Status of Semantic Technologies

What is semantic technology useful for today?
And what can we expect within the coming years?

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Semantic Technologies Seen as Data Generators

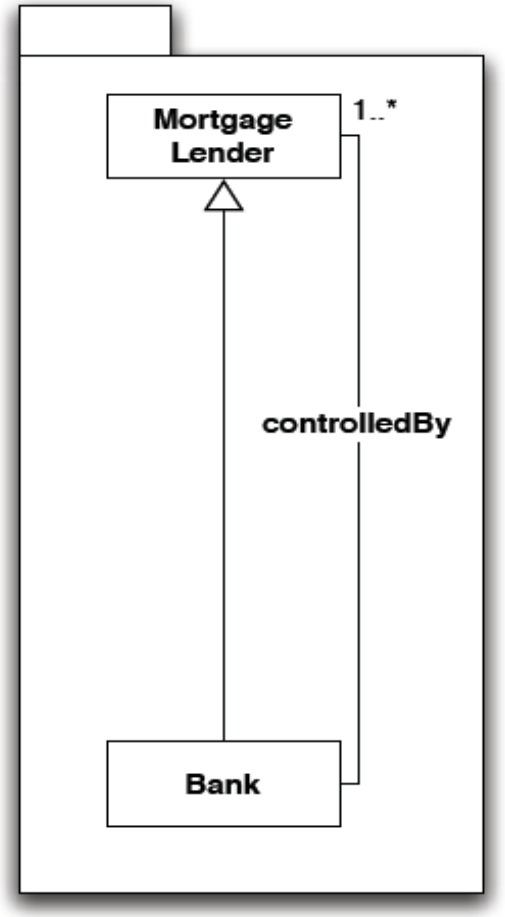
- Ontology (in the narrow sense = KB):

```
(define-role controlledBy
    :domain MortgageLender :range Bank)

(implies Bank MortgageLender)

(implies MortgageLender
   (at-least 1 controlledBy Bank))

(related Halifax LeedsBS controlledBy)

(instance RBS Bank)
```

- Query:

?- { (X) | controlledBy(X, Y) }

X=Halifax, X=RBS, X=LeedsBS



Bank
RBS

controlledBy	
Halifax	Leeds BS

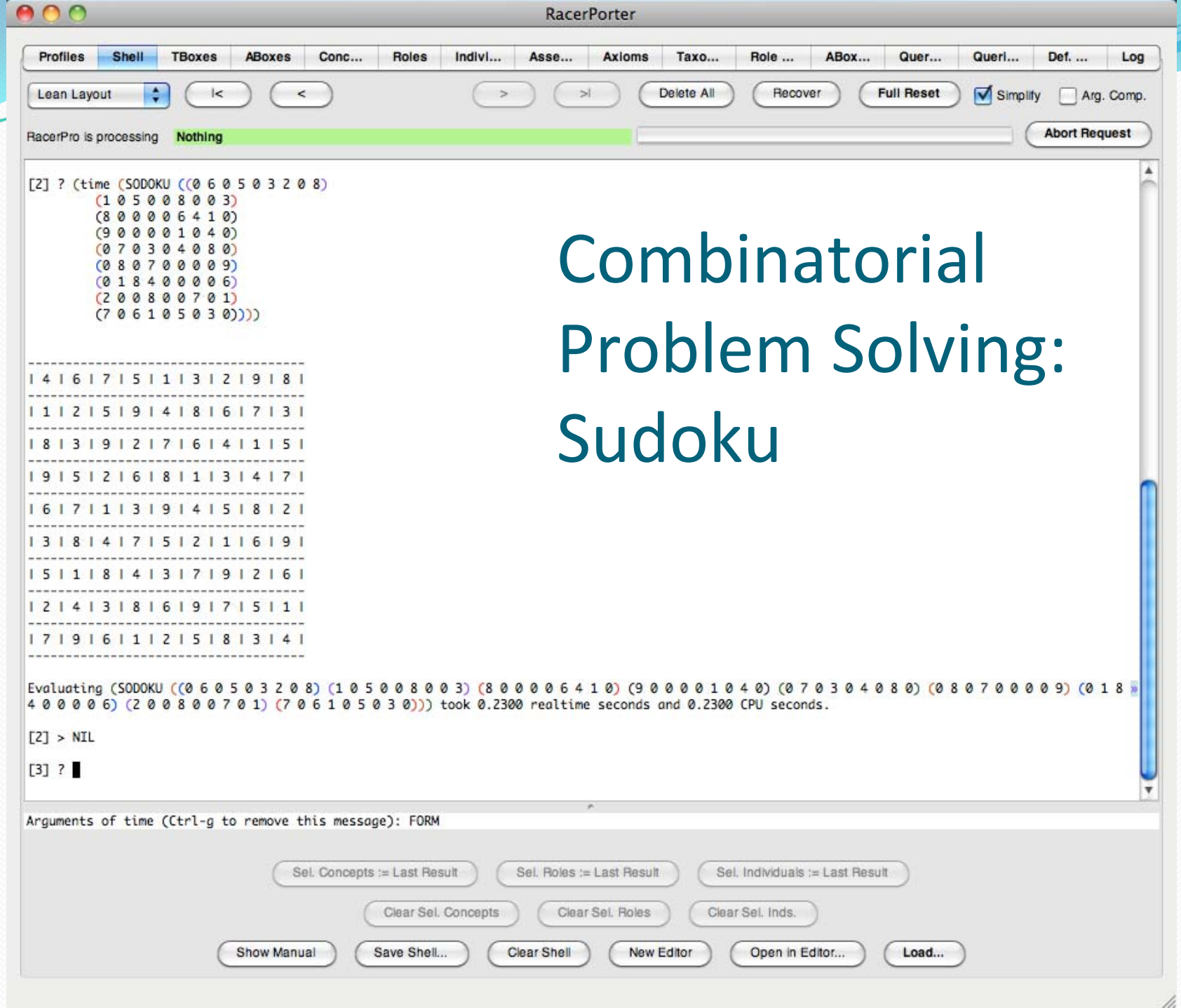
Comparison to DBs

- **Standard databases**: Use schemata for being able to (effectively) ***retrieve only stored data***
  (or aggregations thereof)
- **Semantic technologies**: Use schemata (knowledge bases, ontologies) to ***retrieve more than stored data***
  - No schemata (axioms) needed to just store data
  - The less axioms,
    - the more data can be stored
      (no inconsistencies), but…
    - the less data is implicitly added
  - Deal with ***data descriptions*** rather than data

Semantic Technologies Now: Definition

- All **representation formalisms** (and corresponding reasoning systems)
- whose representation language has a **formal semantics**,
- and whose basic decision/inference problems are **decidable**,
- and, based on a **formal query language**, potentially **data is augmented**

What can you do with semantic technologies now?



Combinatorial Problem Solving: Sudoku

Development of Domain Models

- Expressive domain modeling (EXPTIME-hard w.r.t. kb size)
  - SROIQ (+ some additions proposed)
  - SHIQ-(D) (e.g., for UML diagrams)
  - Horn-SHIQ
- Restricted expressivity such that QA scales
  - DL-Lite (for large parts of UML, subsumes RDFS)
    - Query answering can be directly done by relational engines after query is transformed (QA for conjunctive queries in AC_0)
  - Horn-SHIQ
    - Polynomial data complexity for QA (conjunctive queries)
- EL expressivity (or EL++ expressivity)
  - Basic ontology inference problems (e.g., subsumption) are tractable
  - QA can be done by rel. engines if data descriptions are extended

Ontology Development: Some Benchmark Ontologies

- Galen (A: 2700 classes, B: >20000 classes, versions without functionalities and inverses)
- Gene Ontology (GO, > 20000 classes)
- National Cancer Institute Ontology (NCI, > 20000 cl.)
- Snomed-CT (> 380,000 classes, EL)

Many others:

- Foundational Model of Anatomy (FMA)
- UMLS
- ….

SOTA

- Classifying ontologies (in secs)

	FaCT++	Pellet	HermiT	CEL	CB
GO	15.24	72.02	199.52	1.84	1.17
NCI	6.05	26.47	169.47	5.76	3.57
GalenA$^-$	3166.74	133.25	91.98	3.27	0.26
GalenA	465.35	—	45.72	*n/a*	0.32
GalenB$^-$	—	—	—	189.12	4.07
GalenB	—	—	—	*n/a*	9.58
Snomed	650.37	—	—	1185.70	49.44

Table by Yevgeny Kazakov 09

- Snomed with some axioms involving negation
  - Classify (1 hour, RacerPro)
  - Find all unsatisfiable concept names (9 mins, RacerPro)

New Reasoning Services

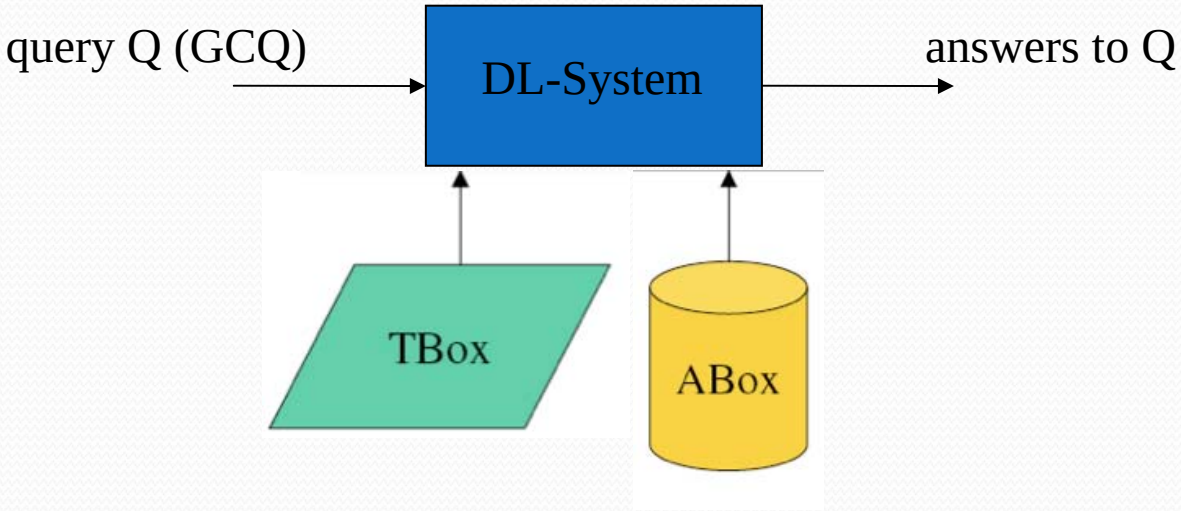
- Ontology development support
  - Explanation
    - White-box approaches
    - Black-box approaches
  - Suggestions for concepts which might be worth a name in order to better structure the ontology
- Ontology reuse support
  - Modularization

Querying w.r.t. Ontologies

- Ontologies produce (more) data
- But there might be multiple variants to produce data depending on the expressivity of the ontology language
- If some data is considered for an answer it must be available in all variants (-> certain answers)

Ontology-based Query Answering: Main-memory

- ALNHf: CLASSIC (90-96)
- SHIQ: RacerPro (99-), Pellet (04-), KAON (06-)
  - Sytems (constantly improved)
    - Pellet 2.0 (SROIQ(D)$^-$/OWL 2)
    - RacerPro 2.0 (SHIQ(D)$^-$/OWL-Lite+Q)

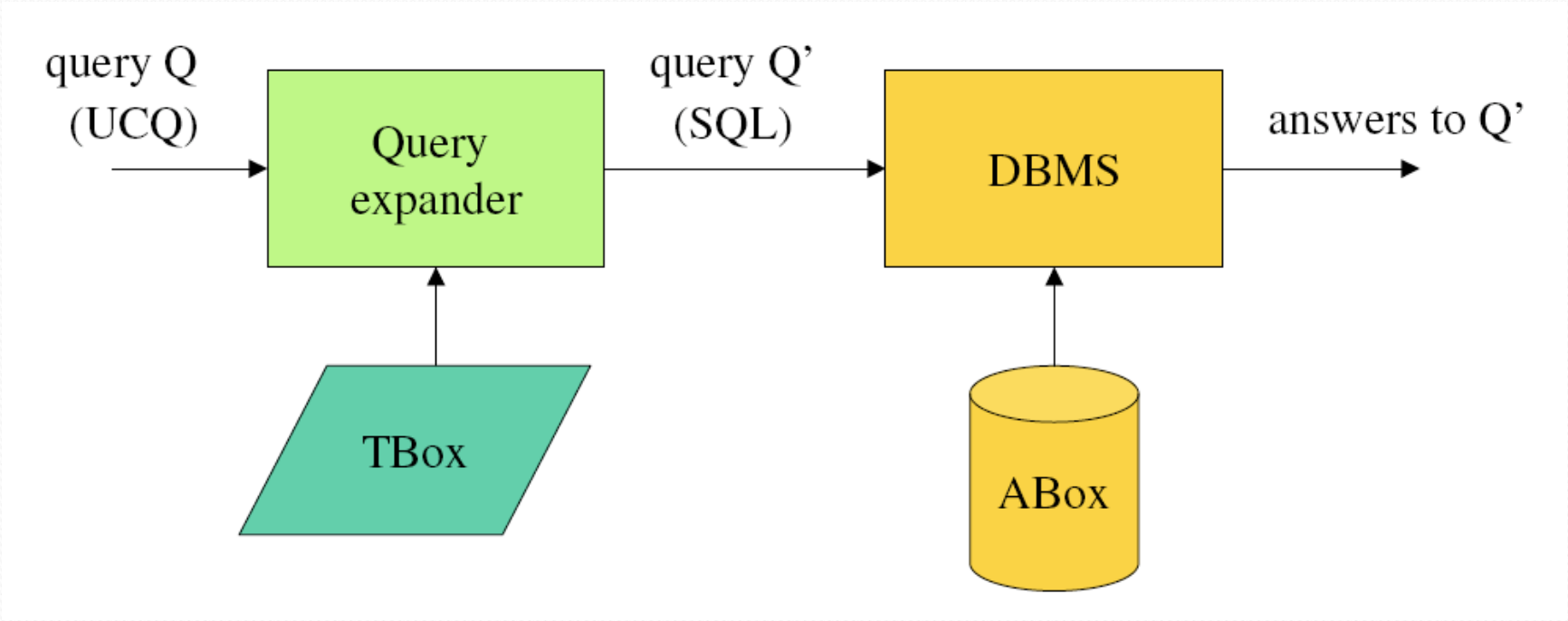


Expressivity of the Query Language

- **Conjunctive queries**
  - Quonto (DIG, SPARQL)
- **Grounded conjunctive queries**
  - Pellet (SPARQL)
  - RacerPro (DIG, OWLlink, nRQL, SPARQL)
  - SHER (SPARQL)
- **Epistemic first-order queries**
  - Expressive enough for invariant checking
  - RacerPro (nRQL)
- **Server-side functional programming**
  - RacerPro

Ontology-based Query Answering: Secondary Memory

DL-Lite: Quonto (06-)



Taken from a presentation by Riccardo Rosati

Example

TBox:

$\text{MALE} \sqsubseteq \text{PERSON}$ $\quad\quad$ $\text{FEMALE} \sqsubseteq \text{PERSON}$

$\text{MALE} \sqsubseteq \neg\text{FEMALE}$ $\quad\quad$ $\text{PERSON} \sqsubseteq \exists\text{hasFather}$

$\exists\text{hasFather}^{-} \sqsubseteq \text{MALE}$ $\quad\quad$ $\text{PERSON} \sqsubseteq \exists\text{hasMother}$

$\exists\text{hasMother}^{-} \sqsubseteq \text{FEMALE}$

input query:

$q(x) \leftarrow \text{PERSON}(x)$

rewritten query:

$$q'(x) \leftarrow \text{PERSON}(x) \vee \text{FEMALE}(x) \vee \text{MALE}(x) \vee \text{hasFather}(y,x) \vee \text{hasMother}(y,x)$$

Taken from a presentation by Riccardo Rosati

Example (contnd)

rewritten query:

$q'(x) \leftarrow \text{PERSON}(x) \vee$
$\text{FEMALE}(x) \vee$
$\text{MALE}(x) \vee$
$\text{hasFather}(y,x) \vee$
$\text{hasMother}(y,x)$

ABox:

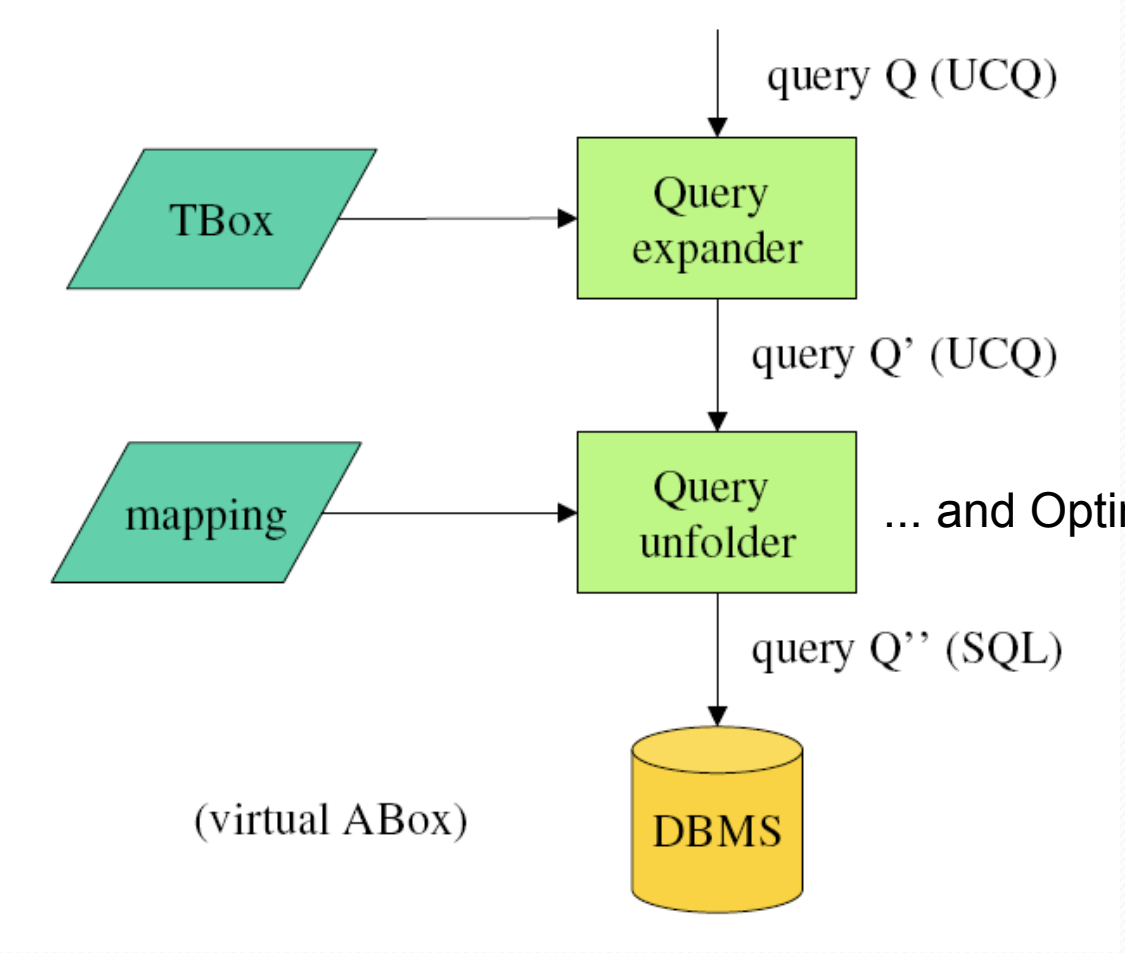
MALE(Bob)
MALE(Paul)
FEMALE(Ann)
hasFather(Paul,Ann)
hasMother(Mary,Paul)

answers to query:

{ Bob, Paul, Ann, Mary }

Taken from a presentation by Riccardo Rosati

DB Mappings (MASTRO)



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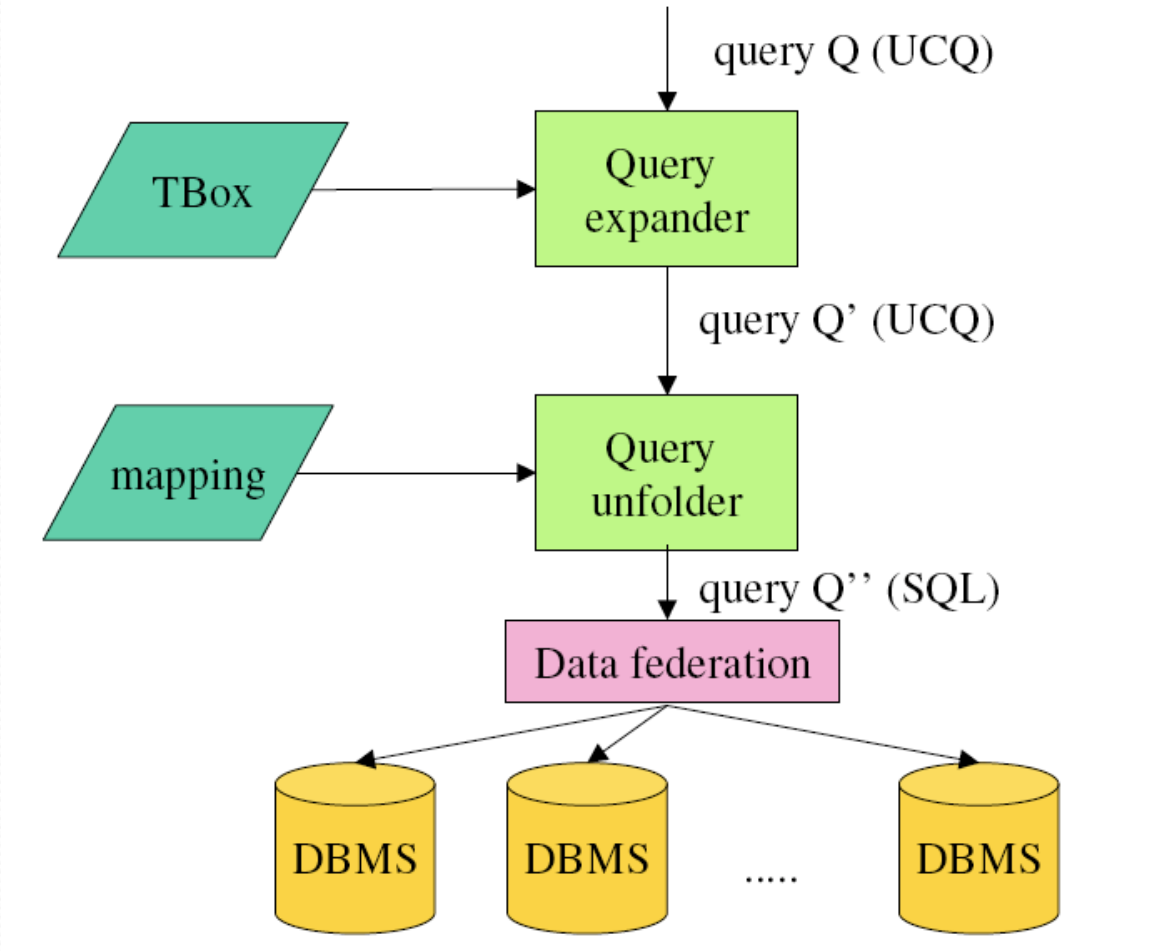
Ontology-Based Data Access

- Relational data model
  - Databases (OBDA with Quonto for DL-Lite)
- RDF data model
  - Triple stores (OBDA with AllegroGraph for RDFS++)
    - Besides query languages, often additional analysis routines are provided (e.g., social network analysis in AllegroGraph)
- Object-oriented data model
  - OO databases
- XML
  - XML databases

Data Integration (MASTRO-I)



Taken from a presentation by Riccardo Rosati

Summary: What can semantic technologies be used for today?

- Combinatorial **problem solving** (e.g., Sudoku)
- Systematic **construction of domain models**
  - Consistency checks, subsumption checks
  - Explanation, modularization, concept suggestions
- Instance retrieval / **query answering**
  - Main-memory-scalable for expressive ontology languages *(if expressivity is not excessively used)*
  - Secondary-memory-scalable *(almost)* for data-oriented ontology languages
- **Data integration**

This list is definitely incomplete

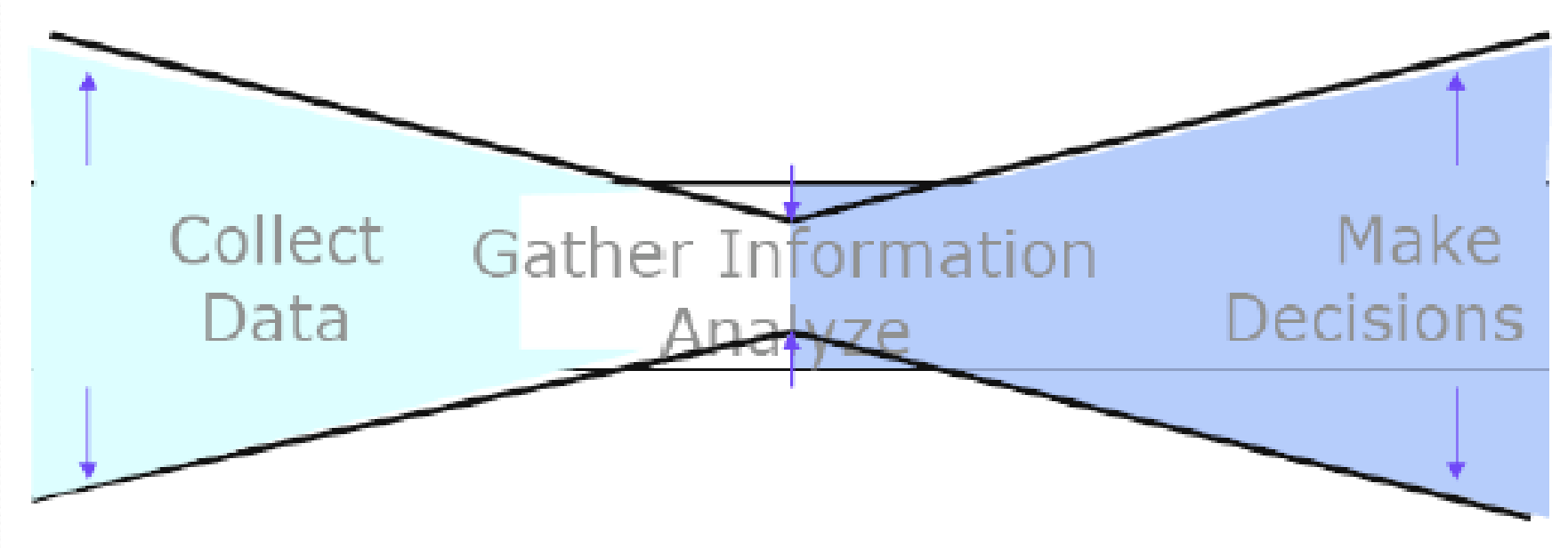
There's More to Semantic Technologies in the Future

- In some cases, only content-oriented retrieval is possible (e.g., for text, image, video, or audio data)
- Symbolic content descriptions are not directly available but have to be provided/derived(**interpretation**, see my presentation tomorrow ☺)

What techniques will be available in the future?

- Fast QA for more expressive ontology languages (based on complete approximation and sound partitioning)
- Stream-oriented data processing
  - Situation awareness / event recognition
- Systems supporting combinations of representation languages (e.g., OWL+ASP)
- Scalable reasoning with probabilistic and fuzzy representations considered
- Semantically well-founded programming with indefinite information (null values avoided)

Integrate, yes…

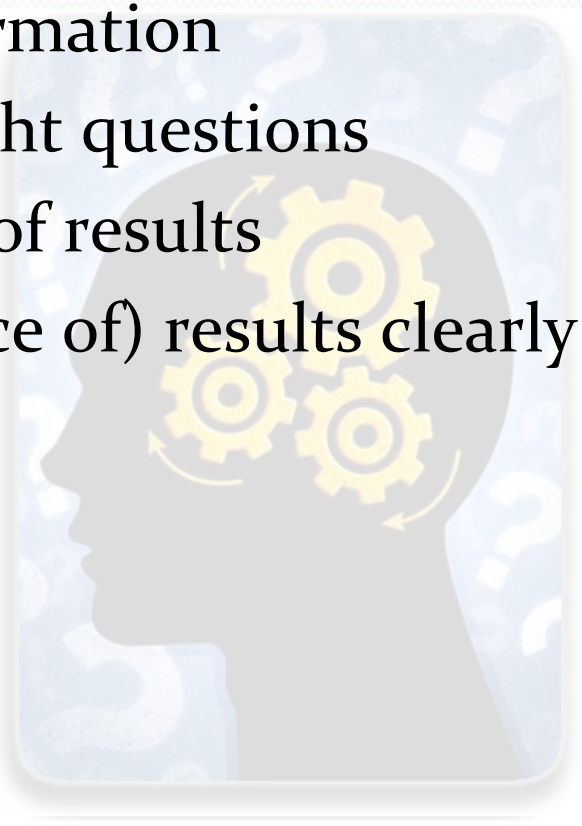


- Decisions based on information
- Analysis of data is the bottleneck

…, and understand?

Need to help decision-makers **understand** integrated information

- Find the right information
- Let user ask the right questions
- Create summaries of results
- Explain (provenance of) results clearly



Thank you

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