CMSC 724: XML

Amol Deshpande

University of Maryland, College Park

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XML

- eXtensible Markup Language
  - Came out of document community
  - Simplified subset of: Standard Generalized Markup Language (SGML)
- De facto data exchange format
  - Self-describing (although beware of Semantic Heterogeniety)
  - Text (passes through firewalls, compresses well)

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- De facto data exchange format
  - Self-describing (although beware of Semantic Heterogeniety)
  - Text (passes through firewalls, compresses well)
- NOTE:
  - Somewhat older paper
    - Different languages popular today
    - XPath, XQuery etc..
- Much work since then on this topic
- Also: JSON appears to be overtaking XML

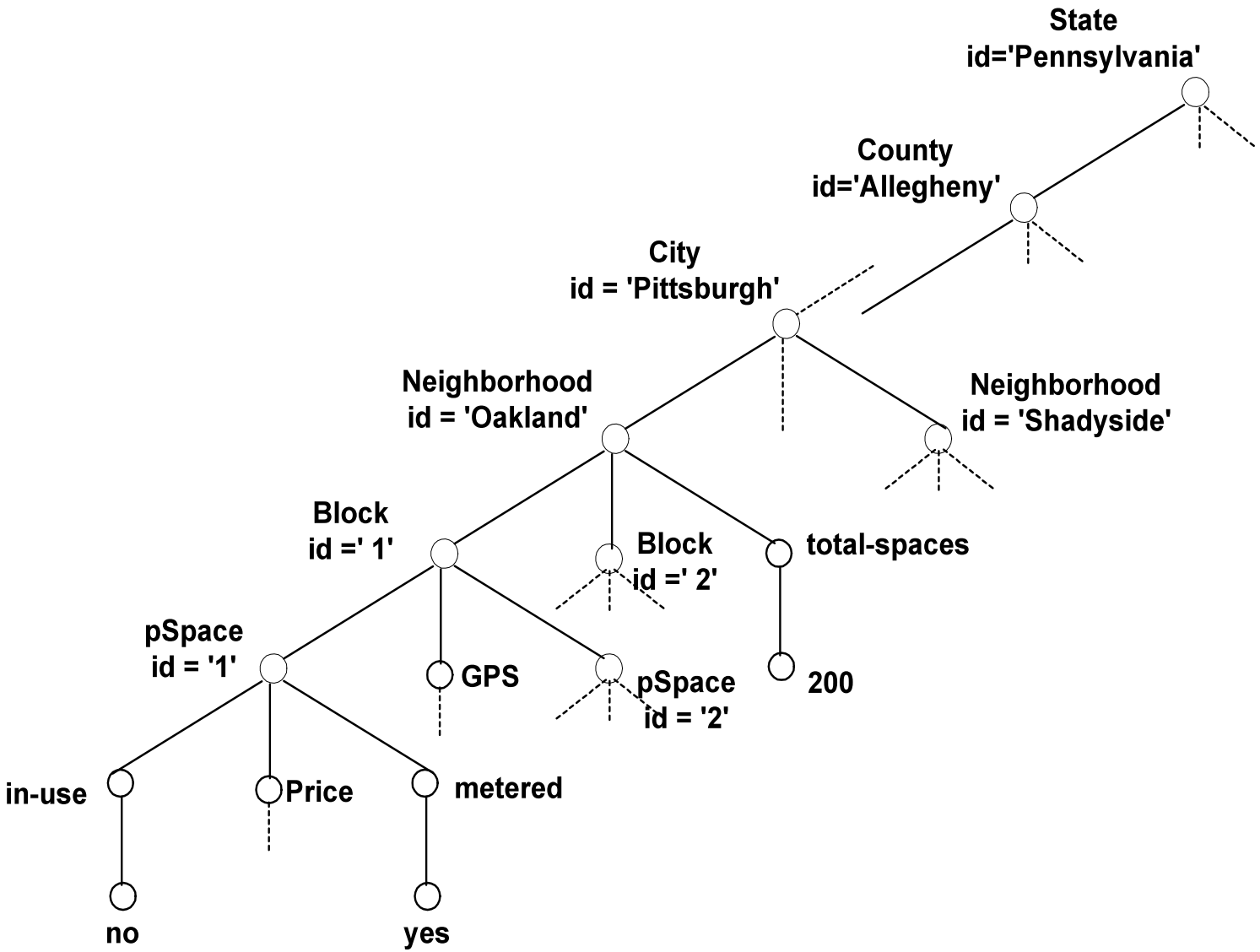
XML: Example

- From the Irisnet project...

Example XML: Parking Space Information

```
<State id="Pennysylvinia">
  <County id="Allegheny">
    <City id="Pittsburgh">
      <Neighborhood id="Oakland">
        <total-spaces>200</total-spaces>
        <Block id="1">
          <GPS>...</GPS>
          <pSpace id="1">                    [[pSpace == parking space ]]
            <in-use>no</in-use>
            <metered>yes</metered>
          </pSpace>
          <pSpace id="2">
            ...
          </pSpace>
        </Block>
      </Neighborhood>
      <Neighborhood id="Shadyside">
        ...
```

Example XML Fragment for PSF



XML Standardization

- XML may allow arbitrary structures, but need **schemas** and **namespaces** to exchange data
- Schema languages
  - Initially DTD (Document Type Definition)
  - XMLSchema is more standard now
  - However XMLSchema is considered too complex, and there are many alternatives
    - RELAX NG
    - Schematron, Examplotron etc...
    - See for a comparison
- Purpose of namespaces is to mainly avoid duplicate attribute/element names
  - But also commonly used to define attributes or elements
  - See here for more information

XML DTDs


```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<!DOCTYPE people_list [
  <!ELEMENT people_list (person)*>
  <!ELEMENT person (name, birthdate?, gender?, socialsecuritynumber?)>
  <!ELEMENT name (#PCDATA)>
  <!ELEMENT birthdate (#PCDATA)>
  <!ELEMENT gender (#PCDATA)>
  <!ELEMENT socialsecuritynumber (#PCDATA)>
]>
<people_list>
  <person>
    <name>Fred Bloggs</name>
    <birthdate>2008-11-27</birthdate>
    <gender>Male</gender>
  </person>
</people_list>
```

XML Schema


```
<?xml version="1.0" encoding="utf-8"?>
<xs:schema elementFormDefault="qualified" xmlns:xs="http://www.w3.org/2001/XMLSchema">
  <xs:element name="Address">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="Recipient" type="xs:string" />
        <xs:element name="House" type="xs:string" />
        <xs:element name="Street" type="xs:string" />
        <xs:element name="Town" type="xs:string" />
        <xs:element name="County" type="xs:string" minOccurs="0" />
        <xs:element name="PostCode" type="xs:string" />
        <xs:element name="Country">
          <xs:simpleType>
            <xs:restriction base="xs:string">
              <xs:enumeration value="FR" />
              <xs:enumeration value="DE" />
              <xs:enumeration value="ES" />
              <xs:enumeration value="UK" />
              <xs:enumeration value="US" />
            </xs:restriction>
          </xs:simpleType>
        </xs:element>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

XML Schema


```
<?xml version="1.0" encoding="utf-8"?>
<Address xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
         xsi:noNamespaceSchemaLocation="SimpleAddress.xsd">
  <Recipient>Mr. Walter C. Brown</Recipient>
  <House>49</House>
  <Street>Featherstone Street</Street>
  <Town>LONDON</Town>
  <PostCode>EC1Y 8SY</PostCode>
  <Country>UK</Country>
</Address>
```

XML Query Languages

- XPath: Identify a set of nodes in the document
  - Used by both XSLT and XQuery to enumerate/identify nodes
- XSLT: Transformation language
  - Fairly verbose... essentially a program that traverses the document
  - "... whose primary goal was to render XML for the human reader on screen"
- XQuery: The current standard
  - Personally, I think it is too complicated
  - Likely only a subset will be used/implemented in practice

Example Queries

- Users issue queries against the document as a whole
  - Find all available parking spots in Oakland

```
/State[@id="Pennsylvania"]/County[@id="Allegheny"]/City[@id="Pittsburgh"]
        /Neighborhood[@id="Oakland"]/Block/pSpace[in-use = "no"]
```

  - Find all blocks in in Allegheny have more than 20 metered parking spots

```
/State[@id="Pennsylvania"]/County[@id="Allegheny"]
                    //Block[count(./pSpace[metered = "yes"]) > 20]
```

  - Find the cheapest parking spot in Oakland Block 1 /

```
State[@id="Pennsylvania"]/County[@id="Allegheny"]/City[@id="Pittsburgh"]
  /Neighborhood[@id="Oakland"]/Block[@id='1']
          /pSpace[not(../pSpace/price > ./price)]
```

XSLT


```
<?xml version="1.0" encoding="UTF-8"?>
<xsl:stylesheet
  version="1.0"
  xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
  xmlns="http://www.w3.org/1999/xhtml">

  <xsl:output method="xml" indent="yes" encoding="UTF-8"/>

  <xsl:template match="/persons">
    <html>
      <head> <title>Testing XML Example</title> </head>
      <body>
        <h1>Persons</h1>
        <ul>
          <xsl:apply-templates select="person">
            <xsl:sort select="family-name" />
          </xsl:apply-templates>
        </ul>
      </body>
    </html>
  </xsl:template>

  <xsl:template match="person">
    <li>
      <xsl:value-of select="family-name"/><xsl:text>, </xsl:text>
      <xsl:value-of select="name"/>
    </li>
  </xsl:template>

</xsl:stylesheet>
```

XQuery

The sample XQuery code below lists the unique speakers in each act of Shakespeare's play Hamlet, encoded in hamlet.xml

```
<html><head/><body>
{
  for $act in doc("hamlet.xml")//ACT
  let $speakers := distinct-values($act//SPEAKER)
  return
    <div>
      <h1>{ string($act/TITLE) }</h1>
      <ul>
      {
        for $speaker in $speakers
        return <li>{ $speaker }</li>
      }
      </ul>
    </div>
}
</body></html>
```

XML Storage

- Option 1: Using a *native XML database*
  - Special purpose data stores
  - Going back to hierarchical/network models?
  - Many developed over the years, some by big names: see e.g., PureXML by IBM
  - Disadvantages: performance; need to re-build transaction/concurrency support etc
    - Often XML constructed from relational for data exchange
    - Often need support to do relational query processing (e.g., OLAP) on XML data

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    - Often XML constructed from relational for data exchange
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- Option 2: Using relational databases
  - May lose structure in the XML document
  - Need to develop schemes to convert back and forth
  - XML queries naturally hierarchical $\rightarrow$ need many joins

XML Storage in Oracle

- From: Oracle XML DB
- Options:
  - Structured: Stored relationally – best performance
  - Binary XML storage: post-parsed binary format
    - Compact, post-parsed, XML Schema-aware
  - Unstructured: Stored in Character Large Object (CLOB)
    - Limited cases, e.g., when "document fidelity" needed
    - Mostly full document retrieval
- The white paper discusses in detail when to use which storage option

XML Storage in Oracle

TABLE 1 XMLTYPE STORAGE MODELS: RELATIVE ADVANTAGES

QUALITY	STRUCTURED STORAGE	BINARY XML STORAGE	UNSTRUCTURED (CLOB) STORAGE
Throughput	– XML decomposition can result in reduced throughput when ingesting or retrieving the entire content of an XML document.	+ High throughput. Fast DOM loading. There is a slight overhead from the binary encoder / decoder.	++ High throughput when ingesting and retrieving the entire content of an XML document.
Indexing support	++ B-tree, Bitmap, Oracle Text, XMLIndex, and function-based indexes.	+ XMLIndex, function-based, and Oracle Text indexes.	+ XMLIndex, function-based, and Oracle Text indexes.
Queries	++ Extremely Fast. Relational query performance. Users can create B-tree indexes on the exploded columns.	+. Fast when using XMLIndex. User queries which cannot use the index use streaming Xpath evaluation, which is reasonably fast as well.	–. Fast when using XMLIndex. Parts of query which can't use the index cannot be optimized.
Update operations (DML)	++ Extremely fast. Relational column gets updated in-place.	+ In-place, piecewise update for SecureFile LOB storage.	– When any part of the document is updated, the entire document must be written back to disk.

XML Storage in Oracle

Space efficiency (disk)	++ Extremely space-efficient.	+ Space-efficient.	– Consumes the most disk space, due to insignificant white space and repeated tags.
Data flexibility	– Limited flexibility. Only documents that conform to the XML schema can be stored in the XMLType table or column.	+ Flexibility in the structure of the XML documents that can be stored in an XMLType column or table.	+ Flexibility in the structure of the XML documents that can be stored in an XMLType column or table.
XML schema flexibility	– One XMLType table can only store documents conforming to one schema. Also provides relational-like in-place schema evolution capability.	++ Can store schemaless or schema based documents. An XMLType table can store documents conforming to any of the registered schemas.	++ Can store schemaless or schema based documents. Cannot use multiple XML schemas for the same XMLType table.
XML fidelity	+ DOM fidelity: A DOM created from an XML document that has been stored in the database will be	+ DOM fidelity (see structured storage description).	++ Document fidelity: Maintains the original XML data, byte for byte. In particular, all original white space is

XML Storage in Oracle

TABLE 1 XMLTYPE STORAGE MODELS: RELATIVE ADVANTAGES			
QUALITY	**STRUCTURED STORAGE**	**BINARY XML STORAGE**	**UNSTRUCTURED (CLOB) STORAGE**
	identical to a DOM created from the original document. However, insignificant white space may be discarded.		preserved.
Optimized memory management	+ XML operations can be optimized to reduce memory requirements.	+ XML operations can be optimized to reduce memory requirements.	– XML operations on the document require creating a DOM from the document.
Validation upon insert	+ XML data is partially validated when it is inserted.	++ XML schema-based data can be fully validated when it is inserted, though this is an expensive operation.	+ XML schema-based data is partially validated when it is inserted.
Partitioning	++ Available	+ Partition based on virtual columns.	+ XMLType columns can be partitioned when the partitioning key is a relational column.
Streams based replication	- Not available	- Not available	++ Available
Compression and Encryption	Each element/attribute can be compressed / encrypted individually	Binary XML with SecureFile storage can be compressed / encrypted	Cannot be compressed / encrypted.

XML in RDBMS

- NOTE: Somewhat older paper... much work since then
- Key issues
  - Converting an XML document to relational
    - Called “shredding”
    - Uses the DTD Information
  - Processing queries
  - Converting the relational data back to XML
    - Essentially a query + some post-processing (maybe as a UDF)

XML in RDBMS

1. Simplify the DTD
   - The conversion can be a one-way process
   - No need to preserve exact structure in the relational schema
   - Order is important in XML
     - See a later paper Handling order when converting

XML in RDBMS

1. Simplify the DTD
   - The conversion can be a one-way process
   - No need to preserve exact structure in the relational schema
   - Order is important in XML
     - See a later paper Handling order when converting
2. Create a set of tables
   - Simple option: Create a table for each element
     - Too many tables; a lot of joins needed later
     - Can think of that as denormalizing
   - Should try *inlining* as much as possible

XML in RDBMS: Example


```
<book>
   <booktitle> The Selfish Gene </booktitle>
   <author id = “dawkins”>
            <name>
                 <firstname> Richard </firstname>
                 <lastname> Dawkins </lastname>
            </name>
            <address>
                 <city> Timbuktu </city>
                 <zip> 99999 </zip>
            </address>
   </author>
</book>
```

Figure 1

```
<!ELEMENT book (booktitle, author)
<!ELEMENT article (title, author*, contactauthor)>
<!ELEMENT contactauthor EMPTY>
<!ATTLIST contactauthor authorID IDREF IMPLIED>
<!ELEMENT monograph (title, author, editor)>
<!ELEMENT editor (monograph*)>
<!ATTLIST editor name CDATA #REQUIRED>
<!ELEMENT author (name, address)>
<!ATTLIST author id ID #REQUIRED>
<!ELEMENT name (firstname?, lastname)>
<!ELEMENT firstname (#PCDATA)>
<!ELEMENT lastname (#PCDATA)>
<!ELEMENT address ANY>
```

Figure 2

XML in RDBMS: DTD Graph

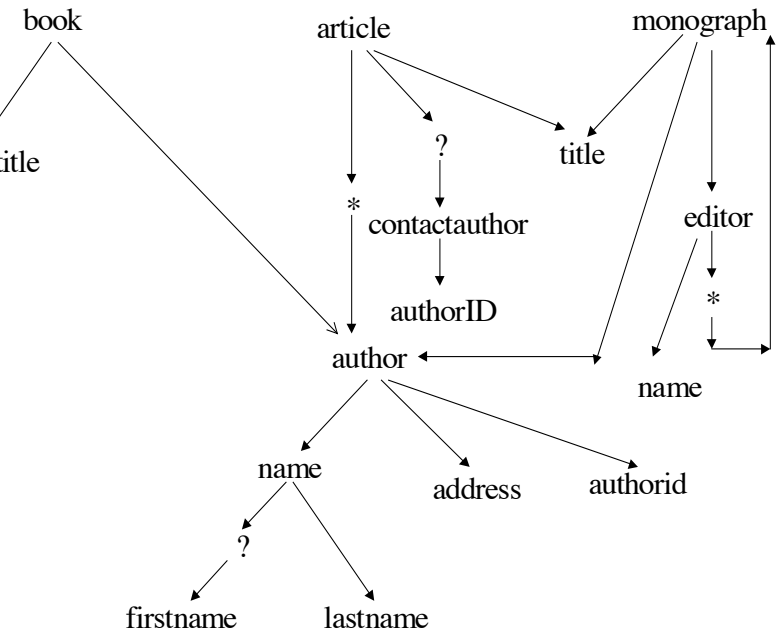
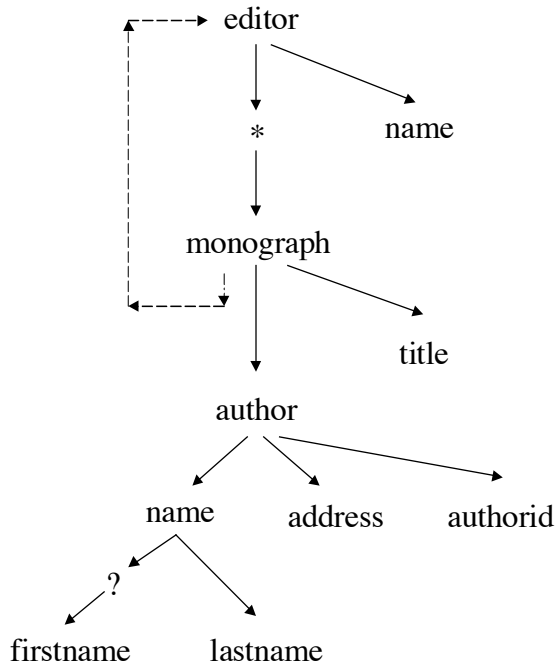


Figure 8



XML in RDBMS: Schema without inlining

book (bookID: integer, book.booktitle : string, book.author.name.firstname: string, book.author.name.lastname: string, book.author.address: string, author.authorid: string)

booktitle (booktitleID: integer, booktitle: string)

article (articleID: integer, article.contactauthor.authorid: string, article.title: string)

article.author (article.authorID: integer, article.author.parentID: integer, article.author.name.firstname: string, article.author.name.lastname: string, article.author.address: string, article.author.authorid: string)

contactauthor (contactauthorID: integer, contactauthor.authorid: string)

title (titleID: integer, title: string)

monograph (monographID: integer, monograph.parentID: integer, monograph.title: string, monograph.editor.name: string, monograph.author.name.firstname: string, monograph.author.name.lastname: string, monograph.author.address: string, monograph.author.authorid: string)

editor (editorID: integer, editor.parentID: integer, editor.name: string)

editor.monograph (editor.monographID: integer, editor.monograph.parentID: integer, editor.monograph.title: string, editor.monograph.author.name.firstname: string, editor.monograph.author.name.lastname: string, editor.monograph.author.address: string, editor.monograph.author.authorid: string)

author (authorID: integer, author.name.firstname: string, author.name.lastname: string, author.address: string, author.authorid: string)

name (nameID: integer, name.firstname: string, name.lastname: string)

firstname (firstnameID: integer, firstname: string)

lastname (lastnameID: integer, lastname: string)

address (addressID: integer, address: string)

Figure 10

XML in RDBMS: Schema with aggressive inlining

book (bookID: integer, book.booktitle.isroot: boolean, book.booktitle : string)

article (articleID: integer, article.contactauthor.isroot: boolean, article.contactauthor.authorid: string)

monograph (monographID: integer,monograph.parentID: integer, monograph.parentCODE: integer, monograph.editor.isroot: boolean, monograph.editor.name: string)

title (titleID: integer, title.parentID: integer, title.parentCODE: integer, title: string)

author (authorID: integer, author.parentID: integer, author.parentCODE: integer, author.name.isroot: boolean, author.name.firstname.isroot: :boolean, author.name.firstname: string, author.name.lastname.isroot: boolean, author.name.lastname: string, author.address.isroot: boolean, author.address: string, author.authorid: string)

Figure 11

XML in RDBMS: Query Conversion

- Left: Original Query (in XML-QL and Lorel syntax), Right: Converted query

```
WHERE <book>
            <booktitle> The Selfish Gene </booktitle>
            <author>
                <name>
                    <firstname> $f </firstname>
                    <lastname> $l </lastname>
                </name>
            </author>
        </book> IN * CONFORMING TO pubs.dtd
CONSTRUCT <result> $f $l </result>
```

```
Select Y.name.firstname,
       Y.name.lastname
From   book X, X.author Y
Where X.booktitle = “Databases”
```

```
Select A.”author.name.firstname”,
       A.”author.name.lastname”
From   author A, book B
Where B.bookID = A.parentID
       AND A.parentCODE = 0
       AND B.”book.booktitle” = “The Selfish Gene”
```

Figure 18

XML in RDBMS: Query Conversion

- Left: Original Query, Right: Converted query

```
WHERE <*.monograph>
            <editor.(monograph.editor)*>
                  <name> $n </name>
            </>
            <title> Subclass Cirripedia </title>
          </> IN * CONFORMING TO pubs.dtd
CONSTRUCT <result> $n </result>
```

```
Select Y.name
From   *.monograph X, X.editor.(monograph.editor)* Y
Where X.title = “Subclass Cirripedia”
```

```
With Q1 (monographID, name) AS
(Select X.monographID, X.”editor.name”
 From monograph X
 Where X.title = “Subclass Cirripedia”
UNION ALL
 Select Z.monographID, Z.”editor.name”
 From Q1 Y, monograph Z
 Where Y.monographID = Z.parentID AND
          Z.parentCODE = 0
)
Select A.name
From Q1 A
```

Figure 19

XML in RDBMS: Query Conversion

- Left: Original Query, Right: Converted query

```
WHERE <*.monograph>
            <editor.(monograph.editor)*>
                  <name> $n </name>
            </>
            <title> Subclass Cirripedia </title>
          </> IN * CONFORMING TO pubs.dtd
CONSTRUCT <result> $n </result>
```

```
Select Y.name
From   *.monograph X, X.editor.(monograph.editor)* Y
Where X.title = “Subclass Cirripedia”
```

```
With Q1 (monographID, name) AS
(Select X.monographID, X.”editor.name”
 From monograph X
 Where X.title = “Subclass Cirripedia”
UNION ALL
 Select Z.monographID, Z.”editor.name”
 From Q1 Y, monograph Z
 Where Y.monographID = Z.parentID AND
          Z.parentCODE = 0
)
Select A.name
From Q1 A
```

Figure 19

- Note: (right) is a recursive query
  - The query (WITH part) creates a table (Q1) and refers to it in the FROM clause

XML in RDBMS: Converting results to XML

- Some result construction can be done using SQL
- More complex ones require a post-processing step
  - Can be done using a user-defined function or embedded SQL or like
  - Can use "group by" etc to create the appropriates sets

Limitations of RDBMS

- Simple XML queries required too many joins or unions
- No support for sets
  - XML data usually set-valued
- No support for untyped references
  - IDREF is not typed, so storing it is problematic
- No text indices
- Need flexible comparison operators
  - XML treats everything as string
- More powerful recursion
  - SQL3 (latest version) allows recursion
  - Not very commonly used
    - Somewhat hard to reason about