ECS 165B: Database System Implementation
Lecture 18

UC Davis

May 7, 2010

Some slide content due to Zack Ives

Class Agenda

- Last time:
  - Overview of DavisDB Part 3: System Manager
  - Mid-course evaluation
- Today:
  - Results of mid-course evaluation
  - Querying XML
- Reading:
  - none

Mid-Course Evaluation Results

- First, thanks for your thoughtful and constructive answers!
- Things that seem to be working well:
  - Lectures seem well-received (only one of you dislikes powerpoint?!?)
  - Availability of extra help
  - Most find class relevant and useful
  - High-level ideas seem clear
- Main complaints:
  - Project is way, way, way too time-consuming
  - Not enough guidance on project; how to turn high-level ideas into code
  - My other classes are suffering

What Could Be Done Differently Next Year

- Gentler ramp-up and slower pacing for the project
- More time on preliminary fundamentals
  - General C++ refresher
  - C++ memory management
  - Serialization/deserialization techniques
- Preparatory written assignments before starting the project?
- More cookbook code for early parts of project?
- 5 credits?

What Could be Done Differently this Quarter

- Ease up on the project?
  - No, seriously. EASE UP DUDE. We know where you live.
- Some down time between assignments?
- A little more credit for those of us who worked hard but still came up short?
- Extra credit opportunities?
- Make Quiz #2 worth a little more?

Adjustments for the Rest of the Quarter

- Grading for Part 2 will weight effort (% implementation complete) higher than was done in Part 1
- More time for Part 3
  - **Now due Sunday, 5/16 @11:59pm**
  - Part 4 due date pushed back to Friday, 6/4
- Part 4 will be significantly easier than planned:
  - Bar for full credit will be relatively low
  - More starting code will be provided
  - There will be opportunities for significant extra credit
  - Details TBD
- Remember: the class will be graded on a curve

The Plan for the Rest of the Quarter (2)

Vote: should Quiz #2 be worth more (say, 20% of grade)?

Result of vote: NO

Clarifying Some Misconceptions

- "This course won't be useful because I won't be building a database in industry"

- "I don't anticipate passing this class"

Querying XML

How to Query a Directed Graph? A Tree?

General approach used by many XML, semistructured, and object-oriented query languages:

- Define some sort of a *template* describing traversals from the *root* of the directed graph
- In XML, the basis of this template is called an XPath

On the Aesthetics of XML [Wadler|Buneman]

The Evolution of Language

$2x$ (Descartes)

$\lambda x.\, 2x$ (Church)

```
(LAMBDA (X) (* 2 X))
```
(McCarthy)

XPaths

- In its simplest form, an XPath is like a path in a file system:

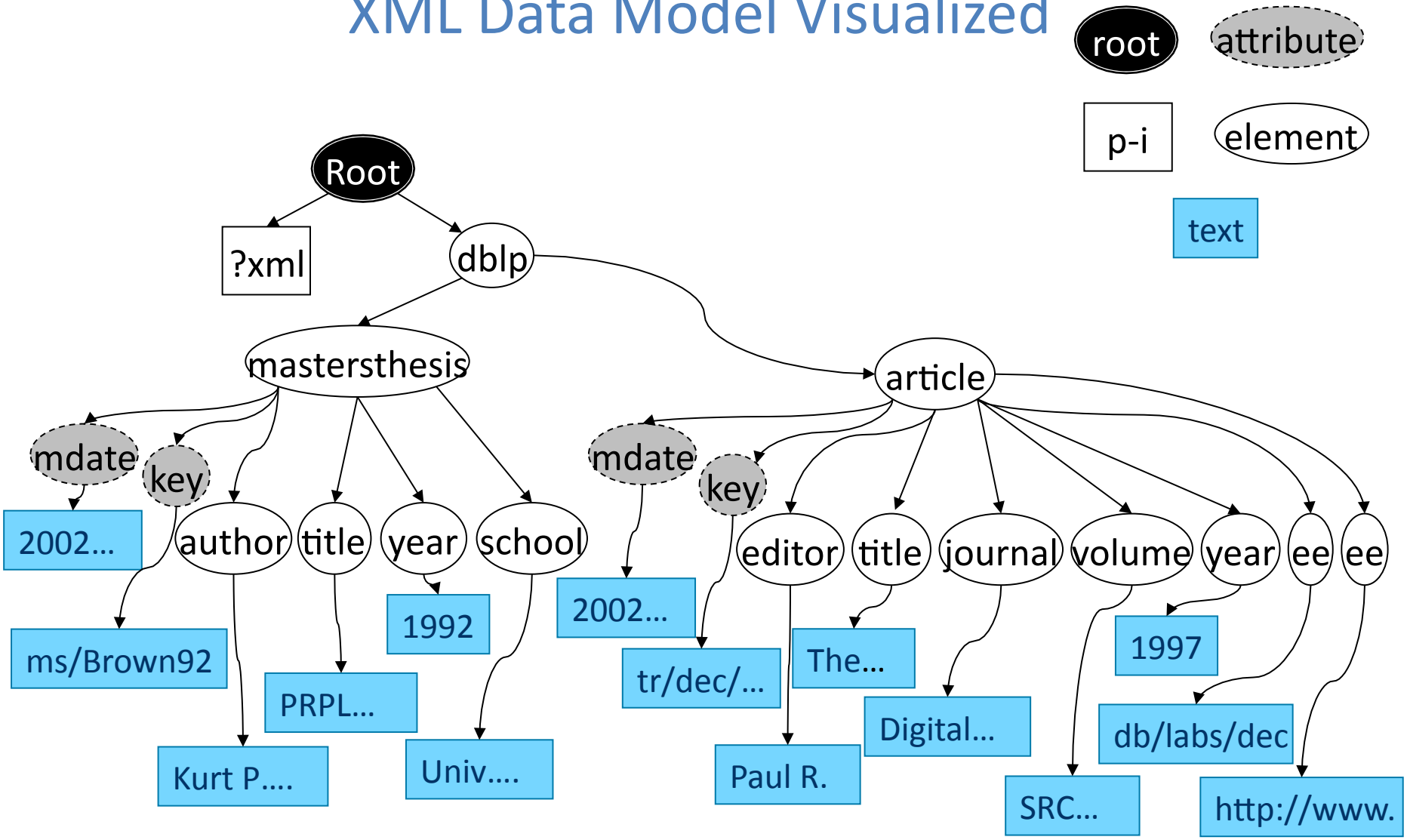
```
/mypath/subpath/*/morepath
```

- The XPath returns a *node set* representing the XML nodes (and their subtrees) at the end of the path
  - XPaths can have *node tests* at the end, returning only particular node types, e.g., `text()`, `processing-instruction()`, `comment()`, `element()`, `attribute()`
  - XPath is fundamentally an *ordered* language: it contains order-based predicates, and it returns nodes in document order

Sample XML

```
<?xml version="1.0" encoding="ISO-8859-1" ?>
<dblp>
  <mastersthesis mdate="2002-01-03" key="ms/Brown92">
    <author>Kurt P. Brown</author>
    <title>PRPL: A Database Workload Specification Language</title>
    <year>1992</year>
    <school>Univ. of Wisconsin-Madison</school>
  </mastersthesis>
  <article mdate="2002-01-03" key="tr/dec/SRC1997-018">
    <editor>Paul R. McJones</editor>
    <title>The 1995 SQL Reunion</title>
    <journal>Digital System Research Center Report</journal>
    <volume>SRC1997-018</volume>
    <year>1997</year>
    <ee>db/labs/dec/SRC1997-018.html</ee>
    <ee>http://www.mcjones.org/System_R/SQL_Reunion_95/</ee>
  </article>
```

XML Data Model Visualized



Some Example XPath Queries

- `/dblp/mastersthesis/title`
- `/dblp/*/editor`
- `//title`
- `//title/text()`

Context Nodes and Relative Paths

XPath has a notion of a *context* node: it's analogous to a current directory

- "`.`" represents this context node
- "`..`" represents the parent node
- We can express relative paths:

  `subpath/sub-subpath/../..`

  gets us back to the context node

➢ By default, the document root is the context node

Predicates – Selection Operations

A *predicate* allows us to filter the node set based on selection-like conditions over sub-XPaths:

```
/dblp/article[title = “Paper1”]
```

which is equivalent to:

```
/dblp/article[./title/text() = “Paper1”]
```

Axes: More Complex Traversals

- Thus far, we've seen XPath exps. that go *down* the tree (or up one step)
- But we might want to go up, left, right, etc.
  - These are expressed with so-called *axes*:

```
self::path-step

child::path-step                    parent::path-step

descendant::path-step               ancestor::path-step

descendant-or-self::path-step       ancestor-or-self::path-step

preceding-sibling::path-step        following-sibling::path-step

preceding::path-step                following::path-step
```

  - The previous XPaths we saw were in "abbreviated form"

Querying Order

- We saw in the previous slide that we could query for preceding or following siblings or nodes
- We can also query a node for its position according to some index:
  - `fn::first()`, `fn::last()` return index of first or last element matching the last step
  - `fn::position()` gives the relative count of the current node
  - e.g.,

```
child::article[fn::position() = fn::last()]
```

Users of XPath

- XML Schema uses simple XPaths in defining keys and uniqueness constraints
- XQuery
- XSLT
- XLink and XPointer, hyperlinks for XML

XQuery

- A strongly-typed, Turing-complete XML manipulation language
  - Attempts to do static typechecking against XML Schema
  - Based on an object model derived from Schema
- Unlike SQL, fully compositional, highly orthogonal:
  - Inputs & outputs collections (sequences or bags) of XML nodes
  - Anywhere a particular type of object may be used, may use the results of a query of the same type
  - Influenced by ideas from functional programming
- Tension: attempts to satisfy the needs of data management *and* document management
  - The database-style core is mostly complete (even has support for NULLs in XML!!)
  - The document keyword querying features are still in the works – shows in the order-preserving default model

XQuery's Basic Form

- Has an analogous form to SQL's `select..from..where..group by..order by` blocks
- Semantics: bind nodes (or node sets) to variables; operate over each legal combination of bindings; produce a set of nodes
- "FLWOR" statement:

  `for` {iterators that bind variables}

  `let` {collections}

  `where` {conditions}

  `order by` {order-conditions}

  `return` {output constructor}

Iteration ("for-loops") in XQuery

A series of (possibly nested) `for` statements binding the results of XPaths to variables

```
for $root in document("http://my.org/my.xml"),
    $sub in $root/rootElement,
    $sub2 in $sub/subElement, …
```

- Essentially, a pattern to be matched, producing a "binding tuple"
- For each binding, evaluate the `where` clause and possibly output results constructed using `return` template
- `document()` or `doc()` function specifies an input file as a URI
  - Old version was "document"; now "doc" but it depends on your XQuery implementation

Two XQuery Examples

```
<root-tag> {
   for $p in document("dblp.xml")/dblp/proceedings,
         $yr in $p/yr
   where $yr = "1999"
   return <proc> {$p} </proc>
} </root-tag>
```

```
for $i in document("dblp.xml")/dblp/inproceedings[
       author/text() = "John Smith"]
   return <smith-paper>
       <title>{ $i/title/text() }</title>
       <key>{ $i/@key }</key>
       { $i/crossref }
    </smith-paper>
```

Nesting in XQuery

- Nesting XML trees is a very common operation
- In XQuery, it's easy – put a subquery in the `return` clause where you want things to repeat!

```
for $u in document("dblp.xml")/universities
where $u/country = "USA"
return <ms-theses-99>
       { $u/title }  {
        for $mt in $u/../mastersthesis
        where $mt/year/text() = "1999" and ____________
        return $mt/title }
      </ms-theses-99>
```

Collections and Aggregation in XQuery

- In XQuery, many operations return collections
  - XPaths, sub-XQueries, functions over these, …
  - The `let` clause assigns the collection to a variable
- Aggregation simply applies a function from collections to values (very elegant compared to SQL!)

```
let $allpapers := document("dblp.xml")/dblp/article in
return <article-authors>
     <count>{
         fn:count(fn:distinct-values($allpapers/authors))
     }</count>{
         for $paper in doc("dblp.xml")/dblp/article
         let $pauth := $paper/author
         return <paper> {$paper/title}
             <count>{
                 fn:count($pauth)
             }</count>
        </paper>
     }
</article-authors>
```

Collections and Aggregation (2)

Unlike in SQL, we can compose aggregations and create new collections from old:

```
<result> {
   let $avgItemsSold := fn:avg(
       for $order in document("my.xml")/orders/order
       let $totalSold = fn:sum($order/item/quantity)
       return $totalSold)
   return $avgItemsSold
} </result>
```

Sorting in XQuery

- SQL allows you to sort query output, with a special `order by` clause
- XQuery borrows this idea
- In XQuery, what we order is the sequence of "result tuples" output by the `return` clause:

```
for $x in document("dblp.xml")/proceedings
order by $x/title/text()
return $x
```

What If Order Doesn't Matter?

- By default:
  - Relations in SQL are unordered
  - Collections in XQuery are ordered
- But, unordered queries are much faster to answer!
- XQuery allows the user to say "don't worry about preserving order here":

```
unordered {
  for $x in (mypath)...
}
```

Removing Duplicates

- In XQuery, duplicate elimination is performed by a function over a collection (returning another collection)
- But since we have nodes with nested structure in XML, can do duplicate removal according to (1) value or (2) node identifier
  - Intuition from C++: (1) "strcmp(s1,s2) == 0" versus (2) "a == b"
  - `fn:distinct-values(collection)`: (1) remove by value
  - `fn:distinct-nodes(collection)`: (2) remove by node identifier

Another Difference wrt SQL: Metadata is Data in XQuery

Can get a node's name by using `node-name()`:

```
for $x in document("dblp.xml")/dblp/*
return node-name($x)
```

Can construct elements and attributes using computed names:

```
for $x in document("dblp.xml")/dblp/*,
 $year in $x/year,
 $title in $x/title/text(),
element node-name($x) {
 attribute {"year-" + $year} { $title }
}
```

XQuery Summary

Very flexible and powerful language for XML

- Clean and orthogonal: can always replace a collection with an expression that creates collections
- DB and document-oriented (we hope)
- The core is relatively clean and easy to understand

Turing Complete – we'll talk more about XQuery functions soon