Semantics and Big Data – Opportunities and Challenges

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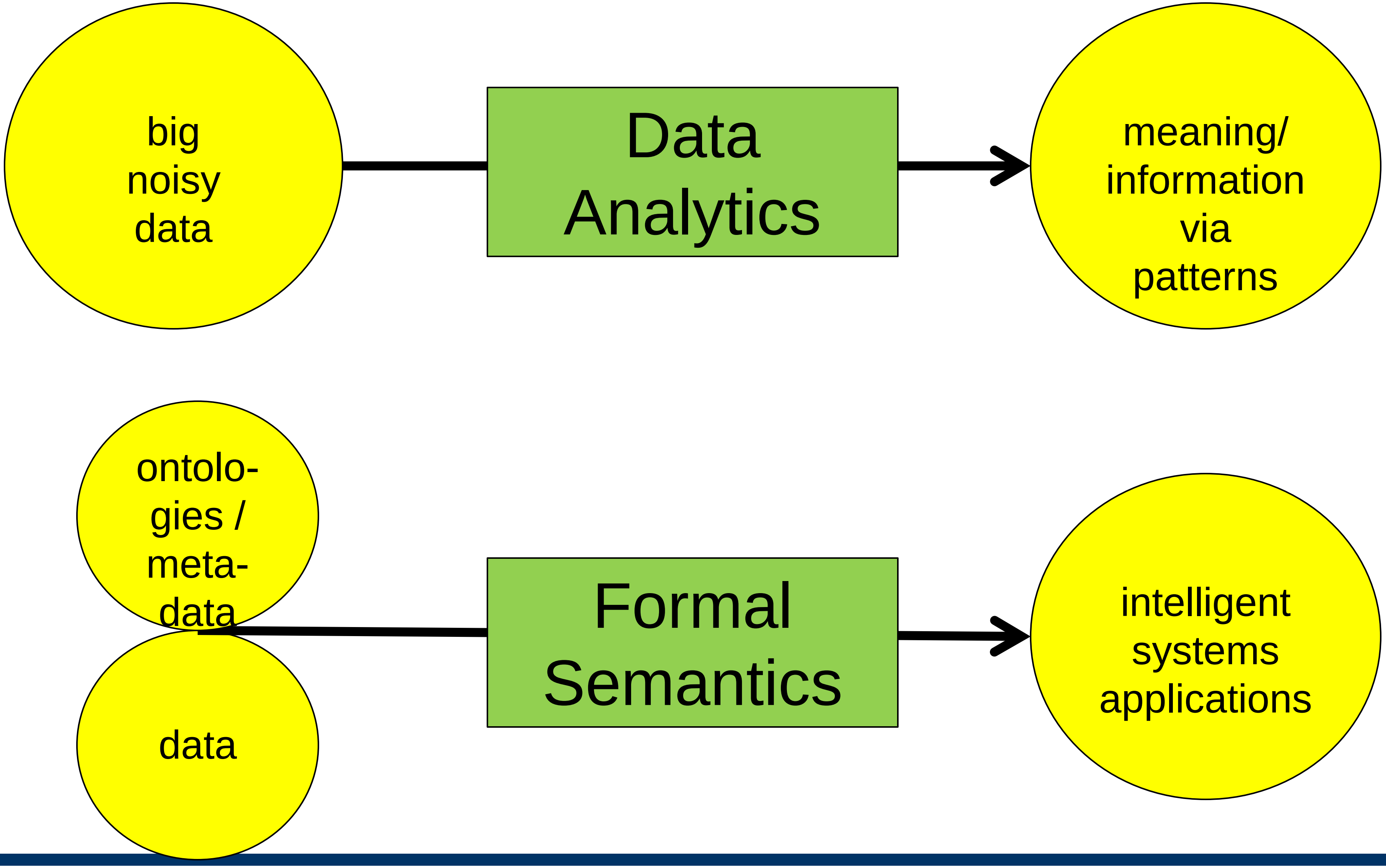
The Big Data Added Value Pipeline



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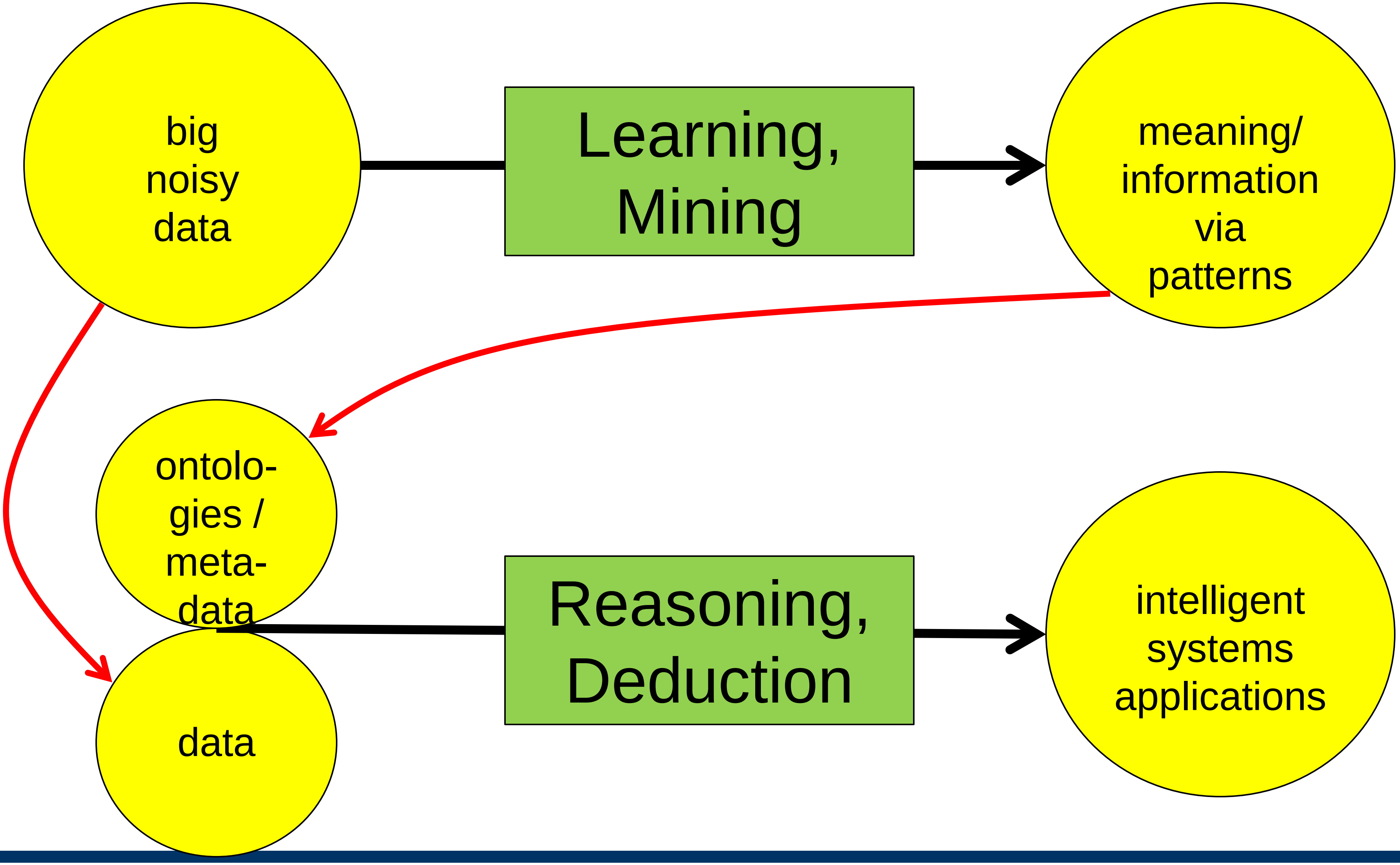
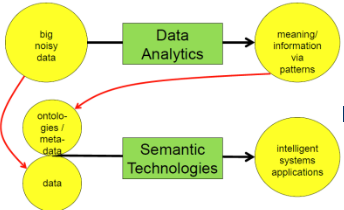
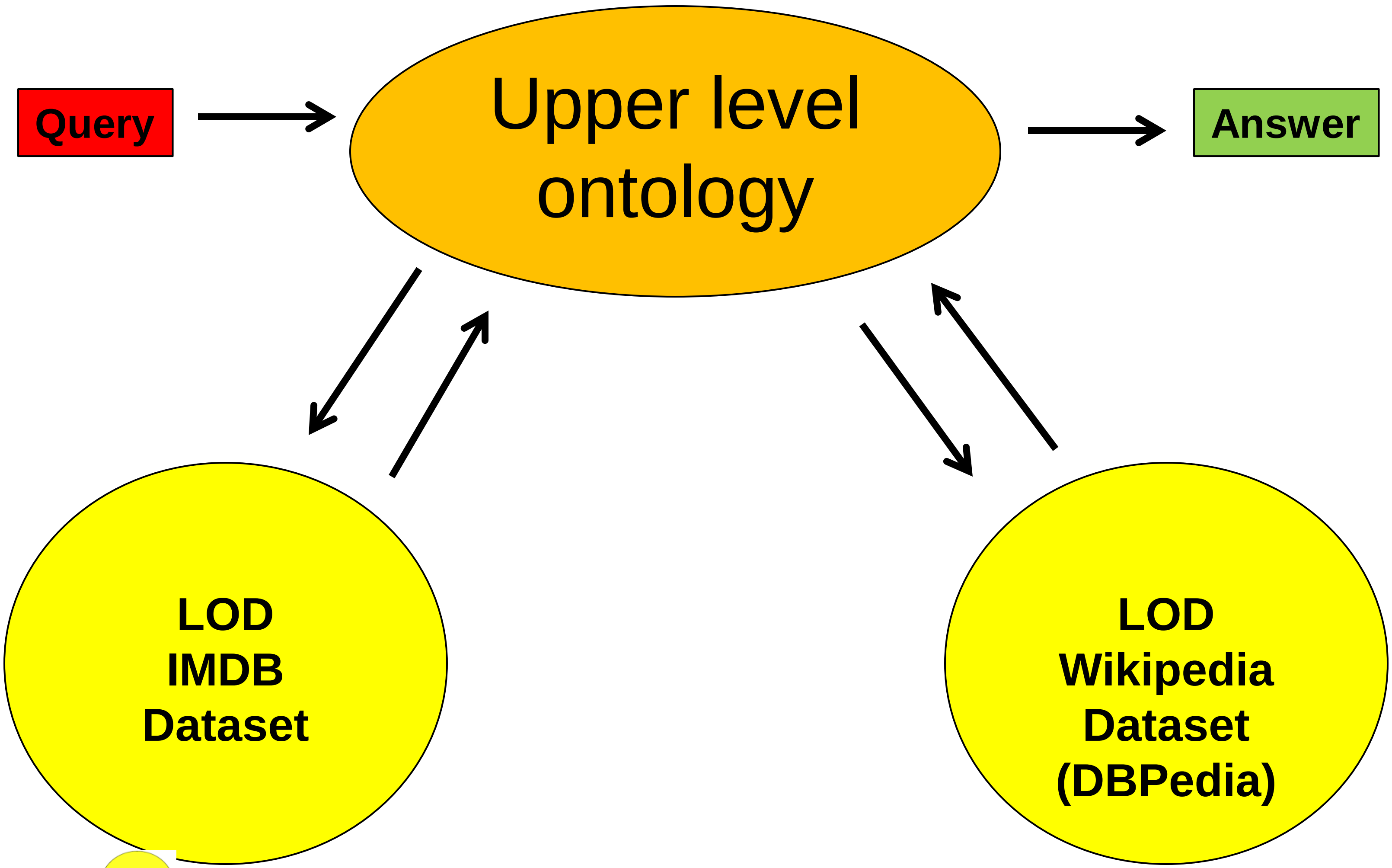


Closing the gap – key dimensions

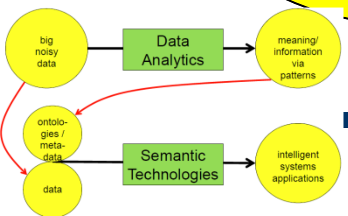
- **scaling tools to Big Data size**
- **learning / acquisition of metadata and ontologies**
- **tolerance for noise and heterogeneity in formal semantics**
- **learning and reasoning paradigms integration**



Linked Data federated querying



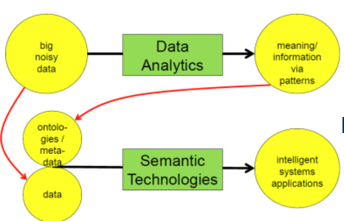
Joshi, Jain, Hitzler et al. ODBASE 2012



Bootstrapping-based alignment

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												
	Alignment API		OMViaUO		RiMoM		S-Match		AROMA		BLOOMS	
Test	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

Partonomy detection

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

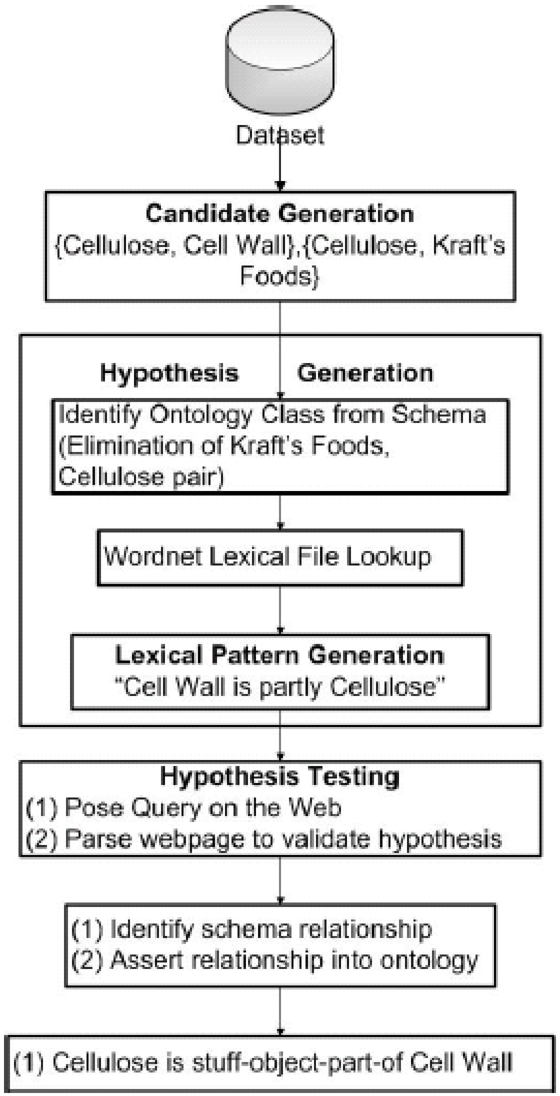
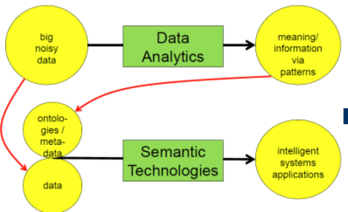


Figure 1: PLATO system flow chart

Jain, Hitzler et al, ACM Hypertext 2012



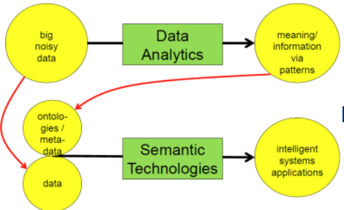
DL-Learner

Generation of schema knowledge from facts / raw data

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

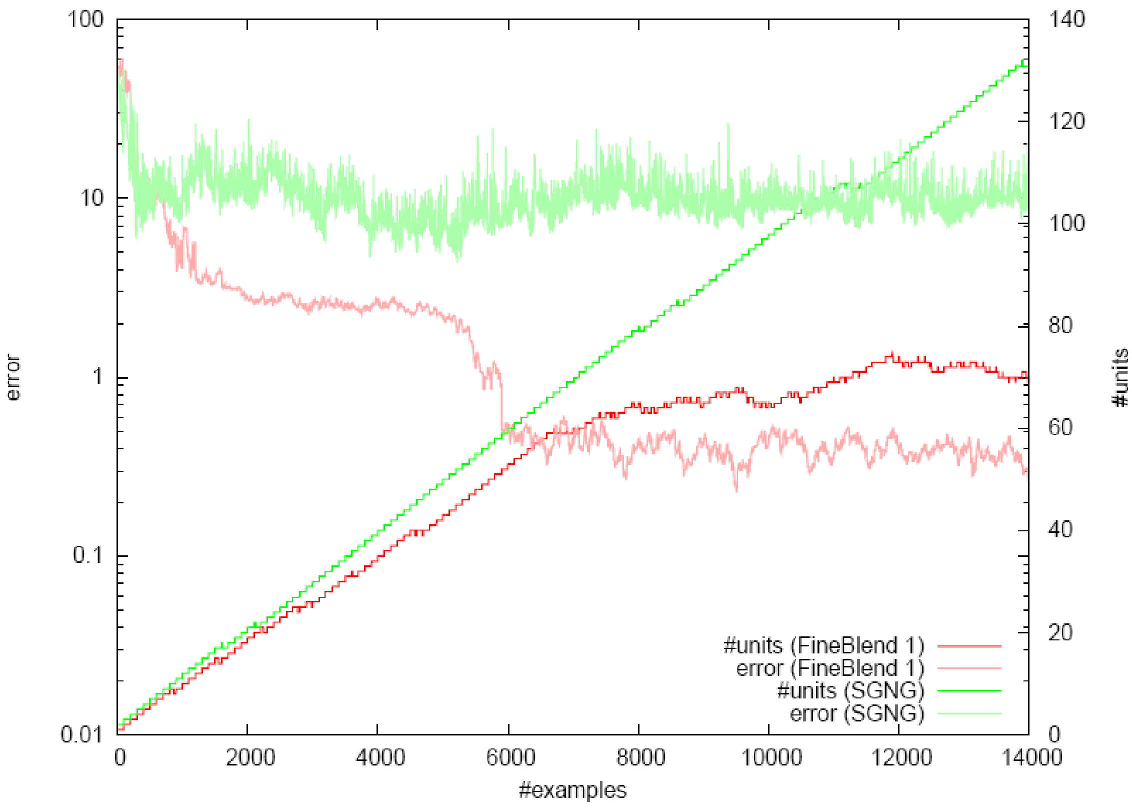
Resulting system DL-Learner is competetive on ILP benchmarks

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

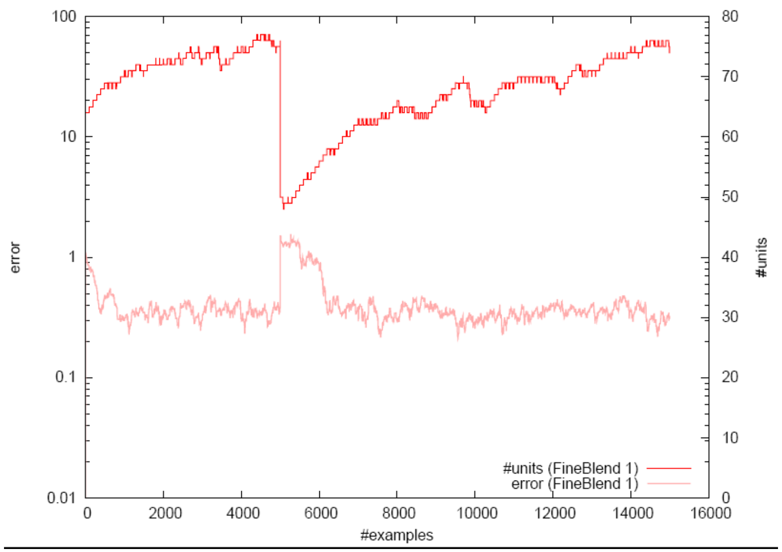


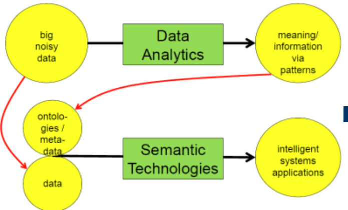
Lehmann, Hitzler, Machine Learning 78(1-2), 203-250, 2010

Neural-Symbolic Integration



unit failure

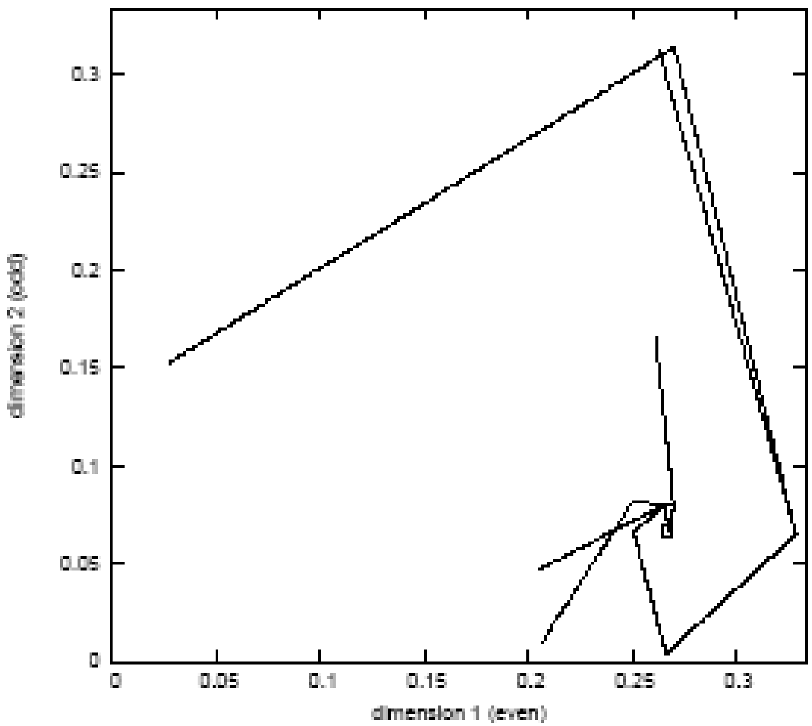


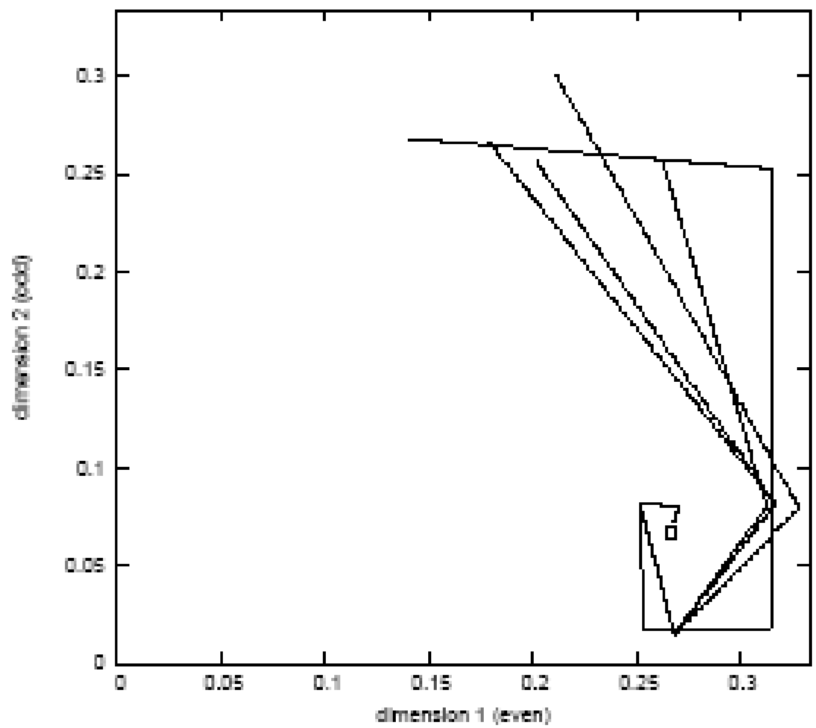


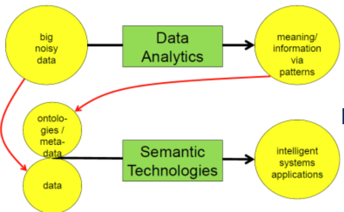
Bader, Hitzler, Hölldobler, Neurocomputing 71, 2420-2432, 2008.

Neural-Symbolic Integration

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







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

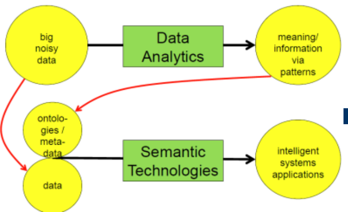
Linked Data Structure Mining

Currently used as a compression method for Linked Data.

Frequent Itemset Mining approach.

Data Set	#triples	#predicates	#transactions	compression ratio	
				intra-property	inter-property
Dog Food	130,178	132	12,695	0.99	0.93
CN 2012	137,484	26	14,553	0.82	0.51
ArchiveHub	431,088	141	51,411	0.92	0.77
Jamendo	1,047,950	25	335,925	0.99	0.83
LinkedMdb	6,147,996	222	694,400	0.97	0.77
DBpedia rdftypes	9,237,320	1	9,237,320	0.49	0.49
RDF About	17,188,323	108	3,132,667	0.97	0.86
DBLP	46,597,620	27	2,840,639	0.96	0.88
Geonames	119,416,854	26	7,711,126	0.97	0.52

Table 1. Compression ratio (based on triple counts) for various linked open datasets



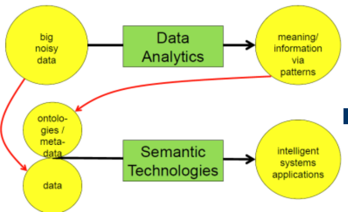
Joshi, Hitzler, Dong, SemQuant 2012

MapReduce for ontology reasoning

Normal Form	Completion Rule	Key
$A_1 \sqcap A_2 \sqsubseteq B$	**R1-1** If $A_1 \in S(X)$ and $A_1 \sqcap A_2 \sqsubseteq B \in \mathcal{O}$ then $P(X) := P(X) \cup \{(A_2, B)\}$	A_1
$(A, B) \in P(X)$	**R1-2** If $A \in S(X)$ and $((A, B) \in P(X)$ or $A \sqsubseteq B \in \mathcal{O})$ then $S(X) := S(X) \cup \{B\}$	A
$A \sqsubseteq \exists r.B$	**R2** If $A \in S(X)$ and $A \sqsubseteq \exists r.B \in \mathcal{O}$ then $R(r) := R(r) \cup \{(X, B)\}$	A
$\exists r.A \sqsubseteq B$ for A	**R3-1** If $A \in S(X)$ and $\exists r.A \sqsubseteq B \in \mathcal{O}$ then $\mathcal{O} := \mathcal{O} \cup \{\exists r.X \sqsubseteq B\}$	A
$\exists r.A \sqsubseteq B$ for r	**R3-2** If $(X, Y) \in R(r)$ and $\exists r.Y \sqsubseteq B \in \mathcal{O}$ then $S(X) := S(X) \cup \{B\}$	r (or Y)
$r \sqsubseteq s$	**R4** If $(X, Y) \in R(r)$ and $r \sqsubseteq s \in \mathcal{O}$ then $R(s) := R(s) \cup \{(X, Y)\}$	r
$r \circ s \sqsubseteq t$	**R5-1** If $(X, Z) \in R(r)$ and $(Z, Y) \in R(s)$ then $R(r \circ s) := R(r \circ s) \cup \{(X, Y)\}$	Z

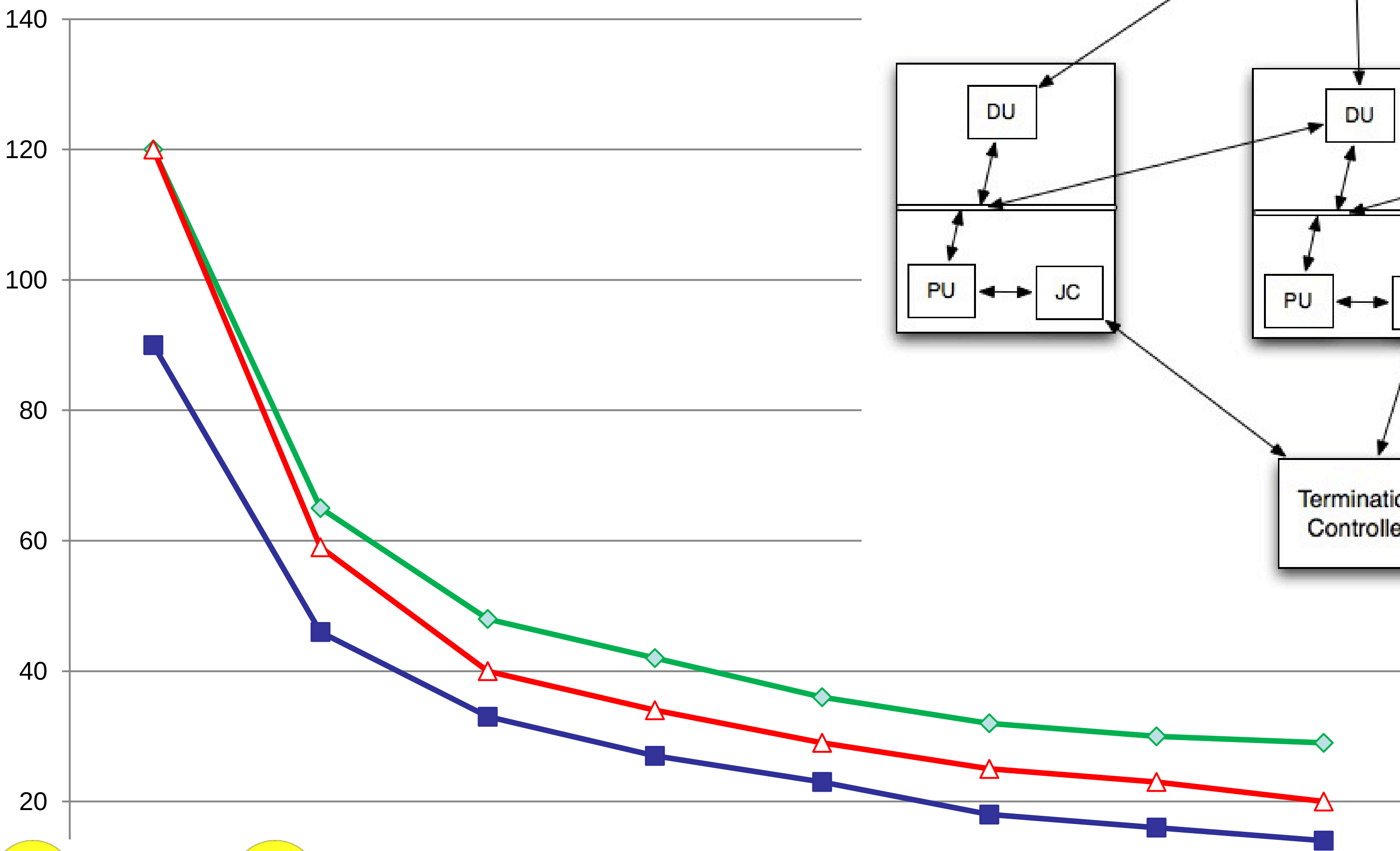
Fig. 2. Revised CEL algorithm for $\mathcal{EL}^+$. The keys are used in the MapReduce algorithm. Note that in R4, r is allowed to be compound, i.e., of the form $s \circ t$.

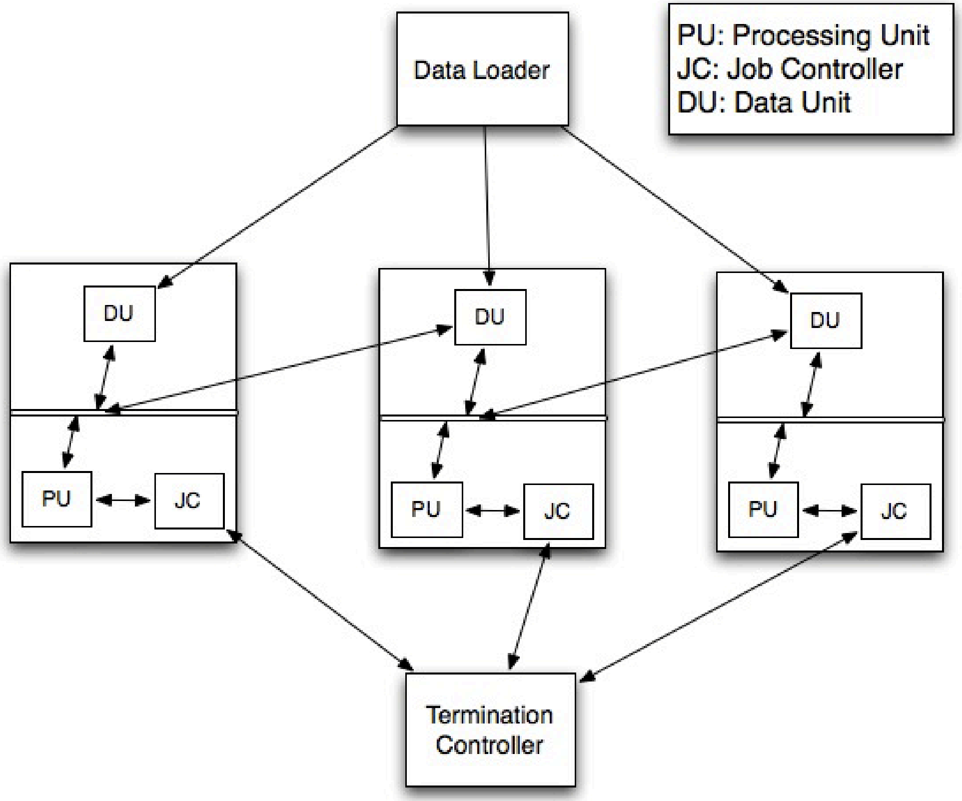
Mutharaju, Maier, Hitzler, DL2010
Zhou, Qi, Liu, Hitzler, Mutharaju, ECAI 2012

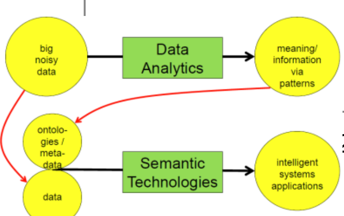


Parallelized ontology reasoning

work in progress





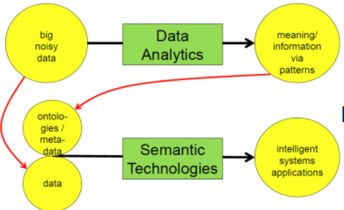


Inconsistency-tolerant reasoning

- **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, Hitlzer, Logic Journal of the IGPL, to appear



Multi-perspective alignment

$$a{:}hasWife \sqsubseteq a{:}hasSpouse$$
$$\mathrm{symmetric}(a{:}hasSpouse)$$
$$\exists a{:}hasSpouse.a{:}Female \sqsubseteq a{:}Male$$
$$\exists a{:}hasSpouse.a{:}Male \sqsubseteq a{:}Female$$
$$a{:}hasWife(a{:}john, a{:}mary)$$
$$b{:}Male(a{:}john)$$
$$b{:}Female(a{:}mary)$$
$$a{:}Male \sqcap a{:}Female \sqsubseteq \bot$$

$$\mathrm{symmetric}(b{:}hasSpouse)$$
$$b{:}hasSpouse(b{:}mike, b{:}david)$$
$$b{:}Male(b{:}david)$$
$$b{:}Male(b{:}mike)$$
$$b{:}Female(b{:}anna)$$

- **Bridging semantic heterogeneity by employing defeasible alignment rules:** $a{:}hasSpouse(x, y) \overset{\text{default}}{\longleftrightarrow} b{:}hasSpouse(x, y)$

Hitzler, Janowicz et al. work in progress
Knorr, Alferes, Hitzler, Artificial Intelligence 175(9-10), 1528-1554, 2011
Knorr, Hitzler, Maier, ECAI 2012
Sengupta, Krisnadhi, Hitzler, ISWC 2011

Reasoning as IR

- **Deductive reasoning can be viewed as a classification task:**

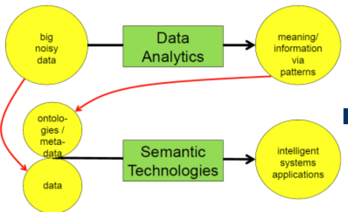
  Input: Knowledge base (Ontology + Data)
  plus a (ground) query

  Output: yes or no

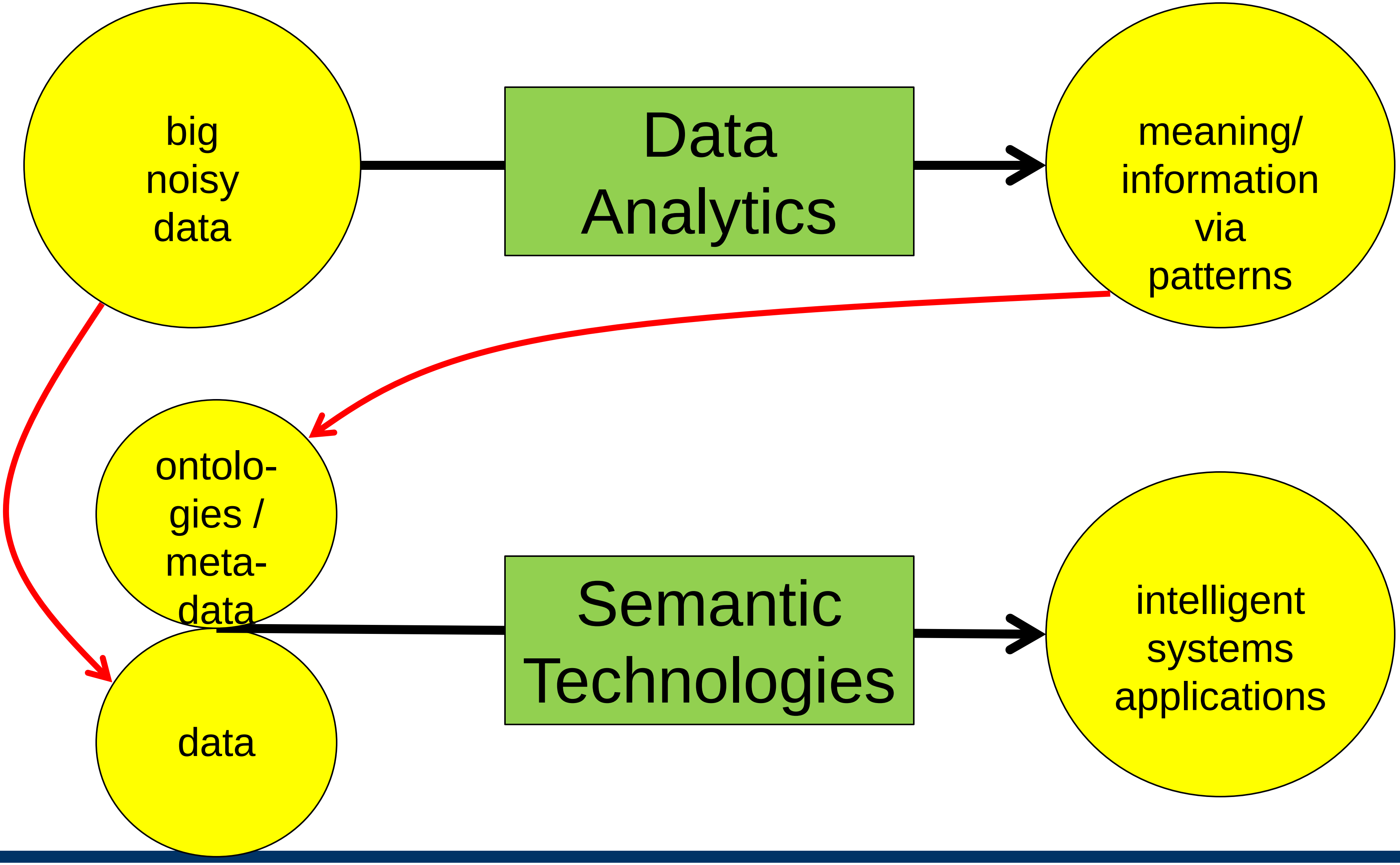
- **To what extent can non-deductive IR methods be used to achieve this?**
- **Deductive reasoning systems available as benchmarks.**

- **IR methods could potentially lift “deductive” reasoning to noisy data?**

Hitzler, van Harmelen, Semantic Web 1(1-2), 39-44, 2010 (vision paper)



Thanks!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Semantic
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intelligent
systems
applications

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