XML-Relational Mapping

CPS 116

Introduction to Database Systems

Announcements (November 1)

- Homework #3 due next Tuesday
  - Yi will conduct a help session next Monday
  - Time/location will be announced by this weekend
- Project milestone #2 due in one week

Approaches to XML processing

- Text files (!)
- Specialized XML DBMS
  - Lore (Stanford), Strudel (AT&T), Timber (Michigan), MonetDB/XQuery (CWI, Netherlands), Tamino (Software AG), eXist, Sedna, Apache XIndice, XML:DB API initiative…
  - Still a long way to go
- Object-oriented DBMS
  - ObjectStore, ozone, …
  - Not as mature as relational DBMS
- Relational (and object-relational) DBMS
  - Middleware and/or object-relational extensions

Mapping XML to relational

- Store XML in a CLOB (Character Large OBject) column
  - Simple, compact
  - Full-text indexing can help (often provided by DBMS vendors as object-relational "extensions")
  - 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

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


```
<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

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

ElementChild

cid	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

cid	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: more 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 e2.eid = c3.eid AND c3.child = t.tid
    AND t.value = 'Abiteboul')
    AND e2.eid = a.eid
    AND a.attrName = 'price';

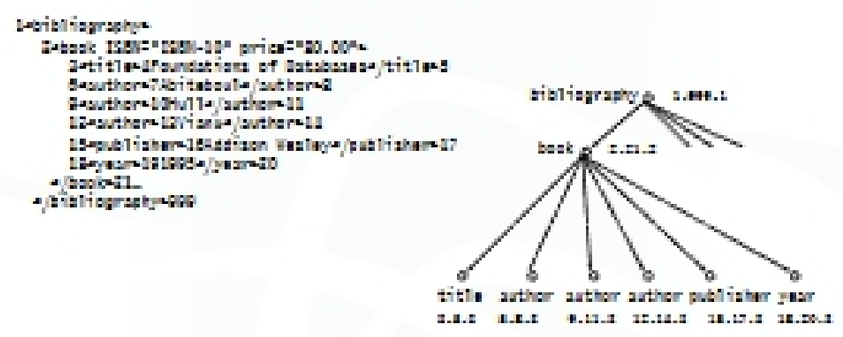
Node/edge-based: descendent-or-self

- //book//title
  - Requires SQL3 recursion
  - WITH ReachableFromBook(id) AS
    ((SELECT eid FROM Element WHERE tag = 'book')
    UNION ALL
    (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*] ⊃ [*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
  - SELECT e2.left
    FROM Element e1, Element e2
    WHERE e1.tag = 'book' AND e2.tag = 'title'
    AND e1.left < e2.left AND e2.right < e1.right;
  - ☛No recursion!

Summary of interval-based mapping

- Path expression steps become containment joins
- No recursion needed for descendent-or-self
- Comprehensive XQuery-SQL translation is possible

A path-based mapping

Label-path encoding

- *Element*(*pathid*, *left*, *right*, …), *Path*(*pathid*, *path*), …
  - *path* is a label path starting from the root
  - Why are *left* and *right* still needed? To preserve structure

Element

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

Path

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

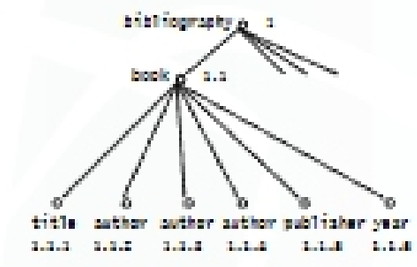
Label-path encoding: queries

- 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']`
  - How to ensure `title` and `publisher` belong to the same book?
  - ☛ Path expression with attached conditions needs to be broken down, processed separately, and joined back

Another path-based mapping

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(*dewey_pid*, *tag*)
Text(*dewey_pid*, *value*)
Attribute(*dewey_pid*, *attrName*, *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?

Schema-aware mapping

- Idea: use DTD to design a better schema
- Basic approach: elements of the same type go into one table
  - Tag name → table name
  - Attributes → columns
    - If one exists, ID attribute → key column; otherwise, need to "invent" a key
    - IDREF attribute → foreign key column
  - Children of the element → foreign key columns
    - Ordering of columns encodes ordering of children

```
<!DOCTYPE bibliography […
  <!ELEMENT book (title, …)>
  <!ATTLIST book ISBN ID #REQUIRED>
  <!ATTLIST book price CDATA #IMPLIED>
  <!ELEMENT title (#PCDATA)>…
]>
```

book(*ISBN*, *price*, *title_id*, …)
title(*id*, *PCDATA_id*)
PCDATA(*id*, *value*)