Querying XML

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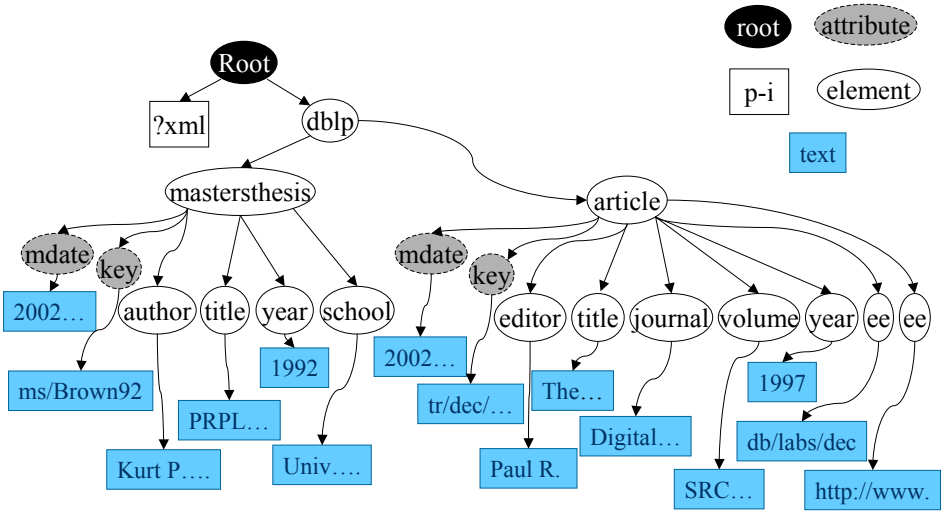
How do you query a directed graph? a tree?

The standard approach used by many XML, semistructured-data, and object 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

XML Data Model Visualized



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>
```

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, which is 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 expressions that go *down* the tree (and 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 0th & last element matching the last step:
  - fn::position() gives the relative count of the current node

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


XPath dereferences

- Recall that ID and IDREF can be used to create a reference between one element and another.
- This can be dereferenced in XPath. For example, to find Joe's wife you would write:

  - /person[@name="Joe"]/@spouse ==> person

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
- Designed mostly by DB and functional language people

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
- The model: 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}
```

"Iterations" in XQuery

A series of (possibly nested) FOR statements assigning the results of XPaths to variables

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

- Something like a template that pattern-matches, produces a "binding tuple"
- For each of these, we evaluate the WHERE and possibly output the RETURN template
- document() or doc() function specifies an input file as a URI

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

Joins in XQuery

Suppose we have a document of addresses, and a document of movies. Who of our contacts was involved in a movie?

```
<XML>
{
for  $p in document("address.xml")//person,
     $m in document("moviedb.xml")//movie[character=$p/name],
return <cine-contact>
                <who>{$p/name/text()}</who>
                <movie>{$m/title/text()}</movie>
                {for $e in $p/email
                  return{<where>{$e/text()}</where>}}
           </cine-contact>
}
<\XML>
```

Nesting in XQuery

Nesting XML trees is perhaps the most common operation

In XQuery, it's easy – put a subquery in the return clause where you want things to repeat!

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


Equality

- Equality
  - node-equal: same node
  - deep-equal: same value

```
let $first:= {<val>1</val>, 2,3}
   $second:={<val>1</val>, 2,3}
return <result>
            Node: {sequence-node-equal($first, $second)}
            Deep: {sequence-deep-equal($first, $second)}
       </result>
```

Result:

```
<result>
   Node: false
   Deep: true
</result>
```

Collections & Aggregation

- In XQuery, many operations return collections
  - XPaths, sub-XQueries, functions over these, …
  - The let clause assigns the results to a variable
- Aggregation simply applies a function over a collection, where the function returns a value

```
let $allpapers := doc("dblp.xml")/dblp/article
return <article-authors>
    <count> {fn:count(fn:distinct-values($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>
```

Sorting in XQuery

- SQL allows you to sort its output, with a special ORDER BY clause (which we haven't discussed)
- XQuery borrows this idea
- In XQuery, what we order is the sequence of "result tuples" output by the return clause:

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

What if order doesn't matter?

- By default:
  - SQL is unordered
  - XQuery is ordered everywhere!
  - But unordered queries are much faster to answer
- XQuery has a way of telling the DBMS to avoid preserving order:
  - for $x in fn:unordered(mypath) …
  - Some of us feel the default is "wrong"…

Distinct-ness

- XQuery has a notion that DISTINCT-ness happens as a function over a collection
  - But since we have nodes, we can do duplicate removal according to value or node
  - Can do fn:distinct-values(collection) to remove duplicate values, or fn:distinct-nodes(collection) to remove duplicate nodes

```
for $years in fn:distinct-
    values(doc("dblp.xml")//year/text()
return $years
```

Querying & Defining Metadata

- Can't do this in SQL..
- Can get a node's name by querying 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: Beyond FLWR

- XQuery has many built-in functions and predicates, such as
  - count(), sum(), min(), max(), position(), first(…), last() which work over sequences
  - index-of() finds the position of a node in a sequence
  - Distinct-values(), distinct-nodes() remove duplicates
  - Set operations: union, intersection
- If-then-else statements and function definition ("define function name (params) returns result") are also included

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

XSL(T): The Bridge Back to HTML

- XSL (XML Stylesheet Language) is actually divided into two parts:
  - XSL:FO: formatting for XML
  - XSLT: a special transformation language
- We'll ignore for now XSL:FO
- XSLT is actually able to convert from XML → HTML, which is how many people do their formatting today
  - Products like Apache Cocoon generally translate XML → HTML on the server side

A Different Style of Language

- XSLT is based on a series of *templates* that match different parts of an XML document
  - There's a policy for what rule or template is applied if more than one matches (it's not what you'd think!)
  - XSLT templates can invoke other templates
  - XSLT templates can be nonterminating (beware!)
- XSLT templates are based on XPath "match"es, and we can also apply other templates (potentially to "select"ed XPaths)
  - Within each template, we describe what should be output

An XSLT Stylesheet

```
<xsl:stylesheet version="1.1">
  <xsl:template match="/dblp">
    <html><head>This is DBLP</head>
    <body>
      <xsl:apply-templates />
    </body>
    </html>
  </xsl:template>
  <xsl:template match="inproceedings">
     <h2><xsl:apply-templates select="title" /></h2>
    <p><xsl:apply-templates select="author"/></p>
  <.xsl:template>
  ...
</xsl:stylesheet>
```

What XSLT Can and Can't Do

- XSLT is great at converting XML to other formats
  - XML → diagrams in SVG; HTML; LaTeX
  - …
- XSLT doesn't do joins (well), it only works on one XML file at a time, and it's limited in certain respects
  - It's not a query language
  - … But it's a very good formatting language
- Most web browsers (post Netscape 4.7x) support XSLT and XSL formatting objects
- But most real implementations use XSLT with something like Apache Cocoon

Wrapping Up

We've seen three XML manipulation formalisms:

- XPath: the basic language for "projecting and selecting" (evaluating path expressions and predicates) over XML
- XQuery: a statically typed, Turing-complete XML processing language
- XSLT: a template-based language for transforming XML documents

- Each is extremely useful for certain applications!