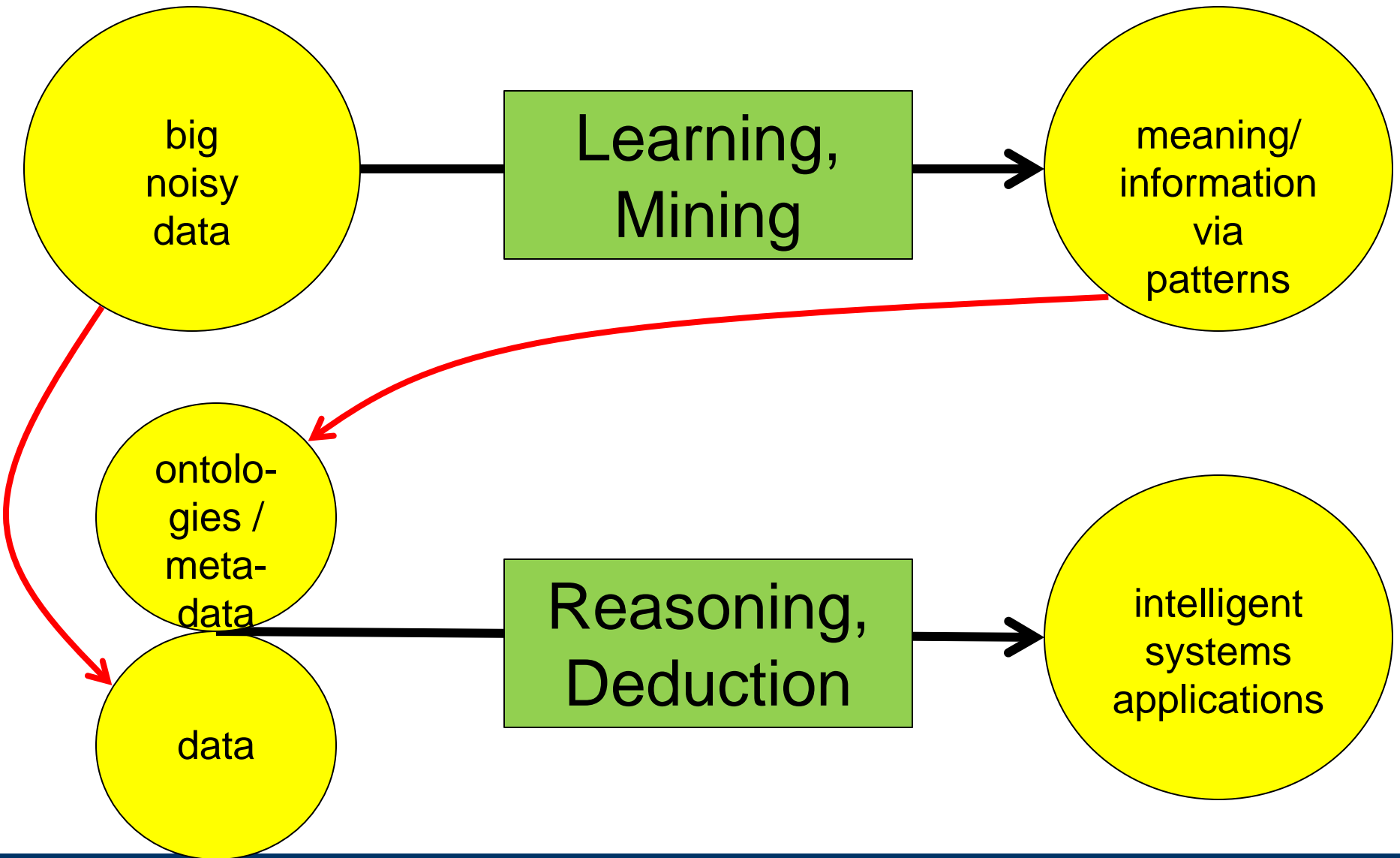


- **Big Data, Linked Data, Semantic Web**
- **The Big Data Added Value Pipeline**
- **Fragments**

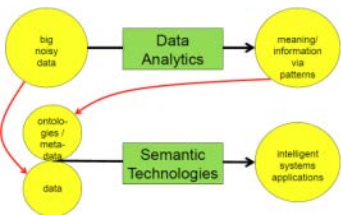
The Big Data Added Value Pipeline



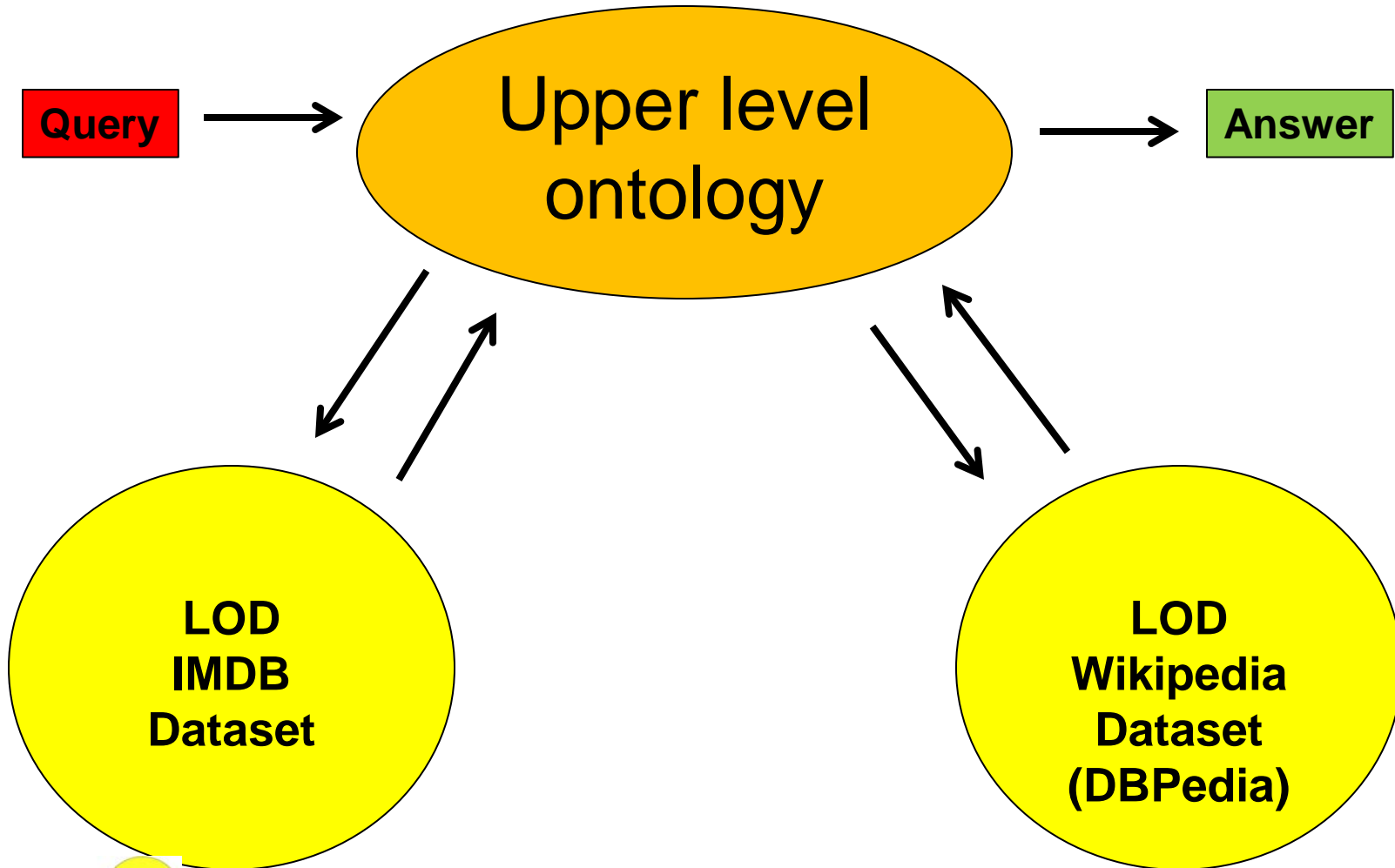
The Big Data Added Value Pipeline



- **scaling tools to Big Data size**
- **learning / acquisition of metadata and ontologies**
- **tolerance for noise and heterogeneity in deductive reasoning**
- **learning and reasoning paradigms integration**



- **Big Data, Linked Data, Semantic Web**
- **The Big Data Added Value Pipeline**
- **Fragments**



Joshi, Jain, Hitzler et al. ODBASE 2012

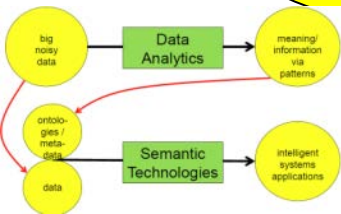
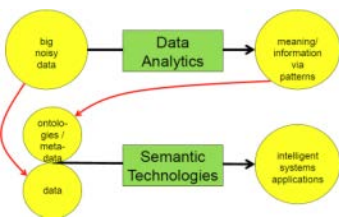


Table 4. Results of various systems for LOD Schema Alignment. Legends: Prec=Precision, Rec=Recall, M=Music Ontology, B=BBC Program Ontology, F=FOAF Ontology, D=DBpedia Ontology, G=Geonames Ontology, S=SIOC Ontology, W=Semantic Web Conference Ontology, A=AKT Portal Ontology, err=System Error, NA=Not Available

Linked Open Data Schema Ontology Alignment												
Test	Alignment API		OMViaUO		RiMoM		S-Match		AROMA		BLOOMS	
	Prec	Rec	Prec	Rec	Prec	Rec	Prec	Rec	Prec	Rec	Prec	Rec
M,B	0.4	0	1	0	err	err	0.04	0.28	0	0	0.63	0.78
M,D	0	0	0	0	err	err	0.08	0.30	0.45	0.01	0.39	0.62
F,D	0	0	0	0	err	err	0.11	0.40	0.33	0.04	0.67	0.73
G,D	0	0	0	0	err	err	0.23	1	0	0	0	0
S,F	0	0	0	0	0.3	0.2	0.52	0.11	0.30	0.20	0.55	0.64
W,A	0.12	0.05	0.16	0.03	err	err	0.06	0.4	0.38	0.03	0.42	0.59
W,D	0	0	0	0	err	err	0.15	0.50	0.27	0.01	0.70	0.40
Avg.	0.07	0.01	0.17	0	NA	NA	0.17	0.43	0.25	0.04	0.48	0.54



Jain, Hitzler et al, ISWC2010

Relation Type	Distinct Entity Pairs	Correctly Found	Precision
Stuff-Object-Part-Of	4178	3427	0.82
Component-Integral-Part-Of	3126	27931	0.89
Feature-Activity-Part-Of	1287	464	0.85
Member-Collection-Part-Of	1912	803	0.85
Portion-Mass-Part-Of	0	0	NA
Place Area-Part-Of	3350	1248	0.48
Total	13853	10557	0.76

Table 2: Precision of the six different relation types between DBpedia entities

Total # of Class Pairs	Correctly Identified	Precision
93	81	0.87

Table 4: Precision as measured on Schema Level Links Between DBpedia entities

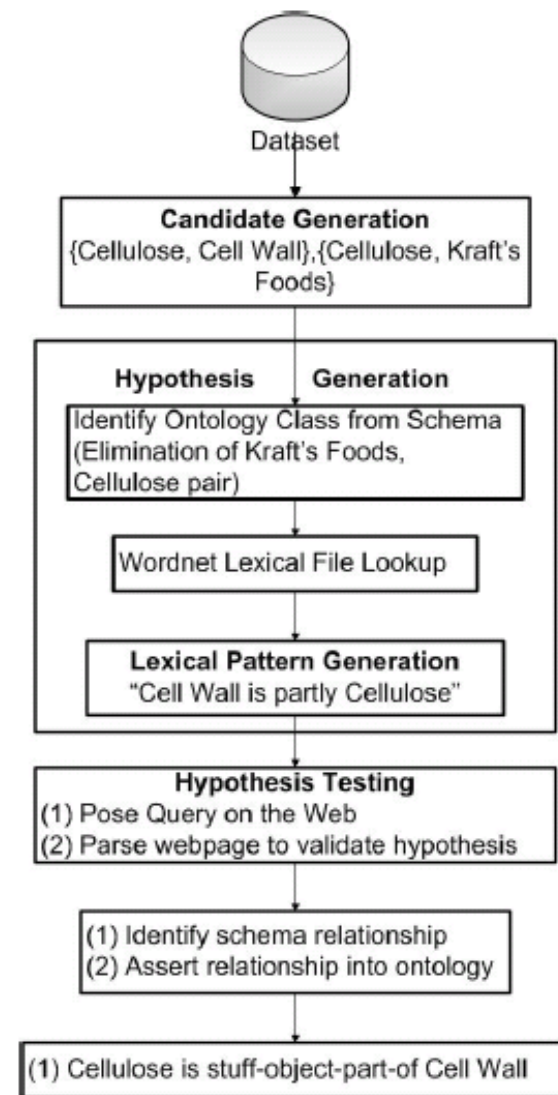
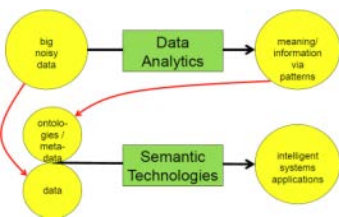


Figure 1: PLATO system flow chart



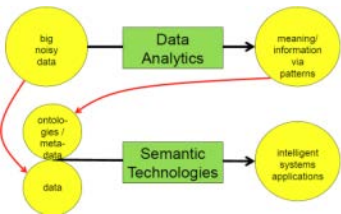
Jain, Hitzler et al, ACM Hypertext 2012

Generation of schema knowledge from facts / raw data

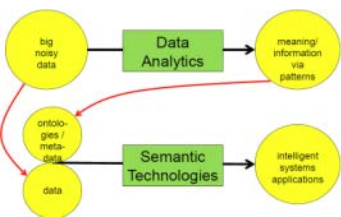
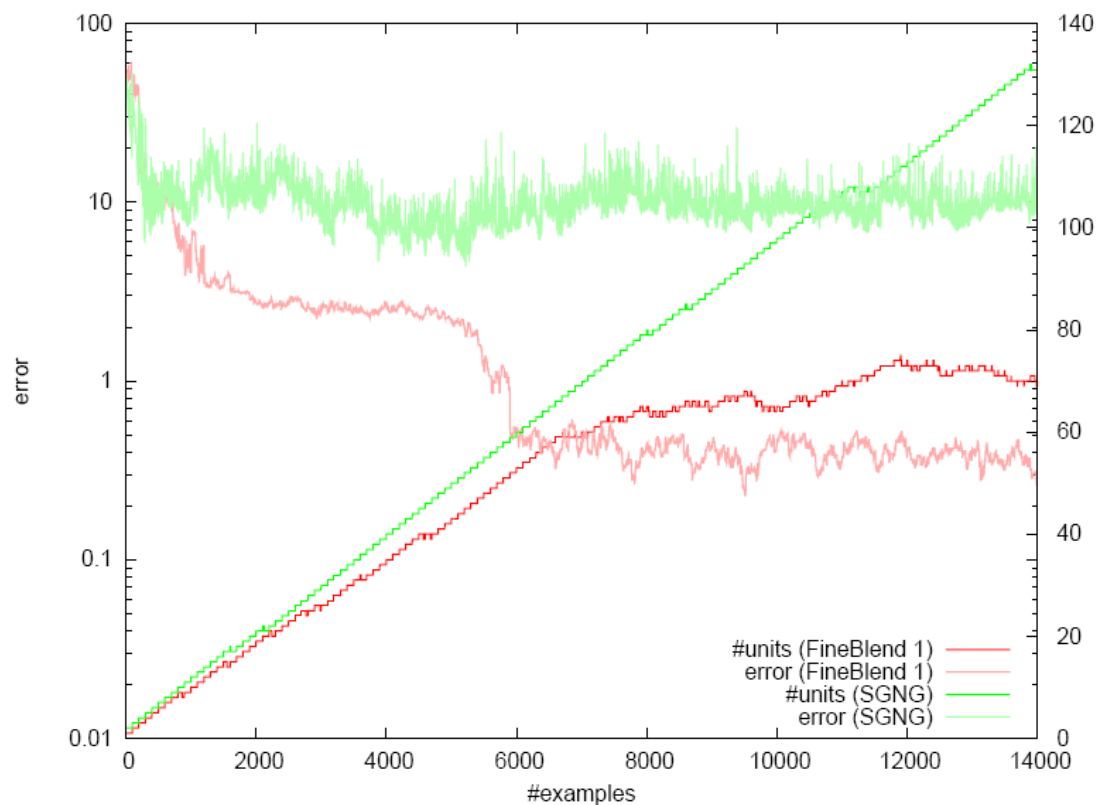
**Employs method from Inductive Logic Programming (ILP)
carried over to Description Logics / OWL**

Resulting system DL-Learner is competitive on ILP benchmarks

- **Ontology Engineering Protégé Plugin**
- **DBPedia Navigator**
- **Traditional Machine Learning use cases**

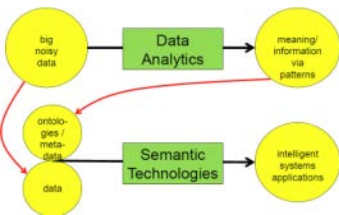
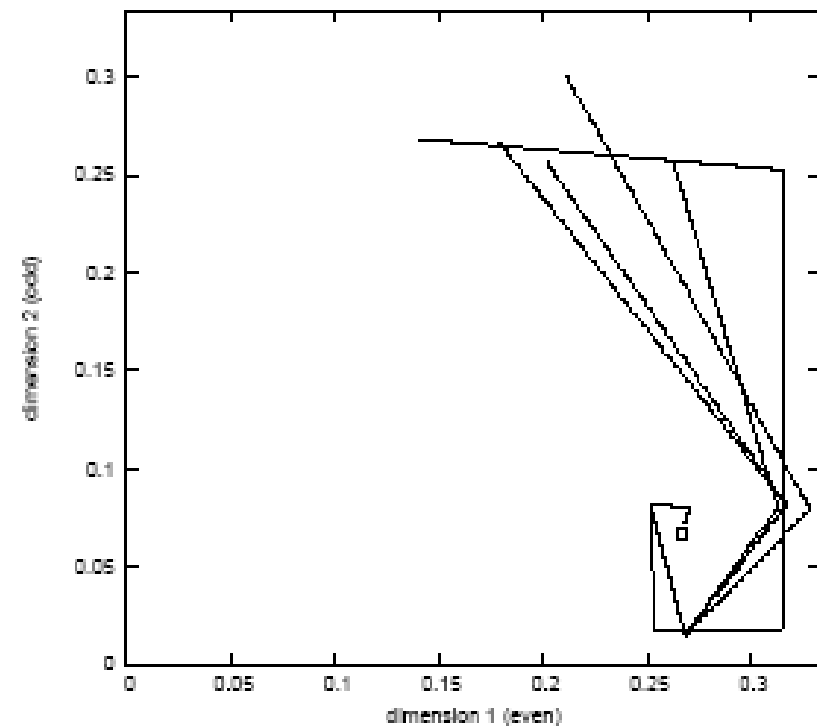
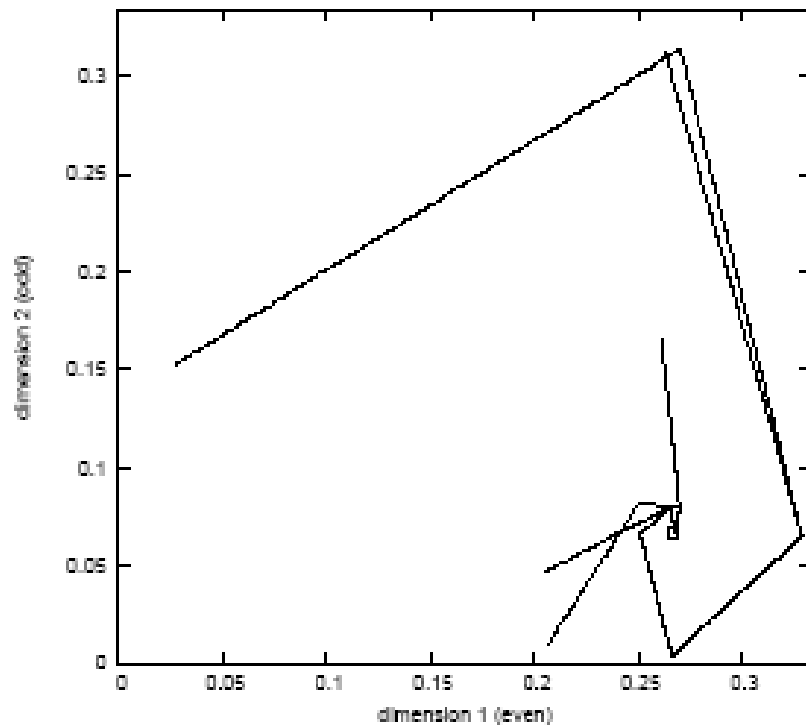


Lehmann, Hitzler, Machine Learning 78(1-2), 203-250, 2010



Bader, Hitzler, Hölldobler, Neurocomputing 71, 2420-2432, 2008.

Iterating Random Inputs: We observe convergence to unique supported model of the program.



Bader, Hitzler, Hölldobler, Neurocomputing 71, 2420-2432, 2008.

$$\text{mouse}(x) \wedge \text{elephant}(y) \rightarrow \text{smallerThan}(x, y)$$
$$(\forall x)(\forall y)(\neg \text{mouse}(x) \vee \text{smallerThan}(x, y) \vee \neg \text{elephant}(y))$$
$$R_{\text{mouse}} \circ R_{\text{elephant}} \sqsubseteq \text{smallerThan}$$
$$\text{mouse} \equiv \exists R_{\text{mouse}}.\text{Self}$$
$$\text{elephant} \equiv \exists R_{\text{elephant}}.\text{Self}$$

Krötzsch, Maier, Krisnadhi, Hitzler, WWW2011

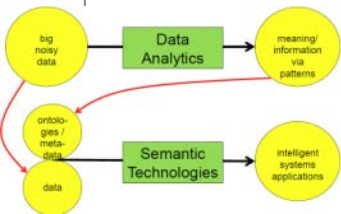
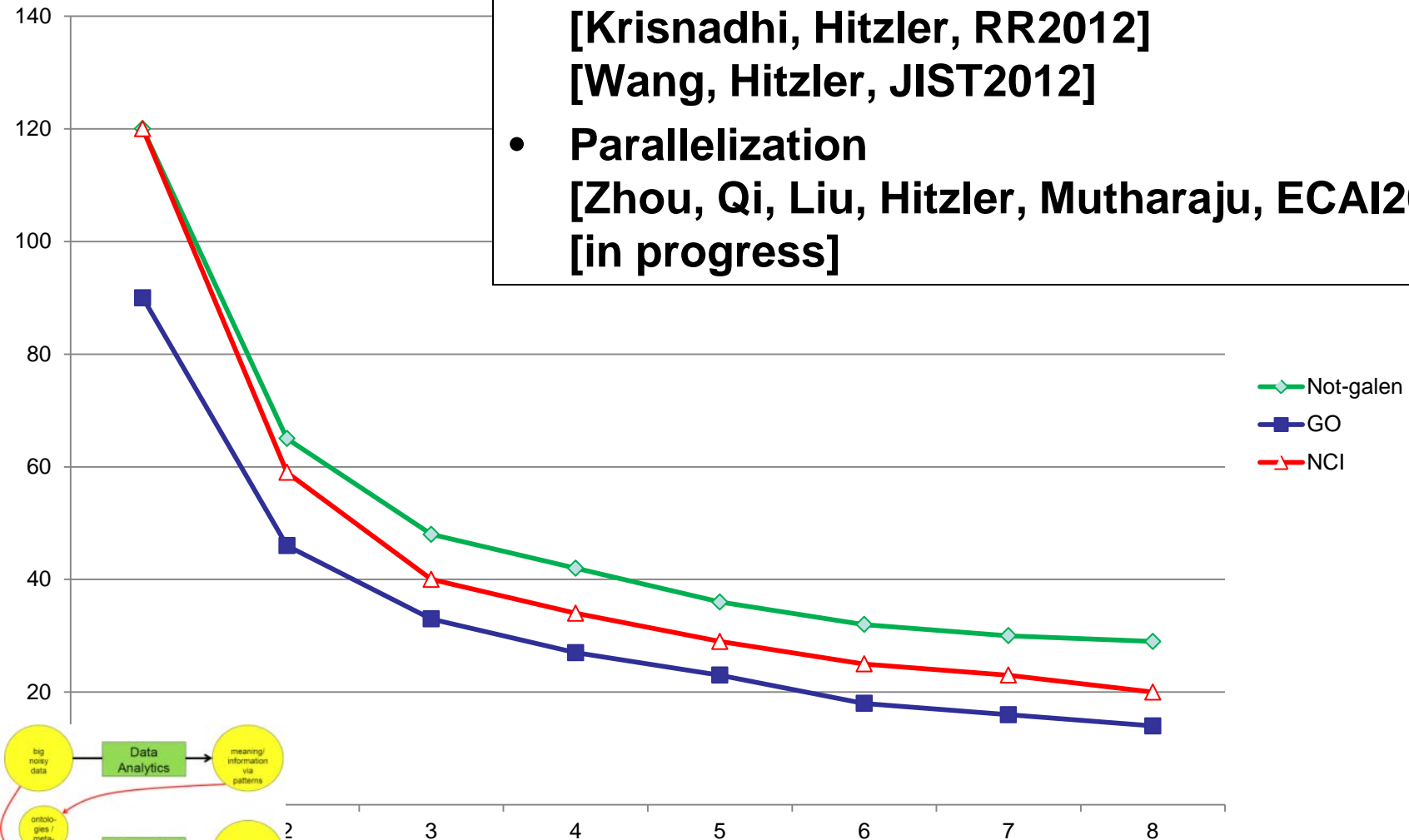
Krisnadhi, Maier, Hitzler, RW2011

Carral Martinez, Hitzler, ESWC2012

Knorr, Hitzler, Maier, ECAI2012

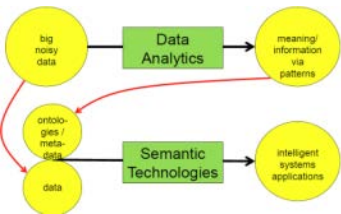
Knorr, Carral Martinez, Hitzler, Krisnadhi, Maier, Wang, RR2012

- **PolyTime Ontology Languages and Reasoning Algorithms**
[Krisnadhi, Hitzler, RR2012]
[Wang, Hitzler, JIST2012]
- **Parallelization**
[Zhou, Qi, Liu, Hitzler, Mutharaju, ECAI2012]
[in progress]



- **Inconsistency-tolerant semantics for the Web Ontology Language.**
- **Compatible with the standard semantics.**

- **Implementation by linear pre-processing, using off-the-shelf OWL reasoner.**



Maier, Ma, Hitzler, Semantic Web journal, to appear
Huang, Li, Hitzler, Logic Journal of the IGPL, to appear

a:hasWife \sqsubseteq a:hasSpouse
symmetric(a:hasSpouse)
 \exists a:hasSpouse.a:Female \sqsubseteq a:Male
 \exists a:hasSpouse.a:Male \sqsubseteq a:Female
a:hasWife(a:john, a:mary)
b:Male(a:john)
b:Female(a:mary)
a:Male \sqcap a:Female \sqsubseteq \perp

symmetric(b:hasSpouse)
b:hasSpouse(b:mike, b:david)
b:Male(b:david)
b:Male(b:mike)
b:Female(b:anna)

- **Bridging semantic heterogeneity by employing defeasible alignment rules:**

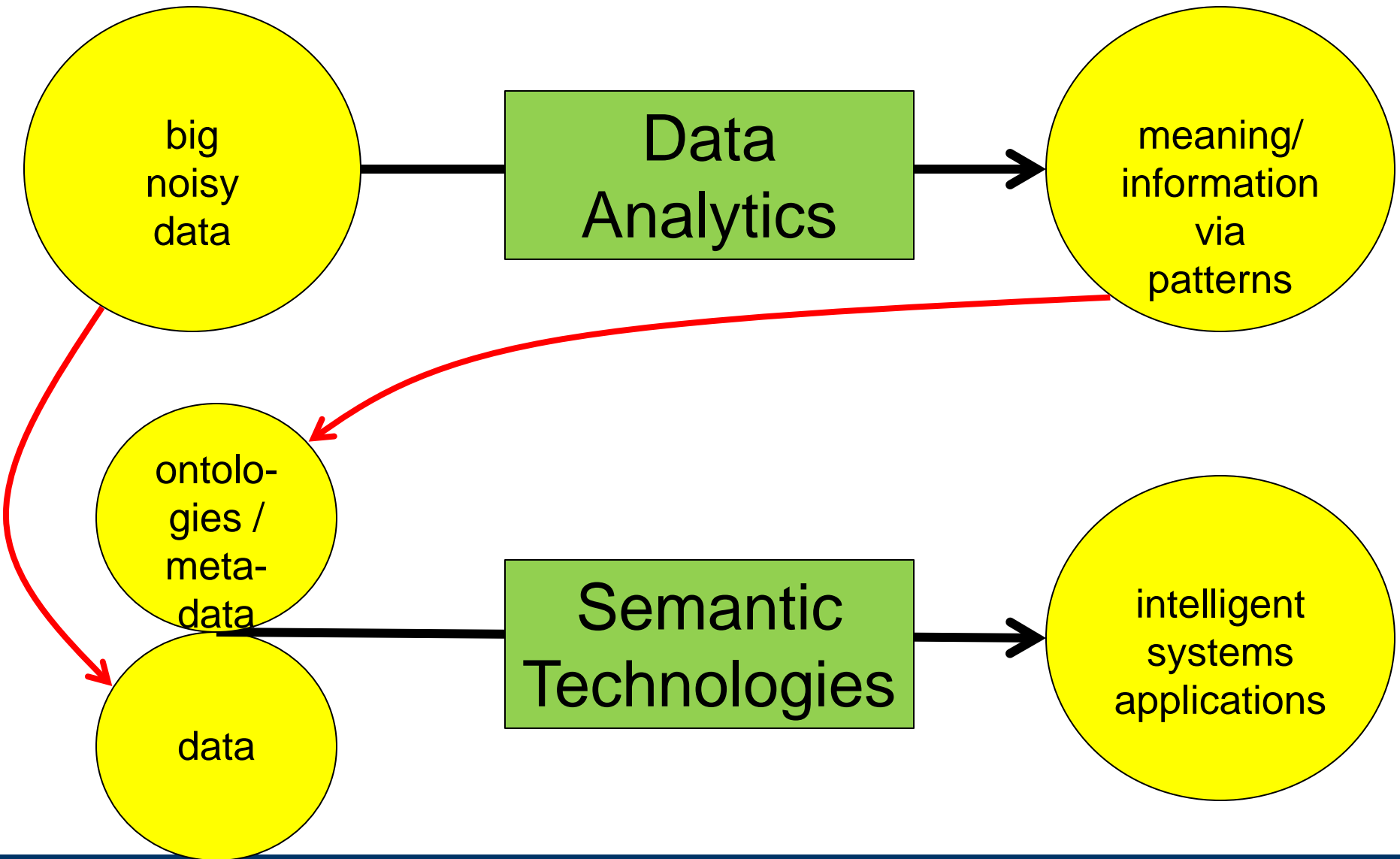
$a:\text{hasSpouse}(x, y) \overset{\text{default}}{\longleftrightarrow} b:\text{hasSpouse}(x, y)$

Hitzler, Janowicz, Sengupta work in progress

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