Extending NoHR for OWL 2 QL

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Motivation: OWA vs. CWA

- Open World Assumption (OWA)
  - Model taxonomic knowledge
  - Ontologies (in Description Logics (DL), such as $\mathcal{EL}$, $DL\text{-}Lite_R$)
  - Example: results of clinical tests
- Closed World Assumption (CWA)
  - Model defaults and exceptions
  - Non-monotonic rules well-suited
  - Example: patient's medication

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Requirements for Integration

1. Flexible framework
   - Expressive language, yet simple to use
   - Full two-way interaction between ontologies and rules
   - As little restrictions as possible
2. Low complexity
   - Large amount of data (on the Web; in applications, e.g., patient records)
   - Interactive response time on reasoning
3. Top-down querying
   - Avoid up-front computation of the entire model
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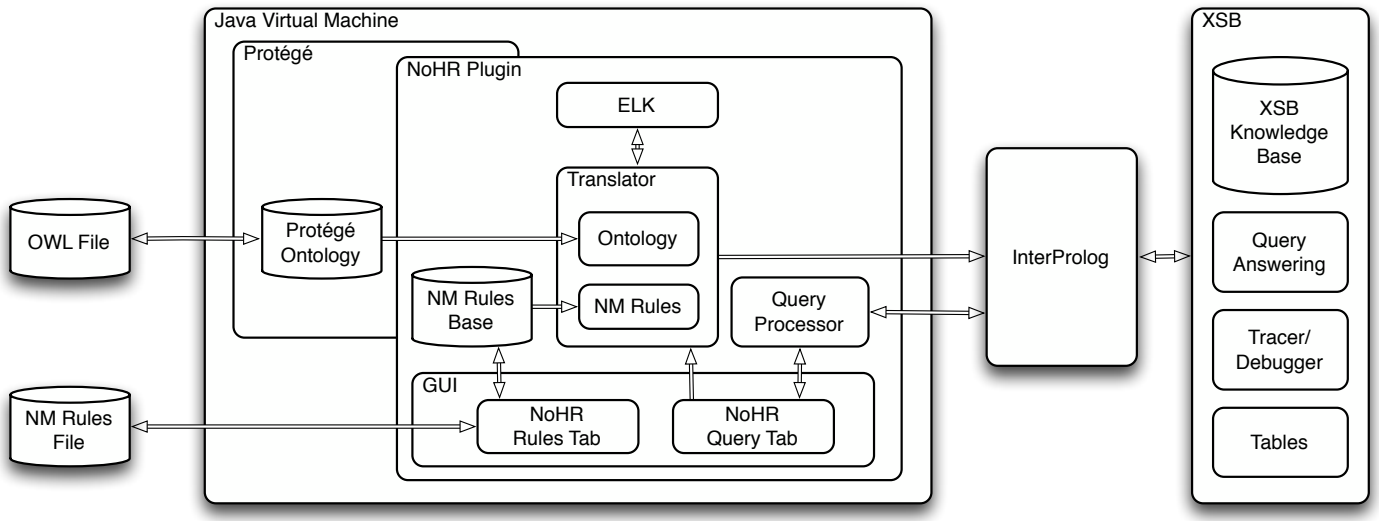
NoHR: EL Ontologies and Non-Monotonic Rules

1. Hybrid MKNF [Motik and Rosati, J. ACM 2010]
2. Its Well-Founded Semantics (WFS) [Knorr et al., AI 2011]
3. Top-down procedure **SLG($\mathcal{O}$)** [Alferes et al., ACM TOCL 2013]



Motivation: Extension to QL

- Applications require DL language features (e.g., inverses) [Calvanese et al., 2011] not covered by OWL EL
- OWL QL based on $DL\text{-}Lite_R$ would serve
  - Covers basic DL languages, the entity relationship model, and basic UML class diagrams
  - Query-answering by rewriting queries by means of the ontology s.t. SQL engines can be used over the data
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Problem

- Negation present in OWL QL requires classification of negated concepts
- Currently no classifier for OWL QL including negated concepts
- Naive adaptation inefficient due to large number of created axioms

Objective

Adapt NoHR to OWL QL

- Direct translation (no prior classification)
- Ensure identical derivation of ground queries
- Implement and evaluate its performance

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$DL\text{-}Lite_R$

$$B \to A \mid \exists Q \qquad C \to B \mid \neg B \qquad Q \to P \mid P^- \qquad R \to Q \mid \neg Q$$

$A \in \mathsf{N_C}$ concept name, $P \in \mathsf{N_R}$ role name, and P^- its inverse

- GCIs $B \sqsubseteq C$ and RIs $Q \sqsubseteq R$
- Standard DL semantics based on interpretations $\mathcal{I} = (\Delta^{\mathcal{I}}, \cdot^{\mathcal{I}})$

$$\exists HasArtist^- \sqsubseteq Artist \qquad Piece \sqsubseteq \exists HasArtist$$
$$\exists HasComposed^- \sqsubseteq Piece \qquad Artist \sqsubseteq \neg Piece$$
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$Piece \sqsubseteq \exists HasArtist$ cannot be translated naively

- $HasArtist(x, y) \leftarrow Piece(x)$ would yield $HasArtist(x, y)$ for any $Piece(x)$ and y
- $HasArtist(x, c) \leftarrow Piece(x)$ would yield $HasArtist(x, c)$ for any $Piece(x)$ for the same c
- Skolemization would cause difficulties for termination

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$DHasArtist(x) \leftarrow Piece(x)$ with $DHasArtist$ the domain of $HasArtist$ (and $RHasArtist$ its range)

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- $DHasArtist(x) \leftarrow HasArtist(x, y)$ associating domains (and ranges) to binary atoms
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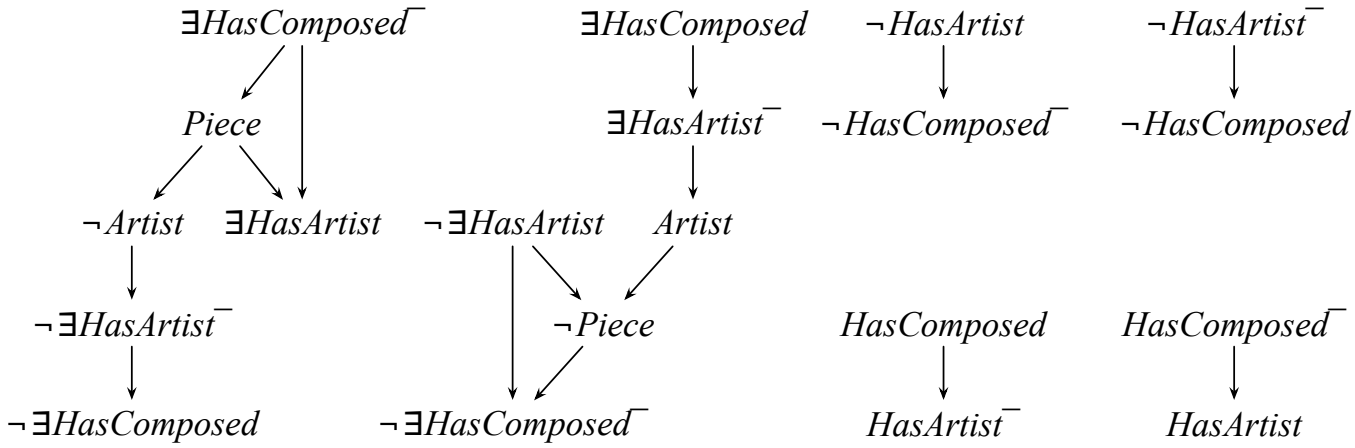
Graph Representation Including Negation

Nodes all general concepts and roles, edges GCIs and RIs (including, e.g., implicit contrapositives)



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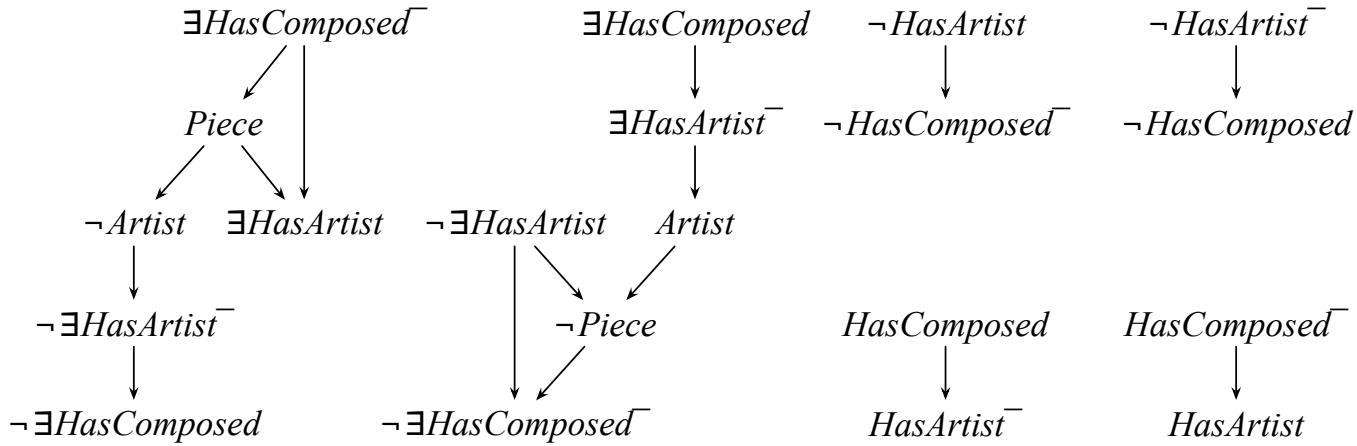

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Results

- Sound and complete translation w.r.t. answering (ground) queries
- Data complexity in P
- Extension of classification on graphs to negated concepts a contribution in its own right
- Implementation as an alternative translator module in NoHR for OWL QL

Evaluation Settings

LUBM benchmark

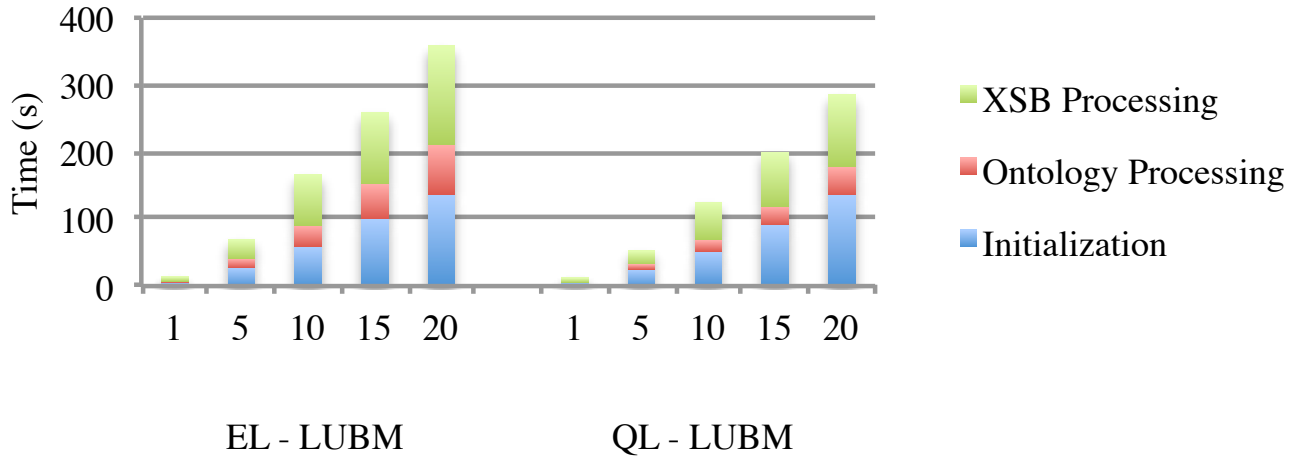
- Small TBox
- Data generator for creating instance data of large sizes
- 14 test queries

Here:

- TBox slightly simplified to match the OWL profile(s)
- Three queries omitted whose results are affected by the simplifications

Evaluation: Preprocessing

Direct translation approach vs. classification-based – LUBM reduced to fit OWL QL and EL to compare NoHR QL and EL approaches



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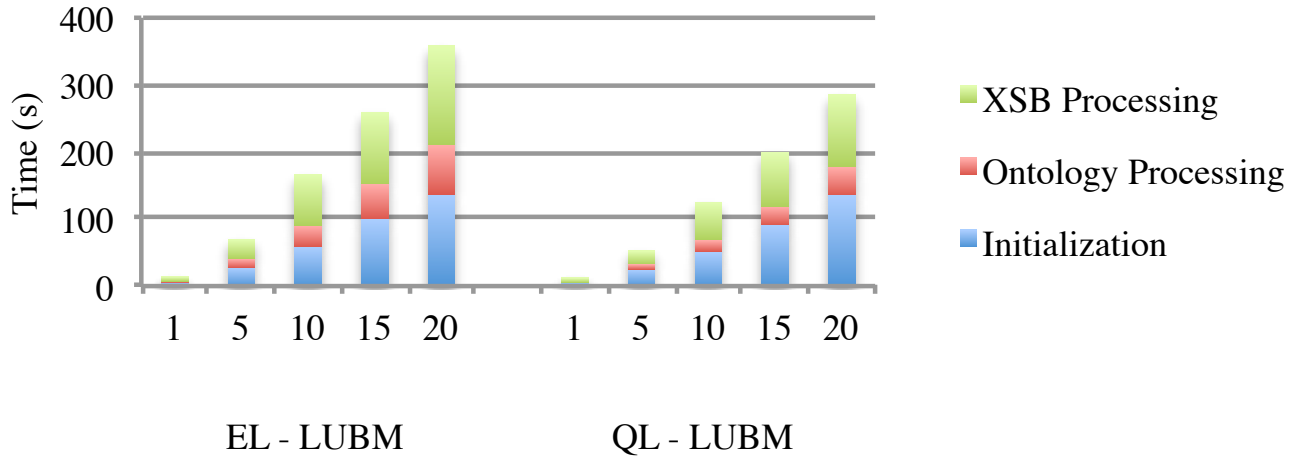

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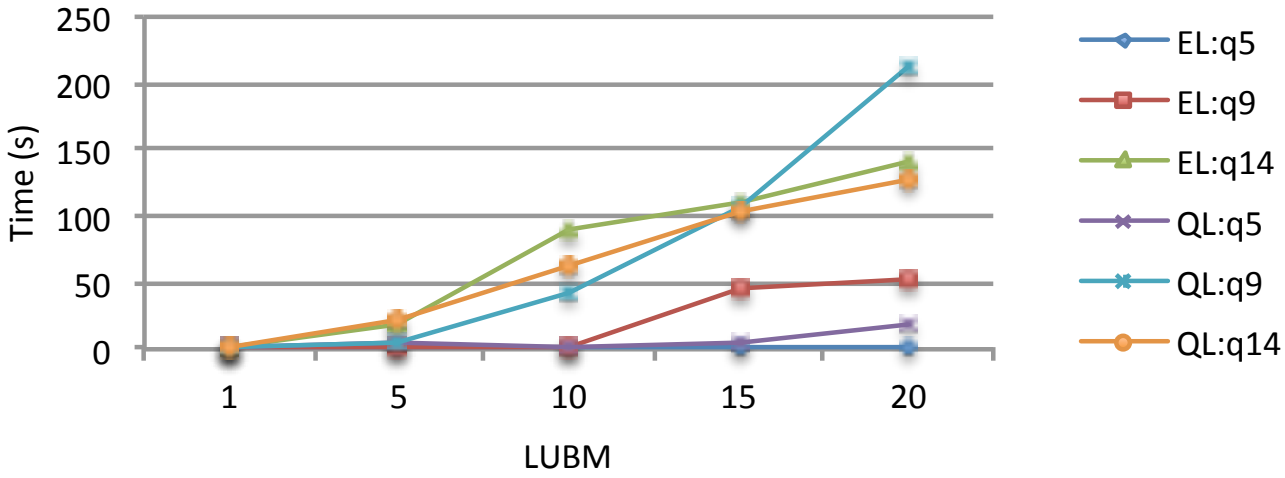

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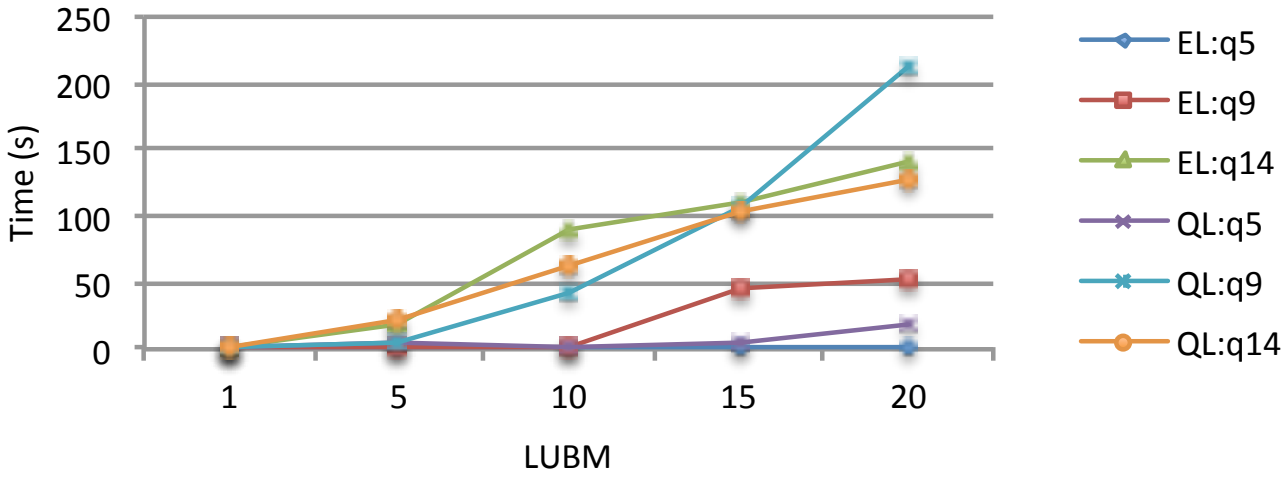

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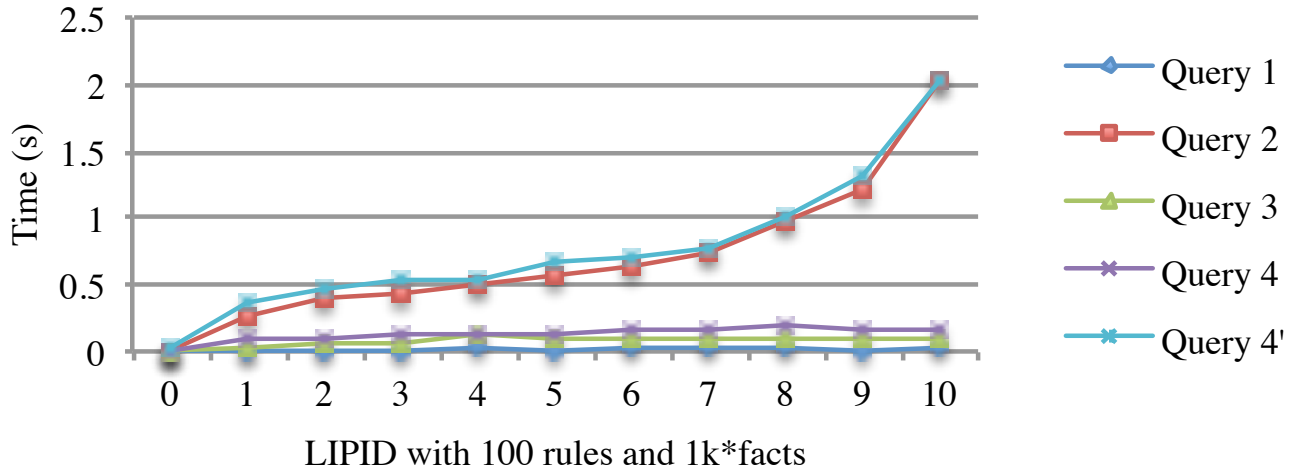
Evaluation: Lipid with Rules

749 subclass axioms, $1,486$ class disjointness axioms and 20 inverse object properties in combination with non-monotonic rules



- Preprocessing very fast and only linearly increasing
- Four atomic queries in different levels of the hierarchy with interactive response time
- 4' – query 4 without the other queries beforehand (tabling)

Conclusions

- NoHR extended to OWL 2 QL based on direct translation
- Theoretically sound and complete including novel extension of graph-based reasoning with negated concepts
- Evaluation results of implementation encouraging as all previously observed results (for EL) persist
- QL is even faster on pre-processing and only slightly slower on average when answering queries

Future Work

- Further comparisons to alternative versions for QL based on, e.g., ontop, Konclude
- OWL RL
- Paraconsistent Semantics