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Updating Wikipedia via DBpedia Mappings and SPARQL

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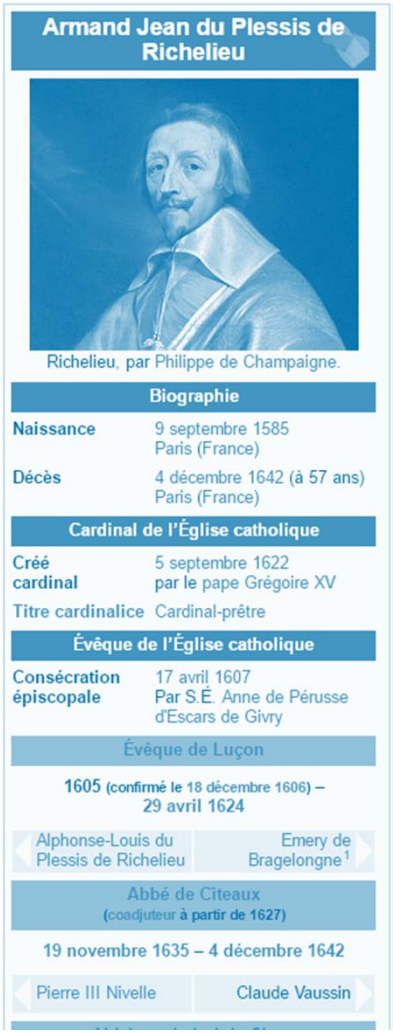
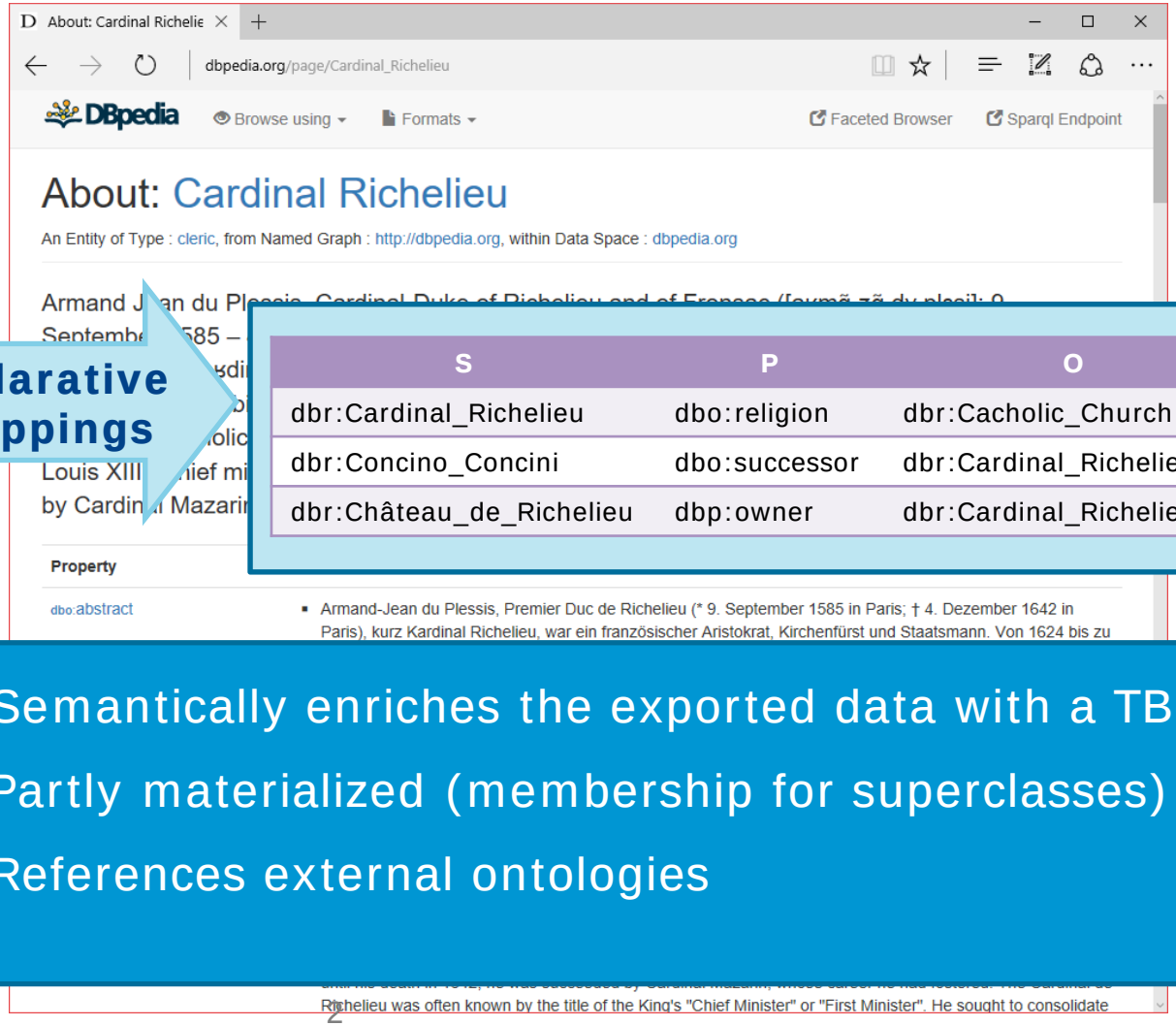
Wikipedia as a Data Service



declarative mappings



S	P	O
dbr:Cardinal_Richelieu	dbo:religion	dbr:Cacholic_Church
dbr:Concino_Concini	dbo:successor	dbr:Cardinal_Richelieu
dbr:Château_de_Richelieu	dbp:owner	dbr:Cardinal_Richelieu

- ✓ Semantically enriches the exported data with a TBox
- ✓ Partly materialized (membership for superclasses)
- ✓ References external ontologies

Motivation for batch updates

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```
DELETE {
 ?X dbo:region dbr:Upper_Normandy .
 ?Y dbo:region dbr:Lower_Normandy .}
INSERT {
 ?X dbo:region dbr:Normandy .
 ?Y dbo:region dbr:Normandy}
WHERE {
 {?X dbo:region dbr:Upper_Normandy}
 UNION
 {?Y dbo:region dbr:Lower_Normandy}
}
```

Ontology Based Data Management (OBDM)

Ontology as a unified interface for querying and updating the data in external sources.

Updates+Entailment: First Steps

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Without mappings: updates can be unambiguously resolved for some simple ontology languages.

Example: RDFS¬ = RDFS core + Class disjointness

[ESWC 2016: Ahmeti, Calvanese, Polleres, S.]

- **Subclass** $A \sqsubseteq B$, **subproperty** $p \sqsubseteq q$
- **Domain and range restrictions**

  domain of p is restricted to A: $\exists p \sqsubseteq A$

  range of p is restricted to A: $\exists p^{-1} \sqsubseteq A$
- **Class disjointness** $A \sqsubseteq \neg B$

DBpedia TBox features

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RDFS¬ +

- Inverse properties $p \sqsubseteq r^-$
- Property disjointness $p \sqsubseteq \neg r$
- Functionality (**data properties only**)
- DifferentFrom $c_1 \neq c_2$
- sameAs $c_1 = c_2$ (to link **external ontologies**)
- redirectsTo: equality with the **canonical representative** of each equivalence class

French Catholic Clergy mapping

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```
Mapping fr:Infobox Prélat catholique{{ConditionalMapping
| cases =
 {{Condition  | templateProperty = titre  | operator = equals  | value = Pape
          | mapping = {{TemplateMapping | mapToClass = Pope | mappings =
             {{IntermediateNodeMapping  |  nodeClass = PersonFunction  | correspondingProperty = occupation
             | mappings =
               {{ConstantMapping | ontologyProperty = title | value = Pape }}
               {{PropertyMapping | templateProperty = début pontificat | ontologyProperty = activeYearsStartYear }}
               {{PropertyMapping | templateProperty = fin pontificat | ontologyProperty = activeYearsEndYear }}
               ...
               {{PropertyMapping | templateProperty = prédécesseur pape | ontologyProperty = predecessor }}
               {{PropertyMapping | templateProperty = successeur pape | ontologyProperty = successor }}
             }}
           }}
 }}
 {{Condition | templateProperty = titre | operator = equals  | value = Évêque
          | mapping = {{TemplateMapping | mapToClass = ChristianBishop }}
 }}
 ...
{{Condition | operator = otherwise | mapping = {{TemplateMapping |mapToClass = Cleric }} }}

| defaultMappings =
  {{PropertyMapping | templateProperty = nom | ontologyProperty = foaf:name }}
  ...
  {{PropertyMapping | templateProperty = nom naissance   | ontologyProperty = birthName }}
  {{PropertyMapping | templateProperty = devise | ontologyProperty = motto }}
  ...
  {{PropertyMapping | templateProperty = bénédiction abbatiale | ontologyProperty = abbeychurchBlessing  }}
}}
```

TemplateMapping and PropertyMapping

Infobox type

```
Mapping fr:Infobox Prélat catholique{{ConditionalMapping
| cases =
 {{Condition  | templateProperty = titre  | operator = equals  | value = Pape
    ...
 }}
 {{Condition | templateProperty = titre | operator = equals  | value = Évêque
        | mapping = {{TemplateMapping | mapToClass = ChristianBishop }}
}}
{{Condition | templateProperty = titre | operator = equals  | value = Cardinal
        | mapping = {{TemplateMapping | mapToClass = Cardinal }}
}}
...
{{Condition | operator = otherwise
        | mapping = {{TemplateMapping |mapToClass = Cleric }}
}}
| defaultMappings =
 {{PropertyMapping | templateProperty = nom | ontologyProperty = foaf:name }}
 ...
 {{PropertyMapping | templateProperty = devise | ontologyProperty = motto }}
 ...
}}
```

<Page URI> a dbr:Pope.

<Page URI> a dbr:ChristianBishop.

<Page URI> a dbr:Cardinal.

<Page URI> a dbr:Cleric.

PropertyMapping Example

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```
Mapping fr:Infobox Prélat catholique{{ConditionalMapping
| cases =
  ...
 {{Condition | templateProperty = titre | operator = equals  | value = Évêque
         | mapping = {{TemplateMapping | mapToClass = ChristianBishop }}
 }}
 ...

{{Condition | operator = otherwise
         | mapping = {{TemplateMapping |mapToClass = Cleric }}
 }}

| defaultMappings =
  {{PropertyMapping | templateProperty = nom | ontologyProperty = foaf:name }}
  ...
    {{PropertyMapping | templateProperty = devise | ontologyProperty = motto }}
  ...
}}
```

<Page URI> foaf:name <nom>.

<Page URI> dbo:motto <devise>.

IntermediateNodeMapping

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<Page URI> dbo:motto <devise>.

```
{{PropertyMapping
  | templateProperty = devise | ontologyProperty = motto }}

{{IntermediateNodeMapping
  | nodeClass = PersonFunction
  | correspondingProperty = occupation
  | mappings =
    {{PropertyMapping
       | templateProperty = ministère 1 | ontologyProperty = title }}

       [...]
    {{PropertyMapping
       | templateProperty = successeur 1 | ontologyProperty = successor
    }}
}}
```

<Fresh IRI> a dbr:PersonFunction.

<Page URI> dbo:occupation <Fresh IRI>.

<Fresh IRI> dbo:title < ministère 1>.

<Fresh IRI> dbo:successor <successeur 1>.

Tuple Generating Dependencies (TGDs)

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- Basic (full) tgds
  - $\forall \vec{x}\left(\psi(\vec{x}) \rightarrow CQ(\vec{x})\right)$
  - $\forall x_1 \forall x_2 \left(Cleric(x_1) \wedge WorksFor(x_1, x_2) \rightarrow Church(x_2)\right)$
- $CQ(\vec{x})$ is a conjunctive query with free variables $\vec{x}$.
- ψ is a FO formula (often also just a CQ).
- Enforcing (aka “chasing“) tgds:
  - For each assignment $\vec{a}$ for $\vec{x}$ satisfying ψ on the source instance, yield the facts instantiating $CQ(\vec{a})$.

The Infobox Schema W

- W_i (Page_**U**RI, Infobox_**T**ype, Infobox_**I**D)
- W_d (Infobox_**I**D, **P**roperty_Name, Property_**V**alue)
- Infobox constraints:
  - UT → I
  - IP → V
  - $W_d.I \subseteq W_i.I$

Mapping rules amenable to full TGDs

Mapping fr:Infobox **Prélat catholique**{{ConditionalMapping

$$\forall U \forall I \left(W_i(U, \text{"Prélat catholique"}, I) \wedge W_d(I, \text{"Èvêque"}, X) \rightarrow dbr\text{:}\, ChristianBishop(U) \right)$$

{{Condition | templateProperty = titre | operator = equals | value = Évêque
| mapping = {{TemplateMapping | mapToClass = ChristianBishop }}
}}

$$\forall U \forall I \left(W_i(U, \text{"Prélat catholique"}, I) \wedge W_d(I, \text{"Cardinal"}, X) \rightarrow dbr\text{:}\, Cardinal(U) \right)$$

{{Condition | templateProperty = titre | operator = equals | value = Cardinal
| mapping = {{TemplateMapping | mapToClass = Cardinal }}
}}

...

{{Condition | operator = otherwise
| mapping = {{TemplateMapping |mapToClass = Cleric }}

$$\forall U \forall I \forall X \left(\begin{array}{l} W_i(U, \text{Prélat catholique}, I) \wedge \neg W_d(I, \text{"}Pape\text{"}, X) \\ \wedge \neg W_d(I, \text{"Èvêque"}, X) \wedge \neg W_d(I, \text{"Cardinal"}, X) \wedge \ldots \rightarrow dbr\text{:}\, Cleric(U) \end{array} \right)$$

PropertyMapping Example

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Mapping fr:Infobox **Prélat catholique**{{ConditionalMapping
| cases =
...

{{Condition | operator = otherwise
| mapping = {{TemplateMapping |mapToClass = Cleric }}
}}

| defaultMappings =
{{**PropertyMapping** | templateProperty = nom | ontologyProperty = foaf:name }}
...

$$\forall U \forall I \left(W_i(U, \text{"Prélat catholique"}, I) \wedge W_d(I, \text{"nom"}, X) \rightarrow foaf{:}name(U, X) \right)$$

{{**PropertyMapping** | templateProperty = devise | ontologyProperty = motto }}

$$\forall U \forall I \left(W_i(U, \text{"Prélat catholique"}, I) \wedge W_d(I, \text{"devise"}, X) \rightarrow dbp{:}motto(U, X) \right)$$

}}

TGDs with existentially quant. variables

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- $\forall \vec{x}\left(\psi(\vec{x}) \rightarrow \exists \vec{y}\, CQ(\vec{x}, \vec{y})\right)$
- $\forall x\left(Cleric(x) \rightarrow \exists z\, PraysFor(x, z)\right)$
- Chase with non-full TGDs:
  - For each assignment $\vec{a}$ for $\vec{x}$ satisfying ψ, construct an assignment $\vec{b}$ of **fresh distinct values** for $\vec{y}$ (often special **labeled null** values);
  - Yield the atoms in $CQ(\vec{a}, \vec{b})$

IntermediateNodeMapping via (non full) TGDs

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$$\forall U \forall I \big(W_i(U, \text{"Prélat catholique"}, I) \wedge W_d(I, \text{"ministère 1"}, X) \rightarrow \exists Z \ \ dbo\colon title(Z, X) \big)$$

$$\forall U \forall I \big(W_i(U, \text{"Prélat catholique"}, I) \wedge W_d(I, \text{"prédécesseur1"}, X) \rightarrow \exists Z \ \ dbo\colon predecessor(Z, X) \big)$$

Chase does not enforce that the same value instantiates Z in both cases.

Nested TGDs

- $\forall \overrightarrow{x_1} \left(\psi_1(\overrightarrow{x_1}) \rightarrow \exists \overrightarrow{y_1} \left(CQ_1(\overrightarrow{x_1}, \overrightarrow{y_1}) \wedge \forall \overrightarrow{x_2} \left(\begin{array}{l} \psi_2(\overrightarrow{x_1}, \overrightarrow{x_2}) \rightarrow \\ \exists \overrightarrow{y_2} \, (CQ_2(\overrightarrow{x_1}, \overrightarrow{x_2}, \overrightarrow{y_1}, \overrightarrow{y_2}) \wedge \cdots) \end{array} \right) \right) \right)$

- $\forall x_1 \left(Pastor(x_1) \rightarrow \exists y \left(PraysFor(x_1, y) \wedge \forall x_2 \left(ParishMember(x_2, x_1) \rightarrow PraysFor(x_2, y) \right) \right) \right)$

- Chase with nested TGDs vs. standard TGDs:
  - Preconditions of nested implications can access the values bound in the preconditions of ancestor implications: e.g., $ParishMember(x_2, x_1)$
  - Fresh values generated in the ancestor implications can be reused in the conclusions of nested implications, e.g.: $PraysFor(x_2, y)$

IntermediateNodeMapping via Nested TGDs

{{PropertyMapping
| templateProperty = devise | ontologyProperty = motto}}

{{**IntermediateNodeMapping**
| nodeClass = PersonFunction
| correspondingProperty = occupation
| mappings =

$$\forall U \forall I \left(W_i(U, \text{"Prélat catholique"}, I) \rightarrow \exists Z \left(dbr{:}\, PersonFunction(Z) \wedge dbo{:}\, occupation(U, Z) \wedge \left(W_d(I, \text{"ministère 1"}, X) \rightarrow dbo{:}\, title(Z, X) \right) \right. \right.$$

$$\ldots\ldots\ldots$$

$$\left. \left. \wedge \left(W_d(I, \text{"prédécesseur 1"}, X) \rightarrow dbo{:}\, predecessor(Z, X) \right) \wedge \left(W_d(I, \text{"successeur 1"}, X) \rightarrow dbo{:}\, successor(Z, X) \right) \right) \right)$$

}}

DBpedia Mappings: syntactic restrictions

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- Only unary interpreted predicates in conditions
  (e.g., “if name = full_name” not possible)
- NO nested conditions
  - At most two atoms on the left-hand side of implications
    (test condition + atomic query of a property value)
- IntermediateNodeMappings are not nested currently.
- Fixed structure of generated triples:
  - Subject: page URI or an intermediate node
  - Predicate: defined by the property mapping
  - Object: infobox property value

Dbpedia mappings: Expressive features

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- Limited forms of negation:
  - only the first satisfied condition triggers,
  - the final „otherwise“ branch
- Generation of new IRIs (existentially quantified variables in the encoding via tgds)
- Special functions:
  (“contains”, “exists”, “not exists” in conditions), string & geocoordinate manipulation, arithmetic operations for property generation

DBpedia update translation

Semantics of updates

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- Input: Dbpedia update $u = (u^-, u^+)$
- u^- atoms to be deleted
- u^+ atoms to be inserted
- Semantics: a set of possible Wiki updates (e_i^-, e_i^+) that

Consistency-oblivious semantics

- Comply with the Infobox schema
- Minimal (e.g., w.r.t. the subset relation)
- Together with the mappings and the TBox, derive a DBpedia instance which contain u^+ and does not contain u^-

Consistency-aware semantics

- Updated instance is consistent with the TBox

Existence of solutions (consistency-oblivious)

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For a fixed mapping:
Given an insert u^+, is its consistency-oblivious semantics empty?

Standard NP completeness proof (in DB context Abiteboul&Duschka 98)

Underlying data source (Database): **colored** graph.

View (ontology): non-colored graph, colors, and **invalid coloring marker** set to false: require a valid coloring

$$(\exists C_1 \exists C_2 \exists A\ \exists B$$
$$Edge(A,B) \wedge Color(A,C_1) \wedge Color(B,C_2) \wedge \boldsymbol{C_1 = C_2}) \rightarrow Invalid$$

No binary predicates (e.g. $\boldsymbol{C_1 = C_2}$) in the conditions of DBpedia mappings!

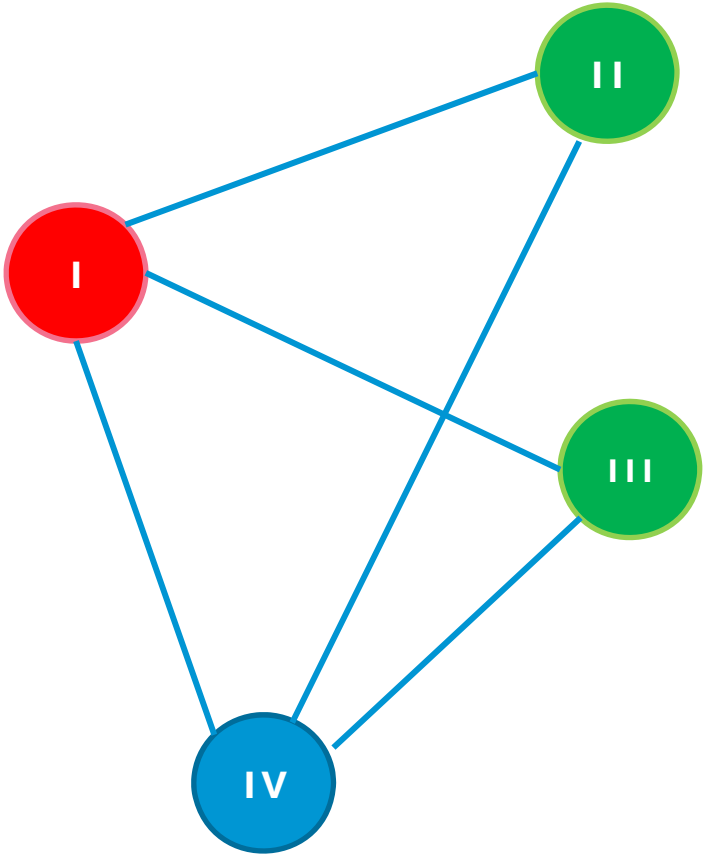
Source consistency of the ABox: Reduction from 3COL

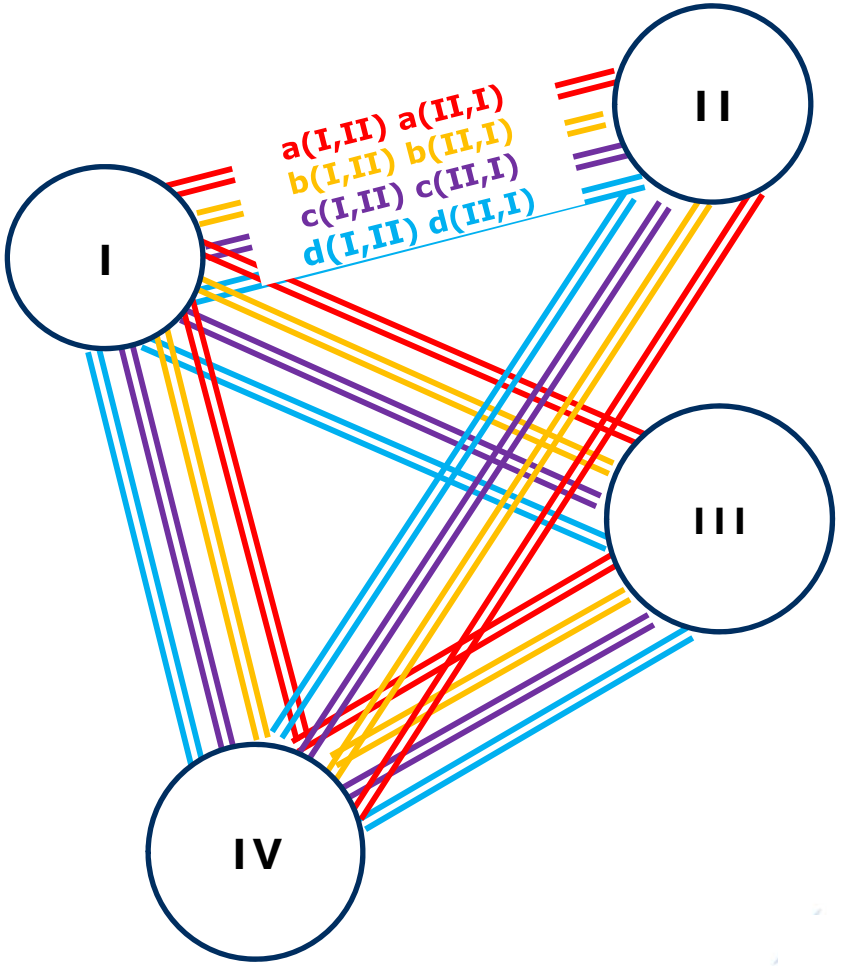
- Graph of degree ≤ 4 (intractable 3COL)
- Proper ABox shape: IRIs connected by symmetric labeled properties **a, b, c, d**

  $\Rightarrow$ 8 property assertions to represent a single graph edge in the materialized ABox.

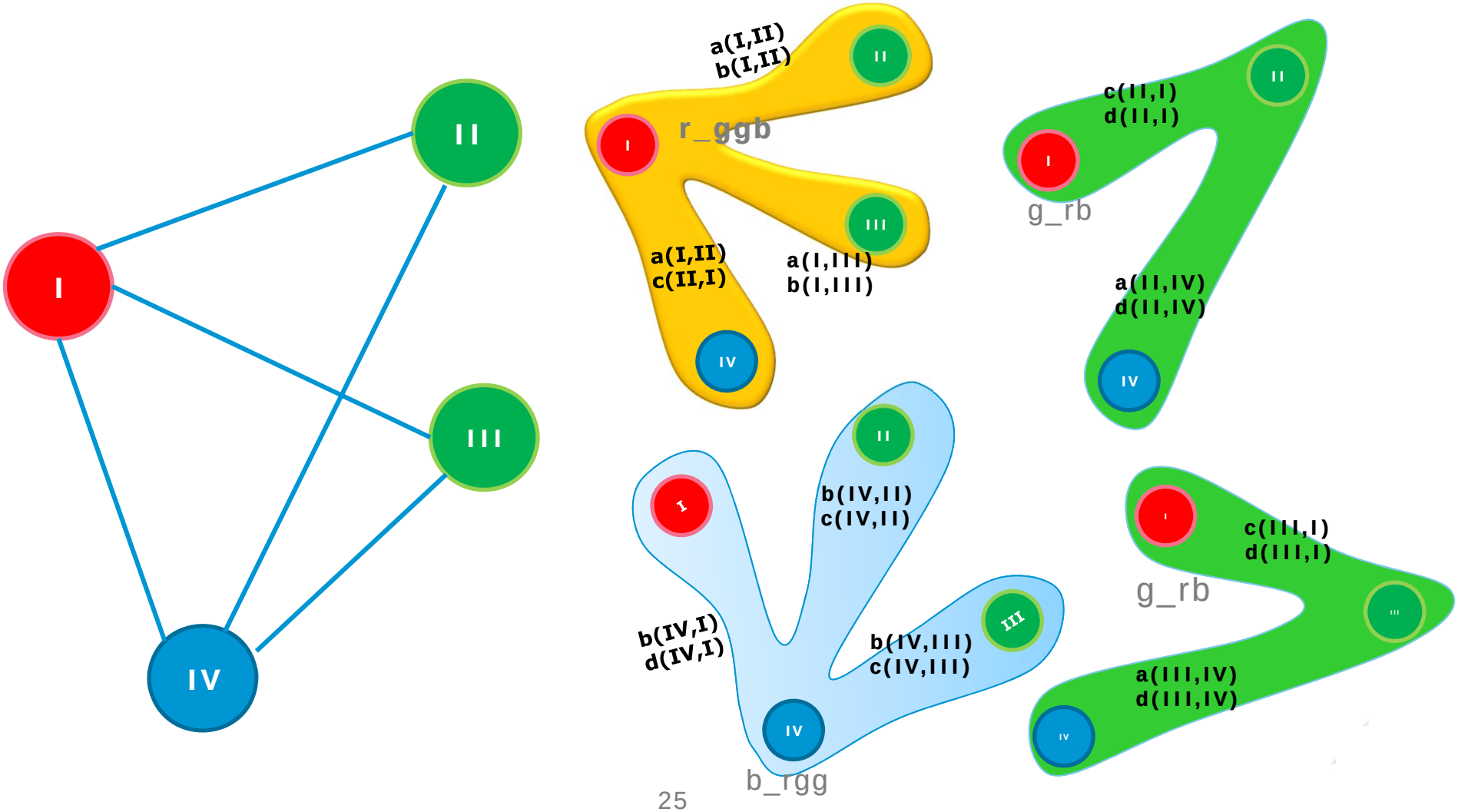
- TBox: $\mathbf{a \sqsubseteq a^-}$, $\mathbf{b \sqsubseteq b^-}$, $\mathbf{c \sqsubseteq c^-}$, $\mathbf{d \sqsubseteq d^-}$

Colored graph and its representation as a Dbpeida ontology





Infoboxes: 1-Neighborhoods of nodes

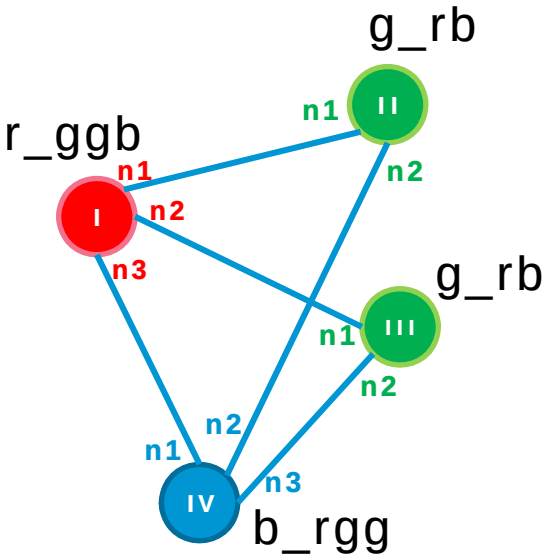


Mapping conditions: ensure consistent color assignment across Infoboxes

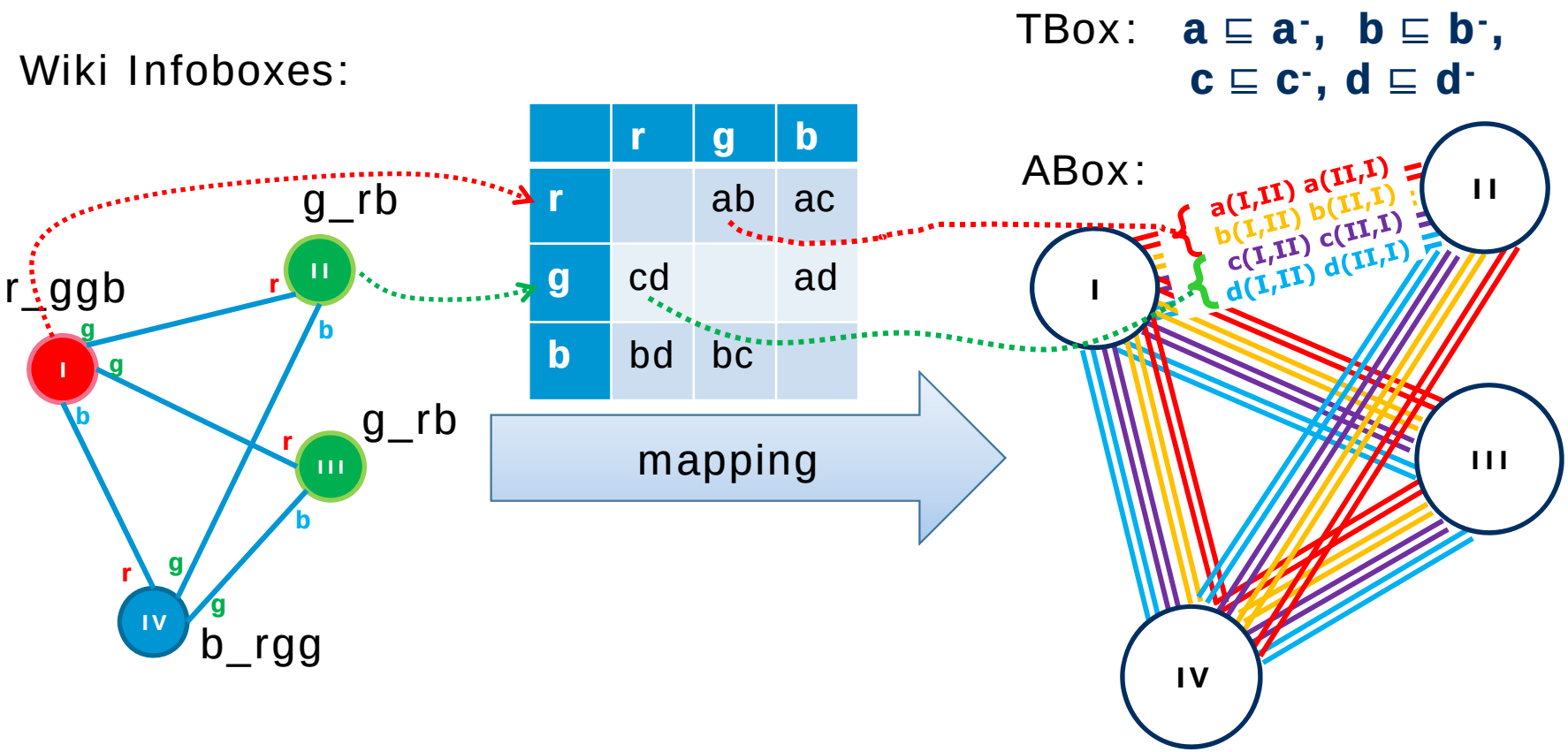
if neighbourhood type = „r_ggb“
<this> dbo:a <neighbor n1>.
<this> dbo:b <neighbor n1>.
<this> dbo:a <neighbor n2>.
<this> dbo:b <neighbor n2>.
<this> dbo:a <neighbor n3>.
<this> dbo:c <neighbor n3>.

if neighbourhood type = „b_rgg “
<this> dbo:b <neighbor n1>.
<this> dbo:d <neighbor n1>.
<this> dbo:b <neighbor n2>.
<this> dbo:c <neighbor n2>.
<this> dbo:b <neighbor n3>.
<this> dbo:c <neighbor n3>.

	r	g	b
r		ab	ac
g	cd		ad
b	bd	bc	



3COL of max. degree 4 graphs via Source consistency of the ABox



3COL iff consistent coverage by 1-neighborhoods (Infoboxes) exist
iff ABox has regular shape.

Worst-case vs. actual mappings

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- DBpedia and many Linked Open Data sources [Glimm,Hogan,Krötzsch,Polleres LDOW'12] is economic in terms of the TBox features used:
  - Especially with respect to inconsistency derivation:
  - Few disjoint classes / properties.
  - Functionality only for data properties.

- Computational intractability is less of a practical issue than infeasibility for verification by curators (Wikipedia maintainers)!

Our Approach

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- Consider each subject (Wiki page) separately
- Find the most likely translation of properties based on evidence, applying update resolution policies
- Construct sound re-usable **patterns of update translation**
- Use patterns to implement batch updates

Update resolution policies

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```
{{PropertyMapping | templateProperty = state1 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = state2 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = state3 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = state4 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = state5 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = state6 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = state7 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = state8 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = state9 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district1 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district2 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district3 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district4 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district5 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district6 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district7 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district8 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district9 | ontologyProperty = region }}
```

Update resolution policies

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Infobox frequency first

- Prefer most frequently used properties
- Based on precomputed statistics across all infoboxes

```
{{PropertyMapping | templateProperty = state7 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = state8 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = state9 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district1 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district2 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district3 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district4 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district5 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district6 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district7 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district8 | ontologyProperty = region }}
{{PropertyMapping | templateProperty = district9 | ontologyProperty = region }}
```

Update resolution policies

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Infobox frequency first

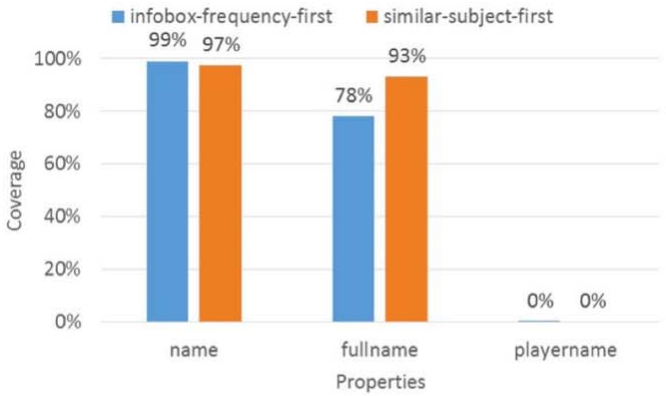
- Prefer most frequently used properties
- Based on precomputed statistics across all infoboxes

{{PropertyMapping | templateProperty = state7 | ontologyProperty = region }}

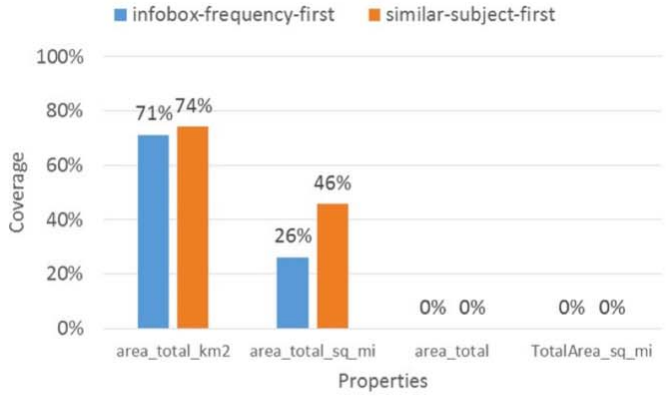
Similar subject first

- Taking only similar subjects into account: same infobox type and having same properties as being insterted.
- “How are other football players are represented in the infobox?”

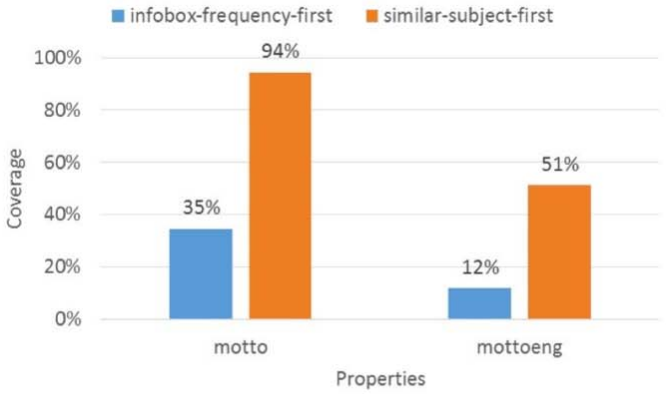
Examples of resolution policies



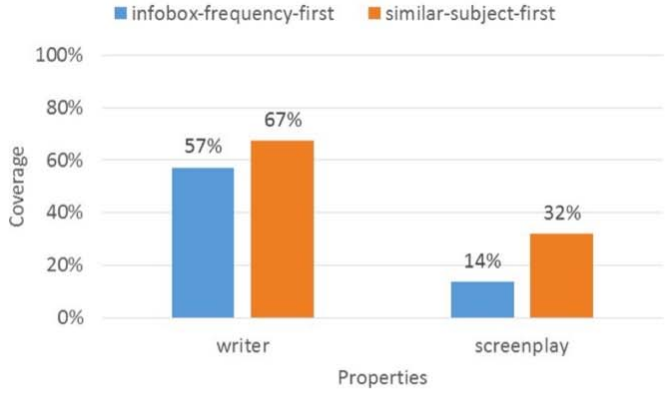
(a) Infobox Football biography



(b) Infobox Settlement



(c) Infobox Universities



(d) Infobox Film

Update resolution patterns

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- GOAL: input update (u^-, u^+) for a single subject
- CONTEXT: relevant pre-existent facts that need to be removed to avoid clashes
- ACTION: single wiki update (e^-, e^+)

IRIs and data values replaced by variables, to enabe reuse across Wiki pages in bulk updates.

Summary and conclusions

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- DBPedia mappings: fixed-depth nested tgds with negation and unary interpreted predicates in preconditions.
- Existence of solutions (DBpedia update feasibility) is intractable even not taking consistency w.r.t. TBox into account.
- Evidence-based update resolution policies.
- Introduce update resolution patterns as a means to formulate **reusable examples of update translation** in OBDM.