Pruning Nested XQuery Queries

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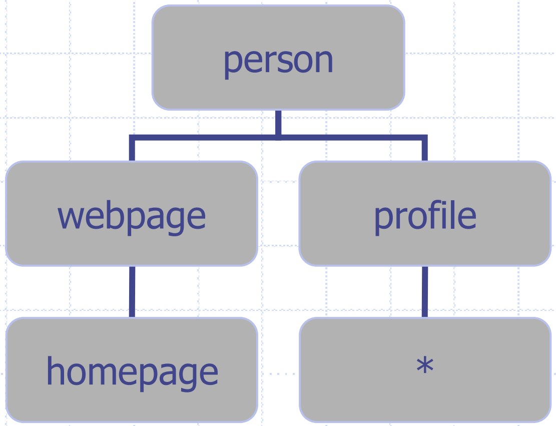
Introduction

- XQuery optimization is crucial and complex
  - Complex : operational semantics
  - Crucial : evaluation efficiency
    - Handling many document accesses is expensive
    - Construction of XML elements is expensive
- Challenge
  - Minimizing document access and intermediary element construction
- Various approaches
  - Projecting XML documents
  - Type based projections
  - Reformulating XQuery queries
  - …
- Our contribution
  - Rewriting rules for nested XQuery queries with composition

Example of query composition

```
for $j in doc("auction.xml")/site/people/person
return <person>
        <webpage>{$j/homepage}</webpage>
        <profile>{$j/profile/*}</profile>
       </person>
```



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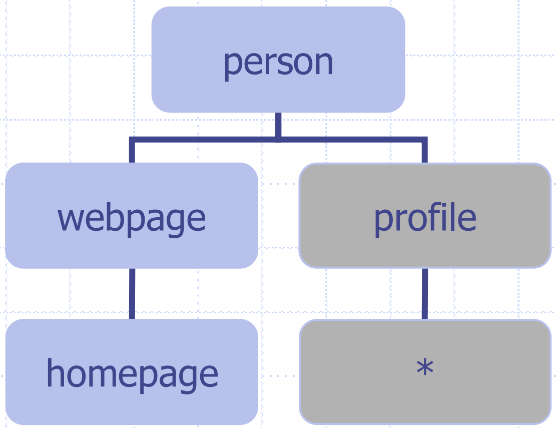

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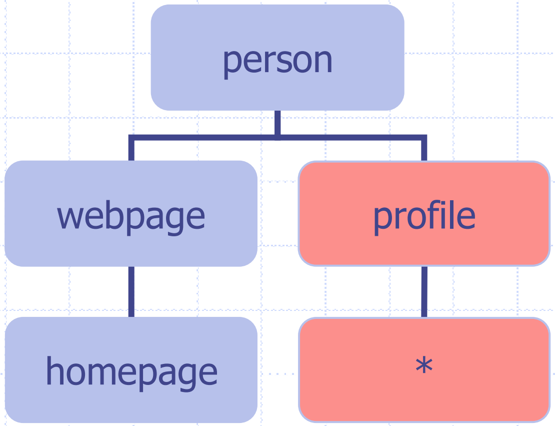

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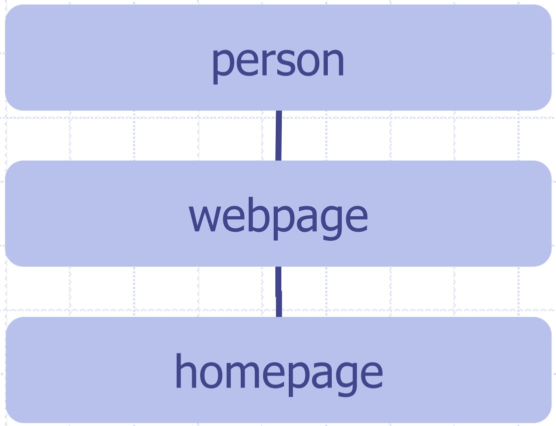

Example of query composition

let $i := (for $j in doc("auction.xml")/site/people/person
return <person>
<webpage>{$j/homepage}</webpage>
~~A FLWR or any sub-expression~~
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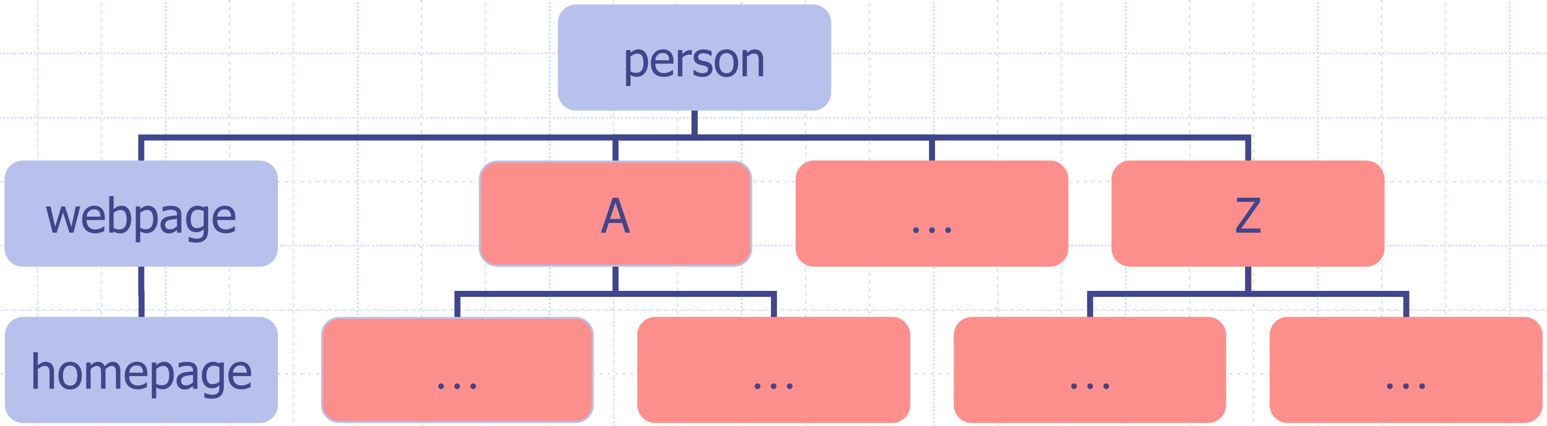
return $i/webpage



The main idea

- In the case of query composition, some intermediate results/computations may not be necessary

  → Sub-expressions generating them are useless

- Our algorithm:
  - Analyzes the input query in order to detect these sub-expressions
  - Projects out (prune) these sub-expressions
  - Maintain equivalence with the original query

Preliminaries

- Intermediate results/computations
  - Associated to variables
- For each variable $i
  - its definition denotes the sub-expression producing the results “stored” in $i
  - its scope denotes the sub-expressions where $i can be used

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let $i := *definition of $i*
where *part of the scope of $i*
return *part of the scope of $i*

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based on the references to $i in the scope, simplify its definition

Algorithm overview

A bottom-up static analysis of input query

For each variable $i, three main steps:

1. Apply recursively the pruning process on its definition and scope

2. Extract from the scope the paths referencing $i
   Explicit references: $i/A/B/…
   Implicit references: $k/A/B/…, while $k is linked to $i
   (ex. for $k in $i/…, or let $k:=$i/…)

3. Using the paths from Step 2, detect and project out the unneeded parts from the definition of $i

Path extraction

- Returned vs used paths [Marian and Simeon, VLDB'03]
  - Paths determine XML result nodes
  - In some cases (used paths), the subtrees rooted at these result nodes are not necessary for the query evaluation

    For example, when the result nodes are only used for iteration

- extractPaths($i, scope of $i) => P, P#
  - Analyze the scope of $i
  - Return the paths referencing $i: P for used paths, and P# for returned paths

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- extractPaths($i, scope of $i) => P, $P^{\#}$
  - Analyze the scope of $i
  - Return the paths referencing $i: P for used paths, and $P^{\#}$ for returned paths
  - Described in the paper by a set of inference rules
    each rule details the path extraction process according to the query structure of the input scope

Pruning $i's definition

projectPaths(P, P#, $i's definition) => definition'

- Analyze the definition of $i and its expected result
- Determine the result nodes that are reached by some paths in P and $P^{\#}$
  - Those that are not reached are unneeded
- Determine whether the descendent nodes are necessary or not

  If a node is only reached by used paths, its descendents are not needed
- Project out the sub-expressions that compute the unneeded nodes (and nothing else)

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- Project out the sub-expressions that compute the unneeded nodes (and nothing else)
- Detailed in the paper by a set of rewriting rules

  each rule describes the path projection process according to the query structure of the input definition

Pruning rule example

FLWR expression:

$$\frac{\begin{array}{c} Env \mid\!- prune(e_1) => e'_1 \\ Env.add(\$i) \\ Env \mid\!- prune(e_2) => e'_2 \\ Env \mid\!- extractPaths(\$i, e_2')) => P, P\# \\ Env \mid\!- projectPaths(P, P\#, e'_1)) => e''_1 \end{array}}{Env \mid\!- prune(let\ \$i := e_1\ return\ e_2) => let\ \$i := e''_1\ return\ e'_2}$$

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$$\frac{\begin{array}{c} Env \vdash prune(e_1) \Rightarrow e'_1 \\ Env.add(\$i) \\ Env \vdash prune(e_2) \Rightarrow e'_2 \\ Env \vdash extractPaths(\$i, e_2')) \Rightarrow P, P\# \\ Env \vdash projectPaths(P, P\#, e'_1)) \Rightarrow e''_1 \end{array}}{Env \vdash prune(let\ \$i := e_1\ return\ e_2) \Rightarrow let\ \$i := e''_1\ return\ e'_2}$$

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Pruning rule example

FLWR expression:

$$\frac{\begin{array}{c} Env \models prune(e_1) \Rightarrow e'_1 \\ Env.add(\$i) \\ Env \models prune(e_2) \Rightarrow e'_2 \quad = () \\ Env \models extractPaths(\$i, e_2')) \Rightarrow P, P\# \\ Env \models projectPaths(P, P\#, e'_1)) \Rightarrow e''_1 \end{array}}{Env \models prune(let\ \$i := e_1\ return\ e_2) \Rightarrow \underbrace{let\ \$i := e''_1\ return\ e'_2}_{= ()}}$$

Pruning rule example

FLWR expression:

$$\frac{Env \mid\!- prune(e_1) \Rightarrow e'_1 \qquad Env.add(\$i) \quad Env \mid\!- prune(e_2) \Rightarrow ()}{Env \mid\!- prune(let\ \$i := e_1\ return\ e_2) \Rightarrow ()}$$

Equivalence

Theorem:

For q an XQuery expression, if Env |- prune(q) => q'
then $\forall I$, $q(I) =_{deep} q'(I)$.

- Proof by induction on the rewrite rules
  - Details can be found in the paper
- Intuition: the computations we remove are not "linked" to the root computations

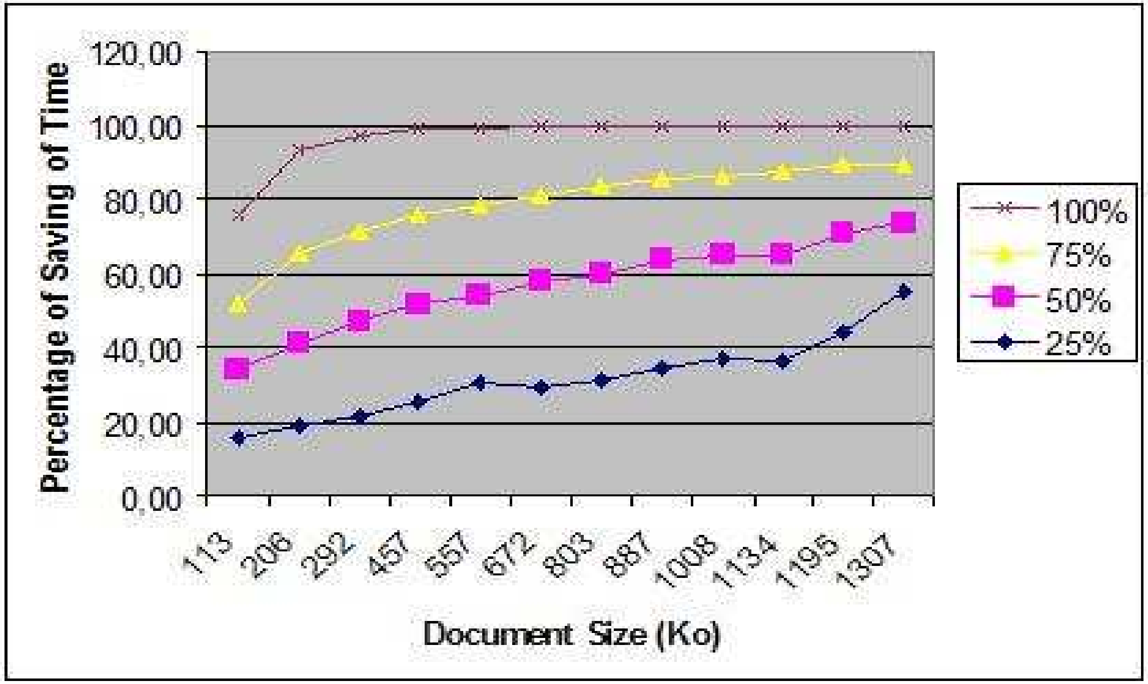
Experiments

- We measured the impact on evaluation time
- Using a template query, we varied
  - the nature and complexity of pruned sub-expressions
    - FLWR blocks
    - explicit element construction
    - XPath expressions
  - the percentage of useless intermediate results
  - the size of the source document

Experiments

```
let $i := <personInf>
            {for $j in doc("xmark.xml")/site/people/person
             return (<name>{test_expr}</name>,<age>{test_expr}</age>,
                     <gender>{test_expr}</gender>,<email>{test_expr}</email>)}
          </personInf>

return scope of $i
```



Conclusion

- A new technique for pruning nested XQuery queries with composition
- A rule based algorithm for a large XQuery fragment
  - FLWR expression, quantifier
  - Sequence, comparison operation, element construction
  - If-the-else expressions
  - …
- Experiments show significant gains in evaluation time
- Useful in many contexts (data integration, security)
- Possible extensions:
  - backward axis
  - taking into account document schema

Thank you for your attention