Integrating OWL-DL with Rule-based Reasoners

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Scalability Problems of DL Reasoning

- Main reasoning problem: query answering
  - assuming the number of instances is large

In a Tableaux Calculus…

- …when I ask a query KB $\models$ C(X), I need to check KB $\models$ C(α) for each α
  - not a very efficient algorithm
- …it is difficult to isolate the part of the ABox relevant to the query
  - usually only a subset of the ABox is relevant to a query
- …it is difficult to apply optimizations
  - DB statistic was shown to be crucial in practice

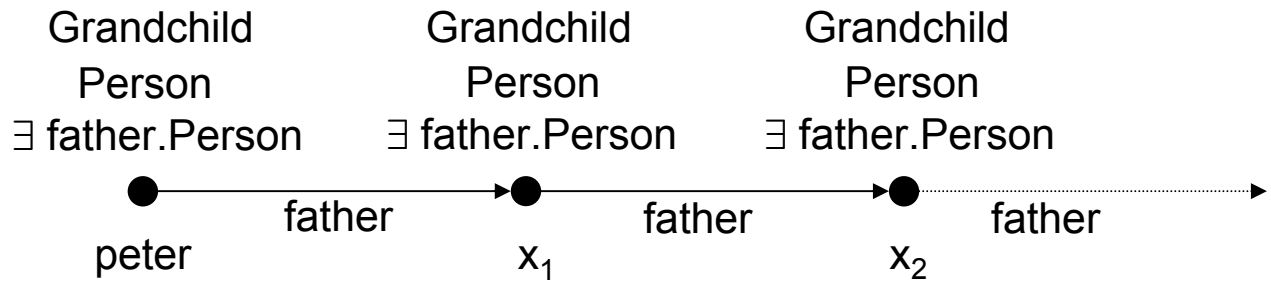
In a Deductive Database…

- …query answer is computed in one pass bottom-up
- …techniques exist to propagate bindings
  - magic sets propagate bindings to select the relevant ABox part
- …efficient statistics-based optimizations exist

So What is the Main Problem?

$Person(Peter)$	Peter is a person.
$Person \sqsubseteq \exists father.Person$	Each person has a father who is a person.
$\exists father.(\exists father.Person) \sqsubseteq Grandchild$	Things having a father of a father who is a person are grandchildren.

- Straightforward application of 'rules' does not terminate:



- The problem is reflected in the clausal form:
  - contains function symbols obtained through skolemization

$$Person \sqsubseteq \exists\, parent.Person \quad \rightsquigarrow \quad \begin{array}{l} Person(f(x)) \leftarrow Person(x) \\ parent(x,f(x)) \leftarrow Person(x) \end{array}$$

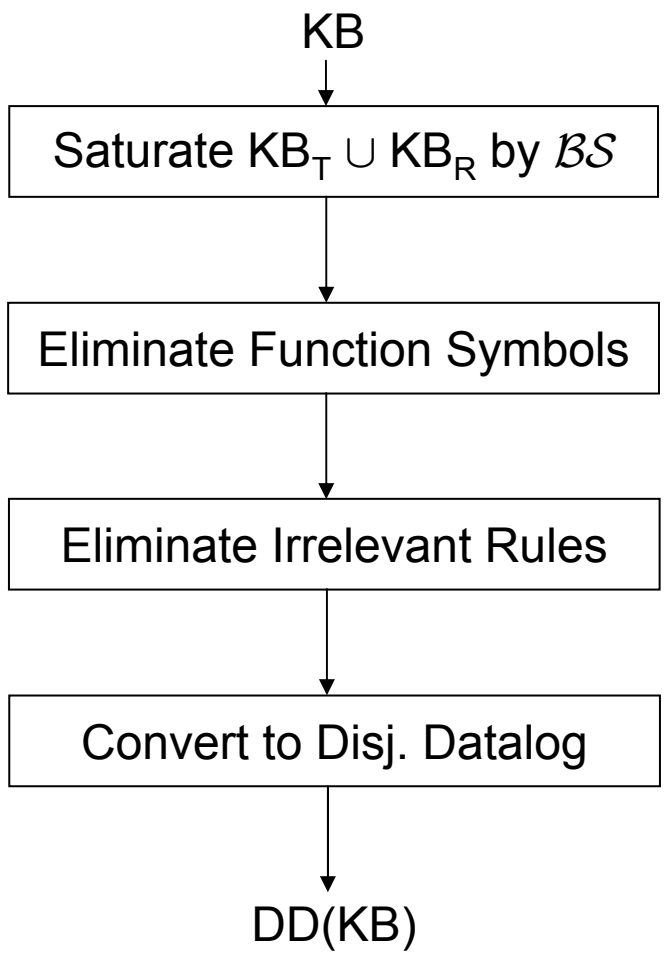
Solution: Eliminate Function Symbols

For a KB, compute a disjunctive datalog program DD(KB) such that

$KB \models \alpha$ iff $DD(KB) \models \alpha$

(α is a ground fact C(a) or R(a,b))

- Handles $\mathcal{SHIQ}$(**D**) (no nominals)
- Principle:
  - find a calculus $\mathcal{C}$ for deciding satisfiability of KB
  - create DD(KB) such that:
    - each refutation by $\mathcal{C}$ in KB can be reduced to a refutation in DD(KB)
    - each refutation in DD(KB) can be reduced to a refutation in KB
  - since refutations can be reduced in both ways, KB and DD(KB) are equisatisfiable



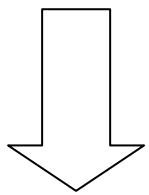
Complexity

- Algorithm runs in ExpTime
  - worst-case optimal
  - tableaux runs in 2NExpTime
- Data complexity is much better:
  - assume that TBox constant; measure complexity in |ABox|
  - NP-complete in general
  - for Horn-$\mathcal{SHIQ}$ it is P-complete
    - does not support disjunctive reasoning (reasoning-by-cases)
- Theoretical hope for providing reasoners capable of dealing with large ABoxes

DL-safe Subset of SWRL

- SWRL is undecidable
  - benefits of DL systems, such as optimized algorithms are lost
- DL-safe rules: decidable fragment of SWRL
  - each variable must occur in one literal with predicate outside KB in body
  - this restricts the applicability of rules to explicit individuals
  - rules can be appended to DD(KB) → practical reasoning algorithm

Homeworker(x) ← Person(x), livesAt(x,y), worksAt(x,y)



Not DL-safe, since x and y occur only in DL-atoms.

Homeworker(x) ← Person(x), livesAt(x,y), worksAt(x,y), $\mathcal{O}$(x), $\mathcal{O}$(y)

We assume there is a fact $\mathcal{O}(\alpha)$ for each individual α in the ABox.

(KB contains Homeworker, livesAt, Person, worksAt).

Global Picture

- Relationship between DLs and DDs has three axes:
  - each axis imposes requirements on the DD system

1. Is KB Horn, i.e. is reasoning by cases allowed?
   – a non-disjunctive system suffices
   \+ must use a disjunctive system
2. Does KB use number restrictions?
   – an ordinary engine suffices
   \+ must use an engine capable of handling equality
3. Does KB use existential quantifiers?
   – a function-free program is obtained
   \+ existential quantifiers must be handled:
     - simple skolemization may lead to undecidability
     - saturation can be used to eliminate function symbols and produce a function-free program