Towards a Declarative Query and Transformation Language for XML and Semistructured Data: Simulation Unification

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Introduction

State-of-the-art for XML Query languages (XQuery, XSLT):

- path-oriented navigation through the data
  (e.g. `/descendant::a[following-sibling::c]/descendant::b`)
- patterns serve to assemble path-selections

$\Rightarrow$ strong intertwining of query and construction parts
$\Rightarrow$ queries tend to be complicated

Introduction – Example


```
<books-with-prices>
 {
   for $b in document("www.bn.com/bib.xml")//book,
       $a in document("www.amazon.com/reviews.xml")//entry
   where $b/title = $a/title
   return
       <book-with-prices>
           { $b/title }
           <price-amazon>{ $a/price/text() }</price-amazon>
           <price-bn>{ $b/price/text() }</price-bn>
       </book-with-prices>
 }
</books-with-prices>
```

This XQuery expression creates a summary of prices for books in two bookstores.

Introduction – Xcerpt

- rule-based transformations and queries
- pattern-based (i.e. “context conscious”) instead of path-based selection
- templates for creating results
- strict separation of query and construction parts
- variables relate query and construction parts

Introduction – Example


```
rule { cons {
    books {
      all book {
         TITLE, price-a { PRICEA }, price-b { PRICEB } }
    }
  },
  and {
    query {
      in { "http://bn.com" },
      bib {{
        book {{ TITLE ⇝ title, price { PRICEA } }}
      }} },
    query {
      in { "http://amazon.com" },
      reviews {{
        entry {{ TITLE ⇝ title, price { PRICEB } }}
      }} }
  }
}
```

Contents

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- Basic Concepts of Xcerpt
- Simulation Unification
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  - Answers
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- Summary

Xcerpt Concepts

Xcerpt programs build upon the following concepts:

- Database Terms represent semistructured databases
- Query Terms are patterns for querying data
- Construct Terms are templates for the result of a query

Construct-Query Rules relate Query Terms with Construct Terms.

Database Terms

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```
bib {
  book {
    title { "TCP/IP Illustrated" },
    authors [ author { last { "Stevens" }, first { "W." } } ],
    publisher { "Addison-Wesley" },
    price { "65.95" }
  },
  book {
    title { "Data on the Web" },
    authors [ author { last { "Abiteboul" }, first { "Serge" } },
              author { last { "Buneman" }, first { "Peter" } },
              author { last { "Suciu" }, first { "Dan" } }      ],
    publisher { "Morgan Kaufmann Publishers" },
    price { "39.95" }
  },
  ...
}
```

A database term representing a bibliography. [ ] denote ordered subterms, { } denote unordered subterms.

Query Terms

Query Terms . . .

- specify (incomplete) patterns for the data
- are very similar to goals in logic programming

Query Terms

Query Terms …

- specify (incomplete) patterns for the data
- are very similar to goals in logic programming

Query Terms may contain the following constructs:

- $l\{t_1, \ldots, t_n\}$ and $l[t_1, \ldots, t_n]$ denote a total term specification
- $l\{\{t_1, \ldots, t_n\}\}$ and $l[[t_1, \ldots, t_n]]$ denote a partial specification
- X and $X \rightsquigarrow t$ (read "X as t") are variables, possibly with restriction to t
- $X \rightsquigarrow desc\ t$ denotes a term at indefinite depth

Construct Terms

Construct Terms are templates that . . .

- serve to reassemble variables in a new structure (i.e. database term)
- are *templates* that are filled in with values gathered in a query
- contain variables (but no $\rightsquigarrow$ restrictions and no $desc$)

Construct-Query Rules

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```
rule { cons {
    books {
      all book {
         TITLE, price-a { PRICEA }, price-b { PRICEB } }
    }
  },
  and {
    query {
      in { "http://bn.com" },
      bib {{
        book {{ TITLE ⇝ title, price { PRICEA } }}
      }} },
    query {
      in { "http://amazon.com" },
      reviews {{
        entry {{ TITLE ⇝ title, price { PRICEB } }}
      }} }
  }
}
```

Return a summary of book prices in two bookstores.

Construct-Query Rules

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```
rule { cons {
    books {
      all book {
         TITLE, price-a { PRICEA }, price-b { PRICEB } }
    }
  },
  and {
    query {
      in { "http://bn.com" },
      bib {{
        book {{ TITLE ⇝ title, price { PRICEA } }}
      }} },
    query {
      in { "http://amazon.com" },
      reviews {{
        entry {{ TITLE ⇝ title, price { PRICEB } }}
      }} }
  }
}
```

Query Term

Query Term

Return a summary of book prices in two bookstores.

Construct-Query Rules


```
rule { cons {
    books {
      all book {
         TITLE, price-a { PRICEA }, price-b { PRICEB } }
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    query {
      in { "http://bn.com" },
      bib {{
        book {{ TITLE ⇝ title, price { PRICEA } }}
      }} },
    query {
      in { "http://amazon.com" },
      reviews {{
        entry {{ TITLE ⇝ title, price { PRICEB } }}
      }} }
  }
}
```

Construct Term

Return a summary of book prices in two bookstores.

Simulation Unification

XML terms require a non-standard form of unification:

- ordered/unordered term specification has to be respected
- partial/total term specification suggests using an order instead of an equality between two terms that are unified
- the descendant construct needs a special treatment

Simulation Unification is a non-standard unification which fulfills these requirements.

Simulation Unification is based on the notion of a *Simulation* of one term in another.

Graph Simulation (1)

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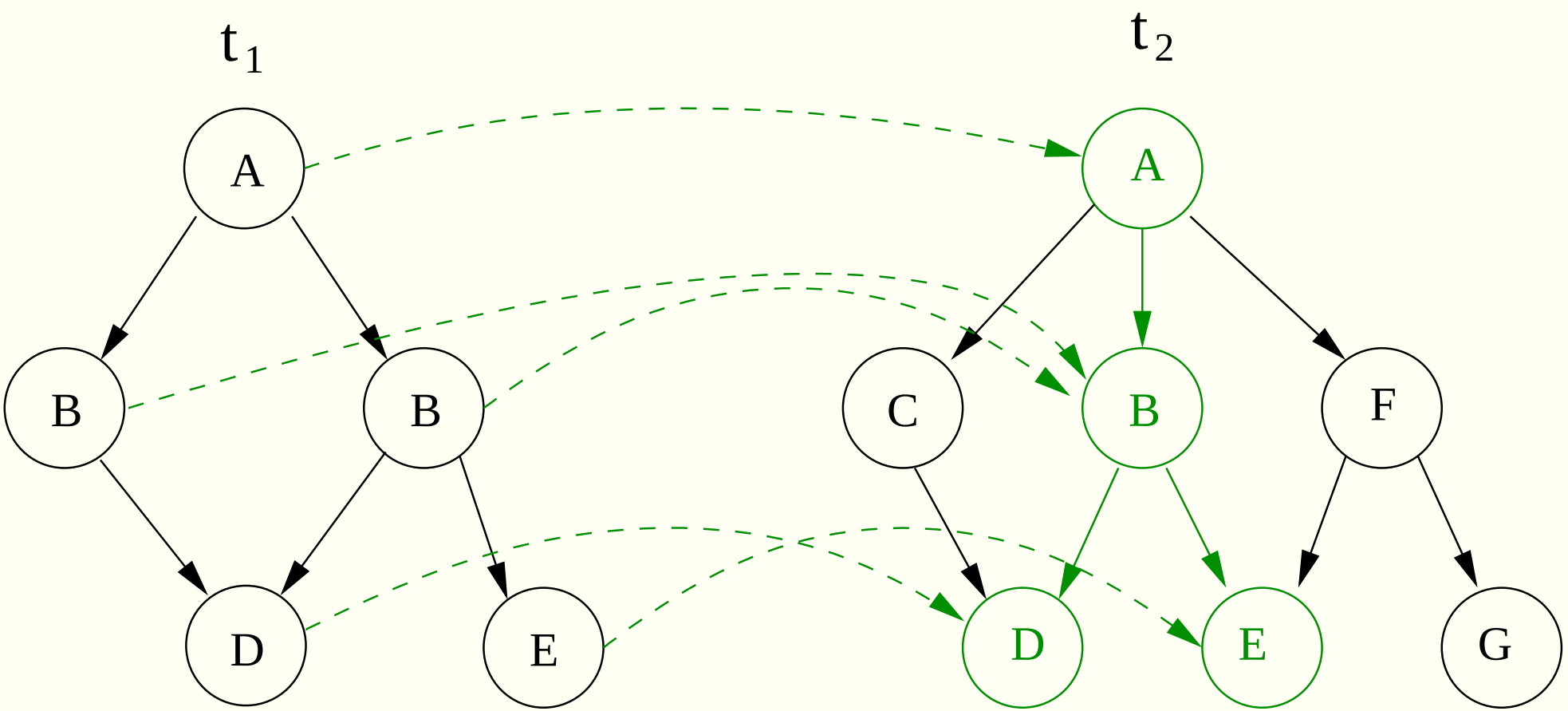

There exists a simulation from t_1 into t_2: $t_1 \preceq t_2$.

Graph Simulation (1)

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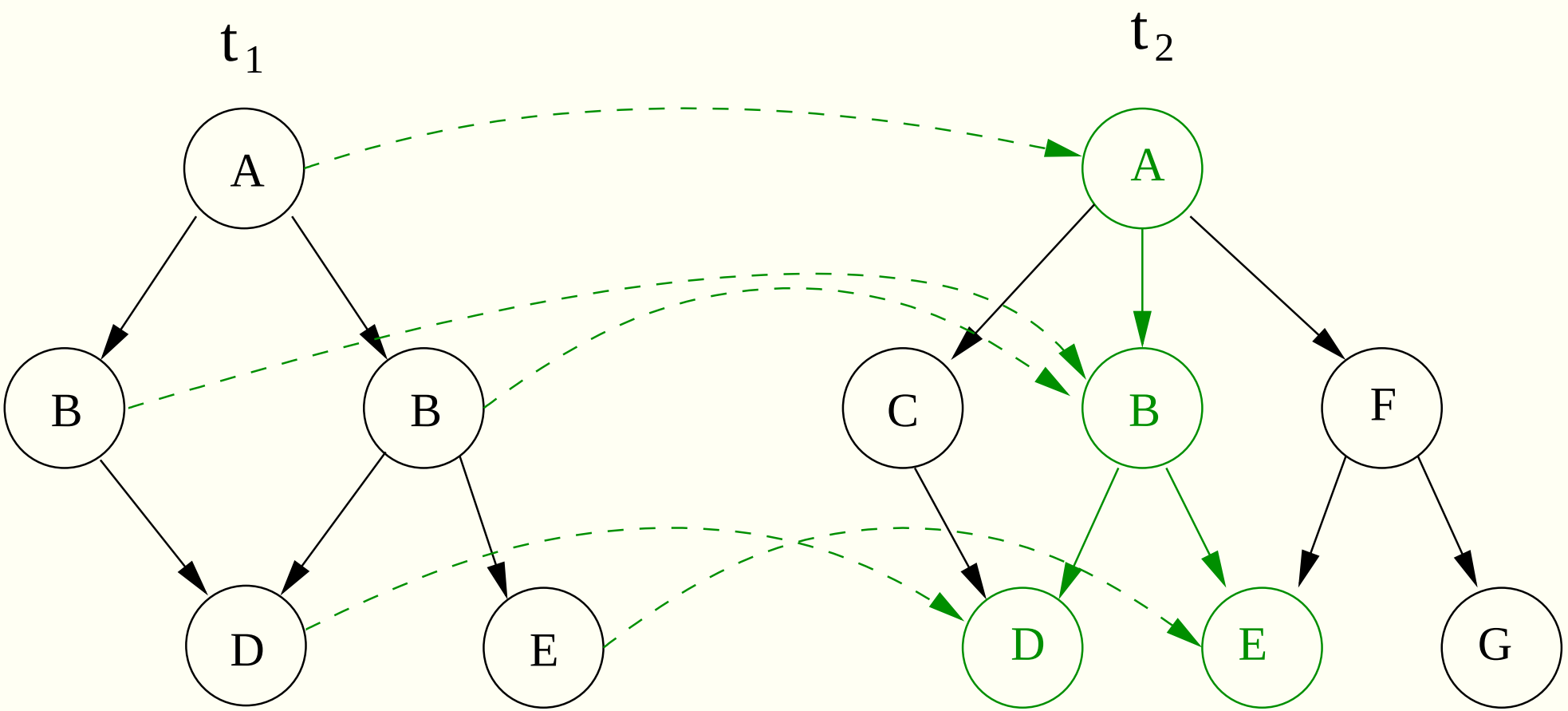
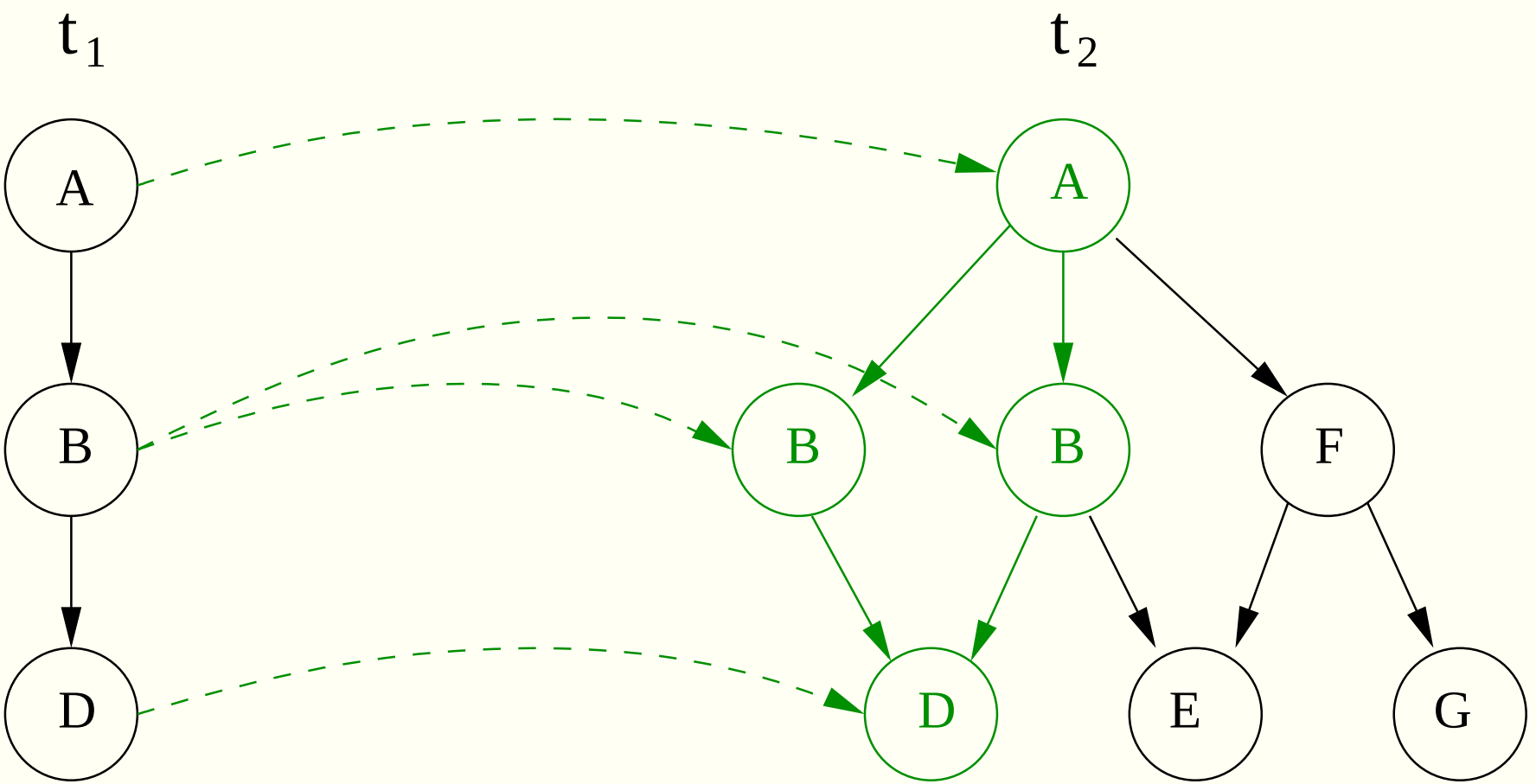


There exists a simulation from t_1 into t_2: $t_1 \preceq t_2$.

Graph Simulation (2)



A non-minimal simulation from t_1 into t_2.

Simulation Unifier (1)

A simulation unification is initialised with an inequation between a query term and a construct term:

$$t_q \preceq t_c$$

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A simulation unification is initialised with an inequation between a query term and a construct term:

$$t_q \preceq t_c$$

A unifier is a substitution σ such that for all grounding substitutions τ of t_c:

- $t_q\sigma\tau \preceq t_c\sigma\tau$
- for all subterms $X \rightsquigarrow t$ of t_q: $t\sigma\tau \preceq X\sigma\tau$

Simulation Unifier (2)

Example:

```
f {{
  X ⇝ g {{ b }},
  X ⇝ g {{ c }}
}}
```

```
f {
  g{ a, b, c },
  h
}
```

Unifiers for these two terms are: $X = g\{a, b, c\}$ and $X = g\{b, c\}$

Answers

An answer in a database $D \subseteq \mathcal{T}_{db}$ to a query term t_q is a database term $t \in D$ such that there exists a simulation unifier σ with $t_q\sigma \preceq t$.

Example:

```
f {{
  X ⇝ g {{ b }},
  X ⇝ g {{ c }}
}}
```

```
D = {
  f { g{ a, b, c }, h },
  f { g{b}, g{c} }
}
```

The only answer to the left query term in the database D is $f\{g\{a, b, c\}, h\}$.

Algorithm

1. **Initialisation:** $C := t^q \preceq t^c$
   (with t^q query term, t^c construct term and t^q, t^c variable disjoint).
2. **Term Decomposition:**
   Until C can no longer be modified, repeat performing one of:
   - Apply a (applicable) Term Decomposition rule to C
   - Put C in disjunctive normal form
3. **Variable Binding:**
   Replace each $X \preceq t$ in C with $X = t$.
4. **Consistency Verification:**
   For each disjunct D of C and for each variable X occurring in D do:

   Replace in D the equations $X = t_1, \ldots, X = t_n$ by $X = t$ where t is a (commutative) unifier of $\{t_1, \ldots, t_n\}$.

Term Decomposition

Root Elimination:

$$l\{\{t_1^1,\ldots,t_n^1\}\} \preceq l\{t_1^2,\ldots,t_m^2\} \quad \Leftrightarrow \bigvee_{\pi\in\Pi}\bigwedge_{1\leq i\leq n} t_i^1 \preceq \pi(t_i^1) \quad \text{if } n,m\geq 1$$

where Π is the set of total functions $\{t_1^1,\ldots,t_n^1\} \rightarrow \{t_1^2,\ldots,t_m^2\}$.

Term Decomposition

Root Elimination:

$$l\{\{t_1^1,\ldots,t_n^1\}\} \preceq l\{t_1^2,\ldots,t_m^2\} \quad \Leftrightarrow \bigvee_{\pi\in\Pi}\bigwedge_{1\leq i\leq n} t_i^1 \preceq \pi(t_i^1) \quad \text{if } n,m\geq 1$$

$\rightsquigarrow$ **Elimination:**

$$X \rightsquigarrow t^1 \preceq t^2 \qquad \Leftrightarrow\ t^1 \preceq t^2 \ \wedge\ t^1 \preceq X \ \wedge\ X \preceq t^2$$

where Π is the set of total functions $\{t_1^1,\ldots,t_n^1\} \rightarrow \{t_1^2,\ldots,t_m^2\}$.

Term Decomposition

Root Elimination:

$$l\{\{t_1^1,\ldots,t_n^1\}\} \preceq l\{t_1^2,\ldots,t_m^2\} \quad \Leftrightarrow \bigvee_{\pi\in\Pi}\bigwedge_{1\leq i\leq n} t_i^1 \preceq \pi(t_i^1) \quad \text{if } n,m\geq 1$$

$\rightsquigarrow$ **Elimination:**

$$X \rightsquigarrow t^1 \preceq t^2 \qquad \Leftrightarrow\ t^1 \preceq t^2 \ \wedge\ t^1 \preceq X \ \wedge\ X \preceq t^2$$

Descendant Elimination:

$$\mathit{desc}\ t^1 \preceq l_2\{t_1^2,\ldots,t_m^2\} \Leftrightarrow t^1 \preceq l_2\{t_1^2,\ldots,t_m^2\} \vee \bigvee_{1\leq i\leq m} \mathit{desc}\ t^1 \preceq t_i^2 \quad \text{if } m\geq 0$$

where Π is the set of total functions $\{t_1^1,\ldots,t_n^1\} \rightarrow \{t_1^2,\ldots,t_m^2\}$.

Summary

This talk presented the language Xcerpt:

- Xcerpt is a rule-based query and transformation language for XML and SSD
- Evaluation is based on ideas from logic programming
- XML data can be represented as terms but need a quite different treatment
- Simulation Unification is a non-standard unification algorithm that meets the requirements of XML data

End

Thank you!

Xcerpt is an ongoing research project. For more information, please visit http://www.xcerpt.org

Term Decomposition (1)

Root Elimination:

(1) $l \preceq l\{t_1^2, \ldots, t_m^2\} \Leftrightarrow$ *true* if $m \geq 1$

$l \preceq l\{\} \Leftrightarrow$ *true*

$l\{\} \preceq l\{t_1^2, \ldots, t_m^2\} \Leftrightarrow$ *false* if $m \geq 1$

$l\{\} \preceq l \Leftrightarrow$ *true*

$l\{\} \preceq l\{\} \Leftrightarrow$ *true*

(2) $l\{\{t_1^1, \ldots, t_n^1\}\} \preceq l \Leftrightarrow$ *false* if $n \geq 1$

$l\{\{t_1^1, \ldots, t_n^1\}\} \preceq l\{\} \Leftrightarrow$ *false* if $n \geq 1$

$l\{t_1^1, \ldots, t_n^1\} \preceq l \Leftrightarrow$ *false* if $n \geq 1$

$l\{t_1^1, \ldots, t_n^1\} \preceq l\{\} \Leftrightarrow$ *false* if $n \geq 1$

Appendix

Term Decomposition (2)

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(3) $l\{\{t_1^1,\ldots,t_n^1\}\} \preceq l\{t_1^2,\ldots,t_m^2\} \quad \Leftrightarrow \bigvee_{\pi\in\Pi}\bigwedge_{1\leq i\leq n} t_i^1 \preceq \pi(t_i^1)$ if $n,m\geq 1$

$l\{t_1^1,\ldots,t_n^1\} \preceq l\{t_1^2,\ldots,t_m^2\} \quad \Leftrightarrow \bigvee_{\pi\in\Phi}\bigwedge_{1\leq i\leq n} t_i^1 \preceq \pi(t_i^1)$ if $n,m\geq 1$

(4) $l_1\{\{t_1^1,\ldots,t_n^1\}\} \preceq l_2\{t_1^2,\ldots,t_m^2\} \Leftrightarrow \mathit{false}$ if $l_1\neq l_2$ $(n,m\geq 0)$

$l_1\{t_1^1,\ldots,t_n^1\} \preceq l_2\{t_1^2,\ldots,t_m^2\} \quad \Leftrightarrow \mathit{false}$ if $l_1\neq l_2$ $(n,m\geq 0)$

where Π (Φ, resp.) is the set of total (total surjective, resp.) functions $\{t_1^1,\ldots,t_n^1\}\rightarrow\{t_1^2,\ldots,t_m^2\}$.

Appendix

Term Decomposition (3)

$\rightsquigarrow$ Elimination:

$$X \rightsquigarrow t^1 \preceq t^2 \qquad \Leftrightarrow\ t^1 \preceq t^2\ \wedge\ t^1 \preceq X\ \wedge\ X \preceq t^2$$

Descendant Elimination:

$$\mathit{desc}\ t^1 \preceq l_2\{t_1^2, \ldots, t_m^2\} \Leftrightarrow t^1 \preceq l_2\{t_1^2, \ldots, t_m^2\} \vee \bigvee\nolimits_{1 \leq i \leq m} \mathit{desc}\ t^1 \preceq t_i^2 \quad \text{if } m \geq 0$$

Simulation Unification – Example

Initialisation:

$$C = f\{\{X \rightsquigarrow g\{\{b\}\}, X \rightsquigarrow g\{\{c\}\}\}\} \quad \preceq \quad f\{g\{a,b,c\}, h\}$$

Root Elimination (3):

$$\begin{aligned} C \quad = \quad & (X \rightsquigarrow g\{\{b\}\} \preceq g\{a,b,c\} \wedge X \rightsquigarrow g\{\{c\}\} \preceq g\{a,b,c\}) \vee \\ & (X \rightsquigarrow g\{\{b\}\} \preceq g\{a,b,c\} \wedge X \rightsquigarrow g\{\{c\}\} \preceq h) \vee \\ & (X \rightsquigarrow g\{\{b\}\} \preceq h \wedge X \rightsquigarrow g\{\{c\}\} \preceq g\{a,b,c\}) \vee \\ & (X \rightsquigarrow g\{\{b\}\} \preceq h \wedge X \rightsquigarrow g\{\{c\}\} \preceq h) \end{aligned}$$

Simulation Unification – Example

$\rightsquigarrow$-Elimination

$$
\begin{aligned}
C \;=\; & (g\{\{b\}\} \preceq g\{a,b,c\} \wedge g\{\{b\}\} \preceq X \wedge X \preceq g\{a,b,c\} \wedge \\
& g\{\{c\}\} \preceq g\{a,b,c\} \wedge g\{\{c\}\} \preceq X \wedge X \preceq g\{a,b,c\}) \vee \\
& (g\{\{b\}\} \preceq g\{a,b,c\} \wedge g\{\{b\}\} \preceq X \wedge X \preceq g\{a,b,c\} \wedge \\
& g\{\{c\}\} \preceq h \wedge g\{\{c\}\} \preceq X \wedge X \preceq h) \vee \\
& (g\{\{b\}\} \preceq h \wedge g\{\{b\}\} \preceq X \wedge X \preceq h \wedge \\
& g\{\{c\}\} \preceq g\{a,b,c\} \wedge g\{\{c\}\} \preceq X \wedge X \preceq g\{a,b,c\}) \vee \\
& (g\{\{b\}\} \preceq h \wedge g\{\{b\}\} \preceq X \wedge X \preceq h \wedge \\
& g\{\{c\}\} \preceq h \wedge g\{\{c\}\} \preceq X \wedge X \preceq h)
\end{aligned}
$$

Simulation Unification – Example

Decomposition

$$
\begin{aligned}
C \quad = \quad & (true \wedge g\{\{b\}\} \preceq X \wedge X \preceq g\{a,b,c\} \wedge \\
& \ true \wedge g\{\{c\}\} \preceq X \wedge X \preceq g\{a,b,c\}) \vee \\
& (true \wedge g\{\{b\}\} \preceq X \wedge X \preceq g\{a,b,c\} \wedge \\
& \ false \wedge g\{\{c\}\} \preceq X \wedge X \preceq h) \vee \\
& (false \wedge g\{\{b\}\} \preceq X \wedge X \preceq h \wedge \\
& \ true \wedge g\{\{c\}\} \preceq X \wedge X \preceq g\{a,b,c\}) \vee \\
& (false \wedge g\{\{b\}\} \preceq X \wedge X \preceq h \wedge \\
& \ false \wedge g\{\{c\}\} \preceq X \wedge X \preceq h)
\end{aligned}
$$

Simulation Unification – Example

Simplification

$$\begin{aligned} C \quad = \quad & (g\{\{b\}\} \preceq X \wedge X \preceq g\{a,b,c\} \wedge \\ & g\{\{c\}\} \preceq X \wedge X \preceq g\{a,b,c\}) \vee \\ & false \vee \\ & false \vee \\ & false \end{aligned}$$

Simplification

$$\begin{aligned} C \quad = \quad & (g\{\{b\}\} \preceq X \wedge X \preceq g\{a,b,c\} \wedge \\ & g\{\{c\}\} \preceq X \wedge X \preceq g\{a,b,c\}) \end{aligned}$$

Simulation Unification – Example

Variable Binding

$$C \quad = \quad (g\{\{b\}\} \preceq X \wedge X = g\{a,b,c\} \wedge g\{\{c\}\} \preceq X \wedge X = g\{a,b,c\})$$

Simulation Unifier

$$\sigma \quad = \quad \{\ X = g\{a,b,c\}\ \}$$