XML-Relational Mapping

Introduction to Databases
CompSci 316 Fall 2016
Announcements (Thu., Nov. 3)

• Homework #3 due next Tuesday
• Project milestone #2 due next Thursday
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:** 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

← Focus of this lecture
Node/edge-based: schema

- **Element**(eid, tag)
- **Attribute**(eid, attrName, attrValue)  Key: (eid, attrName)
  - Attribute order does not matter
- **ElementChild**(eid, pos, child)  Keys: (eid, pos), (child)
  - 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

```xml
<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>...
```

### Attribute

<table>
<thead>
<tr>
<th>eid</th>
<th>attrName</th>
<th>attrValue</th>
</tr>
</thead>
<tbody>
<tr>
<td>e1</td>
<td>price</td>
<td>80</td>
</tr>
</tbody>
</table>

### Text

<table>
<thead>
<tr>
<th>tid</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>t0</td>
<td>Foundations of Databases</td>
</tr>
<tr>
<td>t1</td>
<td>Abiteboul</td>
</tr>
<tr>
<td>t2</td>
<td>Hull</td>
</tr>
<tr>
<td>t3</td>
<td>Vianu</td>
</tr>
<tr>
<td>t4</td>
<td>Addison Wesley</td>
</tr>
<tr>
<td>t5</td>
<td>1995</td>
</tr>
</tbody>
</table>

### Element

<table>
<thead>
<tr>
<th>eid</th>
<th>tag</th>
</tr>
</thead>
<tbody>
<tr>
<td>e0</td>
<td>bibliography</td>
</tr>
<tr>
<td>e1</td>
<td>book</td>
</tr>
<tr>
<td>e2</td>
<td>title</td>
</tr>
<tr>
<td>e3</td>
<td>author</td>
</tr>
<tr>
<td>e4</td>
<td>author</td>
</tr>
<tr>
<td>e5</td>
<td>author</td>
</tr>
<tr>
<td>e6</td>
<td>publisher</td>
</tr>
<tr>
<td>e7</td>
<td>year</td>
</tr>
</tbody>
</table>

### Element/Child

<table>
<thead>
<tr>
<th>eid</th>
<th>pos</th>
<th>child</th>
</tr>
</thead>
<tbody>
<tr>
<td>e0</td>
<td>1</td>
<td>e1</td>
</tr>
<tr>
<td>e1</td>
<td>1</td>
<td>e2</td>
</tr>
<tr>
<td>e1</td>
<td>2</td>
<td>e3</td>
</tr>
<tr>
<td>e1</td>
<td>3</td>
<td>e4</td>
</tr>
<tr>
<td>e1</td>
<td>4</td>
<td>e5</td>
</tr>
<tr>
<td>e1</td>
<td>5</td>
<td>e6</td>
</tr>
<tr>
<td>e1</td>
<td>6</td>
<td>e7</td>
</tr>
<tr>
<td>e2</td>
<td>1</td>
<td>t0</td>
</tr>
<tr>
<td>e3</td>
<td>1</td>
<td>t1</td>
</tr>
<tr>
<td>e4</td>
<td>1</td>
<td>t2</td>
</tr>
<tr>
<td>e5</td>
<td>1</td>
<td>t3</td>
</tr>
<tr>
<td>e6</td>
<td>1</td>
<td>t4</td>
</tr>
<tr>
<td>e7</td>
<td>1</td>
<td>t5</td>
</tr>
</tbody>
</table>
Node/edge-based: simple paths

• //title
  • SELECT eid FROM Element WHERE tag = 'title';

• //section/title
  • SELECT e2.eid
    FROM Element el, ElementChild c, Element e2
    WHERE el.tag = 'section'
    AND e2.tag = 'title'
    AND el.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 el, ElementChild cl, Element e2, Attribute a
  WHERE el.tag = 'bibliography'
  AND el.eid = cl.eid AND cl.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 *left*

• **Text**(left, right, level, value)
  • Key is *left*

• **Attribute**(left, attrName, attrValue)
  • Key is (left, attrName)
Interval-based: example

Where did ElementChild go?

• $e_1$ is the parent of $e_2$ iff:

$$[e_1.left, e_1.right] \supset [e_2.left, e_2.right], \text{ and } e_1.level = e_2.level - 1$$
Interval-based: queries

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

  $\therefore$ Path expression becomes “containment” joins!
    • Number of joins is proportional to path expression length

• //book/title
  • SELECT e2.left
    FROM Element el, Element e2
    WHERE el.tag = 'book' AND e2.tag = 'title'
    AND el.left < e2.left AND e2.right < el.right;

  $\therefore$ 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**\(\text{(pathid, left, right, ...)}\), **Path**\(\text{(pathid, path)}\), ...

  - *path* is a string containing the sequence of labels on a path starting from the root
  - Why are *left* and *right* still needed?

<table>
<thead>
<tr>
<th><strong>Element</strong></th>
<th><strong>Path</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>pathid</td>
<td>left</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
</tr>
</tbody>
</table>
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(\texttt{dewey\_pid}, \texttt{tag})
Text(\texttt{dewey\_pid}, \texttt{value})
Attribute(\texttt{dewey\_pid}, \texttt{attrName}, \texttt{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