XML-Relational Mapping

Introduction to Databases

CompSci 316 Fall 2018

DUKE
COMPUTER SCIENCE

Announcements (Thu., Oct. 25)

- Homework #3 due in 1½ weeks
- Project milestone #2 due in 2 weeks
  - Milestone #1 feedback available through Gradescope

Approaches to XML processing

- Text files/messages
- Specialized XML DBMS
  - Tamino (Software AG), BaseX, eXist, Sedna, …
  - Not as mature as relational DBMS
- Relational (and object-relational) DBMS
  - Middleware and/or extensions
  - IBM DB2's pureXML, PostgreSQL's XML type/functions…

Mapping XML to relational

- Store XML in a column
  - Simple, compact
  - CLOB (Character Large OBject) type + full-text indexing, or better, special XML type + functions
  - Poor integration with relational query processing
  - Updates are expensive
- Alternatives?
  - Schema-oblivious mapping: ← *Focus of this lecture*
    well-formed XML → generic relational schema
    - Node/edge-based mapping for graphs
    - Interval-based mapping for trees
    - Path-based mapping for trees
  - Schema-aware mapping:
    valid XML → special relational schema based on DTD

Node/edge-based: schema

- *Element(eid, tag)*
- *Attribute(eid, attrName, attrValue)* Key:
  - Attribute order does not matter
- *ElementChild(eid, pos, child)* Keys:
  - *pos* specifies the ordering of children
  - *child* references either *Element*(*eid*) or *Text*(*tid*)
- *Text(tid, value)*
  - *tid* cannot be the same as any *eid*

☞Need to "invent" lots of *id*'s

☞Need indexes for efficiency, e.g., *Element*(*tag*), *Text*(*value*)

Node/edge-based: example

```
<bibliography>
  <book ISBN="ISBN-10" price="80.00">
    <title>Foundations of Databases</title>
    <author>Abiteboul</author>
    <author>Hull</author>
    <author>Vianu</author>
    <publisher>Addison Wesley</publisher>
    <year>1995</year>
  </book>…
</bibliography>
```

Attribute

eid	*attrName*	*attrValue*
e1	ISBN	ISBN-10
e1	price	80

Text

tid	*value*
t0	Foundations of Databases
t1	Abiteboul
t2	Hull
t3	Vianu
t4	Addison Wesley
t5	1995

Element

eid	*tag*
e0	bibliography
e1	book
e2	title
e3	author
e4	author
e5	author
e6	publisher
e7	year

ElementChild

eid	*pos*	*child*
e0	1	e1
e1	1	e2
e1	2	e3
e1	3	e4
e1	4	e5
e1	5	e6
e1	6	e7
e2	1	t0
e3	1	t1
e4	1	t2
e5	1	t3
e6	1	t4
e7	1	t5

Node/edge-based: simple paths

- `//title`
  - `SELECT eid FROM Element WHERE tag = 'title';`
- `//section/title`
  - ```
    SELECT e2.eid
    FROM Element e1, ElementChild c, Element e2
    WHERE e1.tag = 'section'
    AND e2.tag = 'title'
    AND e1.eid = c.eid
    AND c.child = e2.eid;
    ```

☞ Path expression becomes joins!

- Number of joins is proportional to the length of the path expression
    ```

Node/edge-based: complex paths

- //bibliography/book[author="Abiteboul"]/@price
  - ```
    SELECT a.attrValue
    FROM Element e1, ElementChild c1,
         Element e2, Attribute a
    WHERE e1.tag = 'bibliography'
    AND e1.eid = c1.eid AND c1.child = e2.eid
    AND e2.tag = 'book'
    AND EXISTS (SELECT * FROM ElementChild c2,
                              Element e3, ElementChild c3, Text t
                WHERE e2.eid = c2.eid AND c2.child = e3.eid
                AND e3.tag = 'author'
                AND e3.eid = c3.eid AND c3.child = t.tid
                AND t.value = 'Abiteboul')
    AND e2.eid = a.eid
    AND a.attrName = 'price';
    ```
    ```

Node/edge-based: descendent-or-self

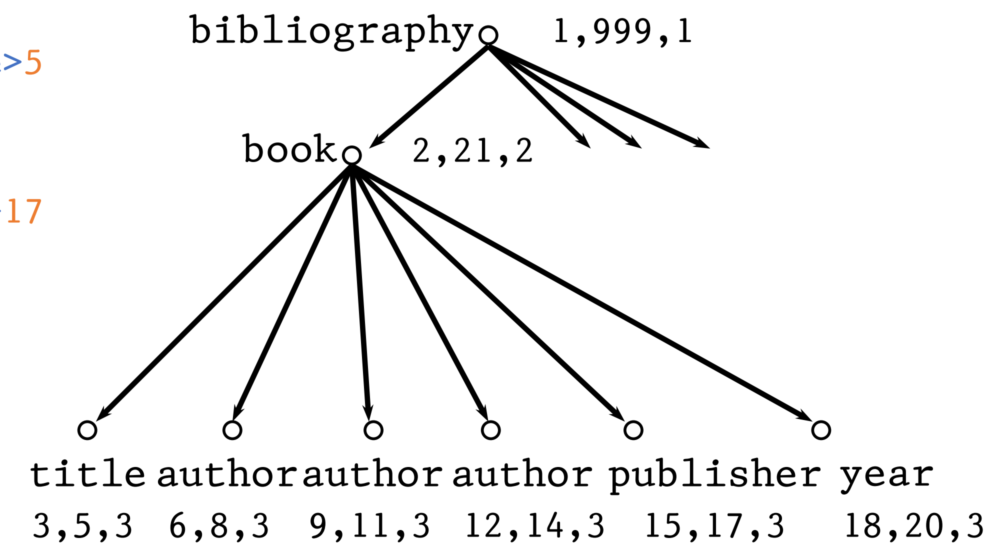
- `//book//title`
  - Requires SQL3 recursion
  -
```
WITH RECURSIVE ReachableFromBook(id) AS
((SELECT eid FROM Element WHERE tag = 'book')
 UNION
 (SELECT c.child
  FROM ReachableFromBook r, ElementChild c
  WHERE r.eid = c.eid))
SELECT eid
FROM Element
WHERE eid IN (SELECT * FROM ReachableFromBook)
AND tag = 'title';
```

Interval-based: schema

- *Element(left, right, level, tag)*
  - *left* is the start position of the element
  - *right* is the end position of the element
  - *level* is the nesting depth of the element (strictly speaking, unnecessary)
  - Key is
- *Text(left, right, level, value)*
  - Key is
- *Attribute(left, attrName, attrValue)*
  - Key is

Interval-based: example

```
1<bibliography>
  2<book ISBN="ISBN-10" price="80.00">
    3<title>4Foundations of Databases</title>5
    6<author>7Abiteboul</author>8
    9<author>10Hull</author>11
   12<author>13Vianu</author>14
   15<publisher>16Addison Wesley</publisher>17
   18<year>191995</year>20
  </book>21…
</bibliography>999
```



☞Where did *ElementChild* go?

- e_1 is the parent of e_2 iff:

  $[e_1.left, e_1.right] \supset [e_2.left, e_2.right]$, and
  $e_1.level = e_2.level - 1$

Interval-based: queries

- `//section/title`
  - ```
    SELECT e2.left
    FROM Element e1, Element e2
    WHERE e1.tag = 'section' AND e2.tag = 'title'
    AND e1.left < e2.left AND e2.right < e1.right
    AND e1.level = e2.level-1;
    ```

  ☞ Path expression becomes "containment" joins!
    - Number of joins is proportional to path expression length
- `//book//title`
  -

  ☞ No recursion!
    ```

Summary so far

Node/edge-based vs. interval-based mapping

- Path expression steps
  - Equality vs. containment join
- Descendent-or-self
  - Recursion required vs. not required

Path-based mapping: approach 1

Label-path encoding: paths as strings of labels

- *Element(pathid, left, right, …), Path(pathid, path)*, …
  - *path* is a string containing the sequence of labels on a path starting from the root
  - Why are *left* and *right* still needed?

Element

pathid	*left*	*right*	…
1	1	999	…
2	2	21	…
3	3	5	…
4	6	8	…
4	9	11	…
4	12	14	…
…	…	…	…

Path

pathid	*path*
1	/bibliography
2	/bibliography/book
3	/bibliography/book/title
4	/bibliography/book/author
…	…

Label-path encoding: queries

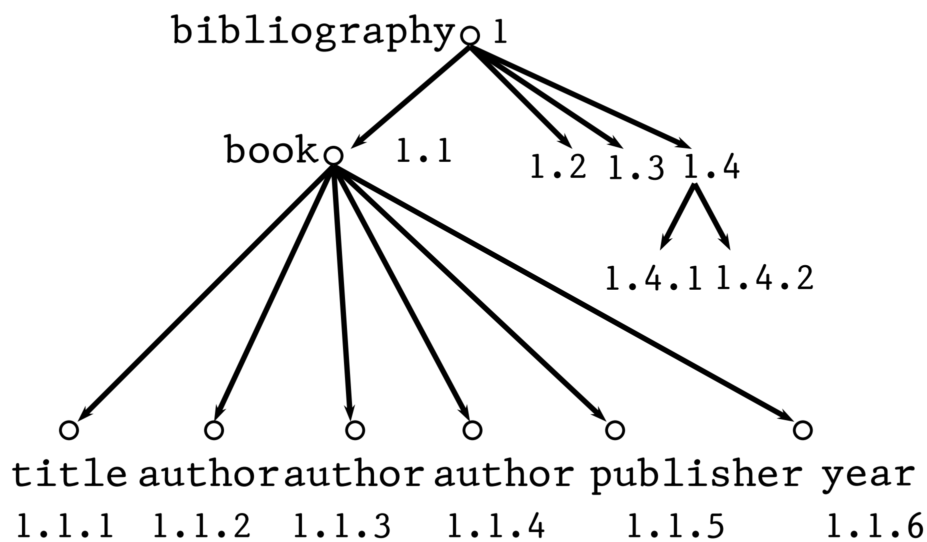
- Simple path expressions with no conditions
  `//book//title`
  - Perform string matching on *Path*
  - Join qualified *pathid*'s with *Element*
- `//book[publisher='Prentice Hall']/title`
  - Evaluate `//book/title`
  - Evaluate `//book/publisher[text()='Prentice Hall']`
  - Must then ensure `title` and `publisher` belong to the same book (how?)

  ☞Path expression with attached conditions needs to be broken down, processed separately, and joined back

Path-based mapping: approach 2

Dewey-order encoding

- Each component of the id represents the order of the child within its parent
  - Unlike label-path, this encoding is "lossless"



Element(<u>dewey_pid</u>, tag)
Text(<u>dewey_pid</u>, value)
Attribute(<u>dewey_pid</u>, <u>attrName</u>, attrValue)

Dewey-order encoding: queries

- Examples:
  `//title`
  `//section/title`
  `//book//title`
  `//book[publisher='Prentice Hall']/title`
  - Works similarly as interval-based mapping
    - Except parent/child and ancestor/descendant relationship are checked by prefix matching
  - Serves a different purpose from label-path encoding
  - Any advantage over interval-based mapping?

Summary

- XML data can be “shredded” into rows in a relational database
- XQueries can be translated into SQL queries
  - Queries can then benefit from smart relational indexing, optimization, and execution
- With schema-oblivious approaches, comprehensive XQuery-SQL translation can be easily automated
  - Different data mapping techniques lead to different styles of queries
- Schema-aware translation is also possible and potentially more efficient, but automation is more complex