Ontology-Based Query Answering
Overview and Relevant Work

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Is Semantics Needed?

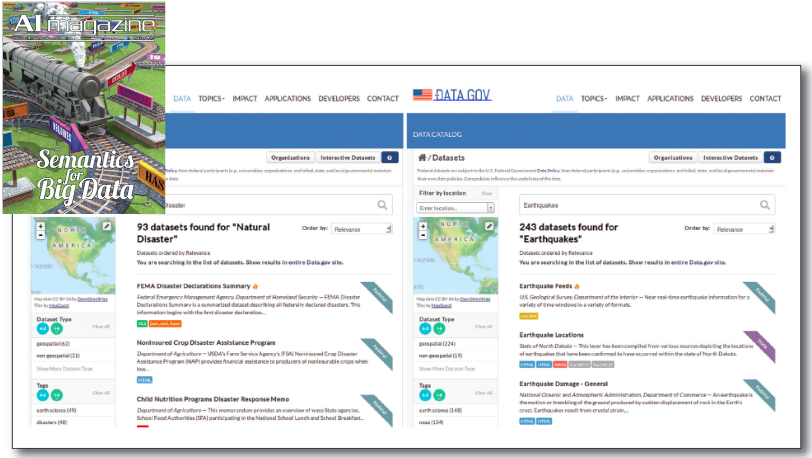


Figure 2: Searching Data.gov for Natural Disaster Data Sets.

Benefits of Ontologies

- dealing with incompleteness of the data
- hiding even more the specifics of data storage
- using a vocabulary that is *familiar* to the user

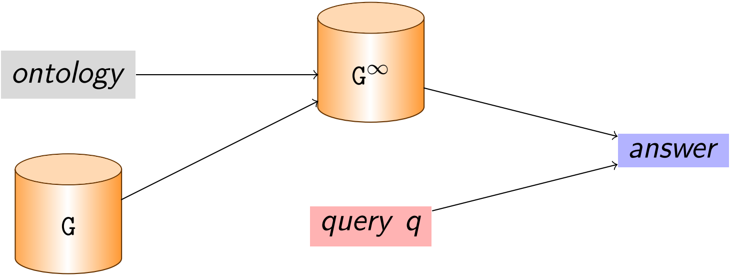
The need for reasoning

Query answering needs explicit and implicit data!

- Materialization-based query answering
- Reformulation-based query answering
- Hybrids of the above: combined approaches

Courtesy of I.Manolescu

Materialization-based query answering



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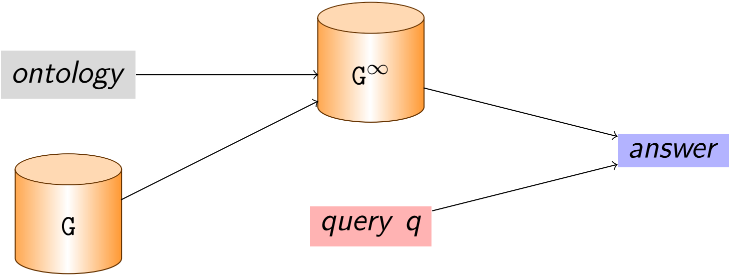
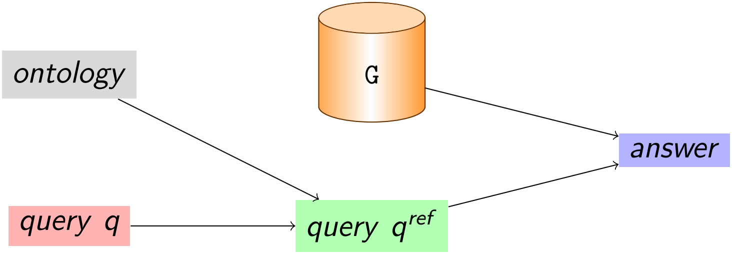


- $q(\mathtt{G}^\infty)$ can be computed using an RDBMS
- $\mathtt{G}^\infty$ needs time to be computed and space to be stored
- Not suitable for high update rate (data and/or schema triples)

Reformulation-based query answering



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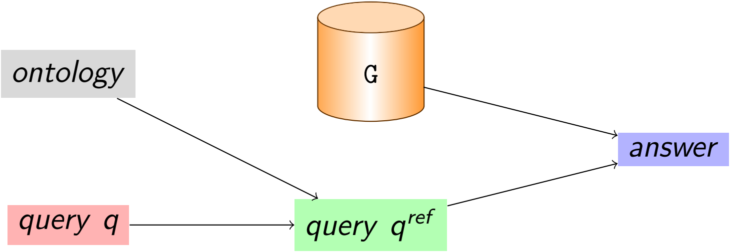
Reformulation-based query answering



- q^{ref}(G) can be evaluated using an RDBMS
- Robust to updates
- Reformulated queries are complex, thus costly to evaluate

Courtesy of I.Manolescu

Ontology Mediated Query Answering

- **Data**: Professor(Alice), Reviewer(Alice)
- **Query** : $\exists x \, \exists y \quad \text{Teacher}(x) \wedge \; \text{reviews}(x, y)$

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Materialization (chase)

Professor(Alice)
Reviewer(Alice)
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$\exists y_1$ reviews(Alice,y_1)

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Query Rewriting

$\exists x \, \exists y \;\; \text{Teacher}(x) \wedge \; \text{reviews}(x, y)$
$\exists x \;\; \text{Professor}(x) \wedge \; \text{Reviewer}(x)$
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Formalization of the Problem

- Input: a set of ground atoms I , a set of existential rules (or a description logic) $\mathcal{R}$, a (Boolean) conjunctive query q
- Output: yes if and only if $I, \mathcal{R} \models q$

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Existential Rule

An existential rule (or TGD) is a formula of the shape:

$$\forall \mathbf{x} \forall \mathbf{y}. [B(\mathbf{x}, \mathbf{y}) \rightarrow \exists \mathbf{z}. H(\mathbf{y}, \mathbf{z})],$$

- B and H are non-empty conjunctions of atoms on variables
- $\mathbf{x}, \mathbf{y}$ and $\mathbf{z}$ are pairwise disjoint

Goal of the Talk

- incomplete...
- highly subjective...
- selection of topics, past, present and future

Problem 1: Does the Chase Terminate?

- it may not terminate:
  - $I = \{\mathrm{Human}(Alice)\}$
  - $\mathcal{R} = \{\mathrm{Human}(x) \rightarrow \mathrm{hasParent}(x, y) \wedge \mathrm{Human}(y)\}$

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References:

- Acyclicity Notions for Existential Rules and Their Application to Query Answering in Ontologies, Cuenca Grau et al., JAIR 2013
- Detecting Chase (Non)Termination for Existential Rules with Disjunctions, Carral et al., IJCAI 2017

Problem 2: Is there a Rewriting of q in a Language $\mathcal{L}$? (1)

Given q and $\mathcal{R}$, given a query language $\mathcal{L}$, does it exist $q' \in \mathcal{L}$ such that for all instance I,

$$I, \mathcal{R} \models q \Leftrightarrow I \models q'.$$

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Several target languages have been proposed:

- UCQs
- first-order logic
- non-recursive Datalog
- Datalog
- ...

Problem 2: Is there a Rewriting of q in a Language $\mathcal{L}$? (2)

- this is not always the case: transitivity rules do not play well with first-order logic
- checking the existence of a rewriting is usually undecidable
- sufficient conditions have been proposed
- the **size** of generated rewritings has been studied

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References:

- Sound, complete and minimal UCQ-rewriting for existential rules, König et al., SWJ 2015
- The price of query rewriting in ontology-based data access, Gottlob et al., AIJ 2014

Problem 3: Towards more Expressive Query Languages

- CQs are basic
- extension with aggregation
- extension with restricted form of recursivity (for instance, RPQs or CRPQs)

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References:

- Complexity of Answering Counting Aggregate Queries over DL-Lite, Kostylev et al., DL 2013
- Answering Conjunctive Regular Path Queries over Guarded Existential Rules, Baget et al., IJCAI 2017

Problem A: Optimization of Query Evaluation (1)

- the **size** of generated rewritings has been studied
- it does not tell much on the efficiency of query evaluation
- even small positive existential first-order rewritings are not easy to evaluate
- cost-based optimization of queries generated by rewriters is not a closed topic

Problem A: Optimization of Query Evaluation (2)

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Optimizing through unions is **crucial** for the kind of queries we are faced with.

References:

- Optimizing Reformulation-based Query Answering in RDF, Bursztyn et al., EDBT 2015

Problem B: Consistent Query Answering (1)

- in presence of inconsistencies, FOL semantics is not interesting
  $\rightarrow$ everything is entailed
- alternative to FOL need to be studied to keep some robustness
- variety of semantics based on the notion of *repair*
  - most common: keeping maximum consistent subset of the data
  - modifications of the data are also sometimes allowed

References:

- Inconsistency-Tolerant Semantics for Description Logics, Lembo et al., RR 2010
- Inconsistency-Tolerant Querying of Description Logic Knowledge Bases, Bienvenu et al. RW 2016

Problem C: Temporal OBQA

- time is important for applications
- several ways to integrate it
- interactions between time and reasoning explode quickly

References:

- Temporalizing Ontology-Based Data Access, Baader et al., CADE 2013
- Temporalized $\mathcal{EL}$ Ontologies for Accessing Temporal Data: Complexity of Atomic Queries, Gutiérrez-Basulto et al., IJCAI 2016

Recap

Chase Termination	Query Optimization
Rewritability	Consistent Query Answering
Query Languages	Temporal Data and Ontologies

Recap

Chase Termination	**Query Optimization**
Rewritability	Consistent Query Answering
Query Languages	**Temporal Data and Ontologies**