XPath & XQuery

CPS 196.3

Introduction to Database Systems

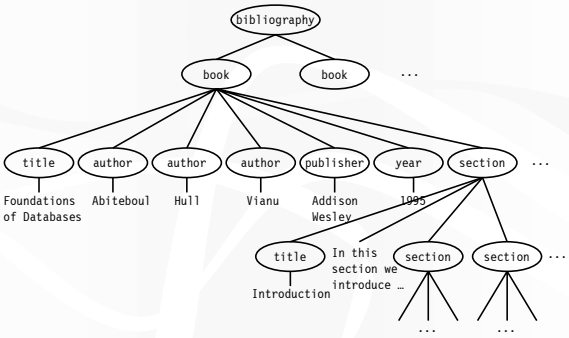
Query languages for XML

- XPath
  - Path expressions with conditions
  - ☞Building block of other standards (XQuery, XSLT, XLink, XPointer, etc.)
- XQuery
  - XPath + full-fledged SQL-like query language
- XSLT
  - XPath + transformation templates

Example DTD and XML

```
<?xml version="1.0">
<!DOCTYPE bibliography [
  <!ELEMENT bibliography (book+)>
  <!ELEMENT book (title, author*, publisher?, year?, section*)>
  <!ATTLIST book ISBN CDATA #REQUIRED>
  <!ATTLIST book price CDATA #IMPLIED>
  <!ELEMENT title (#PCDATA)>
  <!ELEMENT author (#PCDATA)>
  <!ELEMENT publisher (#PCDATA)>
  <!ELEMENT year (#PCDATA)>
  <!ELEMENT section (title, (#PCDATA)?, section*)>
]>
<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>
    <section>…</section>…
  </book>
  …
</bibliography>
```

A tree representation



XPath

- XPath specifies path expression that match XML data by navigating down (and occasionally up and across) the tree
- Example
  - Query: `/bibliography/book/author`
    - Like a UNIX directory
  - Result: all author elements reachable from root via the path `/bibliography/book/author`

Basic XPath constructs

/ separator between steps in a path

name matches any child element with this tag name

* matches any child element

@*name* matches the attribute with this name

@* matches any attribute

// matches any descendent element (including the current element itself)

. matches the current element

.. matches the parent element

Simple XPath examples

- All book titles
  `/bibliography/book/title`
- All book ISBN numbers

- All title elements, anywhere in the document
  `//title`
- All section titles, anywhere in the document

- Authors of bibliographical entries (suppose there are articles, reports, etc. in addition to books)
  `/bibliography/*/author`

Predicates in path expressions

[*condition*] matches the current element if *condition* evaluates to true on the current element

- Books with price lower than $50
  `/bibliography/book[@price<50]`
  - XPath will automatically convert the price string to a numeric value for comparison
- Books with author "Abiteboul"

- Books with a publisher child element
  `/bibliography/book[publisher]`
- Prices of books authored by "Abiteboul"

More complex predicates

Predicates can have `and`'s and `or`'s

- Books with price between $40 and $50
  `/bibliography/book[40<=@price and @price<=50]`
- Books authored by "Abiteboul" or those with price lower than $50

Predicates involving node-sets

`/bibliography/book[author='Abiteboul']`

- There may be multiple authors, so `author` in general returns a node-set (in XPath terminology)
- The predicate evaluates to true as long as it evaluates true for at least one node in the node-set, i.e., at least one author is "Abiteboul"
- Tricky query
  `/bibliography/book[author='Abiteboul' and author!='Abiteboul']`
  - Will it return any books?

XPath operators and functions

Frequently used in conditions:

x `+` y, x `-` y, x `*` y, x `div` y, x `mod` y

`contains(`x`,` y`)` true if string x contains string y

`count(`*node-set*`)` counts the number nodes in *node-set*

`position()` returns the position of the current node in the currently selected node-set

`last()` returns the size of the currently selected node-set

`name()` returns the tag name of the current element

More XPath examples

- All elements whose tag names contain "section" (e.g., "subsection")
  `//*[contains(name(), 'section')]`
- Title of the first section in each book
  `/bibliography/book/section[position()=1]/title`
  - A shorthand: `/bibliography/book/section[1]/title`
- Title of the last section in each book
  `/bibliography/book/section[position()=last()]/title`
- Books with fewer than 10 sections
  `/bibliography/book[count(section)<10]`
- All elements whose parent's tag name is not "book"

De-referencing IDREF's

`id(`*identifier*`)` returns the element with the unique *identifier*

- Suppose that books can make references to other books

```
<section><title>Introduction</title>
  XML is a hot topic these days; see <bookref
ISBN="ISBN-10"/> for more details…
</section>
```

- Find all references to books written by "Abiteboul" in the book with "ISBN-10"

```
/bibliography/book[@ISBN='ISBN-10']
  //bookref[id(@ISBN)/author='Abiteboul']
```


General XPath location steps

- Technically, each XPath query consists of a series of location steps separated by `/`
- Each location step consists of
  - An axis: one of `self`, `attribute`, `parent`, `child`, `ancestor`, `ancestor-or-self`, `descendent`, `descendent-or-self`, `following`, `following-sibling`, `preceding`, `preceding-sibling`, and `namespace`
  - A node test: either a name test (e.g., `book`, `section`, `*`) or a type test (e.g., `text()`, `node()`, `comment()`), separated from the axis by `::`
  - Zero of more predicates (or conditions) enclosed in square brackets

Example of verbose syntax

Verbose (axis, node test, predicate):

```
/child::bibliography
  /child::book[attribute::ISBN='ISBN-10']
  /descendent-or-self::node()
  /child::title
```

Abbreviated:

```
/bibliography/book[@ISBN='ISBN-10']//title
```

- `child` is the default axis
- `//` stands for `/descendent-or-self::node()/`

XQuery

- XPath + full-fledged SQL-like query language
- XQuery expressions can be
  - XPath expressions
  - FLWR (❀) expressions
  - Quantified expressions
  - Aggregation, sorting, and more…

A simple XQuery based on XPath

Find all books with price lower than $50

```
<result>
{
   document("bib.xml")/bibliography/book[@price<50]
}
</result>
```

- Things outside {}'s are copied to output verbatim
- Things inside {}'s are evaluated and replaced by the results
  - `document("bib.xml")` specifies the document to query
  - The XPath expression returns a set of book elements
  - These elements (including all their descendents) are copied to output

FLWR expressions

- Retrieve the titles of books written by "Abiteboul" published before 2000, together with their publisher

```
<result>{
  for $b in document("bib.xml")/bibliography/book
  let $p := $b/publisher
  where $b/year < 2000
  return
    <book>
      { $b/title }
      { $p }
    </book>
}</result>
```

- `for`: loop
  - `$b` ranges over the result node-set, getting one node at a time
- `let`: assignment
  - `$p` gets the entire result of `$b/publisher` (possibly many nodes)
- `where`: filter condition
- `return`: result structuring
  - Invoked in the "innermost loop," i.e., once for each successful binding of all query variables

An equivalent formulation

- Retrieve the titles of books written by "Abiteboul" published before 2000, together with their publisher

```
<result>{
  for $b in document("bib.xml")/bibliography/book[year<2000]
  return
    <book>
      { $b/title }
      { $b/publisher }
    </book>
}</result>
```


Yet another formulation

- Retrieve the titles of books written by "Abiteboul" published before 2000, together with their publisher

```
<result>{
  for $b in document("bib.xml")/bibliography/book,
      $p in $b/publisher
  where $b/year < 2000
  return
    <book>
      { $b/title }
      { $p }
    </book>
}</result>
```

- Is this query equivalent to the previous two?

Existentially quantified expressions

`(some $`*var* `in` *node-set* `satisfies` *condition*`)`

- Can be used in `where` as a condition

- Find titles of books in which XML is mentioned in some section

```
<result>{
  for $b in document("bib.xml")//book
  where (some $section in $b//section satisfies
         contains($section, "XML"))
  return {$b/title}
}</result>
```

Universally quantified expressions

`(every $`*var*` in `*node-set*` satisfies `*condition*`)`

- Can be used in `where` as a condition

❖ Find titles of books in which XML is mentioned in every section

```
<result>{
  for $b in document("bib.xml")//book
  where (every $section in $b//section satisfies
         contains($section, "XML"))
  return {$b/title}
}</result>
```


Aggregation

❖ List each publisher and the average prices of all its books

```
<result>{
  for $pub in distinct-values(document("bib.xml")//publisher)
  let $price :=
avg(document("bib.xml")/book[publisher=$pub]/@price)
  return
    <publisherpricing>
      {$pub}
      <avgprice>{$price}</avgprice>
    </publisherpricing>
}</result>
```

- `distinct-values(`*node-set*`)` removes duplicates
  - Two elements are considered duplicates if their names, attributes, and "normalized contents" are equal (still under active discussion)
- `avg(`*node-set*`)` computes the average of *node-set* (assuming each node in *node-set* can be converted to a numeric value

Ordering and sorting

❖ An XPath expression always returns a node-set in document order

❖ `for` loop will respect the ordering of nodes in a node-set

❖ Use `sort by (`*sort-by-expression-list*`)` to output results in a user-specified order

❖ List all books with price higher than $100, in order by first author; for books with the same first author, order by title

```
<result>{
  document("bib.xml")//book[@price>100]
  sort by (author[1], title)
}</result>
```

A tricky sorting example

- List titles of all books, sorted by their prices

```
<result>{
  (document("bib.xml")//book sort by (@price))/title
}</result>
```

  - What is wrong?
  - Correct versions

Summary

- Many, many more features not covered in class
- XPath is fairly mature and stable
  - Already a W3C recommendation
  - Implemented in many systems
  - Used in many other standards
- XQuery is still evolving
  - Still a W3C working draft
  - Some vendors are coming out with implementations
  - To become the SQL for XML?
  - Wait… Where did the join go?