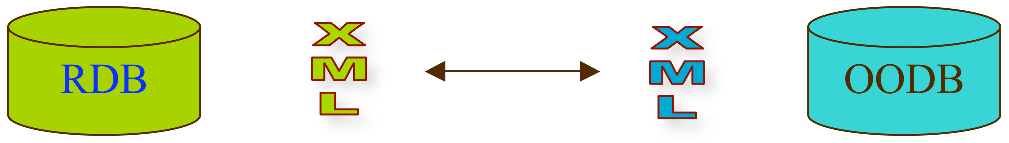
Documents vs. Databases

- ✓ Documents are typically small, while databases can be large
- ✓ Documents are usually static, whereas databases are typically dynamic
- ✓ A documents has an implicit structure, while a database has an explicit structure
- ✓ Documents are usually semi-structured (without an explicit type), while databases are structured, constrained by a schema
- ✓ Documents are human friendly, while databases are machine friendly
- ✓ Concerns about documents include presentation, editing, character encoding, language; while databases focus on models, queries, concurrency control, performance

Why study XML?

- ✓ Huge demands for data exchange
  - Across platforms
  - Across enterprises
- ✓ Huge demands for data integration
  - Heterogeneous data sources
  - Data sources distributed across different locations
- ✓ XML (eXtensible Markup Language) has become the prime standard for data exchange on the Web and a uniform data model for data integration.



What is wrong with HTML?

HTML (HyperText Markup Language)

```
<h3>  Book  </h3>
        <ul>
        <il> <i>  Database Systems</i>  R. Ramarkishnan <br>
                      <b>   1999 </b>
        <il> <b>  Complexity Theory  </b>  C. Papadimitriou <br>  …
        </ul>
```

A minor format change to the HTML document may break the parser – and yield wrong answer to the query

Why? HTML tags are

- ✓ predefined and fixed
- ✓ describing display format rather than structure of data

HTML is good for presentation (human friendly), but does not help automatic data extraction by means of programs

An XML solution

XML (eXtensible Markup Language):

```
        <book >
              <title>    Database Systems</title>
              <author>   R. Ramakrishnan</author>
              <year>   1999  </year>
        </book>
        <book  id  =  “B2” >
              <title>    Complexity Theory  </title>
              <author   C. Papadimitriou </author>
        </book>
        . . .
```

XML vs. HTML

- ✓ XML tags:
  - user-defined
  - describing the structure of the data

XML is both human friendly and computer friendly.

- ✓ HTML is human friendly but not computer friendly;

HTML tags:

  - predefined and fixed
  - describing display format rather than structure of data
    indented for human consumption

What we shall in this course

- ✓ XML basics: elements, attributes, tree model
- ✓ Document Type Definition
  - “types”: element type definition
  - “constraints”: ID/IDREF
- ✓ XML query Languages
  - XPath
  - XQuery, XSLT
- ✓ To learn XML properly, take QSX!

History: SGML, HTML, XML

SGML: Standard Generalized Markup Language

-- Charles Goldfarb, ISO 8879, 1986

- ✓ DTD (Document Type Definition)
- ✓ powerful and flexible tool for structuring information, but
  - – complete, generic implementation of SGML proven extremely difficult
  - – tools for working with SGML documents proven expensive
- ✓ two sub-languages that have outpaced SGML:
  - – HTML: HyperText Markup Language (Tim Berners-Lee, 1991). Describing presentation.
  - – XML: eXtensible Markup Language, W3C, 1998. Describing content.

From HTML to XML

HTML is good for presentation (human friendly), but does not help automatic data extraction by means of programs (not computer friendly).

Why? HTML tags:

- ✓ predefined and fixed
- ✓ describing display format, not the structure of the data.

```
<h3>  John Smith </h3>
 <b>    Taking CS 101  </b> <br>
 <em> GPA: 1.5  </em> <br>
 <h3>  CS 101   </h3>
 <b>   Intro to CS    </b>
```

XML: a first glance

XML tags:

- ✓ user defined
- ✓ describing the structure of the data

```
<school>
     <student    id = “011”>
          <name>
              <firstName>John</firstName>   <lastName>Smith</lastName>
          </name>
          <taking> CS 101 </taking>
          <GPA>   1.5  </GPA>
     </student>
     <course    cno = “CS 101”>
            <title> Intro to CS </title>
    </course>
</school>
```

XML vs. HTML

- ✓ user-defined new tags, describing structure instead of display
- ✓ structures can be arbitrarily nested (even recursively defined)
- ✓ <u>optional</u> description of its grammar (DTD) and thus validation is possible

What is XML for?

- ✓ The prime standard for data exchange on the Web
- ✓ A uniform data model for data integration

XML presentation:

- ✓ XML standard does not define how data should be displayed

Tags and Text

- ✓ XML consists of tags and text

```
<course   cno = “CS 101”>
     <title> Intro to CS </title>
</course>
```

- ✓ tags come in pairs: markups
  - start tag, e.g., <course>
  - end tag, e.g., </course>
- ✓ tags must be properly nested
  - <course> <title> … </title> </course> -- good
  - <course> <title> … </course> </title> -- bad
- ✓ XML has only one “basic” type: text, called PCDATA (Parsed Character DATA)

XML Elements

- ✓ Element: the segment between an start and its corresponding end tag
- ✓ subelement: the relation between an element and its component elements.

```
<person>
   <name> John Smith</name>
   <email> john.smith@abc.com</email>
   <oldemail> j.smith@abc.com </oldemail>
    <oldemail> john.smith@xyz.com</oldemail>
   </person>
```

Special elements

- ✓ root element: an XML document consists of a single element called the **root** element, e.g.,

```
<db>
        <person> … </person>
        <person> … </person> ...
</db>
```

- ✓ empty element: special element indicating non-textual content,
  - <foo></foo> or simply <foo/>
  - an element may carry attributes

    <image img=“picture.gif” />

  to be interpreted by applications

XML attributes

A start tag may contain attributes describing certain “properties” of the element (e.g., dimension or type)

```
<picture>
        <height dim=“cm”> 2400</height>
        <width dim=“in”> 96 </width>
        <data encoding=“gif”> M05-+C$ … </data>
</picture>
```

References (meaningful only when a DTD is present):

```
<person id = “011”   pal=“012”>
        <name> John Smith</name>
</person>
<person id = “012”   pal=“011”>
        <name> Mary Brown </name>
</person>
```

The “structure” of XML attributes

- ✓ XML attributes cannot be nested -- flat
- ✓ the names of XML attributes of an element must be unique.

  one can’t write <person pal=“John” pal=“Mary”> ...
- ✓ XML attributes are not ordered

```
<person   id = “011”    pal=“012”>
   <name> John Smith</name>
</person>
```

is the same as

```
<person  pal=“012”    id = “011”>
   <name> John Smith</name>
</person>
```

- ✓ Attributes vs. subelements: unordered vs. ordered, and
  - attributes cannot be nested (flat structure)
  - subelements cannot represent references

Well-formed XML documents

a document is well-formed if it satisfies two constraints (when only elements and attributes are considered):

- ✓ tags have to nest properly
- ✓ attributes have to be unique

Very weak constraints: it does little more than ensure that XML data will parse into a labeled tree

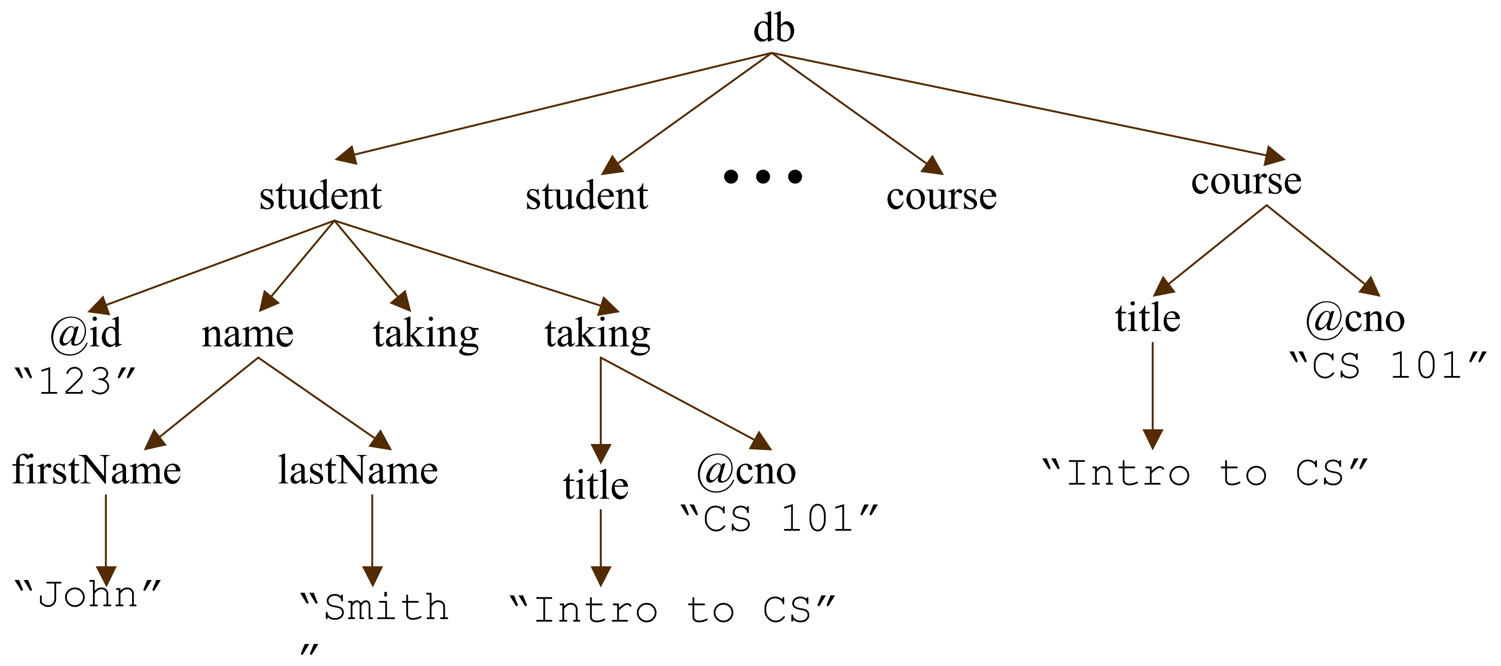
A complete XML document

```
<?xml  version= ‘1.0’?>
<!DOCTYPE  book PUBLIC   “~/school.dtd”>
<?xml:stylesheet  href=“school.xsl”  type=“text/xsl”?>
<school>                 <!-- school database -->
    <student    id = “011”>
        <name>
            <firstName>John</firstName>   <lastName>Smith</lastName>
        </name>
        <taking> CS 101 </taking>
        <GPA>   1.5  </GPA>
    </student>
    <course    cno = “CS 101”>
        <title> Intro to CS </title>
    </course>
</school>
```

The XML tree model

An XML document is modeled as a node-labeled ordered tree.

- ✓ Element node: typically internal, with a name (tag) and children (subelements and attributes), e.g., student, name.
- ✓ Attribute node: leaf with a name (tag) and text, e.g., @id.
- ✓ Text node: leaf with text (string) but without a name.



Query Languages for XML

- ✓ XPath
- ✓ XSLT
- ✓ XQuery

Common Querying Tasks

- ✓ Filter, select XML values
  - Navigation, selection, extraction
- ✓ Merge, integrate values from multiple XML sources
  - Joins, aggregation
- ✓ Transform XML values from one schema to another
  - XML construction

Query Languages

- ✓ XPath
  - Common language for navigation, selection, extraction
  - Used in XSLT, XQuery, XML Schema, . . .
- ✓ XSLT: XML ⇒ XML, HTML, Text
  - Loosely-typed scripting language
  - Format XML in HTML for display in browser
  - Highly tolerant of variability/errors in data
- ✓ XQuery 1.0: XML ⇒ XML
  - Strongly-typed query language
  - Large-scale database access
  - Safety/correctness of operations on data

XML data

```
<book   year=“1996”>
      <title>  HTML </title>
      <author>  <last> Lee </last>  <first> T. </first></author>
      <author>  <last> Smith</last> <first>C.</first></author>
      <publisher>  Addison-Wesley </publisher>
      <price>  59.99 </price>
</book>
<book   year=“1999”>
      <title>Database Systems  </title>
      <author>  <last> Ramakrishnan</last>
            <first> Raghu</first>
      </author>
      <publisher> white house </publisher>
</book>
```

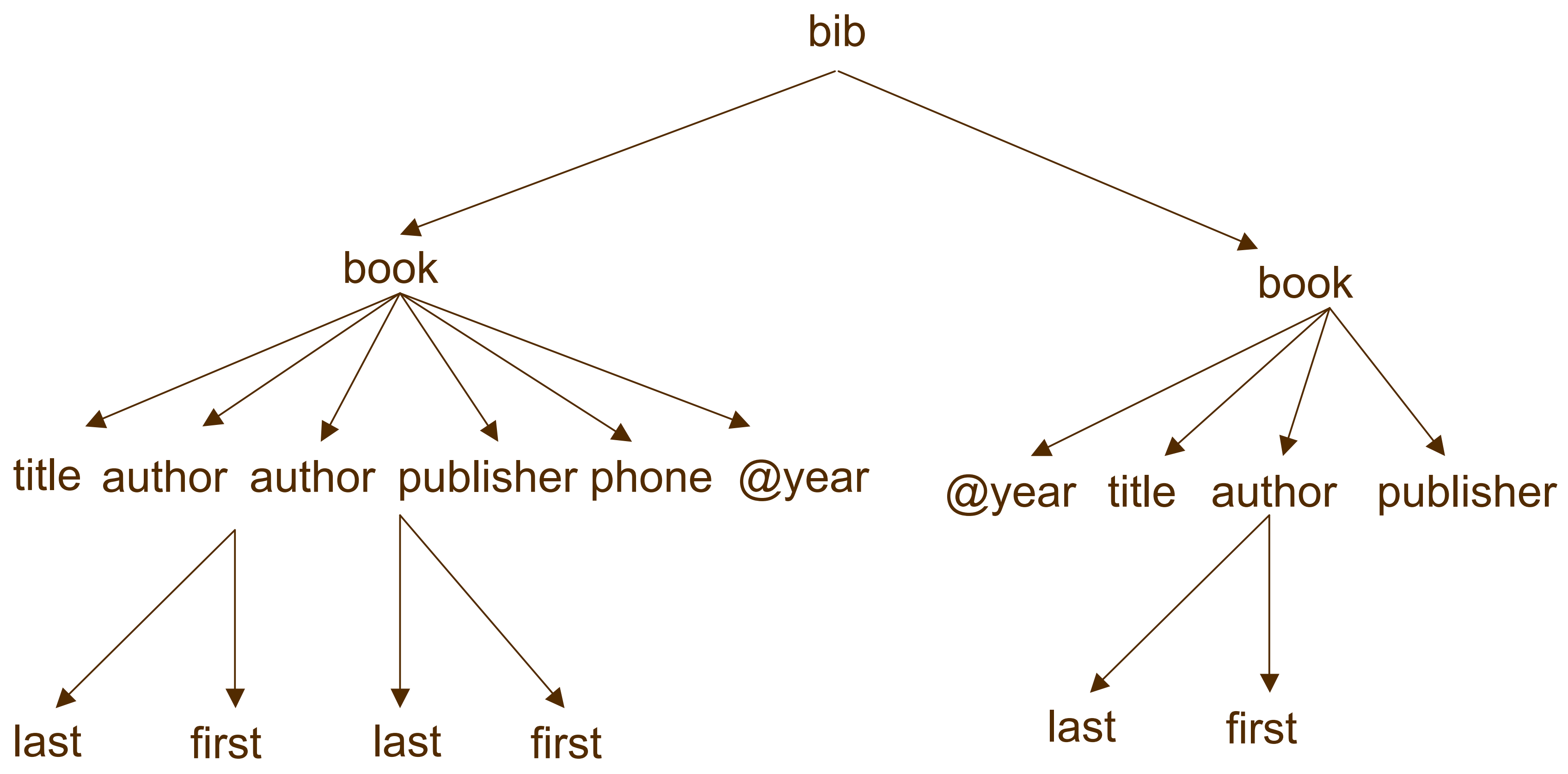
DTD

```
<!ELEMENT      bib        (book*) >
<!ELEMENT      book       (title, (author+  | editor+),
                            publisher?,  price?)  >
<!ATTLIST      book       year    CDATA      #required >
<!ELEMENT      author     (last, first)>
<!ELEMENT      editor     (last, first, affiliation)>

<!ELEMENT      publisher  (#PCDATA) >
….
```

Data model

Node-labeled, ordered tree



XPath

W3C standard: www.w3.org/TR/xpath

- ✓ Navigating an XML tree and finding parts of the tree (node selection and value extraction)

  Given an XML tree T and a context node n, an XPath query Q returns

  - the set of nodes reachable via Q from the node n in T – if Q is a binary query
  - truth value indicating whether Q is true at n in T – if Q is a Boolean query.
- ✓ Implementations: XALAN, SAXON, Berkeley DB XML – freeware, which you can play with
- ✓ A major element of XSLT, XQuery and XML Schema
- ✓ XPath 2.0 (Turing-Complete)

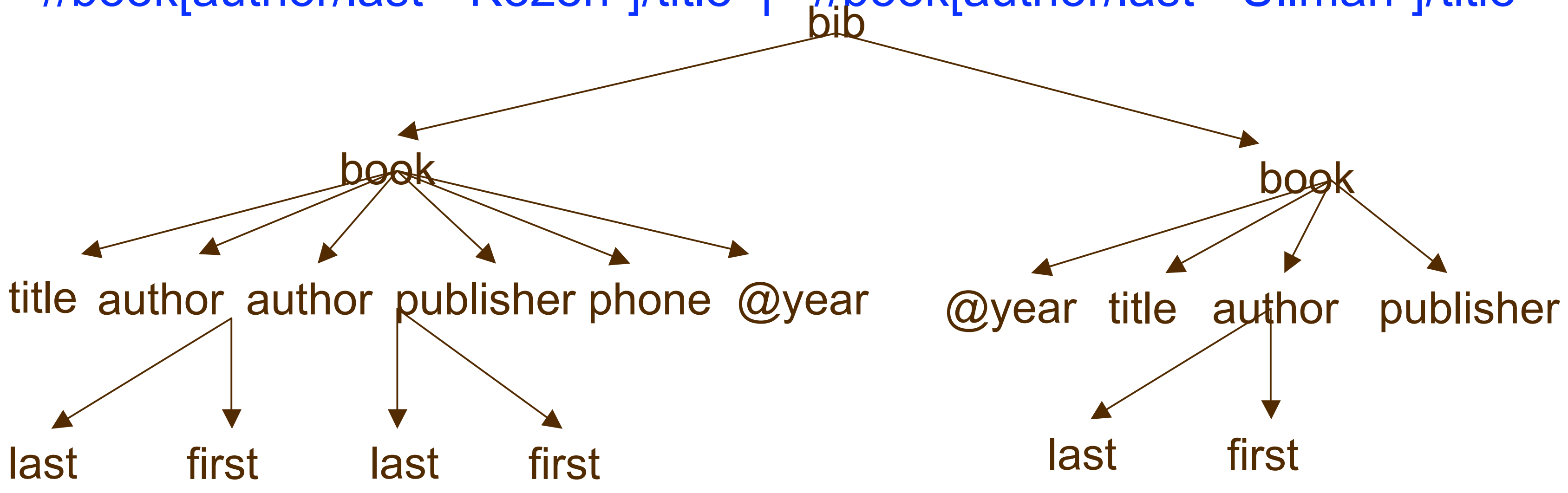
XPath constructs

XPath query Q:

- Tree traversal: downward, upward, sideways
- Relational/Boolean expressions: qualifiers (predicates)
- Functions: aggregation (e.g., count), string functions

//author[last="Ramakrishnan"]

//book[author/last="Kozen"]/title | //book[author/last="Ullman"]/title



Downward traversal

Syntax:

Q ::= . | l | @l | Q/Q | Q | Q | //Q | /Q | Q[q]

q ::= Q | Q op c | q and q | q or q | not(q)

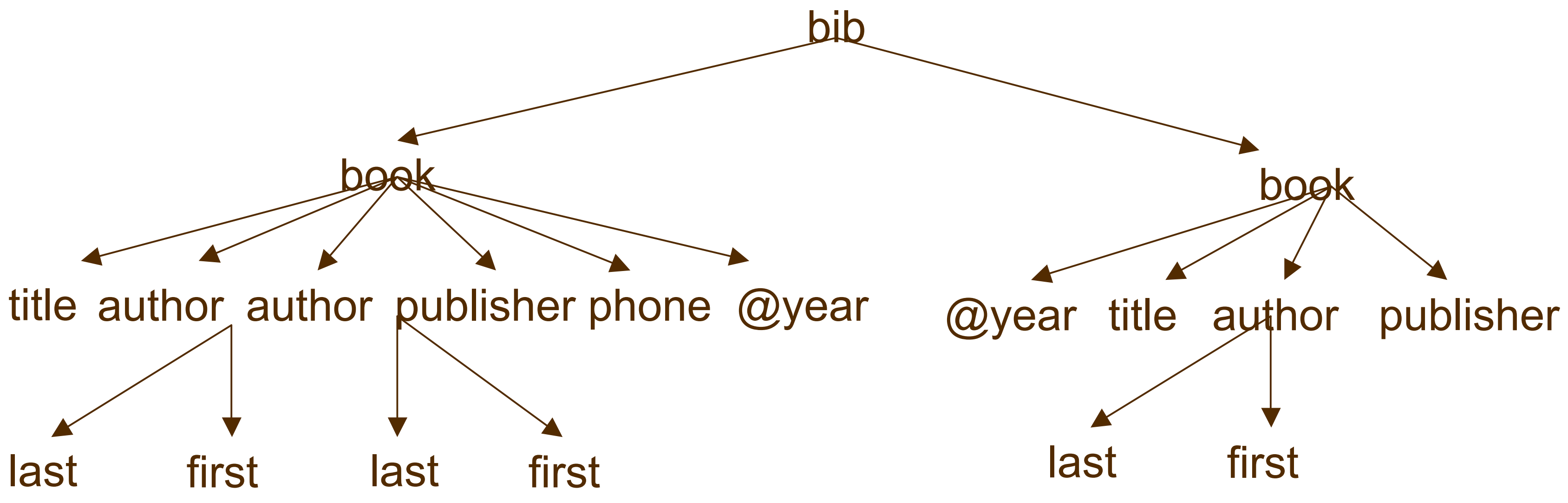
- ✓ .: self, the current node
- ✓ l: either a tag (label) or *: wildcard that matches any label
- ✓ @l: attribute
- ✓ /, |: concatenation (child), union
- ✓ //: descendants or self, “recursion”
- ✓ [q]: qualifier (filter, predicate)
  - op: =, !=, <=, <, >, >=, >
  - c: constant
  - and, or, not(): conjunction, disjunction, negation

  Existential semantics: /bib/book[author/last=“Ramakrishnan”]

Examples:

- ✓ parent/child: /bib/book
- ✓ ancestor//descendant: bib//last, //last
- ✓ wild card: bib/book/*
- ✓ attributes: bib/book/@year
- ✓ attributes with wild cards: //book/@*
- ✓ union: book/(editor | author)

Are book/(editor | author) and //(editor | author) “equivalent” at context nodes (1) root, (2) book, (3) author?



Filters (qualifiers)

- ✓ //book[price]/title -- titles of books with a price
- ✓ //book[@year > 1991]/title -- titles of books published after 1991
- ✓ //book[title and author and not(price)]/title

  titles of books with authors, title but no price
- ✓ //book[author/last = “Ramakrishnan”]/title

  titles of books with an author whose last name is Ramakrishnan
- ✓ //book[editor | author]/title

  titles of books with with either an author or an editor

Upward traversal

Syntax:

Q ::= . . . | ../Q | ancestor ::Q | ancestor-or-self::Q

- ✓ ../: parent
- ✓ ancestor, ancestor-or-self: recursion

Example:

- ✓ //author[../title = “Databases”]/last

  find last names of authors of books with the title “Databases”

- ✓ ancestor :: book[//last=“Ramakrishnan”]

  find book ancestors with “Ramakrishnan” as its last descendant

Sideways

Syntax:

Q ::= . . . | following-sibling ::Q | preceding-sibling::Q

- ✓ following-sibling: the next sibling
- ✓ preceding-sibling: the previous sibling
- ✓ position function: e.g., //author[position( ) < 2]

Example:

- ✓ following-sibling :: book [//last="Ramakrishnan"]

  find the next book written by Ramakrishnan
- ✓ preceding-sibling :: book[//last="Ramakrishnan"]

  find the last book written by Ramakrishnan

Query Languages for XML

- ✓ XPath
- ✓ XSLT
- ✓ XQuery

XSL (eXtensible Stylesheet Language)

W3C recommendation www.w3.org/Style/XSL

- ✓ Two separate languages:
  - XSLT: transformation language, Turing complete
  - a formatting language
- ✓ Purpose: stylesheet specification language
  - displaying XML documents: XML -> HTML
  - transforming/querying XML data: XML -> XML
- ✓ Implementations: SAXON, XALAN, …

XSL programs

XSL program: a collection of template rules

- ✓ template rule = pattern + template
- ✓ computation:
  - starts from the root
  - apply a pattern to each node. If it matches, execute the corresponding template (to construct XML/HTML), and apply templates recursively on its children.
- ✓ patterns:
  - match pattern: determine content – whether or not to apply the rule?
  - select pattern: identify nodes to be processed, set of nodes

An example XSLT program

Q1: Find titles and authors of all books published by Addison-Wesley after 1991.

```
<xsl:template    match="/bib/book[@year > 1991 and
                          publisher='Addison-Wesley']" >
  <result>
        <title> <xsl:value-of  select="title" /> </title>
        <xsl:for-each select="author" />
          <author><xsl:value-of /> </author>
        </xsl:for-each>
  </result>
</xsl:template>
```

Basic XSLT constructs

- ✓ a collection of templates: <xsl:template>
- ✓ match pattern: match="bib/book[@year > 1991 and
                                        publisher='Addison-Wesley']"
- ✓ select pattern: select="title", xsl:for-each select="author"
- ✓ value-of: string
- ✓ constructing XML data:

```
<result>
        <title> <xsl:value-of   select="title" /> </title>
        ...
</result>
```

Patterns

- ✓ match pattern: (downward) XPath
  - parent/child: bib/book
  - ancestor//descendant (_*): bib//last, //last, …
- ✓ select patterns: XPath

Example:

```
<xsl:template  match="/bib/book/title >
        <result>
        <title> <xsl:value-of  /> </title>
        <author> <xsl:value-of select="../author" ></author>
       </result>
</xsl:template>
```

note: first author only (without xsl:for-each)

Apply templates

Recursive processing:

```
<xsl:template  match=XPath >
        . . .
        <xsl:apply-templates  select=XPath/>
        . . .
</xsl:template>
```

- ✓ Compare each selected child (descendant) of the matched source element against the templates in your program
- ✓ If a match is found, output the template for the matched node
- ✓ One can use xsl:apply-templates instead of xsl:for-each
- ✓ If the select attribute is missing, all the children are selected
- ✓ When the match attribute is missing, the template matches every node:

```
<xsl:template> <xsl:apply-templates /> </xsl:template>
```

XML to HTML: display

Q5: generate a HTML document consisting of the titles and authors of all books.

```
<xsl:template   match="/">
      <html>
             <head> <title> Books  </title>   </head>
             <body> <ul> <xsl:apply-templates select="bib/book "></ul></body>
     </html>
</xsl:template>

<xsl:template    match="book">
      <li>  <b> <xsl:value-of   select="title" />,  </b>
            <xsl:for-each select="author" /> <em><xsl:value-of /> </em>
            </xsl:for-each> <br>
      </li>
</xsl:template>
```

Query Languages for XML

- ✓ XPath
- ✓ XSLT
- ✓ XQuery

XQuery

W3C working draft www.w3.org/TR/xquery

Functional, strongly typed query language: Turing-complete

✓ XQuery = XPath + …

for-let-where-return (FLWR) ~ SQL's SELECT-FROM-WHERE

Sort-by

XML construction (Transformation)

Operators on types (Compile & run-time type tests)

+ User-defined functions

Modularize large queries

Process recursive data

+ Strong typing

Enforced statically or dynamically

FLWR Expressions

For, Let, Where, OrderBy, return

Q1: Find titles and authors of all books published by Addison-Wesley after 1991.

```
<answer>{
    for  $book  in /bib/book
    where $book/@year > 1991  and  $book/publisher='Addison-Wesley'
    return    <book>
                  <title>  {$book/title } </title>,
                   for  $author  in $book/author   return
                     <author>  {$author } </author>
              </book>
}</answer>
```

- ✓ for loop; $x: variable
- ✓ where: condition test; selection
- ✓ return: evaluate an expression and return its value

join

Find books that cost more at Amazon than at BN

```
<answer>{
    let  $amazon := doc(“http://www.amazon.com/books.xml”),
           $bn  :=  doc(“http://www.BN.com/books.xml”)
    for    $a  in $amozon/books/book,
           $b  in $bn/books/book
    where    $a/isbn  = $b/isbn    and     $a/price > $b/price
    return   <book> {$a/title, $a/price, $b/price }  <book>
}</answer>
```

- ✓ let clause
- ✓ join: of two documents

Conditional expression

Q2: Find all book titles, and prices where available

```
<answer>{
    for  $book  in /bib/book
    return   <book>
                  <title>  {$book/title } </title>,
                   { if   $book[price]
                     then  <price> {$book/price } </price>
                     else   ( )  }
             </book>
}</answer>
```

Indexing

Q3: for each book, find its title and its first two authors, and returns <et-al/> if there are more than two authors

```
<answer>{
     for  $book  in /bib/book
     return   <book>
                    <title>  {$book/title } </title>,
                     {  for  $author  in $book/author[position( ) <= 2]
                             return <author>  {$author } </author>  }
                     {  if  (count($book/author) > 2
                        then <et-al/>
                        else  ( )
                  </book>
}</answer>
```

Order by

Q4: find the titles of all books published by Addison-Wesley after 1991, and list them alphabetically.

```
<answer>{
    for  $book  in /bib/book
    where $book/@year > 1991  and  $book/publisher=‘Addison-Wesley’
    order  by  $book/title
    return
             <book>
                  <title>  {$book/title } </title>,
                   for  $author  in $book/author   return
                     <author>  {$author } </author>
              </book>
}</answer>
```

Grouping

Q5: For each author, find titles of books he/she has written

```
<answer>{
    for  $author  in   distinct(/bib/book/author)
    return    <author    name="{$author}" >{
                   for  $book  in  /bib/book
                   where   $book/author  =  $author
                   return  <title>  {$book/title } </title>
               </author>
}</answer>
```

- ✓ Constructing attributes: <author   name="{$author}" >
- ✓ Grouping: for $book in /bib/book …

Recursion

Consider a part DTD

```
<!ELEMENT   part  (part*)>
<!ATTLIST   part  name   CDATA   #required>
<!ATTLIST   part  cost   CDATA   #required>
```

part – subpart hierarchy

Given a part element, we want to find the total cost of the part – recursive computation that descends the part hierarchy

function

```
define   function   total  (element   part   $part)
returns   element  part {
          let   $subparts   :=
                    for   $s   in   $part/part    return   total($s)
          return {
              <part   name="$part/@name"
                      cost="$part/@cost + sum($subparts/@cost)">
              } </part>
}
```

- ✓ recursive function: it recursively descends the hierarchy of $part
- ✓ $subparts: a list
- ✓ $part: parameter

Document Type Definition (DTD)

An XML document may come with an optional DTD – “schema”

```
<!DOCTYPE  db [
    <!ELEMENT    db  (book*)>
    <!ELEMENT    book   (title,  chapter*, ref*)>
    <!ATTLIST      book  isbn   ID   #required>
    <!ELEMENT    chapter  (number, section*) >
    <!ELEMENT    section  (number, (text | section)*)>
    <!ELEMENT    ref  EMPTY>
    <!ATTLIST      ref  to    IDREFS   #implied>
    <!ELEMENT   title  #PCDATA>
    <!ELEMENT   text  #PCDATA>
]>
```

What is a DTD?

- ✓ A DTD constraints the structure of an XML document, and may help us formulate/optimize our queries.
- ✓ There is a relationship between a DTD and a databases schema or a type/class declaration of a program, but it is not close – hence the need for additional “typing” systems, such as XML Schema.
- ✓ A DTD is a syntactic specification. Its connection with any “conceptual” model may be quite remote.
- ✓ DTDs do not act like type systems for XQuery, XPath or XSLT. You can “validate” your XML documents, but that does not mean that your programs are checked for type errors.

Element Type Definition (1)

For each element type E, a declaration of the form:

```
<!ELEMENT   E   P>
```

where P is a regular expression, i.e.,

```
P ::= EMPTY | ANY | #PCDATA | E’ |
          P1, P2 |   P1 | P2   |  P?  | P+  | P*
```

- E’: element type
- P1 , P2: concatenation
- P1 | P2: disjunction
- P?: optional
- P+: one or more occurrences
- P*: the Kleene closure

Element Type Definition (2)

- ✓ Extended context free grammar: <!ELEMENT E P>

  Why is it called extended?

  E.g., <!ELEMENT book (title, authors*, section*, ref*)>

- ✓ single root: <!DOCTYPE db […] >
- ✓ subelements are ordered.

  The following two definitions are different. Why?

  <!ELEMENT section (text | section)*>

  <!ELEMENT section (text* | section*)>

- ✓ recursive definition, e.g., section, binary tree:

  <!ELEMENT node (leaf | (node, node))

  <!ELEMENT leaf (#PCDATA)>

Element Type Definition (3)

- more on recursive DTDs

  <!ELEMENT person (name, father, mother)>

  <!ELEMENT father (person)>

  <!ELEMENT mother (person)>

  What is the problem with this? How to fix it?

  - Attributes
  - optional (e.g., father?, mother?)

Element Type Definition (4)

- ✓ EMPTY element:

  <!ELEMENT ref EMPTY>

  <!ATTLIST ref to IDREFS #implied>

  observe that it has attributes

- ✓ ANY: may contain any content

  <!ELEMENT generic ANY>

- ✓ mixed content

  <!ELEMENT section (#PCDATA | section)*>

Element Type Definition (5)

- ✓ global definition:

  <!ELEMENT person (name, ssn)>

  <!ELEMENT course (name, credit, instructor)>

  The type definition associated with an element is unique -- only one declaration for name is allowed.

  To avoid name clashes, one may use two distinct tags: e.g., personname, coursename.

Attribute declarations (1)

General syntax:

```
<!ATTLIST  element_name
           attribute-name  attribute-type  default-declaration>
```

example: “keys” and “foreign keys”

```
<!ATTLIST      book
               isbn   ID   #required>
<!ATTLIST      ref
               to    IDREFS   #implied>
```

Note: it is OK for several element types to define an attribute of the same name, e.g.,

```
<!ATTLIST     person  name  ID  #required>
<!ATTLIST     pet      name   ID  #required>
```

Attribute declarations (2)

```
<!ATTLIST  element_name
           attribute-name  attribute-type  default-declaration>
```

- ✓ attribute types:
  - CDATA
  - ID, IDREF, IDREFS
  - …
- ✓ default declarations:
  - #required, #implied
  - “default value”, #fixed “default value”

Specifying ID and IDREF attributes

```
<!ATTLIST      person
                id         ID         #required
                father     IDREF      #implied
                mother     IDREF      #implied
                children   IDREFS     #implied>
e.g.,
<person  id="898"  father="332"  mother="336"
            children="982  984  986">
  ….
</person>
```

XML reference mechanism

- ✓ ID attribute: unique within the entire document.
  - An element can have at most one ID attribute.
  - No default (fixed default) value is allowed.
    - #required: a value must be provided
    - #implied: a value is optional
- ✓ IDREF attribute: its value must be some other element's ID value already in the document.
- ✓ IDREFS attribute: its value is a set, each element of the set is the ID value of some other element in the document.

  <person id="898" father="332" mother="336"

  children="982 984 986">

Keys and Foreign Keys

Example: school document

```
<!ELEMENT   db        (student+,   course+) >
<!ELEMENT   student   (id,    name,   gpa,     taking*)>
<!ELEMENT   course    (cno,  title,    credit,   taken_by*)>
<!ELEMENT   taking    (cno)>
<!ELEMENT   taken_by   (id)>
```

- ✓ keys: locating a specific object, an invariant connection from an object in the real world to its representation

  $\text{student.@id} \rightarrow \text{student}$, $\quad \text{course.@cno} \rightarrow \text{course}$

- ✓ foreign keys: referencing an object from another object

  $\text{taking.@cno} \subseteq \text{course.@cno}$, $\quad \text{course.@cno} \rightarrow \text{course}$

  $\text{taken\_by.@id} \subseteq \text{student.@id}$, $\quad \text{student.@id} \rightarrow \text{student}$

The limitations of ID/IDREF

ID and IDREF attributes in DTD vs. keys and foreign keys in RDBs

- ✓ Scoping:
  - ID unique within the entire document (like oids), while a key needs only to uniquely identify a tuple within a relation
  - IDREF untyped: one has no control over what it points to -- you point to something, but you don't know what it is!

    <student id="01" name="John Smith" taking="CS2"/>

    <student id="02" name="Mary Brown" taking="CS2 01"/>

    <course id="CS2"/>

The limitations of the XML standard (DTD)

- ✓ keys need to be multi-valued, while IDs must be single-valued (unary)

  enroll (sid: string, cid: string, grade:string)

- ✓ a relation may have multiple keys, while an element can have at most one ID (primary)
- ✓ ID/IDREF can only be defined in a DTD, while XML data may not come with a DTD/schema
- ✓ ID/IDREF, even relational keys/foreign keys, fail to capture the semantics of hierarchical data