XML and Databases

Lecture 13
Update Languages for XML

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CSE@UNSW -- Semester 1, 2010

Outline

1. Update Languages for XML

   → XQuery Update Facility: delete,insert,replace,rename,remove
   → type issues
   → snapshot semantics

2. The physical site

   → how to update a DAG?
   → how to update PRE/POST encoding?
   → other storage schemes?

XML Updates -- History

Updates = write operations, e.g., *delete, insert, replace, rename*, etc

Want to have Update Language, i.e., a formalism for "update programs".

Currently, there is **no** accepted standard XML Update Language

→ XUpdate (XML:DB, working draft from 9/2000)

→ XQuery! (by the implementors of the Galax XQuery engine)

→ XQuery Update Facility (W3C Candidate Recommendation,
09 June 2009)

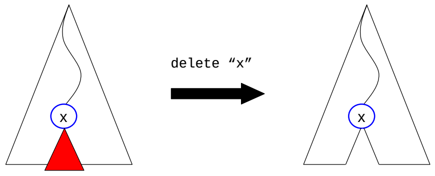
plus lots of other smaller projects…

XML Updates

Note
Every node has an "identity" = a unique identifier.
Also: there may be attributes of type "ID"!

Example updates for XML data

(1) *delete subtree* rooted at node x



XML Updates

Example updates for XML data

(1) *delete subtree* rooted at node x

Use XPath to specify
the nodes x
to be deleted.

Explicit examples

Delete the last author of the first book in a given bibliography.

```
do delete fn:doc("bib.xml")/books/book[1]/author[last()]
```

Delete all email messages that are more than 365 days old.

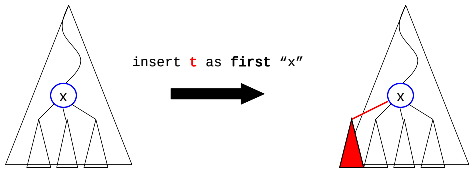
```
do delete /email/message[fn:currentDate()-date >
                                       xs:dayTimeDuration("P365D")]
```

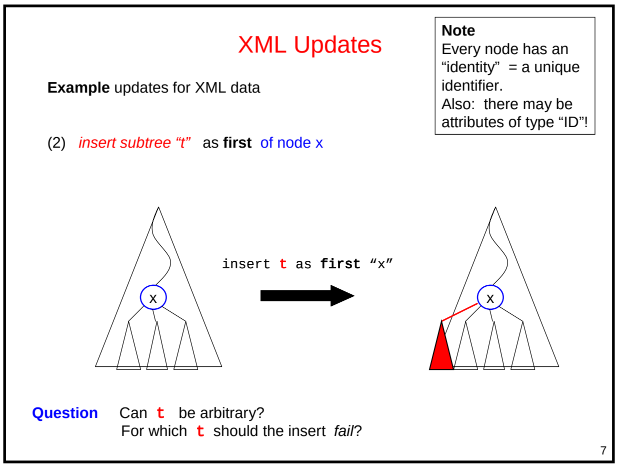
XML Updates

Note
Every node has an "identity" = a unique identifier.
Also: there may be attributes of type "ID"!

Example updates for XML data

(2) *insert subtree "t"* as **first** of node x





XML Updates

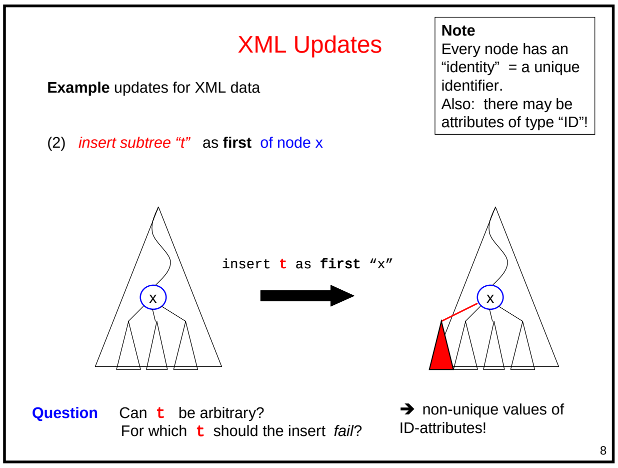
Note
Every node has an "identity" = a unique identifier.
Also: there may be attributes of type "ID"!

Example updates for XML data

(2) *insert subtree "t"* as **first** of node x

`insert t as first “x”`

Question Can t be arbitrary?
For which t should the insert *fail*?



XML Updates

Note
Every node has an "identity" = a unique identifier.
Also: there may be attributes of type "ID"!

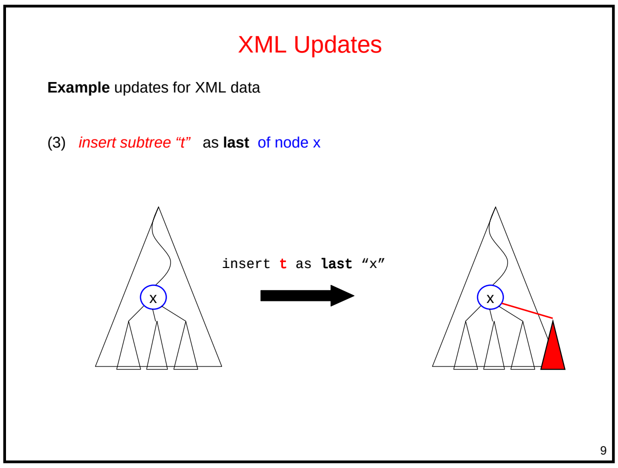
Example updates for XML data

(2) *insert subtree "t"* as **first** of node x

`insert t as first “x”`

Question Can t be arbitrary?
For which t should the insert *fail*?

➔ non-unique values of ID-attributes!

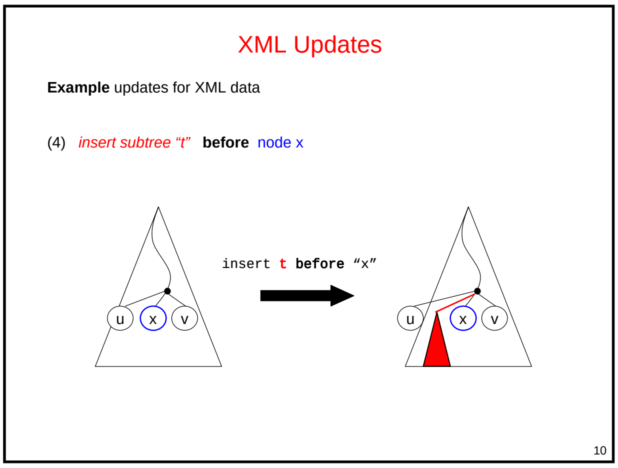


XML Updates

Example updates for XML data

(3) *insert subtree "t"* as **last** of node x

`insert t as last “x”`

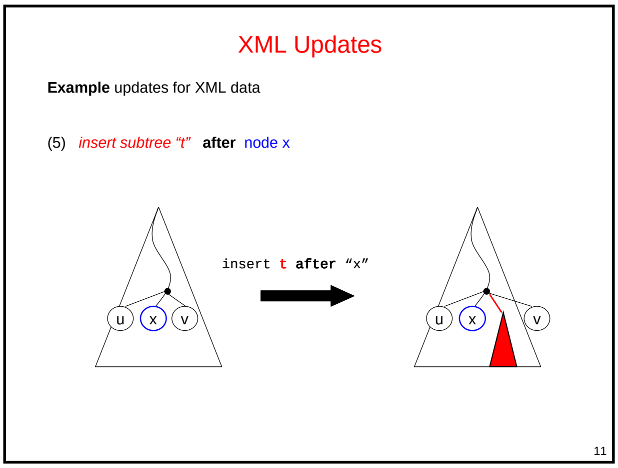


XML Updates

Example updates for XML data

(4) *insert subtree "t"* **before** node x

`insert t before “x”`

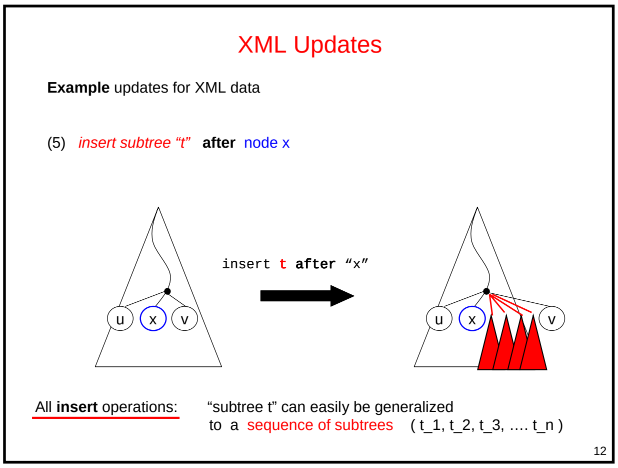


XML Updates

Example updates for XML data

(5) *insert subtree "t"* **after** node x

`insert t after “x”`



XML Updates

Example updates for XML data

(5) *insert subtree "t"* **after** node x

`insert t after “x”`

All **insert** operations: "subtree t" can easily be generalized to a sequence of subtrees (t_1, t_2, t_3, …. t_n)

XML Updates

Example updates for XML data

(5) *insert subtree “t”* **after** node x

Explicit examples

Insert a year element after the publisher of the first book.

```
do insert <year>2005</year>  after
   fn:doc("bib.xml")/books/book[1]/publisher
```

Navigating by means of several bound variables, insert a new police report into the list of police reports for a particular accident.

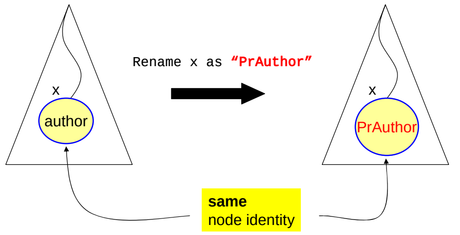
```
do insert $new-police-report
    as last into fn:doc("insurance.xml")/policies
       /policy[id = $pid]
       /driver[license = $license]
       /accident[date = $accdate]
       /police-reports
```

XML Updates

Example updates for XML data

Note
The rename operation preserves node identity!

(6) *rename* node x as *name*



`Rename x as “PrAuthor”`

same
node identity

XML Updates

Example updates for XML data

Note
The rename operation preserves node identity!

(6) *rename* node x as *name*

Explicit examples

Rename the first author element of the first book to `principal-author`.

```
do rename fn:doc("bib.xml")/books/book[1]/author[1]
          as "principal-author"
```

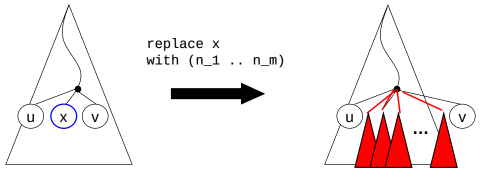
Rename the first `author` element of the first book to the QName that is the value of the variable `$newname`.

```
do rename fn:doc("bib.xml")/books/book[1]/author[1]
          as $newname
```

XML Updates

Example updates for XML data

(7) *replace* node x with (n_1 n_2 n_3 … n_m)



```
replace x
with (n_1 .. n_m)
```

XML Updates

Example updates for XML data

(7) *replace* node x with (n_1 n_2 n_3 … n_m)

Explicit examples

Replace the publisher of the first book with the publisher of the second book.

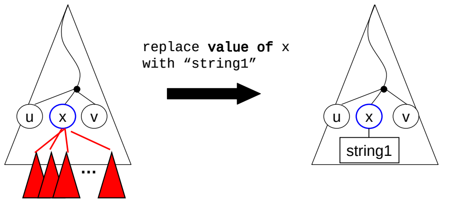
```
do replace  fn:doc("bib.xml")/books/book[1]/publisher

      with  fn:doc("bib.xml")/books/book[2]/publisher
```

XML Updates

Example updates for XML data

Note
The replace-value-of op. preserves node identity!

(8) *replace value of* node x with “some string”



```
replace value of x
with “string1”
```

→ If x is a text-node, then text-content of x becomes “string1”
→ If x is an attribute node, then attribute value becomes “string1”

XML Updates

Example updates for XML data

Note
The replace-value-of op.
preserves node identity!

(8) *replace value of* node x with "some string"

Explicit examples

Increase the price of the first book by ten percent.

```
do replace value of
     fn:doc("bib.xml")/books/book[1]/price
     with fn:doc("bib.xml")/books/book[1]/price * 1.1
```

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XML Updates

Questions

→ What about the different node **types**

Can I insert an attribute node at any position?
Can I replace an attribute node by an element node, or vice versa?
etc

→ Do we really need so many different operations?
Which operation can be **simulated** by other ones?

→ How to *generalize the target*, from a node to an XPath expression?
(bulk updates, using one operation)

Semantical issues: doc changes after first update,
this might affect the subsequent updates! How to deal with this?

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Snapshot Semantics

for $e in //a insert as first <a></a>

Semantics of this
on the document <a></a> ??

```
insert <phone>02 83060405</phone>
as last into //address/name[text()="Jonny Pizzicato"]
for $e in //phone
 rename $e as "telephone"
```

Snapshot Semantics

- ➔ Each update operation is logically applied to a separate snapshot of the original document.
- ➔ Updates are applied independently from each other to the original document. They don't see each others' effects.

- ➔ The order of the update operations is irrelevant.

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Type Issues

do delete TargetExpr ← must eval. to a sequence (n_1…n_m) of nodes. Otherwise: Type Error!

Semantics for all n_i, append `upd:delete(n_i)` to *pending update list*

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Type Issues

do delete TargetExpr ← must eval. to a sequence of nodes. Otherwise: Type Error!

do insert SourceExpr (as (first | last) into) | before | after TargetExpr

evaluates to → Otherwise: Type Error

n_1 n_2 … n_p	u_1 u_2 … u_p
$alist	$clist

→ TargetExpr must evaluate to *single node* (called $target)
→ If before/after then $target must have a parent node ($parent)

as first/last

```
upd:insertAttributes($target,$alist);
upd:insertIntoAsLast($target,$clist)
```

} append to *pending update list*

before/after

```
upd:insertAttributes($parent,$alist)
upd:insertBefore($target,$clist)
```

} append to *pending update list*

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Type Issues

do delete TargetExpr ← must eval. to a sequence of nodes. Otherwise: Type Error!

must eval. to a sequence of attribute nodes followed by non-att nodes

do insert SourceExpr (as (first | last) into) | before | after TargetExpr

do replace TargetExpr with ExprSingle

evaluates to → Otherwise: Type Error

n_1 n_2 … n_p	u_1 u_2 … u_p
$alist	$clist

→ TargetExpr must evaluate to *single node* (called $target)
and must have a parent ($parent)

If $target is element, text, comment, or PI node, then

```
upd:insertAttributes($parent,$alist);
upd:insertBefore($target,$clist)
upd:delete($target)
```

} append to *pending update list*

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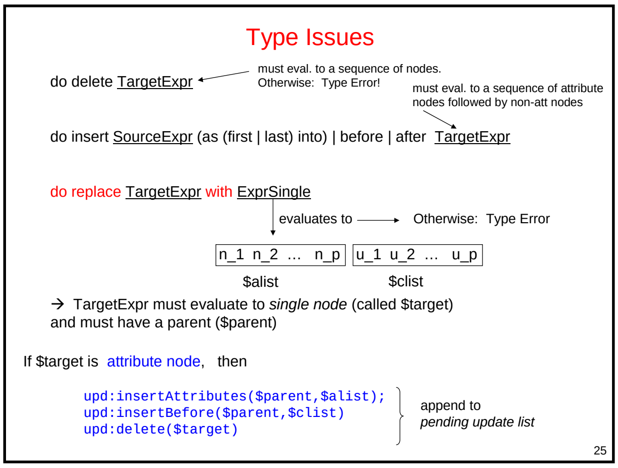

Type Issues

do delete TargetExpr ← must eval. to a sequence of nodes. Otherwise: Type Error!

do insert SourceExpr (as (first | last) into) | before | after TargetExpr ← must eval. to a sequence of attribute nodes followed by non-att nodes

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n_1 n_2 … n_p	u_1 u_2 … u_p
$alist	$clist

→ TargetExpr must evaluate to *single node* (called $target) and must have a parent ($parent)

If $target is attribute node, then

```
upd:insertAttributes($parent,$alist);
upd:insertBefore($parent,$clist)
upd:delete($target)
```

} append to *pending update list*

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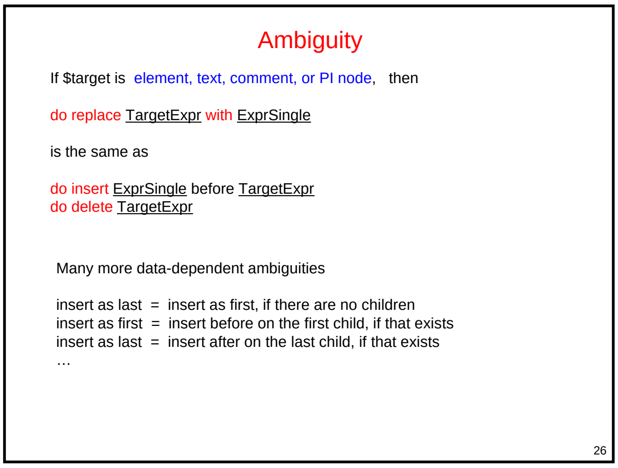

Ambiguity

If $target is element, text, comment, or PI node, then

do replace TargetExpr with ExprSingle

is the same as

do insert ExprSingle before TargetExpr
do delete TargetExpr

Many more data-dependent ambiguities

insert as last = insert as first, if there are no children
insert as first = insert before on the first child, if that exists
insert as last = insert after on the last child, if that exists
…

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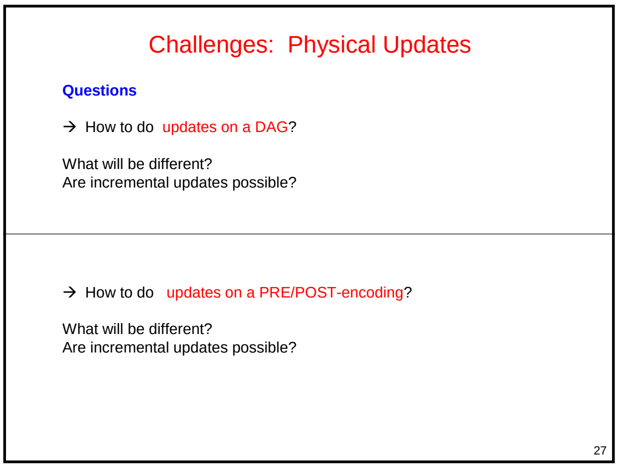

Challenges: Physical Updates

Questions

→ How to do updates on a DAG?

What will be different?
Are incremental updates possible?

→ How to do updates on a PRE/POST-encoding?

What will be different?
Are incremental updates possible?

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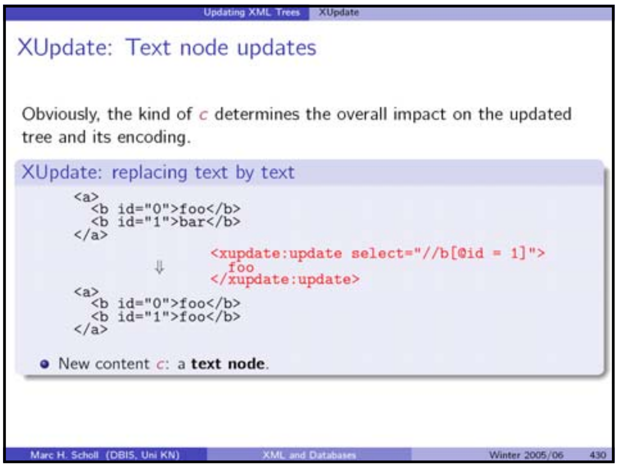

Updating XML Trees | XUpdate

XUpdate: Text node updates

Obviously, the kind of *c* determines the overall impact on the updated tree and its encoding.

XUpdate: replacing text by text

```
<a>
  <b id="0">foo</b>
  <b id="1">bar</b>
</a>
                    <xupdate:update select="//b[@id = 1]">
         ⇓            foo
                    </xupdate:update>
<a>
  <b id="0">foo</b>
  <b id="1">foo</b>
</a>
```

- New content *c*: a **text node**.

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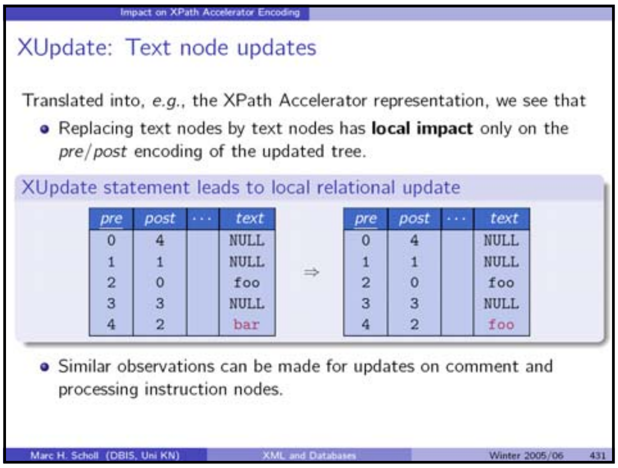

Impact on XPath Accelerator Encoding

XUpdate: Text node updates

Translated into, *e.g.*, the XPath Accelerator representation, we see that

- Replacing text nodes by text nodes has **local impact** only on the *pre*/*post* encoding of the updated tree.

XUpdate statement leads to local relational update

pre	*post*	⋯	*text*
0	4		NULL
1	1		NULL
2	0		foo
3	3		NULL
4	2		bar

⇒

pre	*post*	⋯	*text*
0	4		NULL
1	1		NULL
2	0		foo
3	3		NULL
4	2		foo

- Similar observations can be made for updates on comment and processing instruction nodes.

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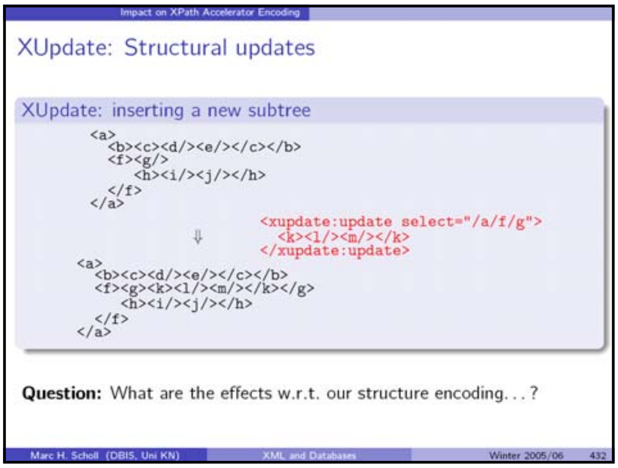

Impact on XPath Accelerator Encoding

XUpdate: Structural updates

XUpdate: inserting a new subtree

```
  <a>
    <b><c><d/><e/></c></b>
    <f><g/>
        <h><i/><j/></h>
    </f>
  </a>
                          <xupdate:update select="/a/f/g">
            ⇓               <k><l/><m/></k>
                          </xupdate:update>
<a>
  <b><c><d/><e/></c></b>
  <f><g><k><l/><m/></k></g>
      <h><i/><j/></h>
  </f>
</a>
```

Question: What are the effects w.r.t. our structure encoding. . . ?

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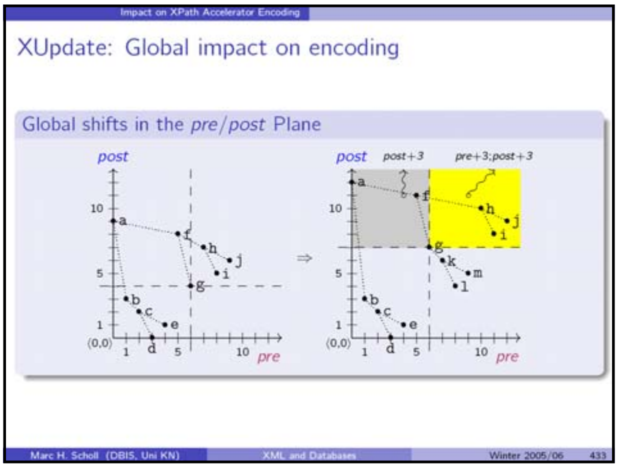
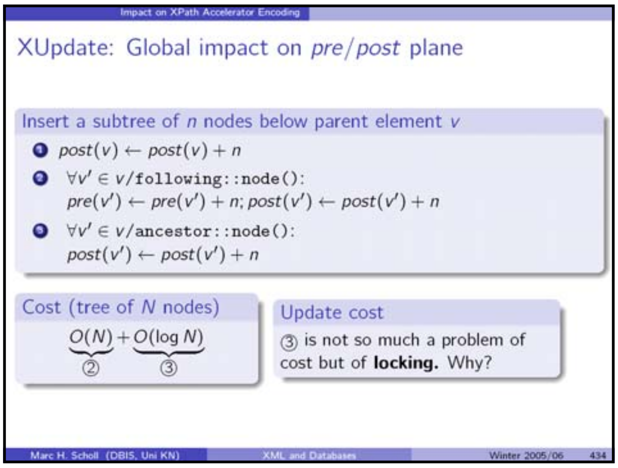


XUpdate: Global impact on encoding

Global shifts in the *pre*/*post* Plane



XUpdate: Global impact on *pre*/*post* plane

Insert a subtree of n nodes below parent element v

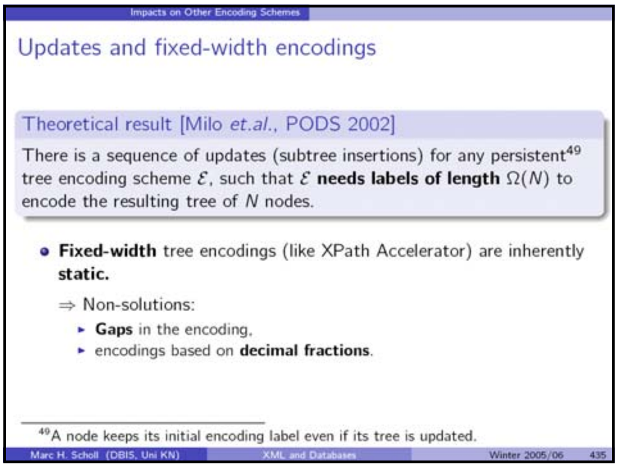
1. $post(v) \leftarrow post(v) + n$
2. $\forall v' \in v/$`following::node()`:
   $pre(v') \leftarrow pre(v') + n$; $post(v') \leftarrow post(v') + n$
3. $\forall v' \in v/$`ancestor::node()`:
   $post(v') \leftarrow post(v') + n$

Cost (tree of N nodes)

$$\underbrace{O(N)}_{②} + \underbrace{O(\log N)}_{③}$$

Update cost

③ is not so much a problem of cost but of **locking.** Why?



Updates and fixed-width encodings

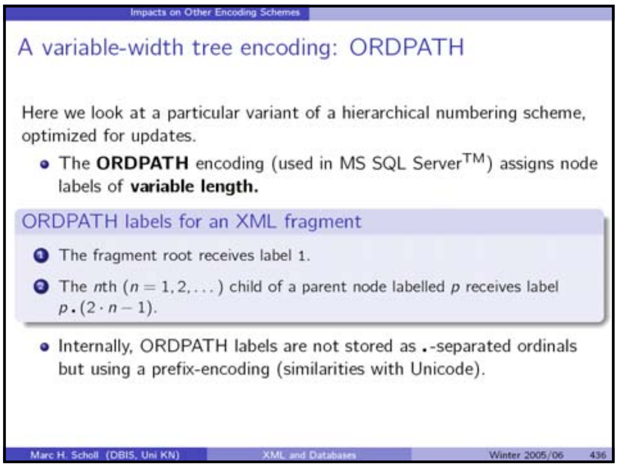
Theoretical result [Milo *et.al.*, PODS 2002]

There is a sequence of updates (subtree insertions) for any persistent[49] tree encoding scheme $\mathcal{E}$, such that $\mathcal{E}$ **needs labels of length** $\Omega(N)$ to encode the resulting tree of N nodes.

- **Fixed-width** tree encodings (like XPath Accelerator) are inherently **static.**

  ⇒ Non-solutions:
  - **Gaps** in the encoding,
  - encodings based on **decimal fractions**.

[49] A node keeps its initial encoding label even if its tree is updated.



A variable-width tree encoding: ORDPATH

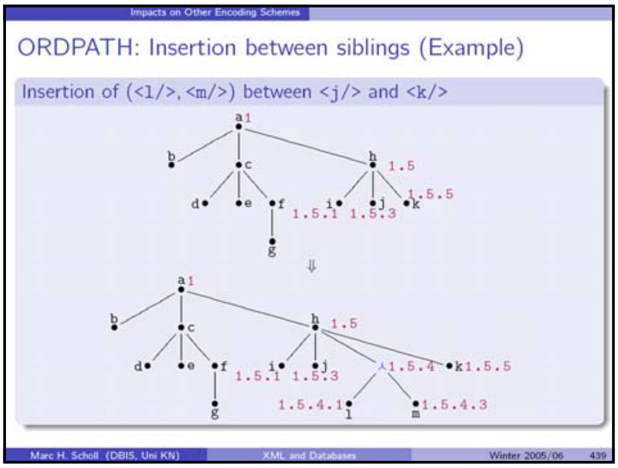
Here we look at a particular variant of a hierarchical numbering scheme, optimized for updates.

- The **ORDPATH** encoding (used in MS SQL Server^{TM}) assigns node labels of **variable length.**

ORDPATH labels for an XML fragment

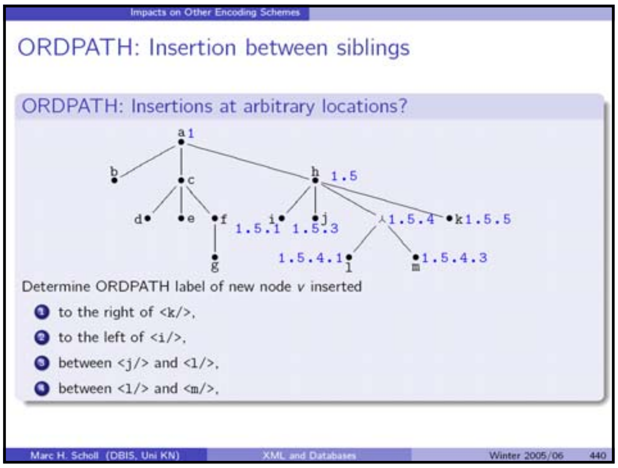
1. The fragment root receives label 1.
2. The nth ($n = 1, 2, \ldots$) child of a parent node labelled p receives label p`.`$(2 \cdot n - 1)$.

- Internally, ORDPATH labels are not stored as `.`-separated ordinals but using a prefix-encoding (similarities with Unicode).



ORDPATH: Insertion between siblings (Example)

Insertion of (`<l/>`, `<m/>`) between `<j/>` and `<k/>`

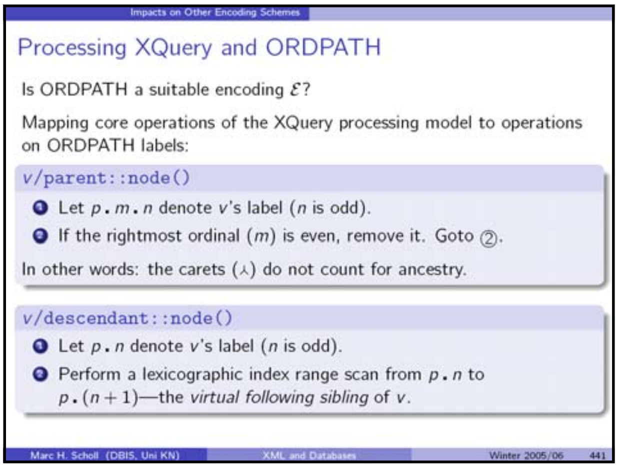


ORDPATH: Insertion between siblings

ORDPATH: Insertions at arbitrary locations?

Determine ORDPATH label of new node v inserted

1. to the right of `<k/>`,
2. to the left of `<i/>`,
3. between `<j/>` and `<l/>`,
4. between `<l/>` and `<m/>`.



Processing XQuery and ORDPATH

Is ORDPATH a suitable encoding $\mathcal{E}$?

Mapping core operations of the XQuery processing model to operations on ORDPATH labels:

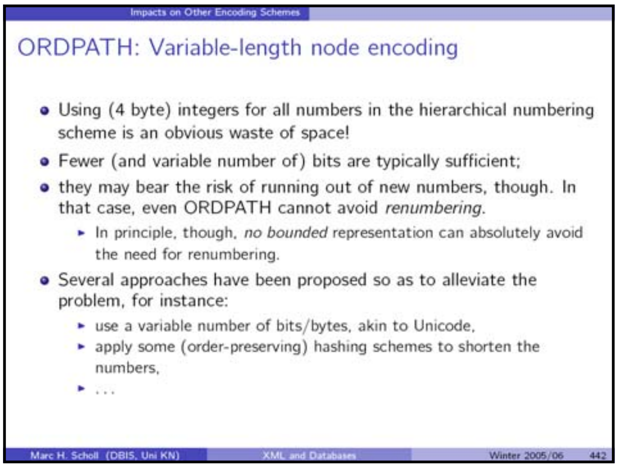
v/parent::node()

1. Let $p.m.n$ denote v's label (n is odd).
2. If the rightmost ordinal (m) is even, remove it. Goto ②.

In other words: the carets ($\curlywedge$) do not count for ancestry.

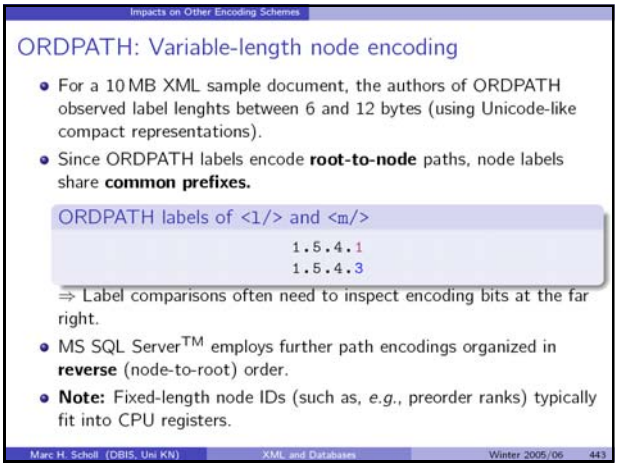
v/descendant::node()

1. Let $p.n$ denote v's label (n is odd).
2. Perform a lexicographic index range scan from $p.n$ to $p.(n+1)$—the *virtual following sibling* of v.



ORDPATH: Variable-length node encoding

- Using (4 byte) integers for all numbers in the hierarchical numbering scheme is an obvious waste of space!
- Fewer (and variable number of) bits are typically sufficient;
- they may bear the risk of running out of new numbers, though. In that case, even ORDPATH cannot avoid *renumbering*.
  - In principle, though, *no bounded* representation can absolutely avoid the need for renumbering.
- Several approaches have been proposed so as to alleviate the problem, for instance:
  - use a variable number of bits/bytes, akin to Unicode,
  - apply some (order-preserving) hashing schemes to shorten the numbers,
  - ...



ORDPATH: Variable-length node encoding

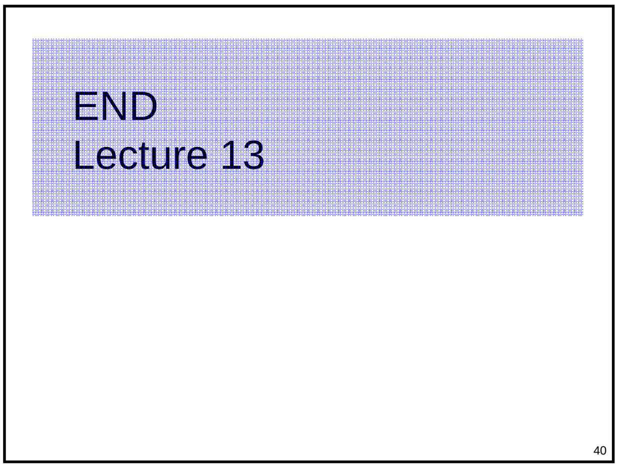
- For a 10 MB XML sample document, the authors of ORDPATH observed label lenghts between 6 and 12 bytes (using Unicode-like compact representations).
- Since ORDPATH labels encode **root-to-node** paths, node labels share **common prefixes.**

ORDPATH labels of <l/> and <m/>

```
1.5.4.1
1.5.4.3
```

⇒ Label comparisons often need to inspect encoding bits at the far right.

- MS SQL Server$^{\text{TM}}$ employs further path encodings organized in **reverse** (node-to-root) order.
- **Note:** Fixed-length node IDs (such as, *e.g.*, preorder ranks) typically fit into CPU registers.



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Lecture 13