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Query Rewriting for Horn-$\mathcal{SHIQ}$ plus Rules

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Conjunctive Queries over Horn-$\mathcal{SHIQ}$

- Ontology Based Data Access is a key application of DLs
- Hence, query answering in DLs is crucial

$$\mathbf{hasDevelopedCapital}(x) \leftarrow \mathbf{country}(x), \mathbf{hasCapital}(x,y), \mathbf{city}(y), \mathbf{hasHDI}(y, \mathit{high})$$

$\mathcal{A}$

$\mathbf{country}(\mathit{Brazil})$ $\mathbf{capital}(\mathit{Brasilia})$ $\mathbf{hasHDI}(\mathit{Brasilia}, \mathit{high})$
$\mathbf{isLocatedIn}(\mathit{Brasilia}, \mathit{RegiãoCentroOeste})$
$\mathbf{isLocatedIn}(\mathit{RegiãoCentroOeste}, \mathit{Brazil})$

- No answers with ABox only

$\mathcal{T}$

$\mathit{trans}(\mathbf{isLocatedIn})$
$\mathbf{country} \sqsubseteq \exists \mathbf{hasCapital}.\mathbf{capital}$
$\mathbf{hasCapital} \sqsubseteq \mathbf{isLocatedIn}^-$
$\mathbf{country} \sqsubseteq \leqslant 1\, \mathbf{isLocatedIn}^-.\mathbf{capital}$
$\mathbf{country} \sqsubseteq \forall \mathbf{hasCapital}.\mathbf{city}$

- $\mathbf{hasDevelopedCapital}(\mathit{Brazil})$ when TBox also taken into account
  $x \rightsquigarrow \mathit{Brazil}$, $y \rightsquigarrow \mathit{Brasilia}$

Motivation

- For lightweight DLs($\mathcal{DL}$-*Lite* and $\mathcal{EL}$), query rewriting is a successful approach for query answering
- Horn-$\mathcal{SHIQ}$ is more expressive, and it has useful features not present in $\mathcal{EL}$ and $\mathcal{DL}$-*Lite*

$\mathit{trans}(\mathbf{isLocatedIn})$ $\mathbf{country} \sqsubseteq \forall \mathbf{hasCapital}.\mathbf{city}$ $\mathbf{country} \sqsubseteq \leqslant 1\, \mathbf{isLocatedIn}^-.\mathbf{capital}$

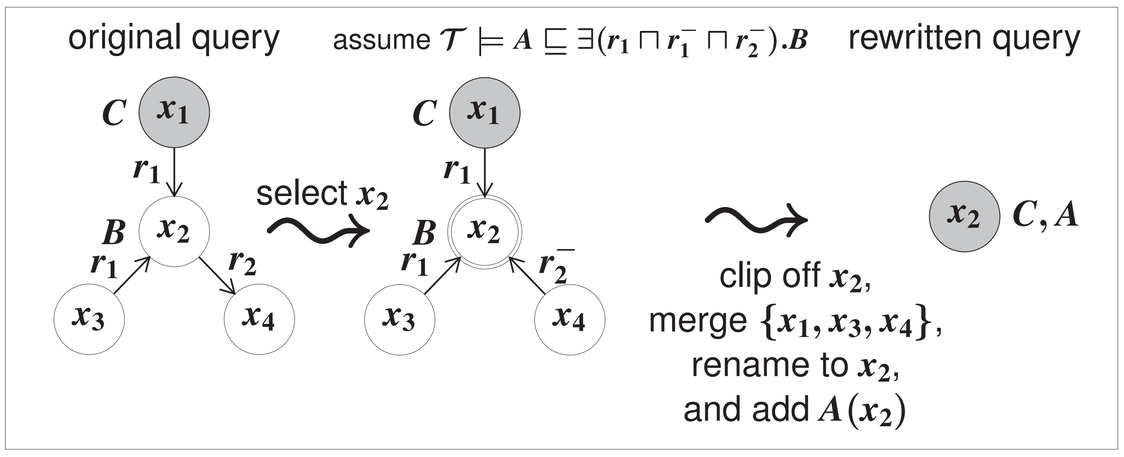
- Horn-$\mathcal{SHIQ}$ is tractable in data complexity (PTIME-complete)
- The combined complexity is the same as for standard reasoning (EXPTIME-complete)
- But no query rewriting for Horn-$\mathcal{SHIQ}$ is known

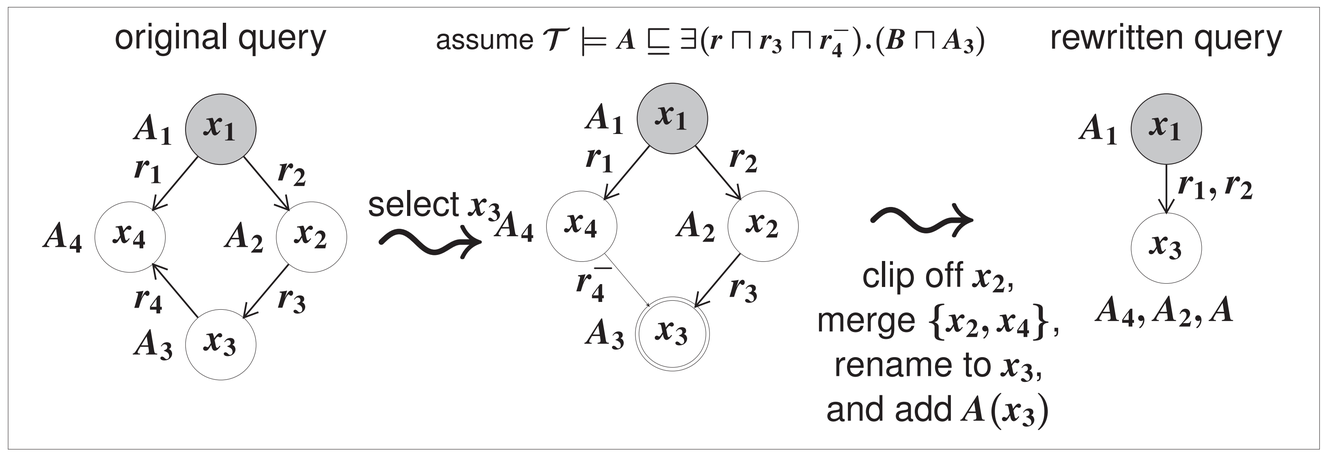
Contribution

Problem definition: given a Horn-$\mathcal{SHIQ}$ ontology $\mathcal{O} = (\mathcal{T}, \mathcal{A})$ and a query q, compute the answers

- We study weakly DL-safe rules (a extension of conjunctive queries)
- We propose a query rewriting technique for Horn-$\mathcal{SHIQ}$
- We reduce the problem to evaluating a Datalog program over ABox
- We support transitive roles in the query
- The prototype system CLIPPER shows promising results

Query Rewriting for Horn-$\mathcal{SHIQ}$





Query Answering over Horn-$\mathcal{SHIQ}$ via Query Rewriting

We have implemented a prototype system called CLIPPER
(`http://www.kr.tuwien.ac.at/research/systems/clipper`)

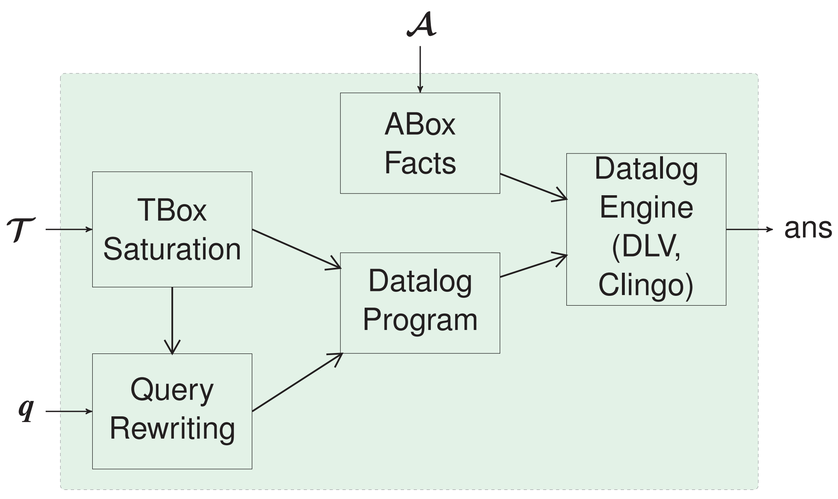


Figure: Architecture of CLIPPER

- Current version supports only conjunctive queries without transitivity roles in the query
- A new version with non-simple roles in queries will be released soon
- Full weakly DL-safe queries in progress

Further extensions planned:

- other DLs, like regular $\mathcal{EL}^{++}$ and Horn-$\mathcal{SRIQ}$, datatypes
- more expressive queries, like *regular path queries*

Experiments

$\mathcal{O}$	Query	# Rules/CQs			Rewriting time, ms (avg. eval. time, DLV)		
		RequiemG	Presto	Clipper	RequiemG	Presto	Clipper
A	Q1	27	53	42	281	45	50
	Q2	50	32	31	184	46	62
	Q3	104	32	31	292	27	65
	Q4	224	43	36	523	32	71
S	Q1	6	7	10	14	7	19
	Q2	2	3	22	263	9	22
	Q3	4	4	9	1717	10	21
	Q4	4	4	24	1611	9	23
U	Q1	2	4	2	14 (1247)	12 (1252)	27 (1255)
	Q2	1	2	45	201 (1247)	23 (1262)	36 (1637)
	Q3	4	8	17	477 (2055)	26 (2172)	29 (1890)
	Q4	2	56	63	2431 (1260)	20 (1235)	28 (1735)

Table: Comparison with other query rewriting engines ove $\mathcal{DL}$-*Lite* ontologies (Adolena, Stock exchange, University)

Query	# Rules	Rewriting Time (ms)	Datalog (DLV) Time (ms)
Q1	2	68	80 / 320 / 560 / 830
Q2	3	63	90 / 330 / 560 / 830
Q3	9	96	90 / 320 / 570 / 810
Q4	172	143	230 / 830 / 1430 / 1580
Q5	16	91	90 / 330 / 570 / 820
Q6	255	177	250 / 890 / 1530 / 1800
Q7	8	89	80 / 320 / 570 / 820
Q8	175	146	230 / 830 / 1430 / 1580
Q9	175	145	230 / 820 / 1400 / 1600
Q10	2	64	80 / 330 / 570 / 830

Table: Experiments on Horn-SHIQ version of UOBM ontology

Observations

- comparable with other query rewriting engines for $\mathcal{DL}$-*Lite*
- For Horn-$\mathcal{SHIQ}$, CLIPPER answers all queries in reasonable time and scales well

FWF
Der Wissenschaftsfonds.