Automatic Extraction of Ontologies Wrapping Relational Data Sources

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Free University of Bozen-Bolzano

September 1, 2009

Semantic data access

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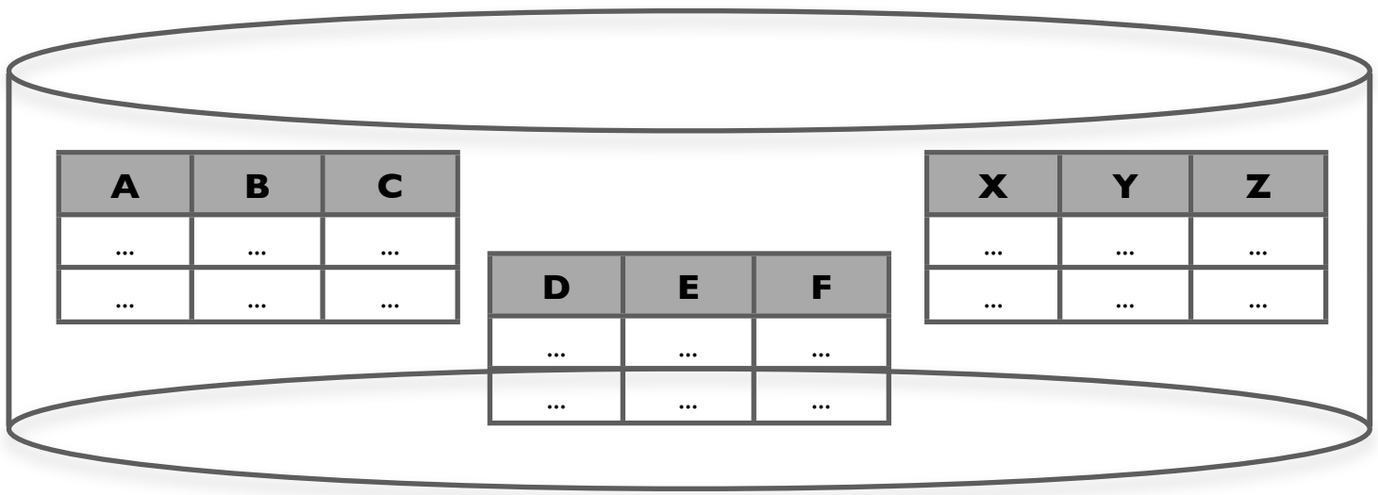

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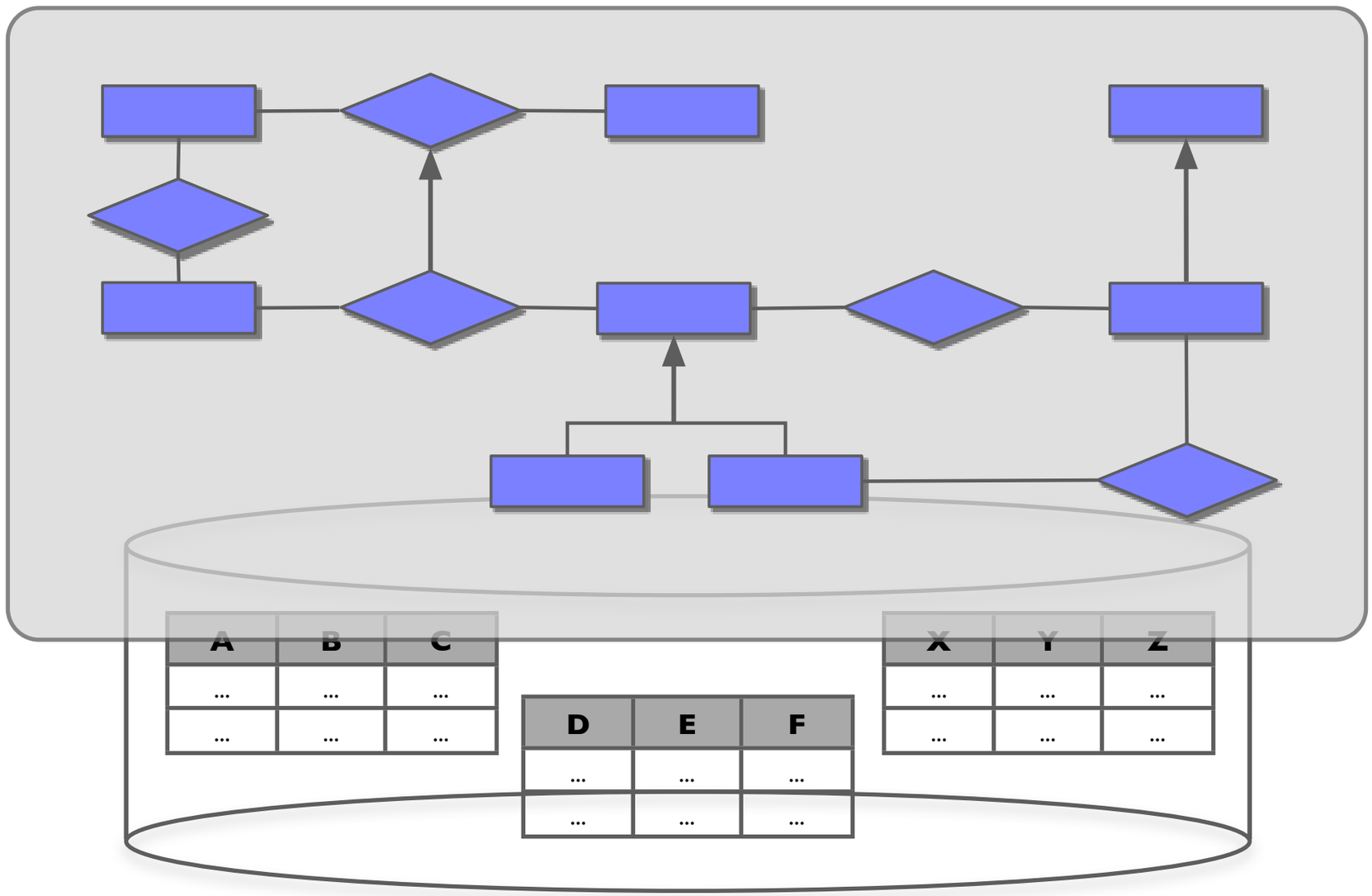

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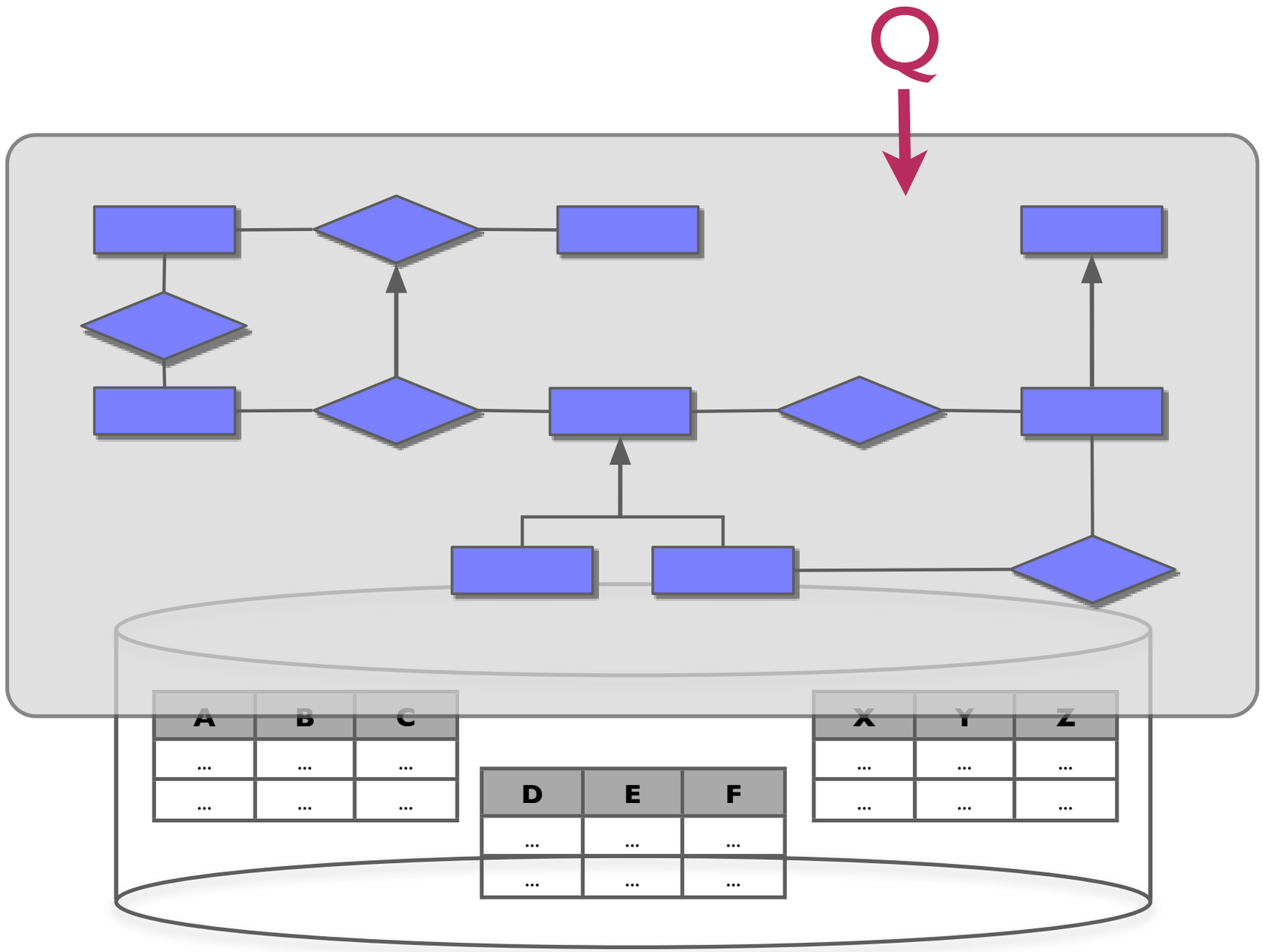

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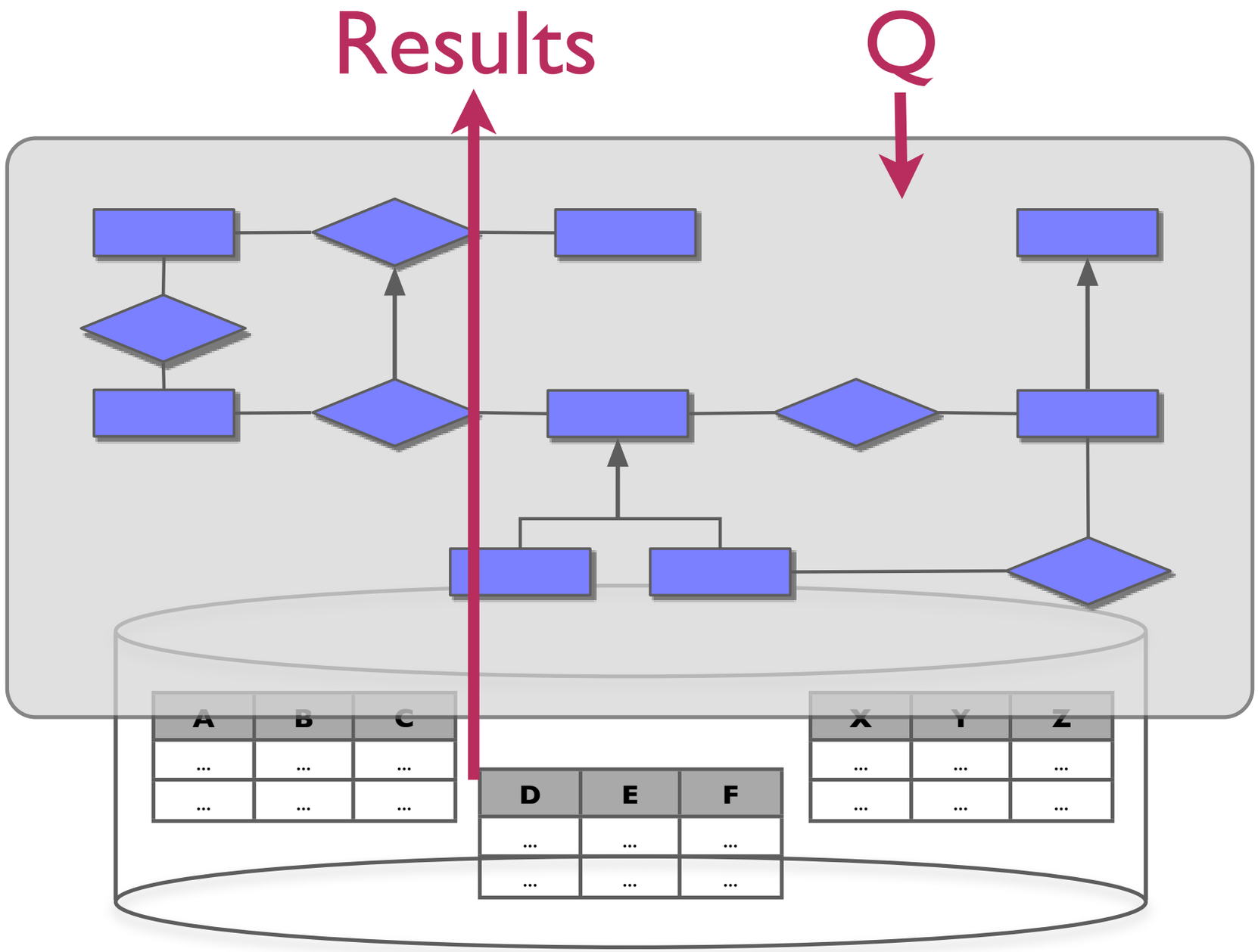

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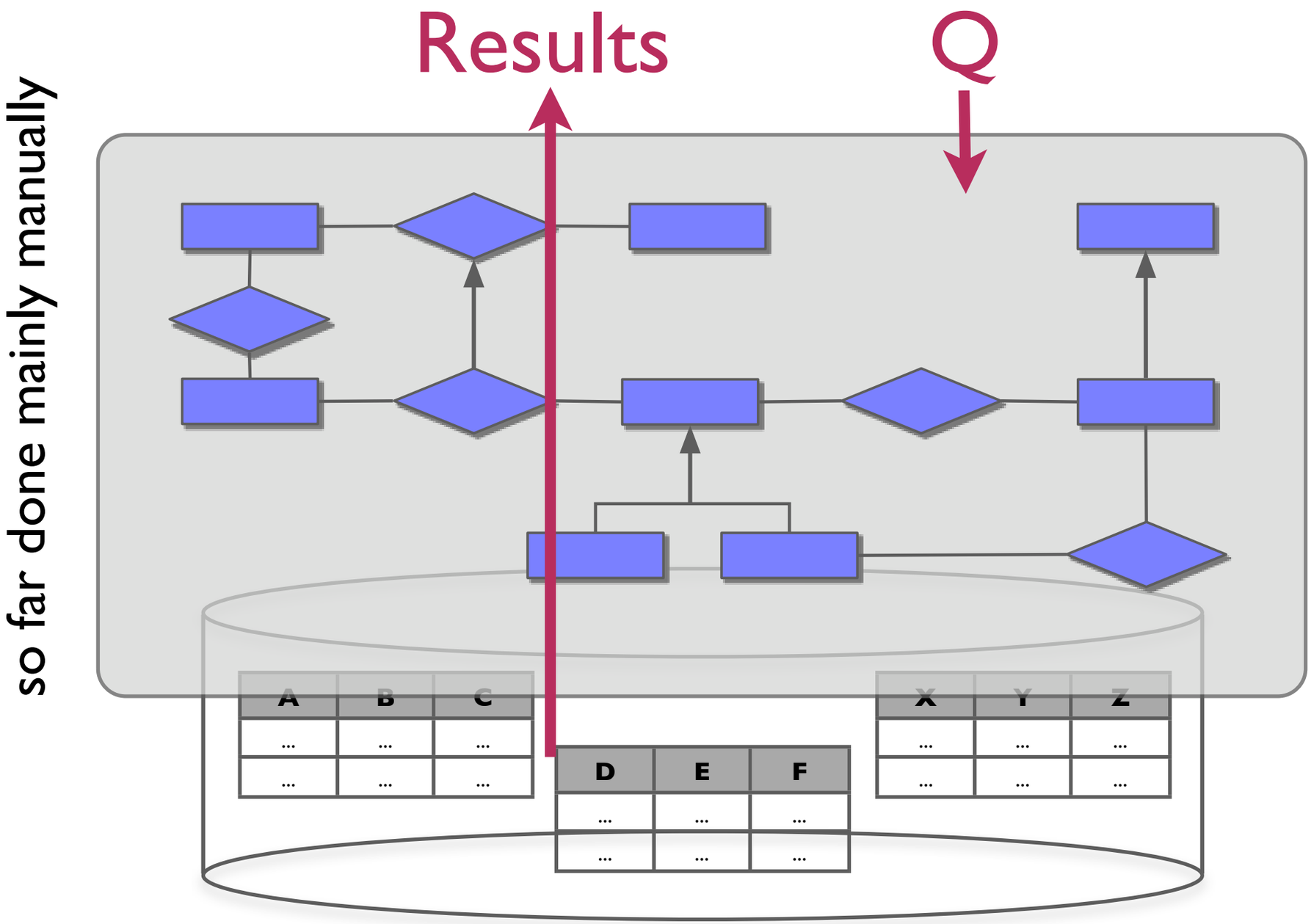

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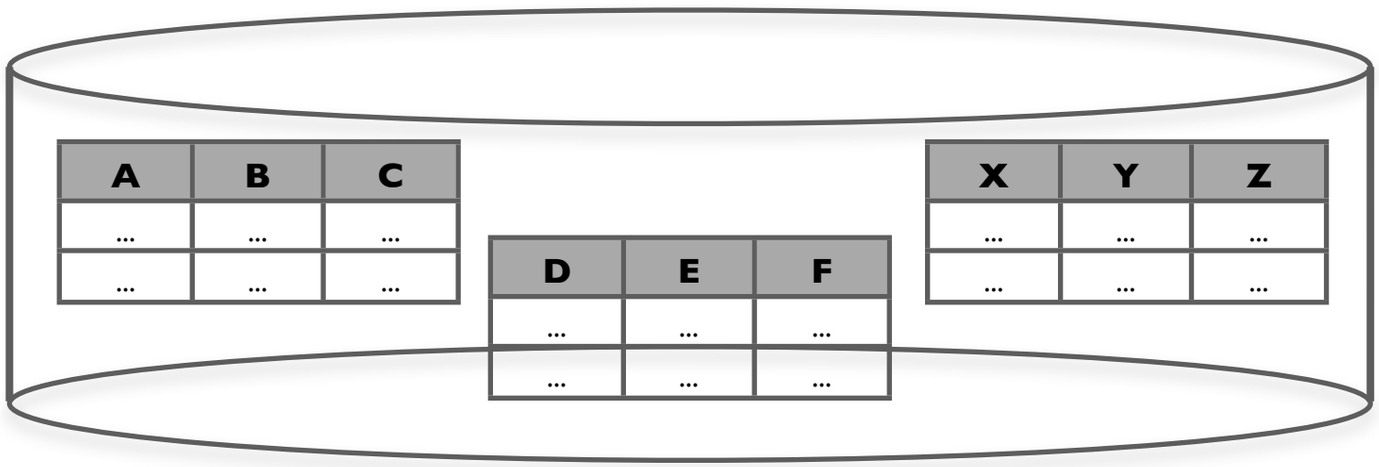

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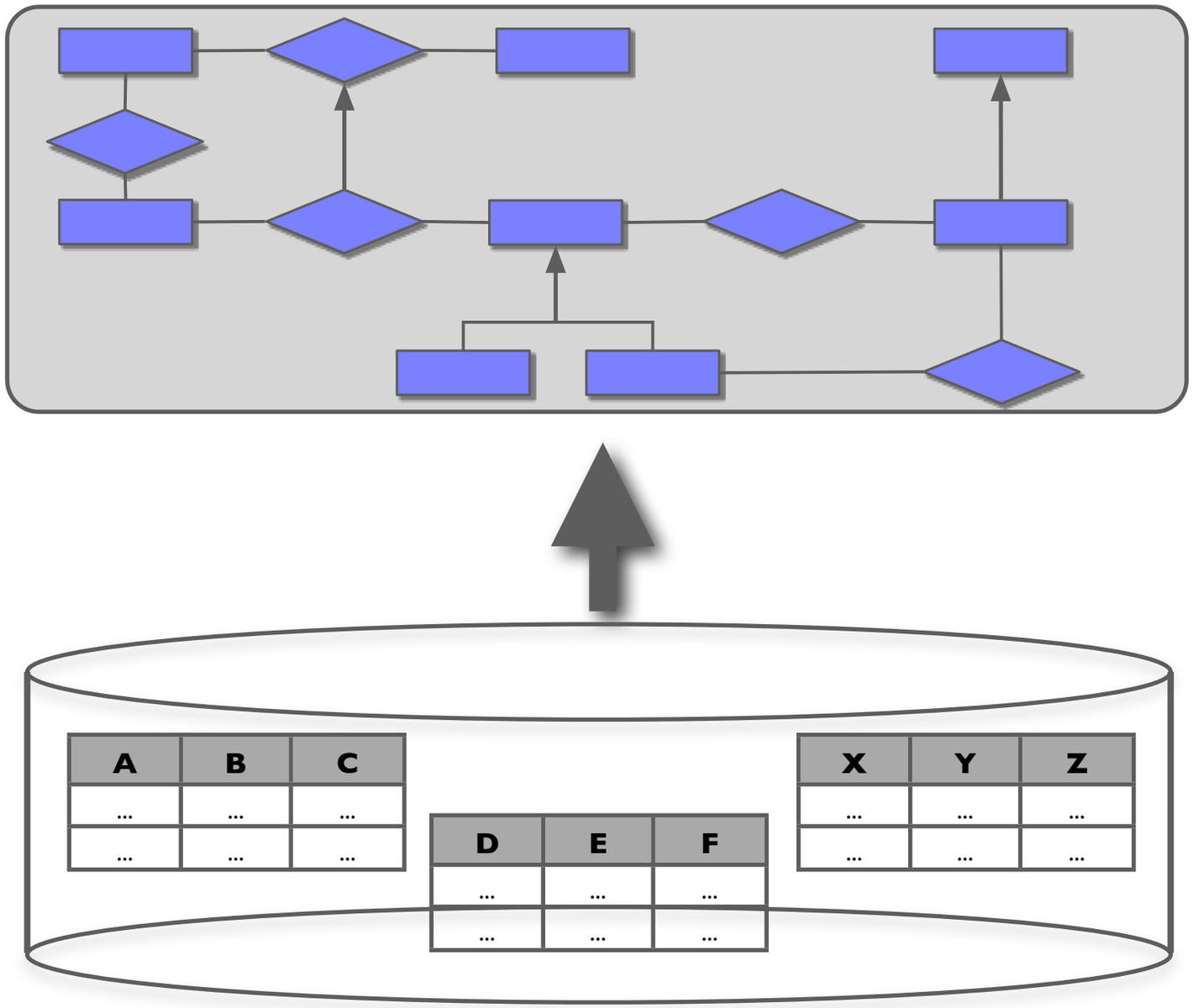

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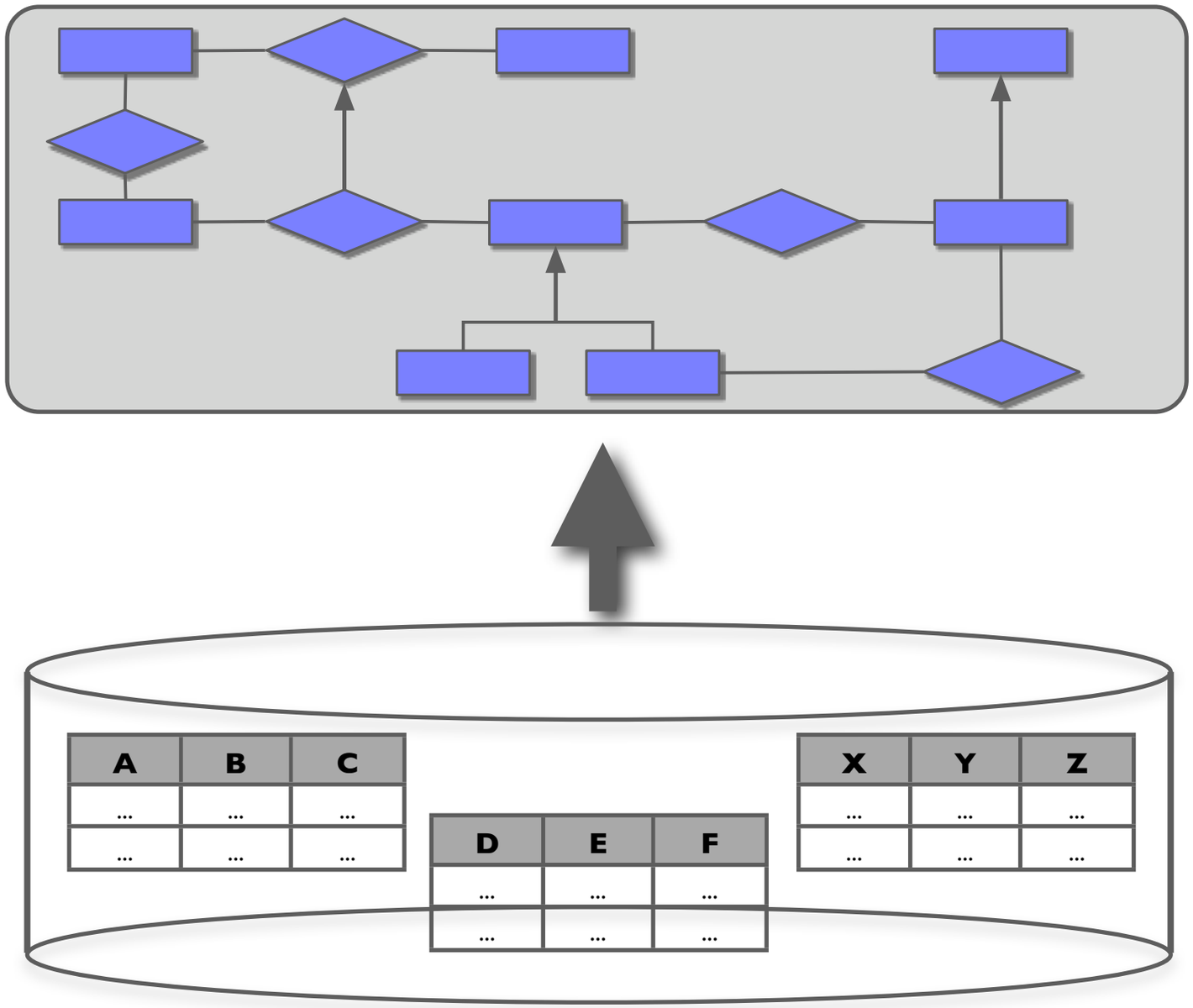

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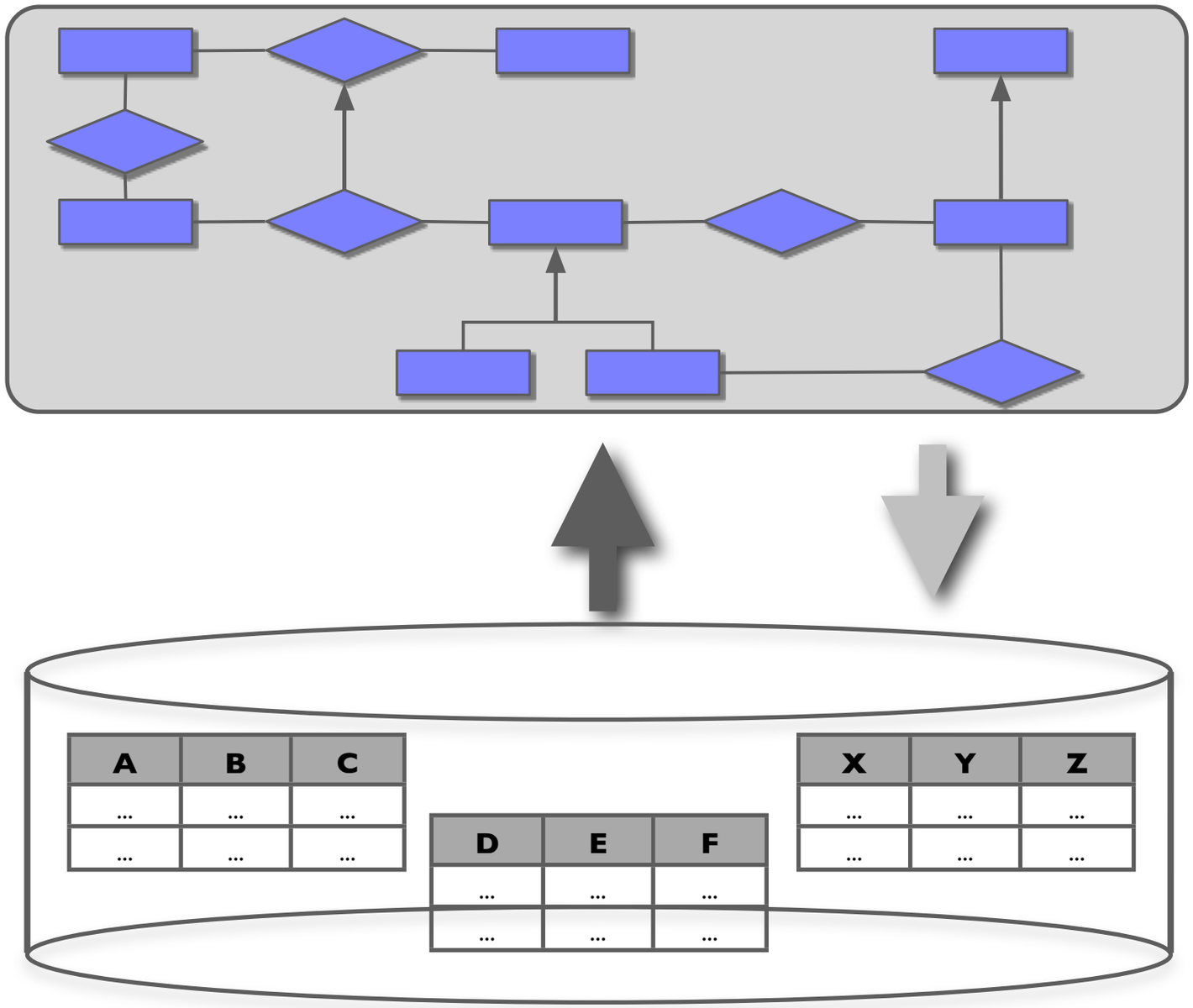


preserve the semantics of the constraints in the DB

maintain the link with the DB

Outline

- Formal Framework
- Ontology Extraction
- Implementation and Case Study
- Related Work
- Current Work

Relational source

- A relational source DB = {Ψ, Σ}, with Ψ a relational schema and Σ set of integrity constraints:
  - nulls-not-allowed: $nonnull(r, A)$
  - unique: $unique(r, A)$
  - key: $key(r, A)$, if $nonnull(r, A)$ and $unique(r, A)$
  - inclusion: $r_1[s_1] \subseteq r_2[s_2]$
  - foreign key: if $r_1[s_1] \subseteq r_2[s_2]$ and $key(r_2, s_2)$
  - exclusion: $(r_1[s_1] \cap r_2[s_2]) = \emptyset$
  - covering: $(r_1[s_1] \cup \ldots \cup r_m[s_m]) \subseteq r_0[s_0]$

Ontology language

- DLR-DB system $S = \{R, K\}$, with R a relational schema and K set of axioms involving names from R:

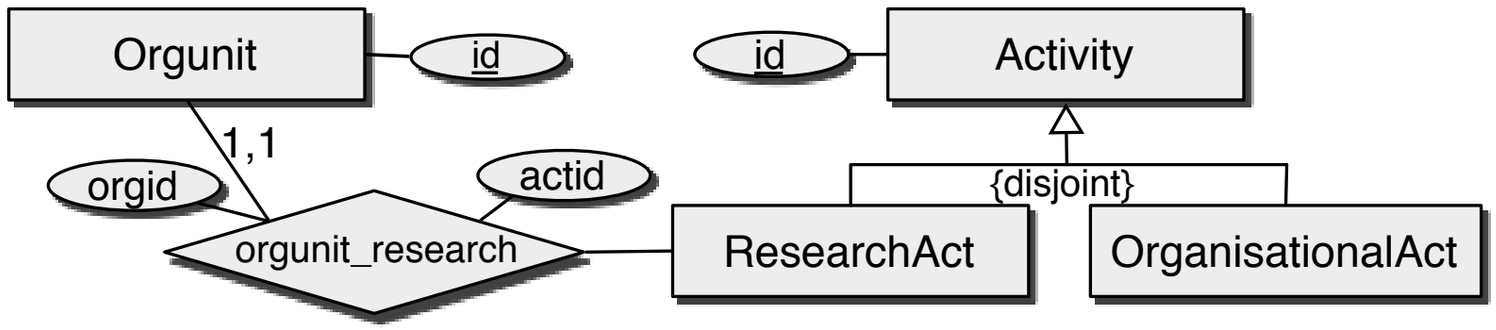
$R[s] \sqsubseteq R'[s']$	$\pi_s R^{\mathcal{D}} \subseteq \pi_{s'} R'^{\mathcal{D}}$	Inclusion
$R[s]$ disj $R'[s']$	$\pi_s R^{\mathcal{D}} \cap \pi_{s'} R'^{\mathcal{D}} = \emptyset$	Disjointness
$\text{key}(R[s_1, \ldots, s_k])$	for all $\phi_1, \phi_2 \in R^{\mathcal{D}}$ with $\phi_1 \neq \phi_2$, we have $\phi_1(s_i) \neq \phi_2(s_i)$ for some s_i, $1 \leq i \leq k$	Key
$R_1[s_1], \ldots, R_k[s_k]$ cover $R[s]$	$\pi_s R^{\mathcal{D}} \subseteq \bigcup_{i=1\ldots k} \pi_{s_i} R_i'^{\mathcal{D}}$	Covering

- able to express common constraints of ER diagrams
- can be reduced to DL DLR-Lite

  ➡ use of efficient (LogSpace) query answering technique

  ➡ compatible with OWL

Ontology language: example



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orgunit_research[actid] ⊑ ResearchAct[id]

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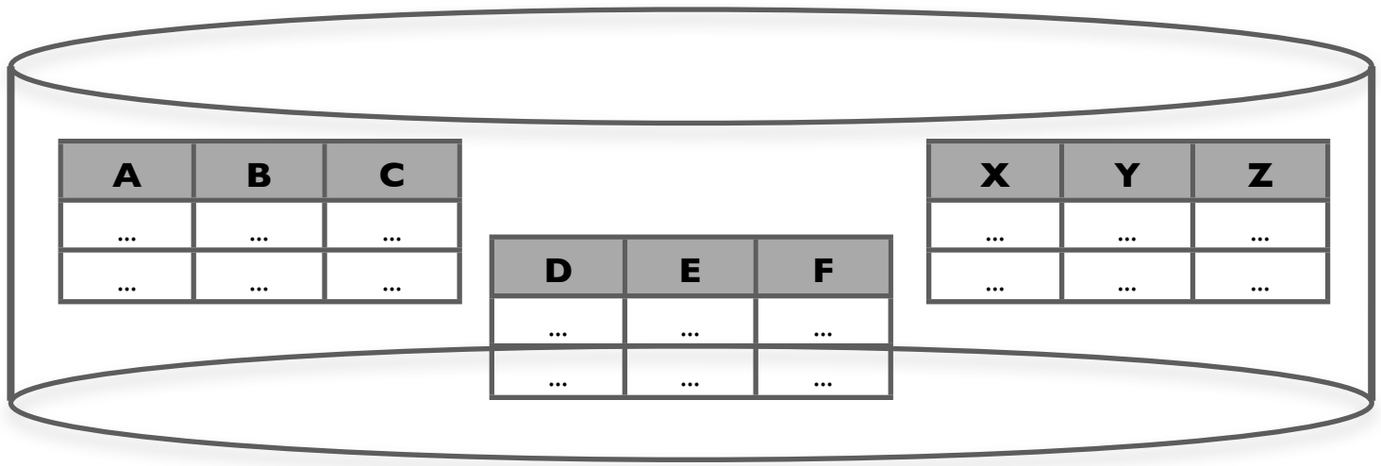
Ontology extraction: intuition

Basic idea: reverse the standard database modeling process



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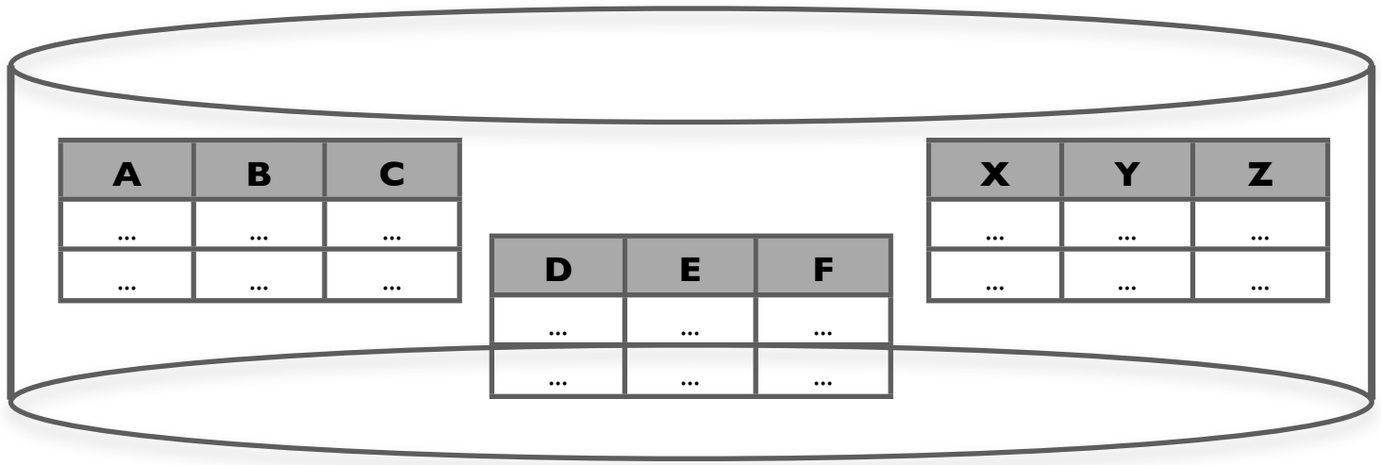

Step 1: classify relations by analyzing the integrity constraints in Σ

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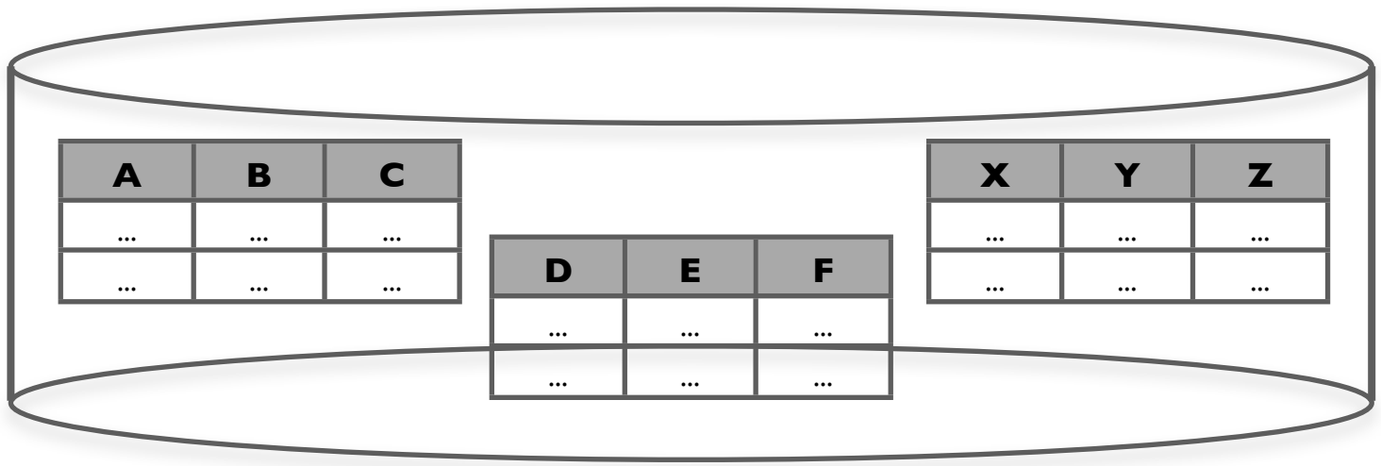

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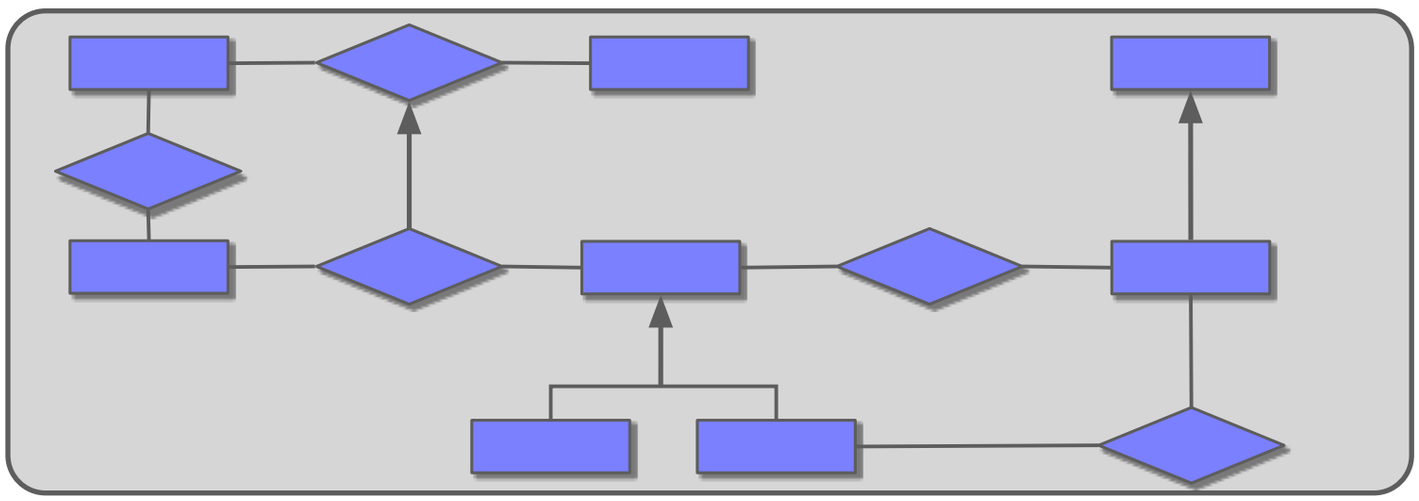

Step 2: build the ontology by means of DLR-DB axioms *K* and generate view in *R* for each ontology element

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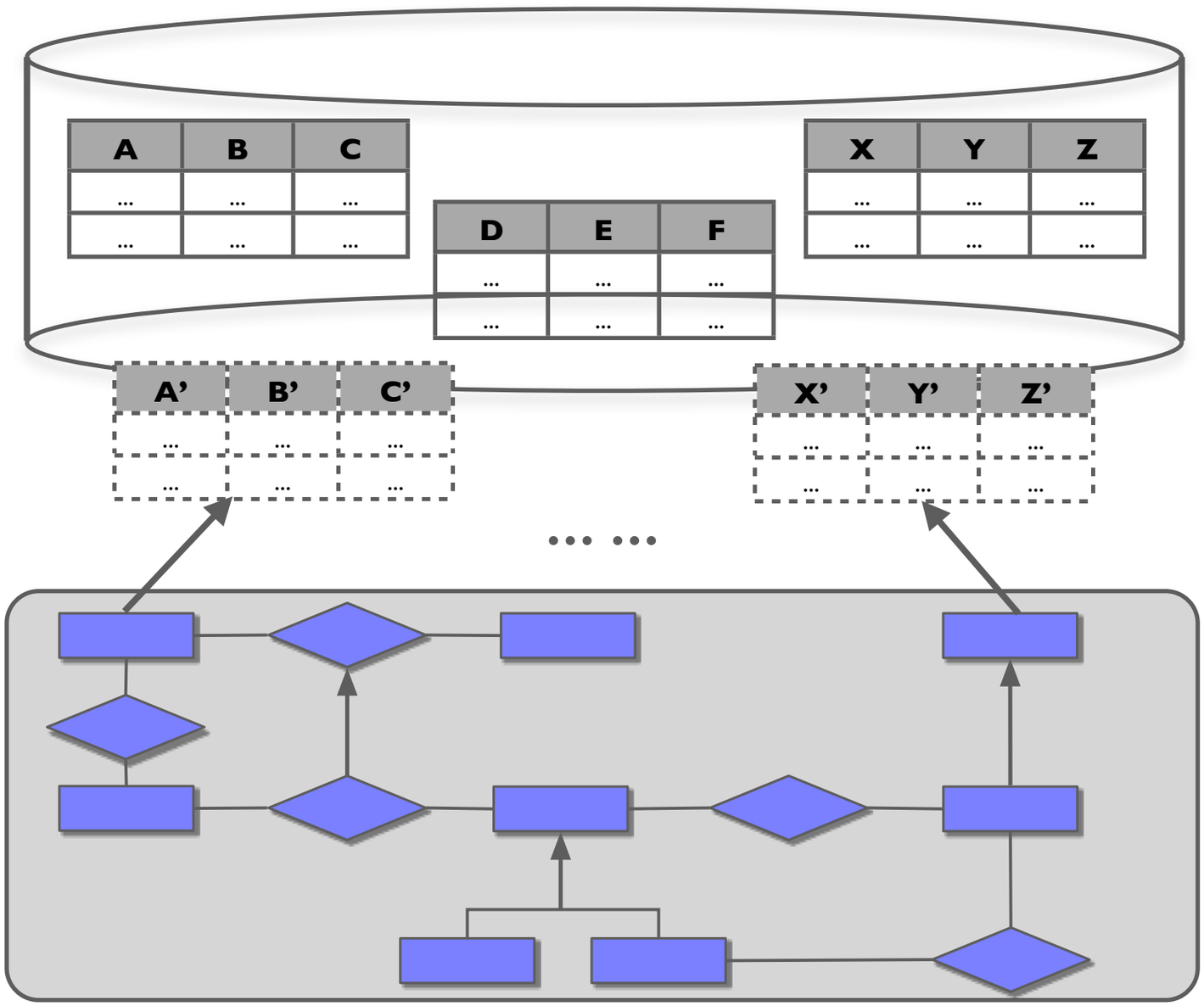

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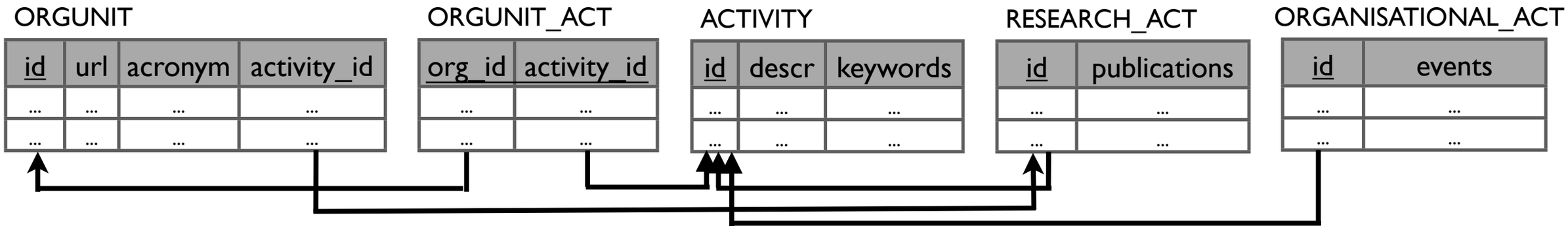
- Relationship, if K is entirely composed of $\boldsymbol{FK}$ and $|\boldsymbol{FK}| > 1$
- Specific, if K is among $\boldsymbol{FK}$ and either $|\boldsymbol{FK}| = 1$, or K is referenced by some other relation
- Ambiguous, otherwise

Ontology extraction by example



nonnull(ORGUNIT, activity_id)

unique(ORGUNIT, activity_id)

RESEARCH_ACT[id] ∩ ORGANISATIONAL_ACT[id] = ∅

Ontology extraction by example

ORGUNIT

id	url	acronym	activity_id
...	...	...	...
...	...	...	...

ORGUNIT_ACT

org_id	activity_id
...	...
...	...

ACTIVITY

id	descr	keywords
...	...	...
...	...	...

RESEARCH_ACT

id	publications
...	...
...	...

ORGANISATIONAL_ACT

id	events
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activity

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key(Orgunit[id])
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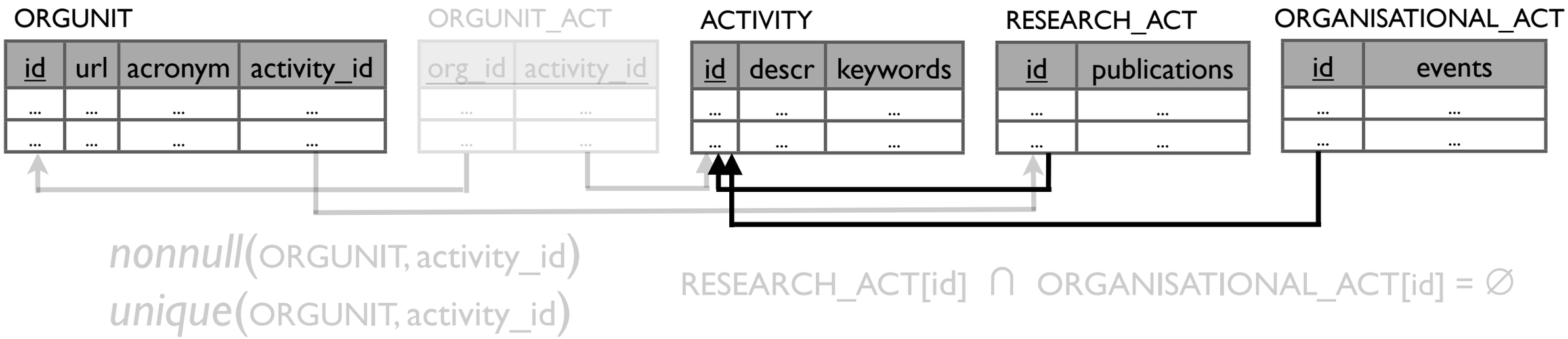

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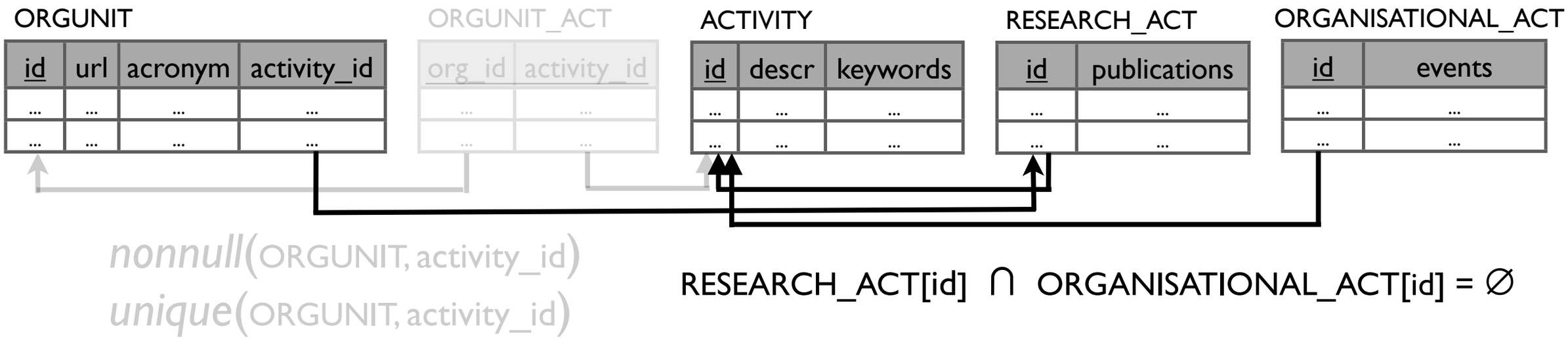

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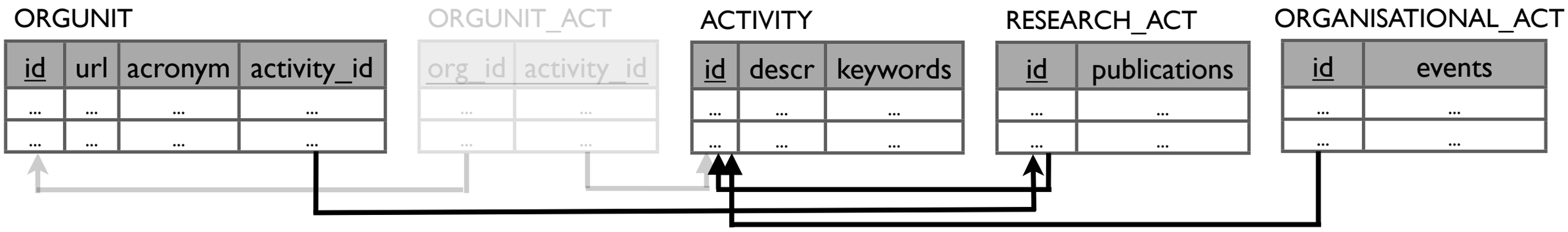

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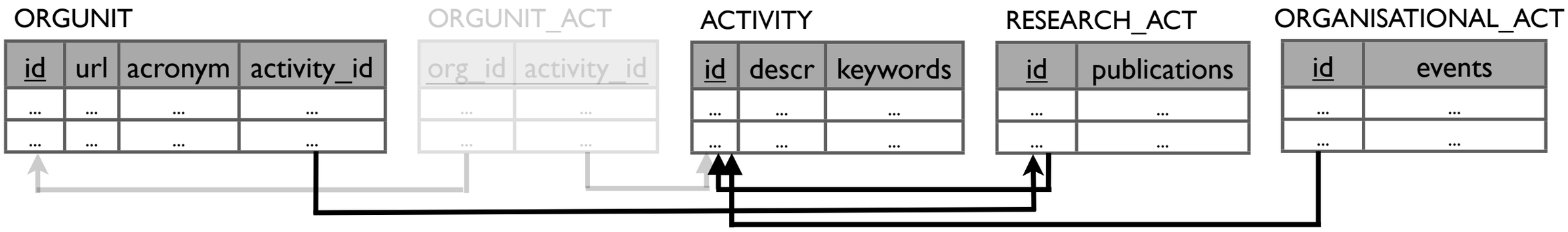

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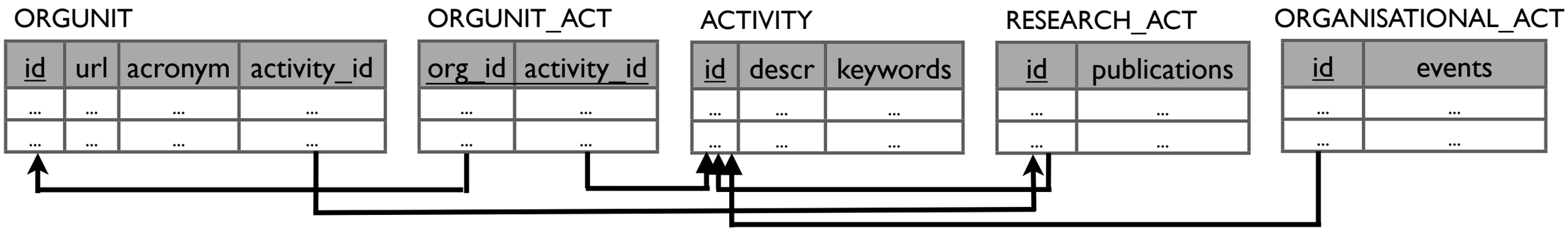

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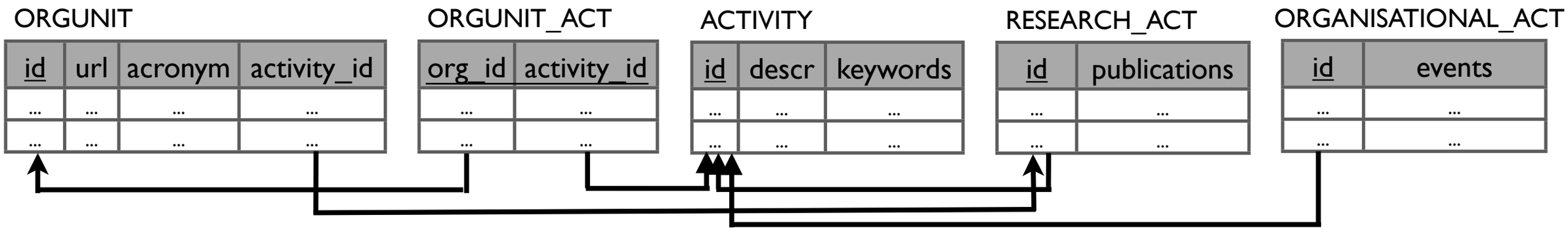

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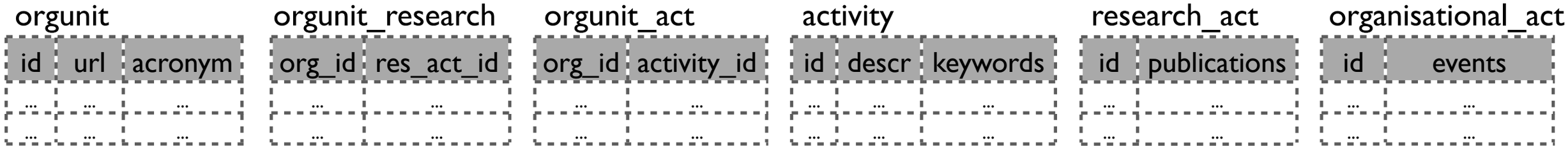

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Correctness and completeness

- Correctness and completeness using the general concept of information capacities [Miller et al.; '93]
- ***Theorem:*** the ontology extraction procedure is an equivalence preserving schema transformation

➡ no information loss

➡ queries expressed over the ontology can be answered by simply expanding the generated views!

Ontology extraction in Protégé

[Rodriguez-Muro et al., IIMAS'08; Poggi et al., OWLED'08; Calvanese et al., OWLED'08],

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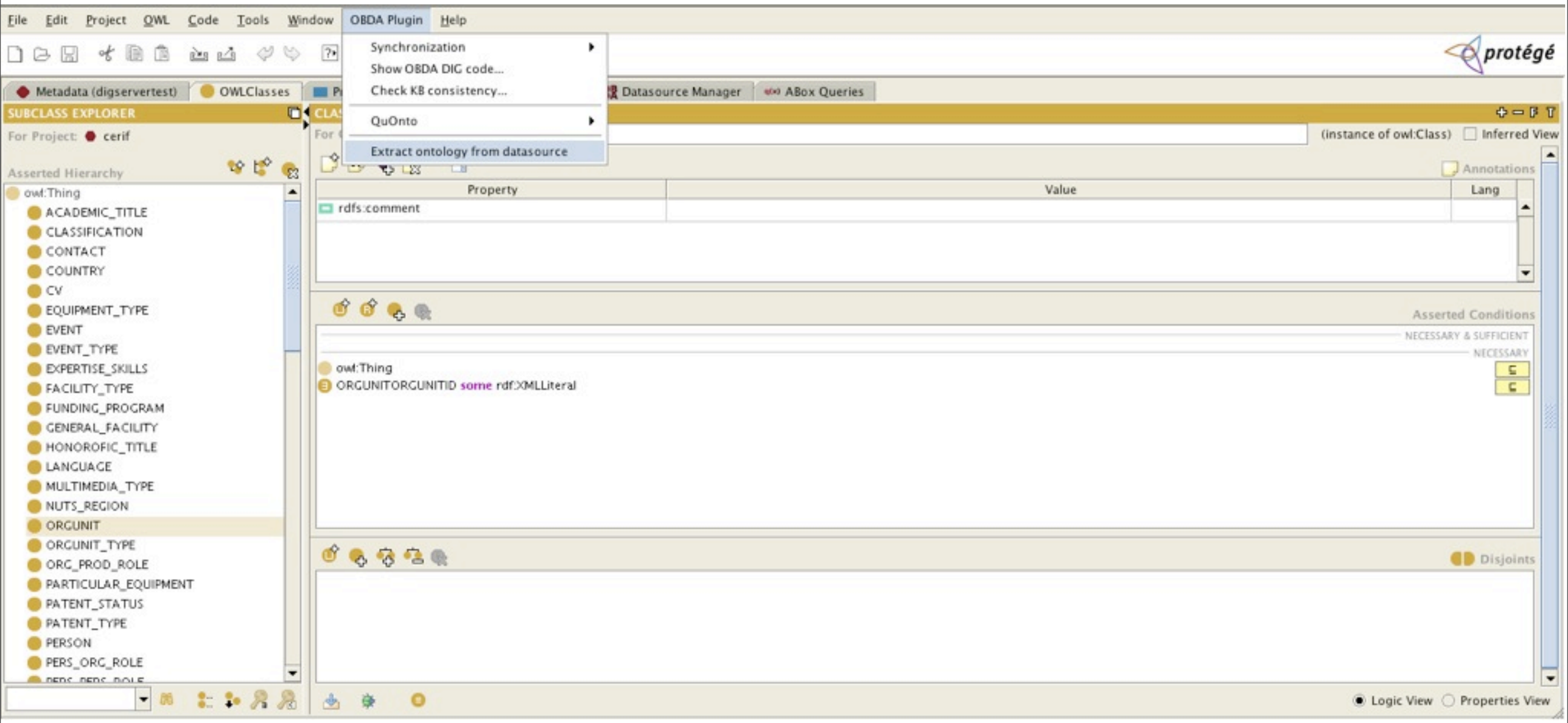

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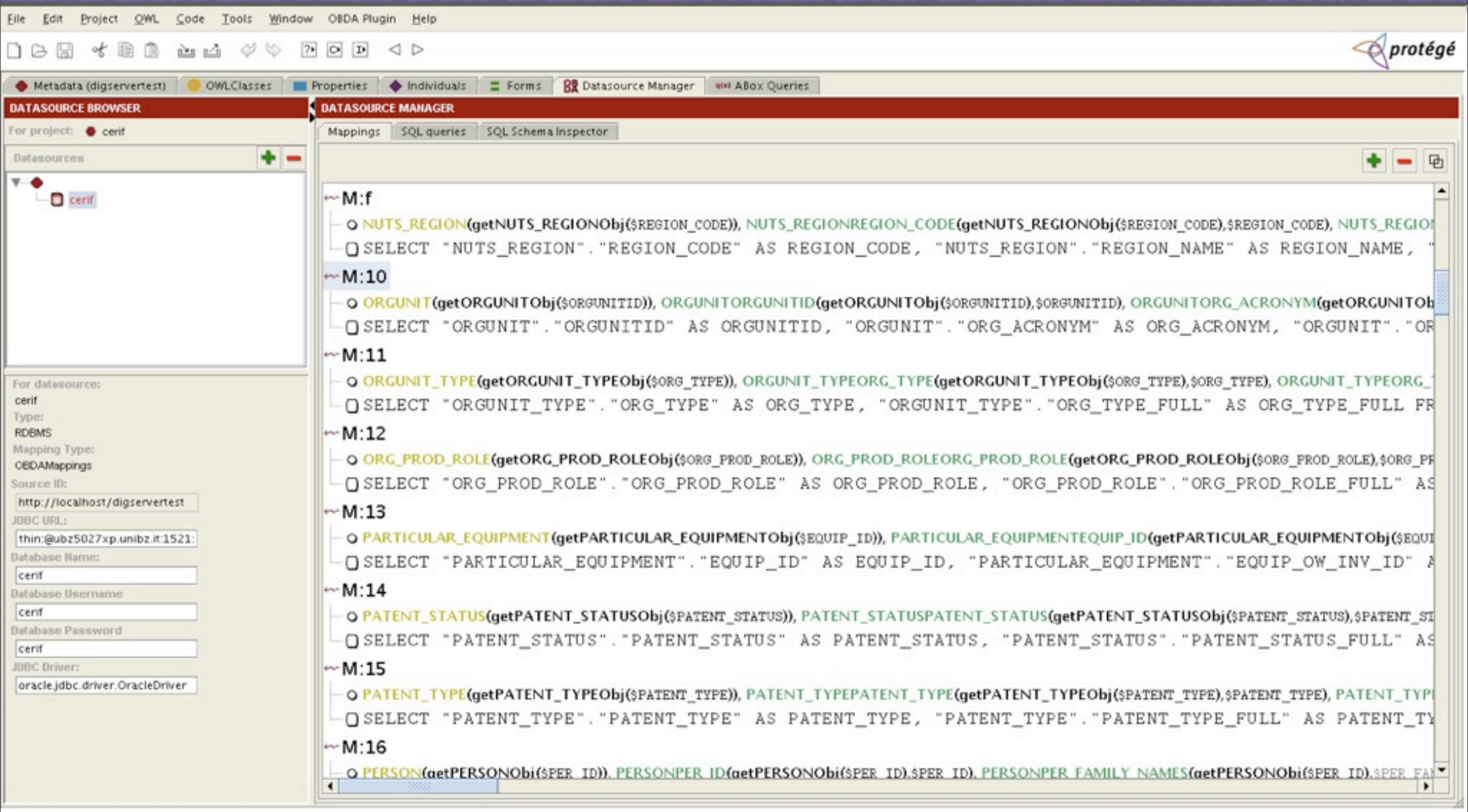

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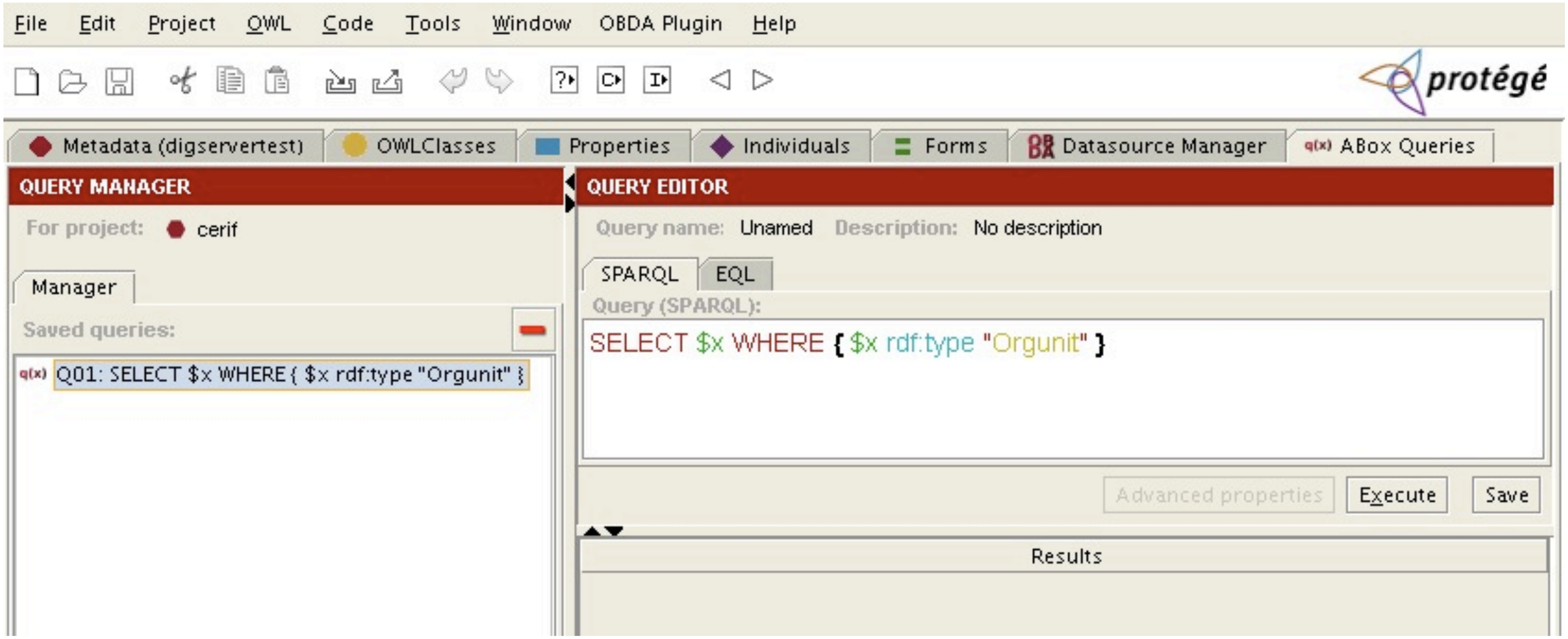

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CERIF case study

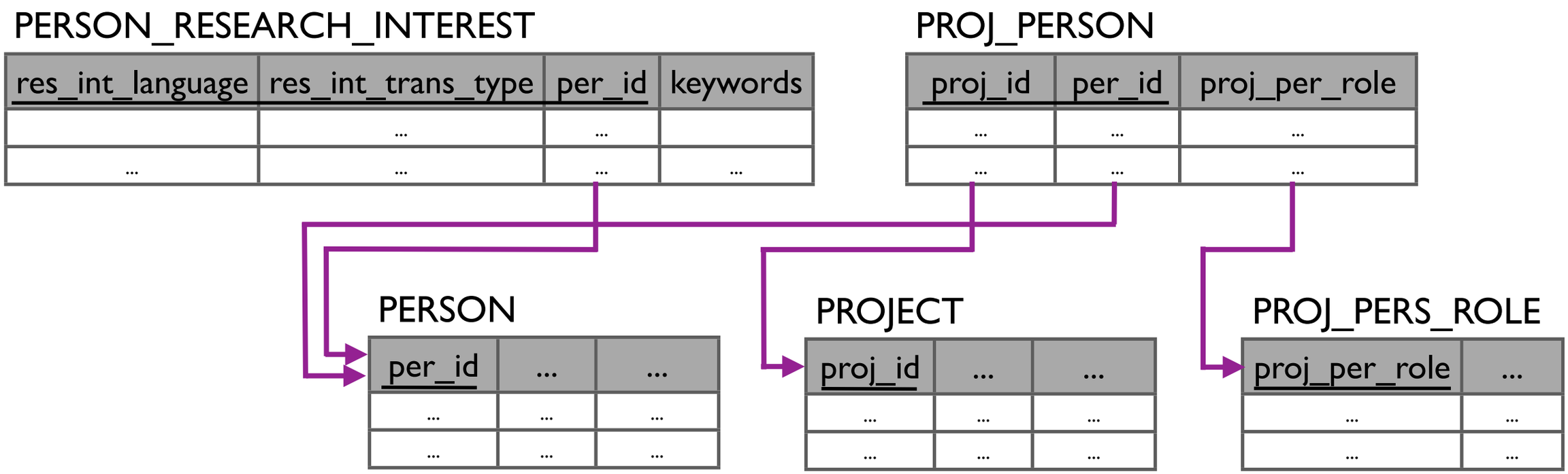
- CERIF (Common European Research Information Framework) database schema
  - http://cordis.europa.eu/cerif/src/toolkit.htm
  - 123 tables; rich with constraints
  - correct ontology constructs were generated for 77 tables

Relation type	#Classified
base	52
relationship	25
specific	0
ambiguous	46

Axiom	#Extracted
inclusion	68
key	63
disjointness	0
covering	0

CERIF: ambiguous relations

- All 46 ambiguous relations fall into one of the two types:



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PERSON_RESEARCH_INTEREST

res_int_language	res_int_trans_type	per_id	keywords
	...	...	
...	...	...	...

PROJ_PERSON

proj_id	per_id	proj_per_role
...	...	...
...	...	...

RESEARCH_INTEREST

language	trans_type
...	...
...	...

PERSON

per_id	...	...
...	...	...
...	...	...

PROJECT

proj_id	...	...
...	...	...
...	...	...

PROJ_PERS_ROLE

proj_per_role	...
...	...
...	...

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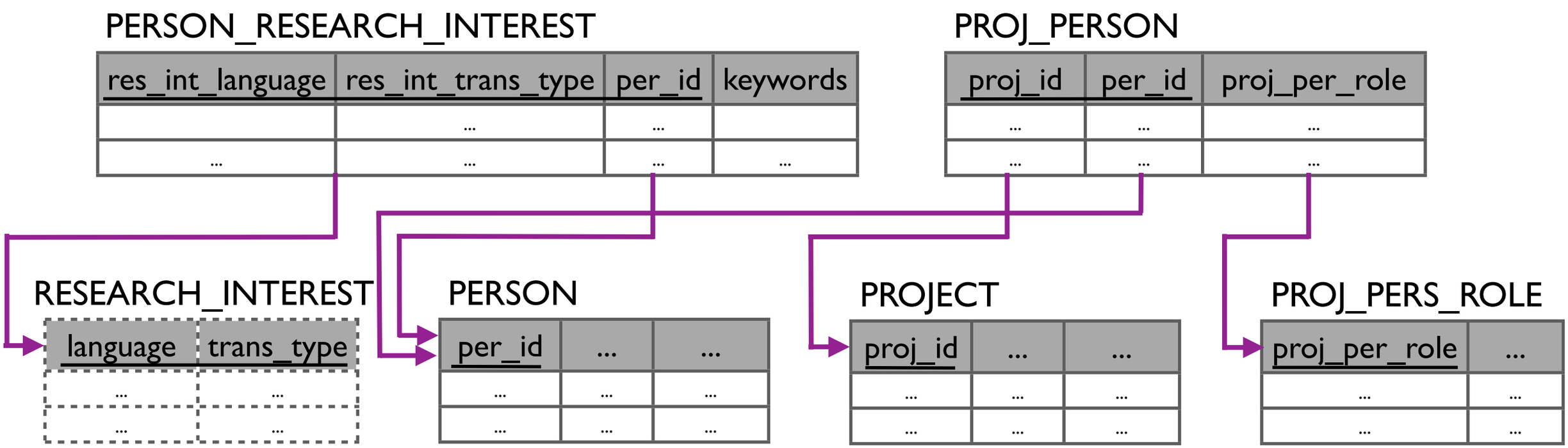

➡ a slight extension of the algorithm correctly generates CERIF ontology

Related work

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  - SWARD and Virtuoso automatically generate RDF views over RDBs
- Linking RDBs and ontologies
  - D2R MAP, R2O, [Poggi et al.;'08] allow to declaratively state mappings
  - [An et al; '05] presents semi-automatic mapping discovery

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  - automatic generation of mappings
  - enables automated reasoning to support the designer
- Ensuring faithfulness of the extracted model
  - no data loss

Current work

- Tool for exploring the logical schema of a DB and for facilitating the annotation of the schema by means of constraints
- Experiments with other real-world DB schemas to identify other peculiarities that schemas exhibit