

XML, DTD, and XML Schema

CompSci 316  
Introduction to Database Systems

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Announcements (Thu. Oct. 17) <sup>2</sup>

- ❖ Project milestone #1 due today!
- ❖ Midterm being graded; sample solution available this weekend

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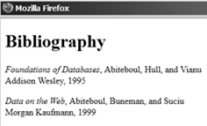
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From HTML to XML (eXtensible Markup Language) <sup>3</sup>

- ❖ HTML describes presentation of content

```
<h1>Bibliography</h1>
<p><i>Foundations of Databases</i>,
Abiteboul, Hull, and Vianu
<br>Addison Wesley, 1995
<p>...
```



- ❖ XML describes only the content

```
<bibliography>
  <book>
    <title>Foundations of Databases</title>
    <author>Abiteboul</author>
    <author>Hull</author>
    <author>Vianu</author>
    <publisher>Addison Wesley</publisher>
    <year>1995</year>
  </book>
</book>_</book>
</bibliography>
```

- ☞ Separation of content from presentation simplifies content extraction and allows the same content to be presented easily in different looks

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## Other nice features of XML

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- ❖ Portability: Just like HTML, you can ship XML data across platforms
  - Relational data requires heavy-weight protocols, e.g., JDBC
- ❖ Flexibility: You can represent any information (structured, semi-structured, documents, ...)
  - Relational data is best suited for structured data
- ❖ Extensibility: Since data describes itself, you can change the schema easily
  - Relational schema is rigid and difficult to change

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## XML terminology

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- ❖ Tag names: `book`, `title`, ...
  - ❖ Start tags: `<book>`, `<title>`, ...
  - ❖ End tags: `</book>`, `</title>`, ...
  - ❖ An element is enclosed by a pair of start and end tags: `<book>...</book>`
    - Elements can be nested: `<book>...<title>...</title>...</book>`
    - Empty elements: `<is_textbook></is_textbook>`
      - Can be abbreviated: `<is_textbook/>`
  - ❖ Elements can also have attributes: `<book ISBN="..." price="80.00">`
- ☞ Ordering generally matters, except for attributes

```
<bibliography>
<book ISBN="ISBN-10" price="80.00">
  <title>Foundations of Databases</title>
  <is_textbook/>
  <author>Abi Tebou</author>
  <author>Hui</author>
  <author>Vianu</author>
  <publisher>Addison Wesley</publisher>
  <year>1995</year>
</book>
</bibliography>
```

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## Well-formed XML documents

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- A well-formed XML document
- ❖ Follows XML lexical conventions
    - Wrong: `<section>We show that  $x < 0$ ...</section>`
    - Right: `<section>We show that  $x \leq 0$ ...</section>`
      - Other special entities: `>` becomes `&gt;`; and `&` becomes `&amp;`;
  - ❖ Contains a single root element
  - ❖ Has properly matched tags and properly nested elements
    - Right:  
`<section>...<subsection>...</subsection>...</section>`
    - Wrong:  
`<section>...<subsection>...</section>...</subsection>`

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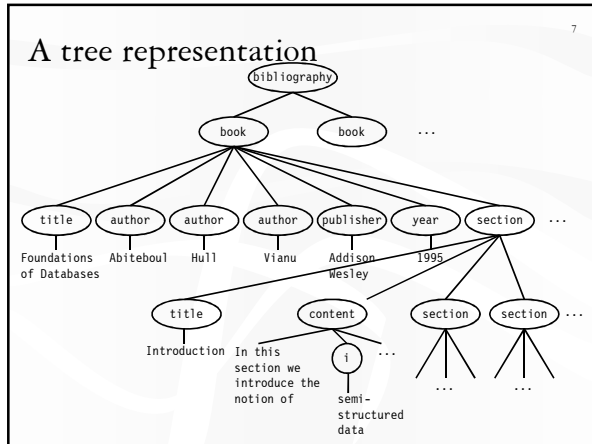
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### More XML features

- ❖ Processing instructions for apps: `<? ... ?>`
  - An XML file typically starts with a version declaration using this syntax: `<?xml version="1.0" ?>`
- ❖ Comments: `<!-- Comments here -->`
- ❖ CDATA section: `<![CDATA[Tags: <book>,...]]>`
- ❖ ID's and references
 

```
<person id="o12"><name>Homer</name></person>
<person id="o34"><name>Marge</name></person>
<person id="o56" father="o12" mother="o34"><name>Bart</name>...</person>...
```
- ❖ Namespaces allow external schemas and qualified names
 

```
<book xmlns:myCitationStyle="http://.../mySchema">
  <myCitationStyle:title>...</myCitationStyle:title>
  <myCitationStyle:author>...</myCitationStyle:author>...
</book>
```
- ❖ And more...

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### Valid XML documents

- ❖ A valid XML document conforms to a Document Type Definition (DTD)
  - A DTD is optional
  - A DTD specifies a grammar for the document
    - Constraints on structures and values of elements, attributes, etc.
- ❖ Example
 

```
<!DOCTYPE bibliography [
  <!ELEMENT bibliography (book+)>
  <!ELEMENT book (title, author*, publisher?, year?, section*)>
  <!ATTLIST book ISBN CDATA #REQUIRED>
  <!ATTLIST book price CDATA #IMPLIED>
  <!ELEMENT title (#PCDATA)>
  <!ELEMENT author (#PCDATA)>
  <!ELEMENT publisher (#PCDATA)>
  <!ELEMENT year (#PCDATA)>
  <!ELEMENT i (#PCDATA)>
  <!ELEMENT content (#PCDATA|i)*>
  <!ELEMENT section (title, content?, section*)>
]>
```

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## DTD explained

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```
<!DOCTYPE bibliography [
  └─ bibliography is the root element of the document
<!ELEMENT bibliography (book+)> └─ One or more
  └─ bibliography consists of a sequence of one or more book elements
<!ELEMENT book (title, author*, publisher?, year?, section*)>
  └─ book consists of a title, zero or more authors,
  └─ an optional publisher, and zero or more sections, in sequence
  └─ └─ Zero or more
  └─ └─ Zero or one
<!ATTLIST book ISBN ID #REQUIRED> └─ book has a required ISBN attribute which is a unique identifier
<!ATTLIST book price CDATA #IMPLIED> └─ book has an optional (#IMPLIED)
  └─ price attribute which contains
  └─ character data
```

Other attribute types include IDREF (reference to an ID), IDREFS (space-separated list of references), enumerated list, etc.

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## DTD explained (cont'd)

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```
<!ELEMENT title (#PCDATA)>
<!ELEMENT author (#PCDATA)>
<!ELEMENT publisher (#PCDATA)>
<!ELEMENT year (#PCDATA)>
<!ELEMENT i (#PCDATA)>
<!ELEMENT content (#PCDATA|i)*>
<!ELEMENT section (title, content?, section*)>
```

PCDATA is text that will be parsed

- &lt; etc. will be parsed as entities
- Use a CDATA section to include text verbatim

author, publisher, year, and i contain parsed character data

content contains mixed content: text optionally interspersed with i elements

Recursive declaration:  
Each section begins with a title, followed by an optional content, and then zero or more (sub) sections

```
<section><title>Introduction</title>
<content>In this section we introduce
the notion of <i>semi-structured data</i>.
</content>
<section><title>XML</title>
<content>XML stands for...</content>
</section>
<section><title>DTD</title>
<section><title>Definitions</title>
<content>DTD stands for...</content>
</section>
<section><title>Usages</title>
<content>You can use DTD to...</content>
</section>
</section>
```

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## Using DTD

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❖ DTD can be included in the XML source file

```
<?xml version="1.0"?>
<!DOCTYPE bibliography [
  ...
]>
<bibliography>
  ...
</bibliography>
```

❖ DTD can be external

```
<?xml version="1.0"?>
<!DOCTYPE bibliography SYSTEM "../dtds/bib.dtd">
<bibliography>
  ...
</bibliography>
<?xml version="1.0"?>
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
<html>
  ...
</html>
```

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## Annoyances: element type declarations <sup>13</sup>

- ❖ Consider this element content (children) declaration:  

```
<!ELEMENT pub-venue  
  ( (name, address, month, year) |  
    (name, volume, number, year) )>
```

  - “|” means “or”
- ❖ Syntactically legal, but won't work
  - Because of SGML compatibility issues
  - When looking at `name`, a parser would not know which way to go without looking further ahead
  - Requirement: content declaration must be “deterministic” (i.e., no look-ahead required)
  - Can we rewrite it into an equivalent, deterministic one?
- ❖ Also, you cannot nest mixed content declarations
  - Illegal: `<!ELEMENT Section (title, (#PCDATA|i)*, section*)>`

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## Annoyances: element name clash <sup>14</sup>

- ❖ Suppose we want to represent book titles and section titles differently
  - Book titles are pure text: `(#PCDATA)`
  - Section titles can have formatting tags: `(#PCDATA|i|b|math)*`
- ❖ But DTD only allows one `title` declaration!
- ❖ Workaround: rename as `book-title` and `section-title`?
  - Not nice—why can't one infer title's contexts from data?

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## Annoyances: lack of type support <sup>15</sup>

- ❖ Too few attribute types: string (CDATA), token (e.g., ID, IDREF), enumeration (e.g., `(red|green|blue)`)
  - What about integer, float, date, etc.?
- ❖ ID not typed
  - No two elements can have the same ID value, even if they are different types of elements (e.g., `book` vs. `section`)
- ❖ Difficult to reuse complex structure definitions
  - E.g.: already defined element E1 as `(blah, bleh, foo?, bar*, ...)`; want to define E2 to have the same structure
  - Parameter entities in DTD provide a workaround
    - `<!ENTITY % E.struct '(blah, bleh, foo?, bar*, ...)'>`
    - `<!ELEMENT E1 %E.struct;>`
    - `<!ELEMENT E2 %E.struct;>`
  - Something less “hacky”?

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## XML Schema

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- ❖ A more powerful way of defining the structure and constraining the contents of XML documents
- ❖ An XML Schema definition is itself an XML document
  - Typically stored as a standalone .xsd file
  - XML (data) documents refer to external .xsd files
- ❖ W3C recommendation
  - Unlike DTD, XML Schema is separate from the XML specification

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## XML Schema definition (XSD)

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```
<?xml version="1.0"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
  ... ..
  ... ..
  ... ..
</xs:schema>
```

↳ Defines XS to be the namespace described in the URL

Uses of xs: within the xs:schema element now refer to tags from this namespace

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## XSD example

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```
<xs:element name="book">
  <xs:complexType> Declares a structure with child elements/attributes as opposed to just text
  <xs:sequence> Declares a sequence of child elements, like "(, .., ..)" in DTD
    <xs:element name="title" type="xs:string"/> A leaf element with string content
    <xs:element name="author" type="xs:string" minOccurs="0" maxOccurs="unbounded"/> Like author* in DTD
    <xs:element name="publisher" type="xs:string" minOccurs="0" maxOccurs="1"/> Like publisher? in DTD
    <xs:element name="year" type="xs:integer" minOccurs="0" maxOccurs="1"/> A leaf element with integer content
    <xs:element ref="section" minOccurs="0" maxOccurs="unbounded"/> Reference to element section defined elsewhere
  </xs:sequence>
  <xs:attribute name="ISBN" type="xs:string" use="required"/>
    Declares an attribute under book... and this attribute is required
  <xs:attribute name="price" type="xs:decimal" use="optional"/>
    This attribute has a decimal value, and it is optional
</xs:complexType>
</xs:element>
```

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## XSD example cont'd

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```
<xs:element name="section">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="title" type="xs:string"/> Another title definition; can be different from book/title
      <xs:element name="content" minOccurs="0" maxOccurs="1">
        <xs:complexType mixed="true"> Declares mixed content
          <xs:choice minOccurs="0" maxOccurs="unbounded"> (text interspersed with structure below)
            <xs:element name="i" type="xs:string"/> A compositor like this one declares a list of alternatives, like "(...|...)" in DTD
            <xs:element name="b" type="xs:string"/> Like (#PCDATA|i|b)* in DTD
          </xs:choice>
        </xs:complexType>
      </xs:element>
      <xs:element ref="section" minOccurs="0" maxOccurs="unbounded"/> Recursive definition
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

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## XSD example cont'd

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### ❖ To complete bib.xsd:

```
<xs:element name="bibliography">
  <xs:complexType>
    <xs:sequence>
      <xs:element ref="book" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

### ❖ To use bib.xsd in an XML document:

```
<?xml version="1.0"?>
<bibliography xmlns:xs="http://www.w3.org/2001/XMLSchema-instance"
  xsi:noNamespaceSchemaLocation="file:bib.xsd">
  <book>...</book>
  <book>...</book>
  ...
</bibliography>
```

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## Named types

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### ❖ Define once:

```
<xs:complexType name="formattedTextType" mixed="true">
  <xs:choice minOccurs="0" maxOccurs="unbounded">
    <xs:element name="i" type="xs:string"/>
    <xs:element name="b" type="xs:string"/>
  </xs:choice>
</xs:complexType>
```

### ❖ Use elsewhere in XSD:

```
...
<xs:element name="title" type="formattedTextType"/>
<xs:element name="content" type="formattedTextType"
  minOccurs="0" maxOccurs="1"/>
...
```

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## Restrictions

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```
<xs:simpleType name="priceType">
  <xs:restriction base="xs:decimal">
    <xs:minInclusive value="0.00"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="statusType">
  <xs:restriction base="xs:string">
    <xs:enumeration value="in stock"/>
    <xs:enumeration value="out of stock"/>
    <xs:enumeration value="out of print"/>
  </xs:restriction>
</xs:simpleType>
```

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## Keys

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```
<xs:element name="bibliography">
  <xs:complexType base="xs:complexType" />
  <xs:key name="bookKey">
    <xs:selector xpath="./book"/>
    <xs:field xpath="@ISBN"/>
  </xs:key>
</xs:element>
```

- ❖ Under any **bibliography** element, elements reachable by selector “./book” (i.e., book child elements) must have unique values for field “@ISBN” (i.e., ISBN attributes)
  - In general, a key can consist of multiple fields (multiple `<xs:field>` elements under `<xs:key>`)
  - More on XPath in next lecture

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## Foreign keys

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- ❖ Suppose content can reference books

```
<xs:element name="content">
  <xs:complexType mixed="true">
    <xs:choice minOccurs="0" maxOccurs="unbounded">
      <xs:element name="i" type="xs:string"/>
      <xs:element name="b" type="xs:string"/>
      <xs:element name="book-ref">
        <xs:complexType>
          <xs:attribute name="ISBN" type="xs:string"/>
        </xs:complexType>
      </xs:element>
    </xs:choice>
  </xs:complexType>
</xs:element>

<xs:element name="bibliography">
  <xs:complexType base="xs:complexType" />
  <xs:key name="bookKey">
    <xs:selector xpath="./book"/>
    <xs:field xpath="@ISBN"/>
  </xs:key>
  <xs:keyref name="bookForeignKey" refer="bookKey">
    <xs:selector xpath="./book-ref"/>
    <xs:field xpath="@ISBN"/>
  </xs:keyref>
</xs:element>
```

- ❖ Under any **bibliography** element, for elements reachable by selector “./book-ref” (i.e., any book-ref element underneath), values for field “@ISBN” (i.e., ISBN attributes) must appear as values of **bookKey**, the key being referred to
  - Make sure keyref is declared in the same scope as the key it refers to

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## Why use DTD or XML Schema?

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- ❖ Benefits of not using them
  - Unstructured data is easy to represent
  - Overhead of validation is avoided
- ❖ Benefits of using them

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## XML versus relational data

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### Relational data

- ❖ Schema is always fixed in advance and difficult to change
- ❖ Simple, flat table structures
- ❖ Ordering of rows and columns is unimportant
- ❖ Data exchange is problematic
- ❖ "Native" support in all serious commercial DBMS

### XML data

- ❖ Well-formed XML does not require predefined, fixed schema
- ❖ Nested structure; ID/IDREF(S) permit arbitrary graphs
- ❖ Ordering forced by document format; may or may not be important
- ❖ Designed for easy exchange
- ❖ Often implemented as an "add-on" on top of relations

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## Case study

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- ❖ Design an XML document representing cities, counties, and states
  - For states, record name and capital (city)
  - For counties, record name, area, and location (state)
  - For cities, record name, population, and location (county and state)
- ❖ Assume the following:
  - Names of states are unique
  - Names of counties are only unique within a state
  - Names of cities are only unique within a county
  - A city is always located in a single county
  - A county is always located in a single state

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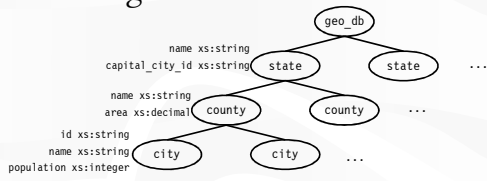
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## A possible design

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Declare `stateKey` in `geo_db` with

- Selector `./state`
- Field `@name`

Declare `countyInStateKey` in `state` with

- Selector `./county`
- Field `@name`

Declare `cityInCountyKey` in `county` with

- Selector `./city`
- Field `@name`

Declare `cityIdKey` in `geo_db` with

- Selector `./state/county/city`
- Field `@id`

Declare `capitalCityIdKeyRef` in `geo_db` referencing `cityIdKey`, with

- Selector `./state`
- Field `@capital_city_id`

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