COS 597A:
Principles of
Database and Information Systems

XML and Information Exchange

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XML
eXtensible Markup Language

History

1988 SGML: Standard Generalized Markup Language
- Annotate text with structure

1992 HTML: Hypertext Mark-up Language
- Documents that are linked pieces
- Simple structure of language

1996 XML
- General-purpose description of content of a *document*
- Includes namespaces → linking across the Web
- Designed by working group of W3C (World Wide Web Consortium)
  - Define standard

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Outline

- XML document structure
- XML querying with XQuery
- XML name spaces
- XML Schema definition

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XML

On surface looks much like HTML:

- Tags: <title> *title of document*</title>
- Structure: tags within tags
  <body><table> …</table> … </body>
  - Must be nested → hierarchy
- Tags have attributes <body bgcolor="#ffffff">

But **Tags are User-defined**
- General *metadata*

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XML

- Originally tags generalized description of document display– allow flexibility in markup
- Now tags can have *any* meaning
  - parties using *agree in advance* as to meaning
- Can use as data specification

XML has become major vehicle of exchanging data among unrelated, heterogeneous parties
- Internet major vehicle of distribution

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Example XML

```
<students>
   <student>
        <startyear>2011</startyear>
        <name><fn>Joe </fn><ln>Jones</ln></name>
        <address>…</address>
        <course type="dept">cos 597A</course>
        <course type="dept">cos 402</course>
        <course type="elective">wri 503</course>
        etc.
   </student>
   <student> ……</student>
        ….
</students>
```

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Important XML concepts

- Information/data contained in a document
  - Document = Database
- Tags contain text and other tags
- Tags can be repeated arbitrary number of times
- Tags may or may not appear
  - Example for <student>: …<generals>April 2011</generals>…
- Attributes of tags (strings) may or may not appear
- Tags need not appear in rigid order

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Benefits of XML representation

- Self documenting by tag names
- Flexible formatting
  - Can introduce new tags or values
- Format can evolve without invalidating old
- Can have multi-valued components
  - e.g. courses of student, authors of book
- Wide variety of tools can process
  - Browsers
  - DB tools

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Undesirable properties of XML representation

- Verbose representation:
  repetition of tag names
  - Inefficient
- Redundant representation
  - Document contains all info, even if much does not change
    - e.g. document containing employee info: basic name, address, etc. repeated even if only assignment changes
    - Compare one table in relational DB

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Board Example

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Specification

Need exchange syntax (semantics?) as well as XML document:

- XSL – eXtensible Style Language
  - How display information
- DTD = Document Type Declaration
  - User specifies own tags and attributes
  - User-defined grammar for syntax

➢ XML Schema – similar to but more general than DTD

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Semistructured Data Model

- XML gives structure, but not fully or rigidly specified
- Tag <> … </> defines XML element
  - Elements may contain sub-elements
  - Elements may contain values
  - Elements may have attributes
- Use labeled tree model
  - Element → node: atomic or compound object
  - Leaves: values and attributes

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Example

```
<students>
   <student>
        <startyear>2011</startyear>
        <name><fn>Joe </fn><ln>Jones</ln></name>
        <address>…</address>
        <course type="dept">cos 597A</course>
        <course type="elective">wri 503 </course>
        etc.
   </student>
   <student> ……</student>
        ….
</students>
```

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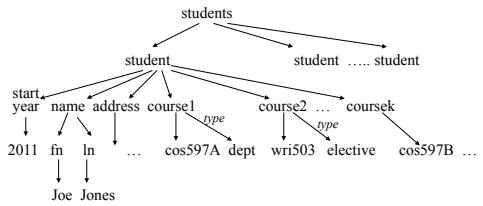

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XML Tools

- Display
  - Very flexible what and how display
- Convert to different representation
  - Example: put in relational database?
- Extract information from XML document
  - ➢Querying

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Querying XML

- Storing data in XML; want to query
- Could map to relational model, but then must restructure data
- Several querying languages
  - XPath : now building block
  - Quilt : historic
  - XQuery
  - XSLT : designed for style sheets but general

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XQUERY

- Specified by W3C working group
  - Circa 2000
  - Latest XQuery 1.1 Dec. 2010
- Derived from older languages
- Modeled after SQL

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Brief look at XQUERY

FLWOR (flower) expression:

- FOR *path expression* – anal. to SQL "FROM"
- LET *variable name = path expression* – anal. To SQL "AS"
- WHERE *condition* – anal. to SQL "WHERE"
- ORDER BY – anal. to SQL "ORDER BY"
- RETURN – constructs XML result – anal to SQL "SELECT"

XQUERY returns XML fragment

- XML $\xrightarrow{\text{XQuery}}$ XML
  - Compare: relations $\xrightarrow{\text{SQL}}$ relation

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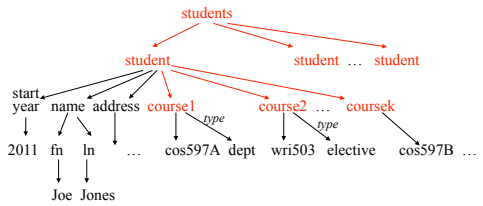
Path expression

- Traverse paths of tree
  - Use element names to name path
- Take ***all*** matching branches
- Returns sequence of nodes of tree
  - Node = XML elements

Doc. Identifier	//	element name	/
e.g. URL root of tree	indicates element nested anywhere- jump down tree at this point in path		indicates immed. child of path so far

e.g. /students/student/course



Path expressions – *some* details

- Returns sequence of matching elements
  - Includes tags of those elements
  - Sequence ordered by appearance in document
- Attributes can be accessed: @attribute_name
- … /* denotes *all children* of elements …/
- Predicates at any point in path
  - Prunes out paths
  - e.g. /students/student/course[@type='dept']
- Doc(*document name*) returns root of a named document
  - File name
  - URL (URI)

XQuery FOR …

For $x in *path expression 1,*
$y *in path expression 2,*
…

- $ precedes variable name
- Each variable ranges over sequence of elements returned by its path expression
- Multiple variables => Cartesian product

XQuery Let …

Let $z := *path expression1*
Let $q := *path expression2*
…

Value of variable (e.g. $z) is entire sequence if path expression returns sequence

XQuery WHERE …

WHERE *predicate*

- Predicate on set defined in FOR
  FOR $b IN /students/student
  WHERE $b/startyear='2011'
- Rich set of functions, comparison operations

XQuery RETURN …

- Constructs XML result
- Give explicit tags for result
- Give expressions to be evaluated
  {*expression*}
- Example

```
FOR $b IN doc_id/students/student
WHERE $b/startyear='2011'
RETURN <Result>{$b/name/fn $b/name/ln} </Result>
```

Gives: <Result><fn>Joe</fn><ln><Jones></ln></Result>
<Result> …
etc.

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Example

```
FOR $x IN doc_id//name/ln
RETURN <LastName>{$x}</LastName>
```

Gives: ?
For :

```
<students>
  <student>
      <startyear>2011</startyear>
      <name><fn>Joe </fn><ln>Jones</ln></name>
      …
  </student>
  <student>
      <startyear>2010</startyear>
      <name><fn>Jane </fn><ln>Smith</ln></name>
      …
  </student>

</students>
```

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Examples

FOR $x IN doc_id//name/ln
RETURN < LastName >{$x}</LastName >

Gives: <LastName><ln>Jones</ln></LastName>
< LastName ><ln>Smith</ln></LastName >

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Examples

FOR $x IN doc_id//name/ln
RETURN < LastName >{$x/text()}</LastName >

Gives: <LastName>Jones</LastName>
< LastName >Smith</LastName >

- Many functions

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FOR versus LET

```
for $title in /BOOKS/BOOK/TITLE
return <TITLES>{$title}</TITLES>

gives:
<TITLES>
    <TITLE>The Tragedy of Romeo
      and Juliet</TITLE>
</TITLES>

<TITLES>
    <TITLE>The Tragedy of Hamlet,
      Prince of Denmark</TITLE>
</TITLES>

<TITLES>
    <TITLE>The Tragedy of
      Macbeth</TITLE>
</TITLES>
```

```
let $title := /BOOKS/BOOK/TITLE
return <TITLES>{$title}</TITLES>

gives:
<TITLES>
    <TITLE>The Tragedy of Romeo
      and Juliet</TITLE>
    <TITLE>The Tragedy of Hamlet,
      Prince of Denmark</TITLE>
    <TITLE>The Tragedy of
      Macbeth</TITLE>
</TITLES>
```

XQuery: A *very* incomplete list of features

- Are aggregation operations
- Can nest XQuery expressions in RETURN clause
  - Can get nested elements in result not nested in original
- Get joins: conditions in WHERE coordinate paths expressions over variables in FOR
- Can have if…then ...else within RETURN clause
- Can have quantification within WHERE clause
  - SOME $e IN *path expression* SATISFIES *predicate with $e free*
  - EVERY $e IN …

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Outline

- ✓ XML document structure
- ✓ XML querying with XQuery
- • XML name spaces
- • XML Schema definition

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Namespaces

- Exchanging XML documents with unrelated sites, unrelated applications requires unambiguous identifiers across sources of documents
- XML allows each source to specify a globally unique name: universal resource identifiers (URIs)
  - URLs
- Names within one source expect source to keep unambiguous

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Namespace specification

- Prepend URI to each tag or attribute name
  http://www.princeton.edu:student
- Verbose – have abbreviation mechanism
  Attribute within *root* tag: xmlns:*abbrev*="*URI*"

```
<students xmlns:PUstu="http://www.princeton.edu">
    <PUstu:student>
    <PUstu:year>2005</PUstu:year>
    …
```

Becomes part of tag name

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Multiple namespaces

- One document can have several namespaces defined and used
  - Different sources
  - Sources need not be sites
- Namespace can denote specific XML standard
  - Extend types
  - Extend functions

xmlns:xs="http://www.w3.org/2001/XMLSchema"
Get types "xs:string", "xs:decimal"

Leads us to …

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Outline

- ✓ XML document structure
- ✓ XML querying with XQuery
- ✓ XML name spaces
- • **XML Schema definition**

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Language ***XML Schema***

Standard for specifying schema of a document:

- Specify tag names, attribute names
- Declare leaf types (contents)
  - Built-in types
  - User-defined types
- Declare tag structure
  - tree model
- Specify constraints:
  - key
  - foreign key

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XML Schema specification

The schema for a document is
an XML document

Says using specific w3c standard from namespace

<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">

. . . *specification of document*

</xs:schema>

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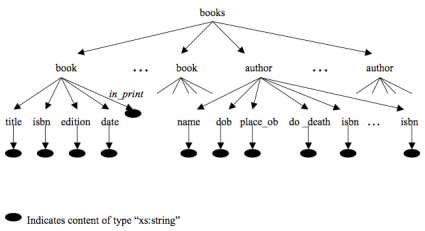
Example for Schema definition

Gives schema for tree model:



Indicates content of type "xs:string"

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XSchema Basics

- Declare elements (nodes of tree)

<xs:element name="…" type="…" > … </xs:element>

name of element declaring — type of element — content: nested elements attributes

– if no nested elements and element has no attributes, can abbreviate to <xs:element name="…" type="…" />

example
<xs:element name="isbn" type="xs:string" />

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Nested elements

- Choice 1:

<xs:element name="…"> — no type declared
  <xs:complexType>
    <xs:sequence>
      <xs: element name="…" …>
      </xs:element>
      . . .
      <xs: element name="…" …>
      </xs:element>
    </xs:sequence>
  </xs:complexType>
</xs:element>

declaration for nested elements

could be nesting within nesting

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<xs:element name="**book**" >
  <xs:complexType >

    <xs:sequence>
      <xs:element name="**title**" type="xs:string"/>
      <xs:element name="**isbn**" type="xs:string"/>
      <xs:element name="**edition**" type="xs:string"/>
      <xs:element name="**date**" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>

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Define named complex type

- Choice 2:

<xs:complexType name="*typename*">
  <xs:sequence>
    <xs: element name="…" …>
    </xs:element>
    …
    <xs: element name="…" …>
    </xs:element>
  </xs:sequence>
</xs:complexType>

sequence as for choice 1

<xs:element name="…" type= "*typename*"/>

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```
<xs:element name="author" type="AuthorType"/>

<xs:complexType  name="AuthorType">
   <xs:sequence>
        <xs:element name="name" type="xs:string"/>
        <xs:element name="dob" type="xs:string"/>
        <xs:element name="place_ob" type="xs:string"/>
        <xs:element name="do_death" type="xs:string"/>
        <xs:element name= "isbn" type="xs:string"
            minOccurs= "0" maxOccurs= "unbounded"/>
   </xs:sequence>
</xs:complexType>
```

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Other parts specification

- attribute declaration: in content part:
  <xs:attribute name="…" type="…" />
- refer to previously defined element:
  <xs:element ref="*name of prev. defined element*" />
- multiple occurrences of element in a sequence
  - specify and quantify

```
<xs:sequence>
    <xs:element … minOccurs="…"  maxOccurs="…" >
</xs:sequence>
```

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```
<xs:element name="book" >
   <xs:complexType >
        <xs:attribute name="in_print" type="xs:string"/>
        <xs:sequence>
              <xs:element name="title" type="xs:string"/>
              <xs:element name="isbn" type="xs:string"/>
              <xs:element name="edition" type="xs:string"/>
              <xs:element name="date" type="xs:string"/>
        </xs:sequence>
   </xs:complexType>
</xs:element>
```

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```
<xs:element name="books" type="ListBooksType"/>

<xs:complexType  name="ListBooksType">
   <xs:sequence>
      <xs:element ref="book"
          minOccurs="1" maxOccurs="unbounded"/>
      <xs:element ref="author"
          minOccurs="1" maxOccurs="unbounded"/>
   </xs:sequence>
</xs:complexType>
```

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Primary keys and Foreign keys

- defining a candidate key:

```
<xs:key name="name you give" >
    <xs:selector  xpath=" a path specification " />
    <xs:field xpath = "names of fields" />
</xs:key>
```

path to key

elements and attributes that make up key

- defining a foreign key constraint:

```
<xs:keyref name="name you give"
            refer="name of candidate key referencing">
    <xs:selector  xpath=" a path specification " />
    <xs:field xpath = "names of fields" />
</xs:keyref>
```

- These top-level definitions within scheme

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```
<xs:key name= "bookKey" >
   <xs:selector  xpath= "/books/book"/>
   <xs:field  xpath= "isbn"/>
</xs:key>

<xs:keyref name= "authorBookFkey" refer= "bookKey" >
   <xs:selector  xpath= "/books/author"/>
    <xs:field  xpath= "isbn"/>
</xs:keyref>
```

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Putting example all together

```
< xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
    <xs:element name="books" type="ListBooksType"/>
    <xs:element name="author" type="AuthorType"/>
    <xs:element name="book">
        …
    </xs:element>
    <xs:complexType  name="AuthorType">
        …
    </xs:complexType>
    <xs:complexType  name="ListBooksType">
        …
    </xs:complexType>
    <xs:key name= "bookKey" > … </xs:key>
    <xs:keyref name= "authorBookFkey" refer= "bookKey" > … </xs:keyref>
</xs:schema>
```

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XML uses for information exchange

- Many and wide range of applications use XML to exchange information (data)
- Some examples:
  - PADS tool here (Prof. Walker) converts "ad hoc" (nonstandard) data file into an XML file
    - XML one of choices
  - XML standards for specifying 3D models
    - U3D (Adobe Acrobat)
    - Collada (Google Earth)
  - describe security vulnerabilities
  - W3C specify XML standards

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SUMMARY

- XML is language for representing information (data) in semi-structured way
  - Self documenting by tag names
  - Flexible formatting
  - Began as language for generalizing specification of document display
- Generality allows XML to be important information exchange format for internet
- ***XML Schema*** provides formal specification of document schema
- ***XQuery*** provides SQL-like query language for extracting information from an XML document

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