XML Technologies and Applications

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V (c). XML Querying: XQuery

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Outline

- Introduction
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- XML Structural Constraint Specification
  - Document Type Definitions (DTDs)
  - XML Schema
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  - Simple API for XML (SAX)
  - Document Object Model (DOM)
- XML Querying and Transformation
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XQuery – XML Query Language

- Integrates XPath with earlier proposed query languages: XQL, XML-QL
- SQL-style, not functional-style
- Much easier to use as a query language than XSLT
- Can do pretty much the same things as XSLT and more, but typically easier
- 2004: XQuery 1.0

transcript.xml

```
<Transcripts>

  <Transcript>
    <Student StudId="111111111" Name="John Doe"/>
    <CrsTaken CrsCode="CS308" Semester="F1997" Grade="B"/>
    <CrsTaken CrsCode="MAT123" Semester="F1997" Grade="B"/>
    <CrsTaken CrsCode="EE101" Semester="F1997" Grade="A"/>
    <CrsTaken CrsCode="CS305" Semester="F1995" Grade="A"/>
  </Transcript>

  <Transcript>
    <Student StudId="987654321" Name="Bart Simpson" />
    <CrsTaken CrsCode="CS305" Semester="F1995" Grade="C"/>
    <CrsTaken CrsCode="CS308" Semester="F1994" Grade="B"/>
  </Transcript>

  … … cont'd  … …
```

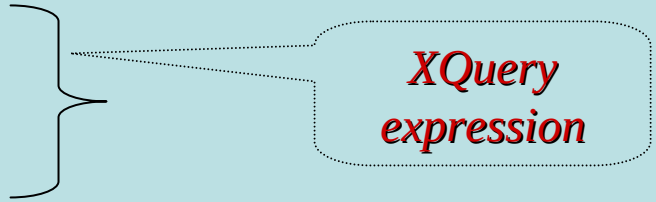
transcript.xml (cont'd)

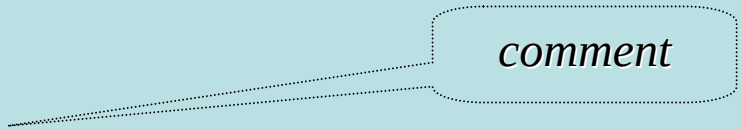
```
  <Transcript>
    <Student StudId="123454321"  Name="Joe Blow" />
     <CrsTaken CrsCode="CS315" Semester="S1997" Grade="A" />
    <CrsTaken CrsCode="CS305" Semester="S1996" Grade="A" />
    <CrsTaken CrsCode="MAT123" Semester="S1996" Grade="C" />
  </Transcript>

  <Transcript>
    <Student StudId="023456789"  Name="Homer Simpson" />
    <CrsTaken CrsCode="EE101" Semester="F1995" Grade="B" />
    <CrsTaken CrsCode="CS305" Semester="S1996" Grade="A" />
  </Transcript>

</Transcripts>
```

XQuery Basics

- General structure (FLWR expressions):

```
FOR variable declarations
LET  variable := expression,
     variable := expression, ...
WHERE    condition
RETURN   document
```





- Example:

```
(:  students who took  MAT123  :)
 FOR  $t  IN  doc("http://xyz.edu/transcript.xml")//Transcript
 WHERE    $t/CrsTaken/@CrsCode = "MAT123"
 RETURN  $t/Student
```

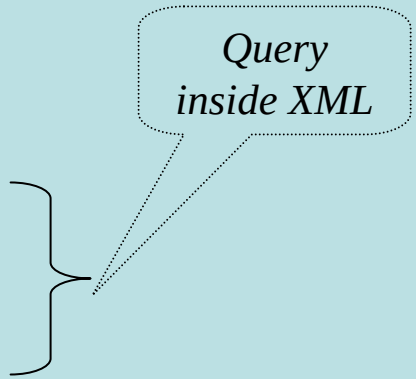
- Result:

```
<Student  StudId="111111111"  Name="John Doe" />
<Student  StudId="123454321"  Name="Joe Blow" />
```

XQuery Basics (cont'd)

- Previous query doesn't produce a well-formed XML document; the following does:

```
<StudentList>
{
      FOR  $t IN  doc("transcript.xml")//Transcript
      WHERE  $t/CrsTaken/@CrsCode = "MAT123"
      RETURN  $t/Student
 }
 </StudentList>
```



- FOR binds $t to Transcript elements one by one, filters using WHERE, then places Student-children as *e*-children of StudentList using RETURN

FOR vs LET

```
FOR $x IN doc("transcript.xml")
RETURN <result> { $x } </result>
```

For: iteration

Returns:

```
<result> <transcript>...</transcript></result>
<result> <transcript>...</transcript></result>
<result> <transcript>...</transcript></result> ...
```

```
LET $x := doc("transcript.xml")
RETURN <result> { $x } </result>
```

Let: set value is assigned to variable.

Returns:

```
<result>
  <transcript>...</transcript>
  <transcript>...</transcript>
  <transcript>...</transcript>
   ...
</result>
```

Document Restructuring with XQuery

Reconstruct lists of students taking each class using the Transcript records:

```
FOR $c IN distinct values(doc("transcript.xml")//CrsTaken)
RETURN
 <ClassRoster CrsCode={$c/@CrsCode} Semester={$c/@Semester}>
    {
     FOR $t IN doc("transcript.xml")//Transcript
     WHERE $t/CrsTaken/[@CrsCode = $c/@CrsCode  and
                        @Semester = $c/@Semester]
     RETURN $t/Student
     ORDER BY $t/Student/@StudId
    }
 </ClassRoster>
 ORDER BY  $c/@CrsCode
```

Query inside RETURN – similar to query inside SELECT in OQL

Document Restructuring (cont'd)

- Output elements have the form:

```
<ClassRoster CrsCode="CS305" Semester="F1995">
  <Student StudId="111111111" Name="John Doe"/>
  <Student StudId="987654321" Name="Bart Simpson"/>
</ClassRoster>
```

- *Problem*: the above element will be output *twice* – for each of the following two bindings of $c:

Bart Simpson's

```
<CrsTaken CrsCode="CS305" Semester="F1995" Grade="C"/>
<CrsTaken CrsCode="CS305" Semester="F1995" Grade="A"/>
```

John Doe's

Note: grades are different – distinct-values( ) won't eliminate transcript records that refer to same class!

Document Restructuring (cont'd)

- *Solution*: instead of

FOR $c IN distinct-values(doc("transcript.xml")//CrsTaken)

use

FOR $c IN doc("classes.xml")//Class

where classes.xml lists course offerings (course code/semester) *explicitly* (no need to extract them from transcript records) – shown on next slide

Then $c is bound to each class exactly once, so each class roster will be output exactly once

http://xyz.edu/classes.xml

```
<Classes>
   <Class  CrsCode="CS308"  Semester="F1997" >
     <CrsName>SE</CrsName> <Instructor>Adrian Jones</Instructor>
   </Class>
   <Class  CrsCode="EE101"  Semester="F1995" >
     <CrsName>Circuits</CrsName> <Instructor>David Jones</Instructor>
   </Class>
     <Class  CrsCode="CS305"  Semester="F1995" >
   <CrsName>Databases</CrsName> <Instructor>Mary Doe</Instructor>
   </Class>
     <Class  CrsCode="CS315"  Semester="S1997" >
   <CrsName>TP</CrsName> <Instructor>John Smyth</Instructor>
     </Class>
   <Class  CrsCode="MAR123"  Semester="F1997" >
     <CrsName>Algebra</CrsName> <Instructor>Ann White</Instructor>
   </Class>
</Classes>
```

Document Restructuring (cont'd)

- *More problems*: the above query will list classes with no students. Reformulation that avoids this:

Test that classes aren't empty

```
FOR  $c  IN doc("classes.xml")//Class
WHERE
  doc("transcripts.xml")//CrsTaken[@CrsCode = $c/@CrsCode
                                   and @Semester = $c/@Semester]
RETURN
<ClassRoster CrsCode={$c/@CrsCode} Semester={$c/@Semester}>
  {
    FOR  $t  IN  doc("transcript.xml")//Transcript
    WHERE $t/CrsTaken[@CrsCode = $c/@CrsCode  and
                      @Semester = $c/@Semester]
    RETURN $t/Student
    ORDER BY $t/Student/@StudId
  }
</ClassRoster>
ORDER BY  $c/@CrsCode
```

XQuery Semantics

- So far the discussion was informal
- XQuery *semantics* defines what the expected result of a query is
- Defined analogously to the semantics of SQL

XQuery Semantics (cont'd)

- *Step 1*: Produce a list of bindings for variables
  - The FOR clause binds each variable to a *list* of nodes specified by an XQuery expression.

    The expression can be:
    - An XPath expression
    - An XQuery query
    - A function that returns a list of nodes
  - End result of a FOR clause:
    - Ordered list of tuples of document nodes
    - Each tuple is a binding for the variables in the FOR clause

XQuery Semantics (cont'd)

Example (bindings):

- Let FOR declare $A and $B
- Bind $A to document nodes {v,w}; $B to {x,y,z}
- Then FOR clause produces the following list of bindings for $A and $B:
  - $A/v, $B/x
  - $A/v, $B/y
  - $A/v, $B/z
  - $A/w, $B/x
  - $A/w, $B/y
  - $A/w, $B/z

XQuery Semantics (cont'd)

- *Step 2*: filter the bindings via the WHERE clause
  - Use each tuple binding to substitute its components for variables; retain those bindings that make WHERE true
  - Example: WHERE $A/CrsTaken/@CrsCode = $B/Class/@CrsCode
    - Binding: $A/w, where w = <CrsTaken CrsCode="CS308" .../>
      $B/x, where x = <Class CrsCode="CS308" ... />
    - Then w/CrsTaken/@CrsCode = x/Class/@CrsCode, so the WHERE condition is satisfied & binding retained

XQuery Semantics (cont'd)

- *Step 3*: Construct result
  - For each retained tuple of bindings, instantiate the RETURN clause
  - This creates a fragment of the output document
  - Do this for each retained tuple of bindings in sequence

Grouping and Aggregation

- Does not use separate grouping operator
  - OQL does not need one either (XML data model is object-oriented and hence similarities with OQL)
  - Subqueries inside the RETURN clause obviate this need (like subqueries inside SELECT did so in OQL)
- Uses built-in aggregate functions count, avg, sum, etc. (some borrowed from XPath)

Aggregation Example

- Produce a list of students along with the number of courses each student took:

```
FOR  $t  IN  fn:doc("transcripts.xml")//Transcript,
     $s  IN  $t/Student
LET   $c :=  $t/CrsTaken
RETURN
  <StudentSummary
     StudId = {$s/@StudId}
     Name = {$s/@Name}
     TotalCourses = {fn:count(fn:distinct-values($c))} />
ORDER BY  StudentSummary/@TotalCourses
```

- The *grouping effect* is achieved because $c is bound to a *new* set of nodes for *each* binding of $t

Quantification in XQuery

- XQuery supports explicit quantification:
  - SOME (∃) and EVERY (∀)

- *Example*: Find students who have taken MAT123.

```
FOR $t IN fn:doc("transcript.xml")//Transcript
WHERE SOME $ct IN $t/CrsTaken
        SATISFIES $ct/@CrsCode = "MAT123"
RETURN $t/Student
```

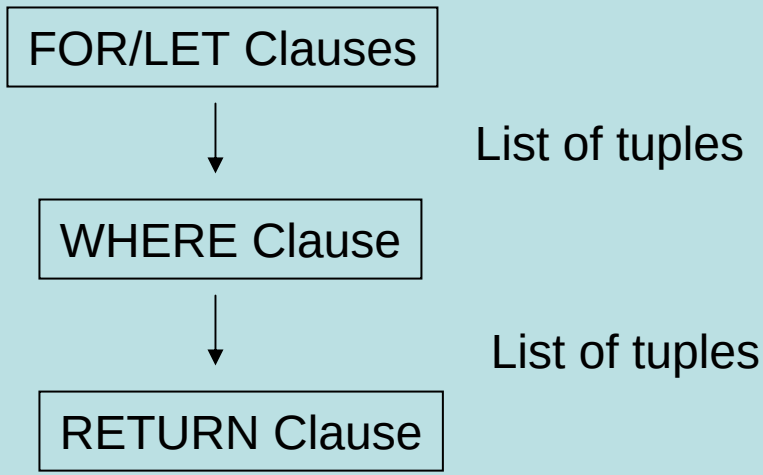
Quantification (cont'd)

- Retrieve all classes (from classes.xml) where each student took the class.

```
FOR  $c  IN  fn:doc(classes.xml)//Class
LET  $g := {
  (:  Transcript records that correspond to class $c  :)
  FOR  $t  IN  fn:doc("transcript.xml")//Transcript
  WHERE  $t/CrsTaken/@Semester = $c/@Semester AND
         $t/CrsTaken/@CrsCode = $c/@CrsCode
  RETURN  $t
}
$h := { FOR $s in fn:doc("transcript.xml")//Transcript
        RETURN $s } (: all transcript records :)
WHERE  EVERY  $tr  IN  $h  SATISFIES
       $tr IN $g
RETURN  $c  ORDER BY $c/@CrsCode
```

XQuery: Summary

FOR-LET-WHERE-RETURN = FLWR



Instance of Xquery data model