# XML-Relational Mapping

Introduction to Databases
CompSci 316 Fall 2016

DUKE
COMPUTER SCIENCE

## 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: *← 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>
```

*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 |

*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 |

## 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';
    ```
    ```

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# 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

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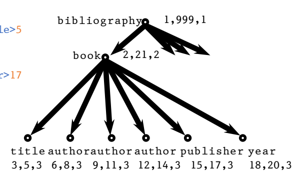
# Interval-based: example

```
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
  $e_1.level = e_2.level - 1$

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# 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`
    ```

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## 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

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## 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 |
| … | … |

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## 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

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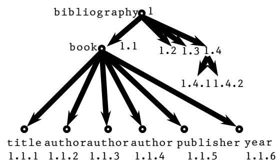
## Path-based mapping: approach 2

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)*

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## 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?

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## 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