Validity-Sensitive Querying of XML Databases

Slawomir Staworko   Jan Chomicki

Department of Computer Science
University at Buffalo

DataX, March 26, 2006

Motivation

Querying Invalid XML

- Integration of XML documents
- Slights differences between schemas (e.g. different cardinality constraints)
- Legacy XML databases
- Database updates

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Document Type Definition (D_0)

$$
\begin{array}{lll}
\text{proj} & \longrightarrow & \text{(name, emp, proj*, emp*)} \\
\text{emp} & \longrightarrow & \text{(name, salary)} \\
\text{name} & \longrightarrow & \text{\#PCDATA} \\
\text{salary} & \longrightarrow & \text{\#PCDATA}
\end{array}
$$

Query: get salaries of all employees that are not managers

//proj/name/following_sibling::emp/following_sibling:emp/salary

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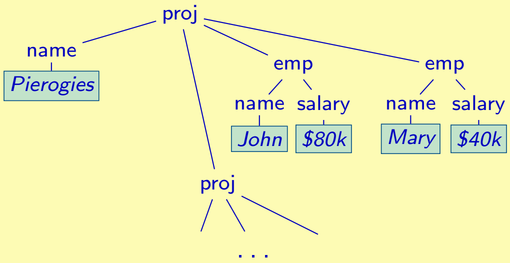

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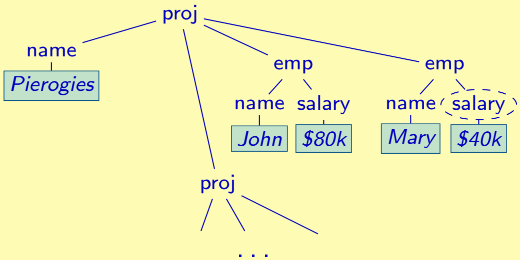

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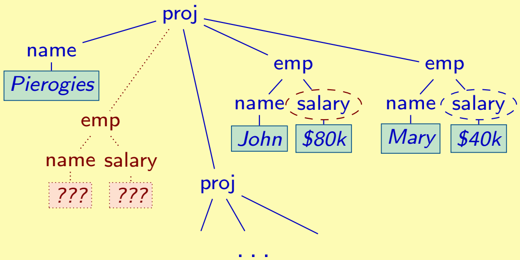

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Positive Core XPath

Positive Core XPath Queries

- text values but without attributes
- all standard axises
- tests with subexpressions and equality:
  `//*[A/B]`, `//*[B//text()='abcd']`
- but no negation in tests:
  `//*[not A/B]`, `//*[B/text()≠'abcd']`
- and no functions

Tree Reachability Fact: (x, Q, y)

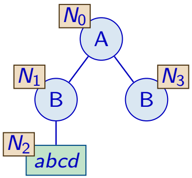
$$\text{node } x \xrightarrow{\text{query } Q} \text{object } y$$

Basic facts use only `/*` and `following_sibling::`

$$(N_0, /*, N_1),\ (N_1, /*, N_2)$$

Other facts are implied nferred by (Horn) rules $(X, Q/P, Y) \Leftarrow (X, Q, Z) \wedge (Z, P, Y)$.

$$(N_0, /*/*, N_2).$$



Query Answers

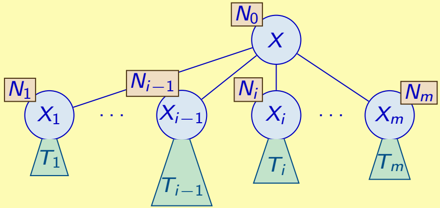
- given query Q and document T with the root node r
- find all tree facts that hold in T
- x in an answer to Q in T iff the tree fact (r, Q, x) holds in T

Monotonic Query Evaluation

Bottom-up approach

- computing tree facts for query Q
- tree facts for $T_1, \ldots, T_m$ computed before
- including implied facts (involving subqueries of Q)

Tree

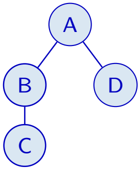


Algorithm

I. start with $\varnothing$

II. for child subtree T_i $(i = 1, \ldots, m)$
   1. add all facts of the child
   2. add $(N_0, /*, N_i)$
   3. if $i > 1$ add $(N_{i-1}, \texttt{following\_sibling::*}, N_i)$

Editing operations



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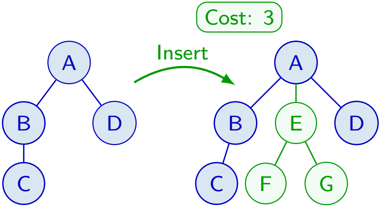
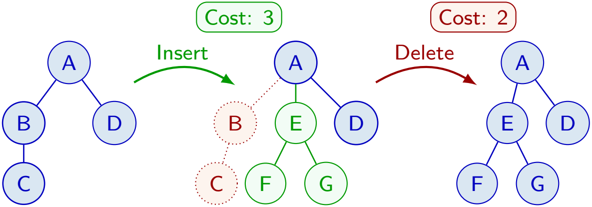


Editing operations

- Inserting a subtree

Editing operations



Editing operations

- Inserting a subtree
- Deleting a subtree

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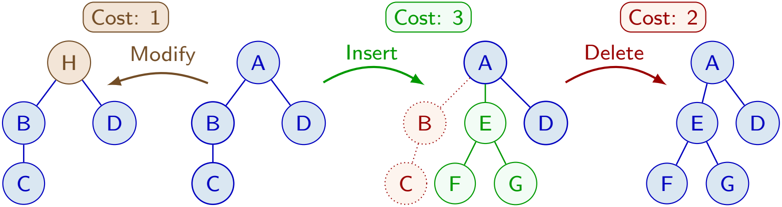


Editing operations

- Inserting a subtree
- Deleting a subtree
- Modifying node's label

Edit Distance and Repairs

Distance between documents

$dist(T, S)$ is the minimal cost of transforming T into S

Distance to a DTD

$dist(T, D)$ is the minimal cost of repairing T w.r.t D i.e.,

$$\min\{dist(T, S) | S \text{ valid w.r.t } D\}$$

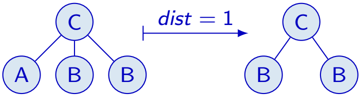
DTD

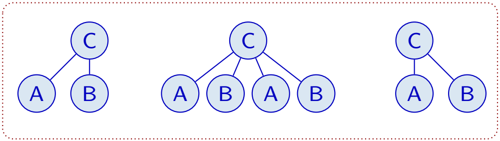
C $\rightarrow$ (A,B)*
A $\rightarrow$ EMPTY
B $\rightarrow$ EMPTY

Repair

T' is a repair of T w.r.t D iff

$$dist(T', T) = dist(T, D)$$





There can be an exponential number of repairs

Valid Query Answers

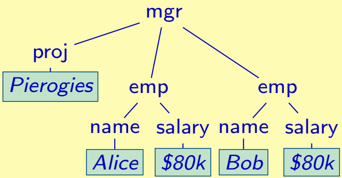
Valid Query Answers

x is a valid answer to query Q in T w.r.t. D iff
x is an answer to Q in every repair of T w.r.t. D.

DTD

mgr	$\rightarrow$	(proj, emp)
proj	$\rightarrow$	#PCDATA
emp	$\rightarrow$	(name, salary)
name	$\rightarrow$	#PCDATA
salary	$\rightarrow$	#PCDATA

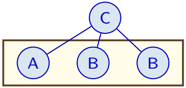
XML Document



Queries

`//mgr[emp/salary='$80K']/proj/text()`	$\rightarrow$	{*Pierogies*}
`//mgr[proj='Pierogies']/emp/salary/text()`	$\rightarrow$	{*$80K*}
`//mgr[proj='Pierogies']/emp/name/text()`	$\rightarrow$	$\emptyset$
`//mgr[proj='Pierogies']/emp/salary`	$\rightarrow$	$\emptyset$

Trace graph



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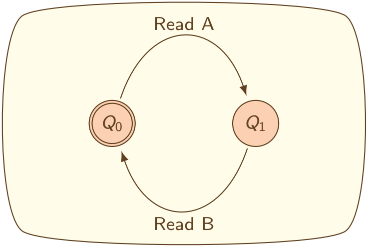

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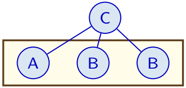

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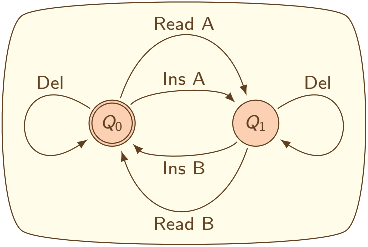

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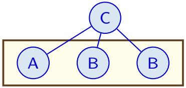

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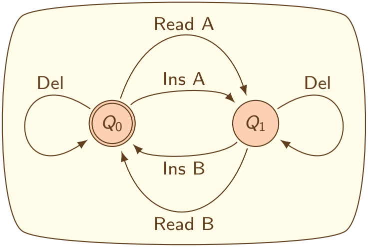

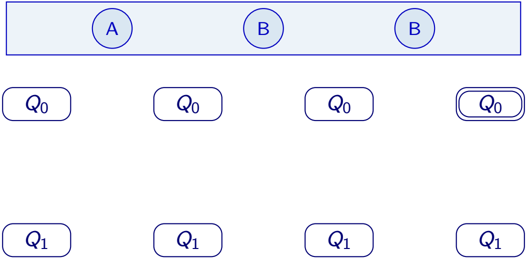

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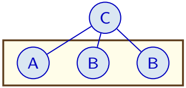

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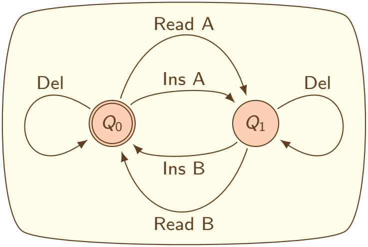

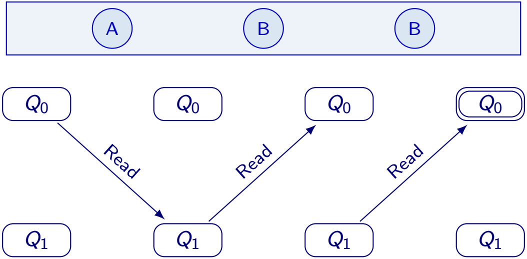

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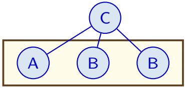

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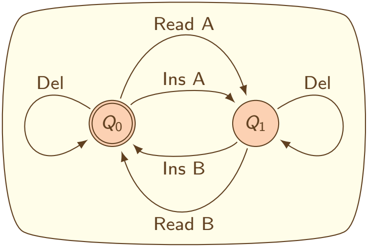

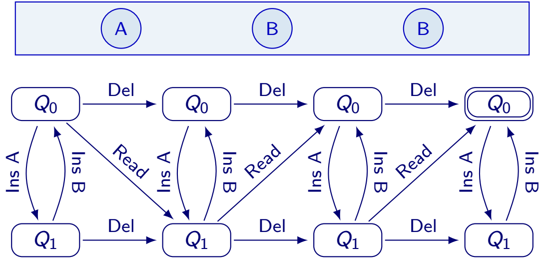

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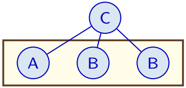

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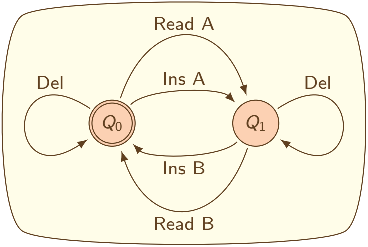

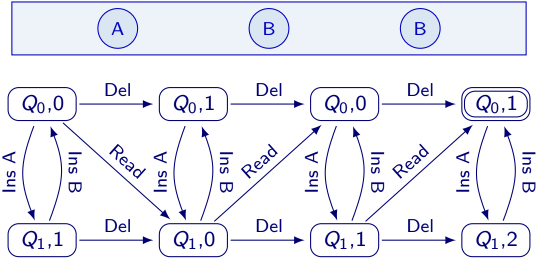

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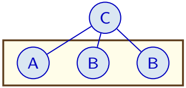

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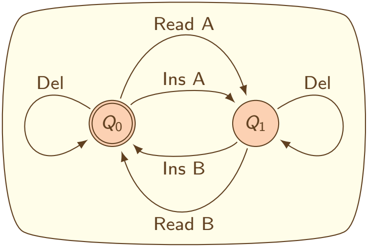

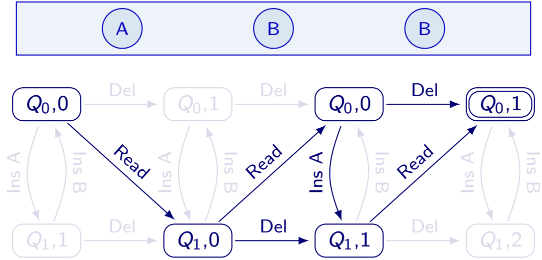

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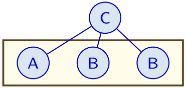

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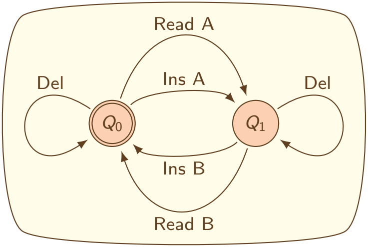
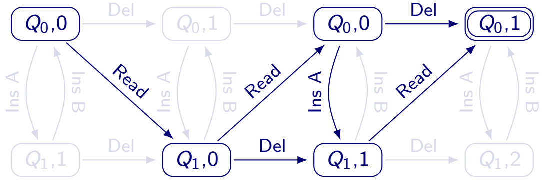


Compact representation of all repairs



Repairing Paths:

- (Read, Read, Del)
- (Read, Read, Ins A, Read)
- (Read, Del, Read)

Computing Valid Query Answers

Certain Tree Facts

Tree facts present in every repair of a given tree

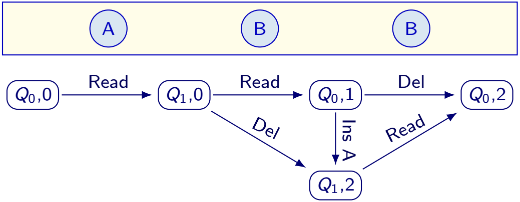
Bottom-up approach

Precomputed values:

- certain facts for all children
- certain facts common for every minimal tree satisfying DTD

Obtain certain facts by

Intersecting sets for all repairing paths



For every repairing path, construct:

set of facts collected "so far":

- start with $\varnothing$
- **Read** add certain facts of the corresponding child
- **Del** add nothing
- **Ins A** add certain facts common for minimal trees labeled with A

Eager intersection

Problem

Possibly an exponential number of paths

Solution: Eager Intersection

For queries without tests of form

`[Q/text() = P/text()]`.

Intersect all sets of certain facts for paths sharing the same last adding operation (Read/Ins).

Data complexity of VQA

Computation of valid answers to positive core XPath queries without tests of form

`[Q/text() = P/text()]`

can be performed in polynomial time in the size of the document.

Combined complexity of VQA

Combined complexity of computing valid query answers is co-NP-complete.

Experimental Results: Edit Distance Computation

Compared algorithms

PARSE	base line
VALIDATE	regular automata
DIST	distance computation

Data generation

1. random valid document
2. removing and adding random nodes
3. invalidity ratio

   $$dist(T, D)/|T| \simeq 0.1\%$$

4. small height (8-10)

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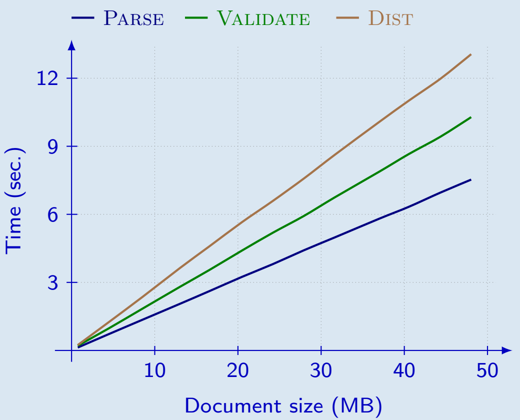

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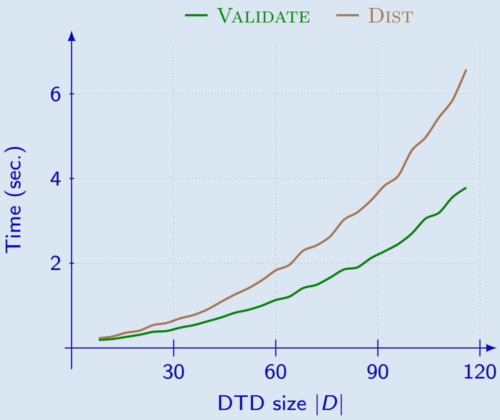

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VQA	eager intersection

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Implemented Queries

- `//`, `/`, `following_sibling::`
- `name()=A,text()=`'*str*'
- QA works in linear time

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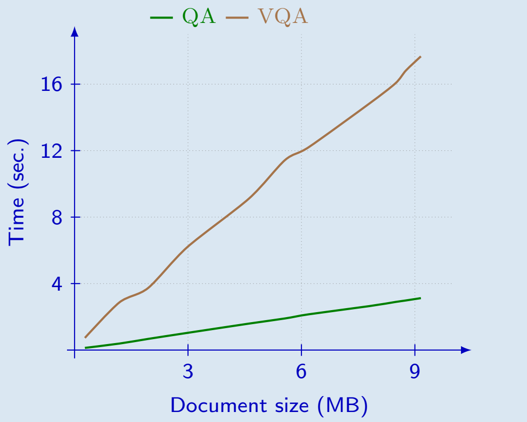

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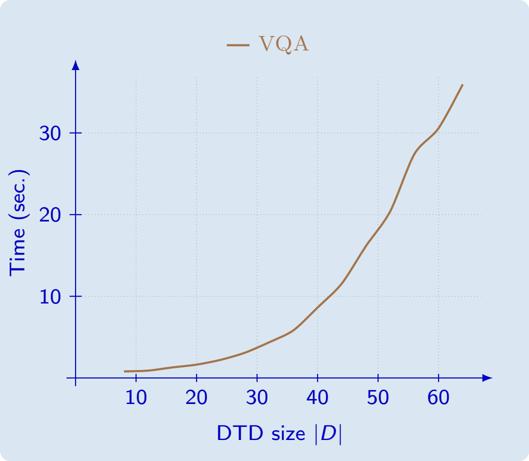

Conclusions and Future Work

Conclusions

- Framework for querying of documents with validity violations of local nature (missing or superfluous nodes)
- Efficient algorithm for computing valid answers to a class of XPath queries

Future Work

- Valid answers by query rewriting
- Valid answers to queries with negation
- Other tree operations (swap, shift, contraction, . . .)
- Semantic inconsistencies (keys, functional dependencies,. . .)