XML & DTDs

csc343, Introduction to Databases
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Introduction

- The relational model is very rigid:
  - Everything must be a table.
  - The schema must be defined in advance.
  - Everything must conform to the schema.
- Relational DBMSs exploit this to give us data we can count on and efficient queries.
- But some data doesn't fit the model well. For example, we may have
  - missing information, and
  - indeterminate quantities.

HTML to XML

- XML grew out of HTML, and is intentionally similar:
  - Tags and attributes
  - Tree-structured format
- But there are important differences:
  - XML data must be well-formed.
  - You define your own tags and attributes.
  - These describe the meaning of the data, and imply nothing about its presentation.

What's XML for?

- XML is great for
  - Recording data that software needs.
  - Exchange of information between pieces of software.
- XML is said to be "self-describing".
  - Schema-like information is part of the data itself.
  - Example:

```
<student stnum="1234" name="Cindylou Who">
  <address>
    <street>99 Alfalfa Way</street>
    <city>Whoville</city>
  </address>
</student>
```

Well-formed vs valid XML

- Well-formed XML
  - Just need a single root element and proper nesting.
  - Any tag or attribute can go anywhere.
- Valid XML
  - A "DTD" (document type definition) specifies what tags and attributes are permitted, where they can go, and how many there must be.
  - A valid XML file is one that has a DTD and follows the rules specified in its DTD.

Well-formed XML

- Begin the document with a declaration, surrounded by `<?xml … ?>`
- Declaration for a document that is merely well-formed (i.e., it has no DTD):
  `<?xml version="1.0" standalone="yes" ?>`
- The rest of the document is a single root tag with tags nested inside it.

Tags

- Tags can be matched pairs, leaving room for text or nested tags in between. Example:

```
<tf-question qid="Q637" solution="False">
   <question>
      The Prime Minister, Stephen Harper,
      is Canada's Head of State.
   </question>
</tf-question>
```

- Or they be unmatched. Example:

```
<response qid="Q637" answer="False" />
```

  Note the placement of the slash.

- Tag names are case-sensitive.

Example: quiz.xml

Attributes

- As we saw, an opening tag can have attribute name-value pairs within it. Example:

```
<tf-question qid="Q637" solution="False">
   <question>
      The Prime Minister, Stephen Harper,
      is Canada's Head of State.
   </question>
</tf-question>
```

- The pairs are separated by blanks.
- If all the information is in the attributes, the tag becomes empty.

One extreme: all data via attributes

```
<tf-question qid="Q637" solution="False">
   <question>
      The Prime Minister ...
   </question>
</tf-question>
```

could become:

```
<tf-question qid="Q637" solution="False"
   question="The Prime Minister ..."/>
```

Other extreme: no attributes at all

```
<tf-question qid="Q637" solution="False">
   <question>
      The Prime Minister...
   </question>
</tf-question>
```

could become:

```
<tf-question>
   <qid>Q637</qid>
   <solution>False</solution>
   <question>
      The Prime Minister...
   </question>
</tf-question>
```

It's a design decision

- In most cases, something in between makes more sense.
- Matched tags make sense when you need structure within.
- Attributes make sense when you want something like keys and foreign keys. (More on that later.)

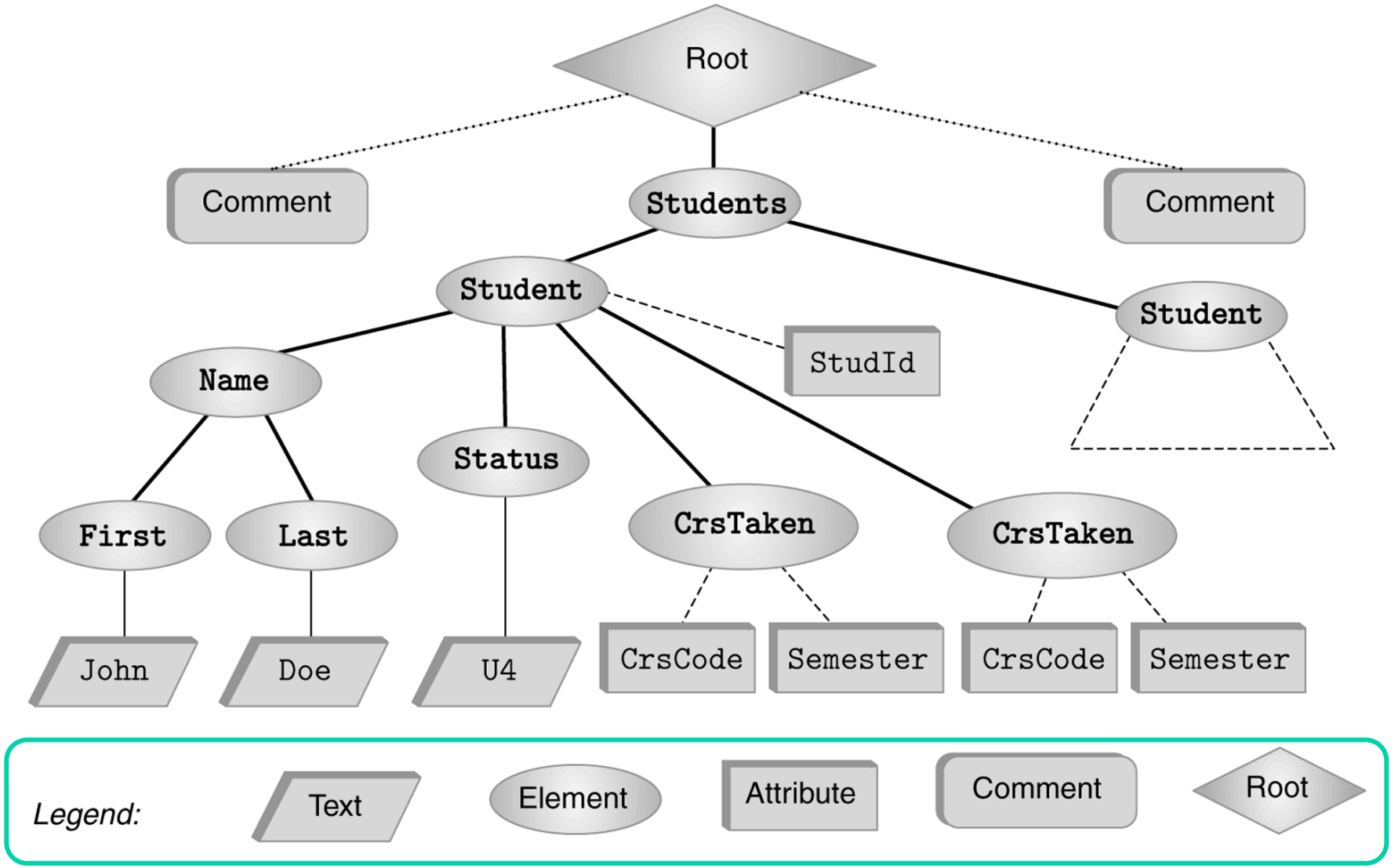
Checking for well-formedness

- `http://validator.w3.org`
- `xmllint` command on cdf.
  Default is to check merely for well-formedness.
- `xmllint --debug`
  Outputs an annotated tree of the parsed document.
  Useful for diagnosis of problems.

XML documents have a tree structure

```
<?xml  version="1.0" ?>
<!-- Some  comment -->
<Students>
  <Student StudId="111111111" >
     <Name><First>John</First><Last>Doe</Last></Name>
     <Status>U2</Status>
     <CrsTaken CrsCode="CS308" Semester="F1997" />
     <CrsTaken CrsCode="MAT123" Semester="F1997" />
  </Student>
  <Student StudId="987654321" >
     <Name><First>Bart</First><Last>Simpson</Last></Name>
     <Status>U4</Status>
     <CrsTaken CrsCode="CS308" Semester="F1994" />
  </Student>
</Students>
<!-- Some other comment -->
```

The document tree



Problems with merely well-formed XML

- There are no restrictions on
  - what tags are allowed
  - what order, nesting
  - what attributes each tag can have
  - what is mandatory and what is optional
- If a program is to process our XML, this would be very useful to know.

Valid XML with DTDs

Content of a DTD

- A series of rules.
- An `ELEMENT` rule defines an element that may occur, and what can be within its opening and closing tags.
- An `ATTLIST` rule defines an attribute of an element.
- Order of the rules doesn't matter.

ELEMENT rules

- Form: `<!ELEMENT` *«name»* `(` *«subcomponents»* `)>`
- *name*: the element's tag.
- *subcomponents*: can be
  - A comma-separated list of elements.
    Meaning: the subcomponents must occur inside the element, and in the order given.
  - `#PCDATA`
    Meaning: The element contains simply text (no subelements).
  - `EMPTY`
    Meaning: This is an "empty" element. It may have attributes, but not matching opening & closing tags.

Examples

```
<!ELEMENT INGREDIENT (NAME, QUANTITY)>
<!ELEMENT NAME (#PCDATA)>
<!ELEMENT QUANTITY EMPTY>
```

More expressiveness for subcomponents

- We can us the pipe symbol `|` to indicate alternatives.
- We specify multiplicity as follows:
  - `*` means zero or more
  - `+` means one or more
  - `?` means zero or one
    (i.e., the subcomponent is optional)
- We can use brackets for grouping.

ATTLIST rules

- Form:
  `<!ATTLIST` *«elName» «attName» «type» «optionality»* `>`
- *elname*: the element whose attribute this is.
- *attName*: the name of this attribute.
- *type*: either `CDATA` or a list of possible values, e.g., `True|False`.
- *optionality*: Either `#REQUIRED` or `#IMPLIED` (which means optional).
- You can define multiple attributes at once.

```
<!ATTLIST person SIN CDATA #REQUIRED
                 age CDATA #IMPLIED >
```

Example

```
<!ELEMENT RECIPES (RECIPE)+>
<!ELEMENT RECIPE (INGREDIENTS, STEPS)>
<!ATTLIST RECIPE name CDATA #REQUIRED>
<!ATTLIST RECIPE type CDATA #IMPLIED>
<!ATTLIST RECIPE keywords CDATA #IMPLIED>
<!ELEMENT INGREDIENTS (INGREDIENT)+>
<!ELEMENT INGREDIENT (NAME, QUANTITY)>
<!ELEMENT NAME (#PCDATA)>
<!ELEMENT QUANTITY EMPTY>
<!ATTLIST QUANTITY amount CDATA #REQUIRED>
<!ATTLIST QUANTITY units CDATA #IMPLIED>
<!ELEMENT STEPS (STEP+)>
<!ELEMENT STEP (#PCDATA)>
```

Using a DTD

- The declaration must say that the document is not standalone:

```
<?xml version="1.0" standalone="no" ?>
```

- Three possible places for the DTD:
  - In the same file, between the declaration and the XML content.
  - In a separate file on the same computer. Specify the filename, or give the full or relative path.
  - At a URL.
- In all cases, you must specify what the root element will be.

DTD in the same file

```
<?xml version="1.0" standalone="no" ?>
<!DOCTYPE People [
   <!ELEMENT People (Person*)>
   <!ELEMENT Person (#PCDATA)>
]>
<People>
   <Person>Tommy Douglas</Person>
   <Person>Terry Fox</Person>
   <Person>Louise Arbour</Person>
   <Person>Chris Hadfield</Person>
</People>
```

DTD in another file

```
<?xml version="1.0" standalone="no" ?>
<!DOCTYPE People SYSTEM "people.dtd">
<People>
    <Person>Tommy Douglas</Person>
    <Person>Terry Fox</Person>
    <Person>Louise Arbour</Person>
    <Person>Chris Hadfield</Person>
</People>
```

DTD at a URL

```
<?xml version="1.0" standalone="no" ?>
<!DOCTYPE People SYSTEM "http://
www.cs.utoronto.ca/~dianeh/xyyz/people.dtd">
<People>
    <Person>Tommy Douglas</Person>
    <Person>Terry Fox</Person>
    <Person>Louise Arbour</Person>
    <Person>Chris Hadfield</Person>
</People>
```

“Keys” and “foreign keys”

Motivation

- Just as in the relational model, we sometimes want
  - unique identifiers.
  - the ability to refer in one place to some data in another place.
- Example: quiz.xml
- We would like the DTD to express these rules and our tools to enforce them.
- DTDs don't have this full capability, but they do have some modest features in this direction.

Using ID to enforce uniqueness

- To specify that values must be unique:
  - Make an attribute of type `ID` rather than `CDATA`.
  - Example:
    ```
    <!ATTLIST mc-question qid ID #REQUIRED>
    ```
- Values of `ID` attributes are restricted.
  - Must not begin with a digit.
  - Must not have blanks.
- Uniqueness is enforced across *all* IDs in the file

Using IDREF to enforce referential integrity

- To specify that a value must refer to some ID:
  - Make an attribute of type `IDREF`.
  - Example:
    ```
    <!ATTLIST response qid IDREF #REQUIRED>
    ```
  - We can allow an attribute to have a *list* of values, each of which references some ID:
    ```
    <!ATTLIST response qid IDREFS #REQUIRED>
    ```
- An IDREF attribute needs only to refer to any ID in the file, not specifically to one of a particular type.

Checking for validity

- `xmllint --valid` command on cdf.

Limitations of DTDs

- ID and IDREF are a pale imitation of keys and foreign keys.
  - All ID values are treated as a single set.
- ID and IDREF only work within a single file.
  - References to an ID in another file are flagged as errors.
  - Duplicate ID values across files cannot be detected.
- There are no other types of constraints.
- The only data type is string.
- It is very inconvenient to specify contents but allow them in any order.

XML Schema

- XML Schema has greater expressive power.
  - Rich set of built-in types, plus user-defined types
  - Finer control over sequences of sub-elements.
  - More effective keys and foreign keys
- It is also much more complex.
- Note: XML Schema Definitions (XSDs) are themselves XML documents.
  - They describe "elements" and
  - the things doing the describing are themselves "elements".