CS2Bh: Current Technologies

Introduction to XML and Relational Databases

Spring 2005

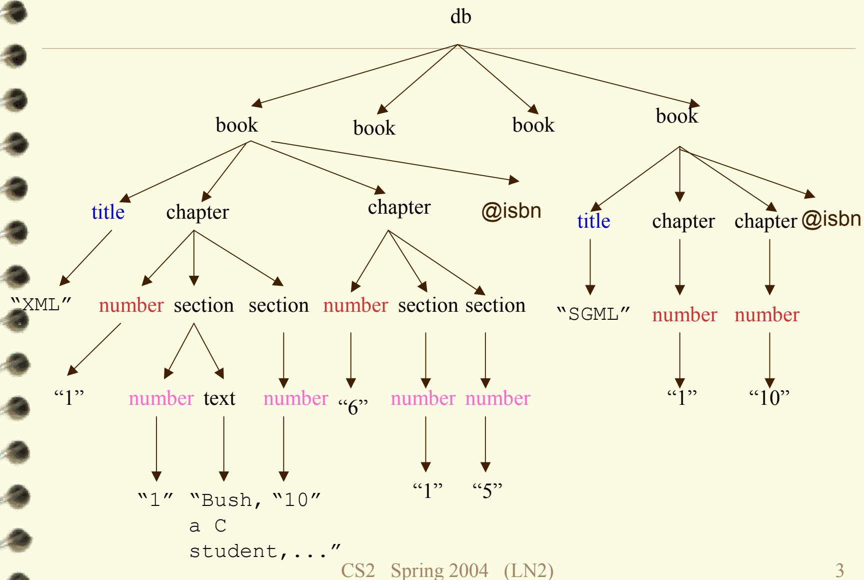
Document Type Definition

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>
]>
```

An instance of the DTD



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, chapter*, 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?)

exercise

- What is the problem with the following?

  <!ELEMENT person (name,
  person?, /*father
  person? /* mother)
  >

- How to declare E to be an unordered pair (a, b)?

  <!ELEMENT E ((a, b) | (b, a)) >

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.

- namespace: define two namespaces

  <MYNAMESPACE xmlns:person="~fan/person.dtd"
  xmlns:course="~fan/course.dtd">

  <person:name> … <course:name> …

  </MYNAMESPACE>

exercise

What is the problem with the following?

```
<!ELEMENT    student   (id,     name,   gpa)>
<!ELEMENT     name     (first-name, last-name)>
. . .
<!ELEMENT    course    (cno,  name,    credit)>
<!ELEMENT     name     (PCDATA)>
```


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 – within a relation

  student.@id $\rightarrow$ student, course.@cno $\rightarrow$ course
- foreign keys: referencing an object from another object

  taking.@cno $\subseteq$ course.@cno, course.@cno $\rightarrow$ course

  taken_by.@id $\subseteq$ student.@id, student.@id $\rightarrow$ 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="Saddam" taking="CS2"/>

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

    <course id="CS2"/>

exercise

What is the problem with the following?

```
<!ELEMENT   people  (person*)>
<!ELEMENT   person  (name, spouse, children)>
<!ATTLIST   person  NIN  ID  #required>
<!ELEMENT   spouse  (person?) >
<!ELEMENT   children  (person*)>
```

In an XML document of the DTD, a person is to appear as a child under both his/her father and mother

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

Valid XML documents

A **valid** XML document must have a DTD.

- The document is well-formed
- It conforms to the DTD:
  - elements conform to the grammars of their type definitions (nested only in the way described by the DTD)
  - elements have all and only the attributes specified by the DTD
  - ID/IDREF attributes satisfy their constraints:
    - ID must be distinct
    - IDREF/IDREFS values must be existing ID values
- Contrast valid documents and well-formed documents (possibly in the absence of a DTD)

DTDs vs. schemas (types)

- By database (or programming language) standard, XML DTDs are rather weak specifications.
  - Only one base type -- PCDATA.
  - No useful “abstractions”, e.g., unordered records.
  - Element type definitions are “global”
  - No methods
  - No sub-typing or inheritance.
  - IDREFs are not typed or scoped -- you point to something, but you don’t know what!
- XML extensions to overcome the limitations.
  - Type systems: XML-Data, XML-Schema, SOX
  - Integrity Constraints

Summary and Review

- DTD provides useful syntactic constraints on documents.
- Element types, attributes
- ID/IDREF, as constraints, are very restricted

Questions:

- How to store large XML documents?
- How to query large documents efficiently?
- How to support XML updates by multiple users simultaneously?
- How to secure access to XML data?
- How to map between XML and other representations?
- How to make XML schemas work like database schemas and programming language types?