CSE 180, Database Systems I

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Lecture 12

Chapter 8.1: XML and JSON Semi-Structured Data

(much material not in book)

Database System Concepts, 7th Ed.

Important Notices

CSE 180 Final Exam is on **Thursday March 19, 4:00 – 7:00pm**, but **it will be given via Canvas, so you must have web access**.

- A Piazza post this weekend will explainihow Canvas will be used for Final.
- **No** early/late Finals. **No** make-up Finals. **No** devices (except to take exam).
- Includes a Multiple Choice Part, and two Long Answers Parts, with time limits.
  - Red Scantron sheets are not required, since you're submitting solution via Canvas.
- Covers entire quarter, with slightly greater emphasis on second half of quarter.
- **During the Final, you may view Lecture slides and Lab Assignment solutions, plus one double-sided 8.5 x 11 sheet (with anything that you want written or printed on it), but you must not do any web searches or receive assistance from anyone else during the Final.**
  - **Your agreement to Academic Integrity terms is required before the Final!**
- Practice Final from Fall 2019 (2 Sections) was posted on Piazza under Resources→Exams on Sunday, March 1.
  - Solution has also been posted on Piazza… but take it yourself first, rather than just reading the solution.
- See Piazza notice @194 about Final, which has reminder about Course Grading.
  - After the class ends, your course score will be determined by your scores on Gradiance, Lab Assignments and Exams.
  - **You won't be able to do any additional work afterwards to improve your grade.**

Important Notices

- Lab3 grades have been unmuted.
  - Deadline for questions about Lab3 was **Thursday, March 12**.
- Lab4 solution has been posted on Piazza.
- Gradiance #5 is due **Saturday, March 14** by 11:59pm.
- Attend Lectures, Lab Sections, Office Hours and LSS Tutoring.
  - Most sessions will be held via Zoom; see Piazza notices.
  - See Piazza notices about LSS Tutoring with Jeshwanth Bheemanpally.
- Winter 2020 Student Experience of Teaching Surveys - SETs are open.
  - SETs close on Sunday March 15 at 11:59pm.
  - Instructors **are not** able to identify individual responses.
  - Constructive responses help improve future courses.

Semi-Structured Data Models

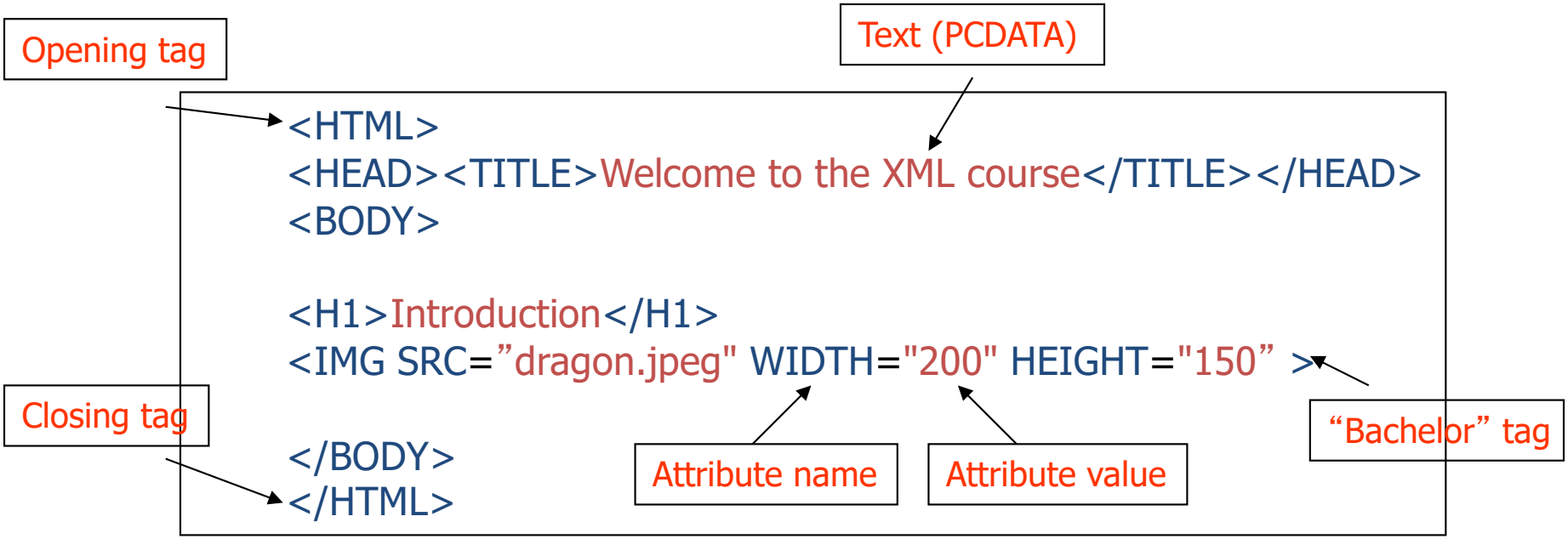
- In the relational database management system, a schema must be defined *before* data can be stored.
  - Schema is known to the query processor.
  - Exploited to derive efficient implementations to access and update data.
- In a semi-structured data model (e.g., XML and JSON), a schema need not be defined prior to "data creation".
  - Flexible data model as the schema need not be defined ahead of time, and there may not be a structured schema associated with the data.
  - Semi-structured data tends to be "self-describing".
  - Also tends to be hierarchical.
  - Non-First Normal Form

Semi-Structured Data

- Many applications require storage of complex data, whose schema changes often
- The relational model's requirement of atomic data types may be an overkill
  - E.g., storing set of interests as a set-valued attribute of a user profile may be simpler than normalizing it
- Data exchange can benefit greatly from semi-structured data
  - Exchange can be between applications, or between back-end and front-end of an application
  - Web-services are widely used today, with complex data fetched to the front-end and displayed using a mobile app or JavaScript
- JSON and XML are widely used semi-structured data models

HyperText Markup Language (HTML)

- Lingua franca for publishing hypertext on the World Wide Web.
- Designed to describe how a Web browser should arrange text, images and push-buttons on a page.
- Easy to learn, but does not convey structure.
- Fixed tag set.



The Structure of XML

- XML consists of *tags* and *text*

- Tags come in pairs <date> ...</date>

- They must be properly nested

<date> <day> ... </day> ... </date> --- good

<date> <day> ... </date>... </day> --- bad

(You can't do ... ... in HTML)

Well-Formed XML

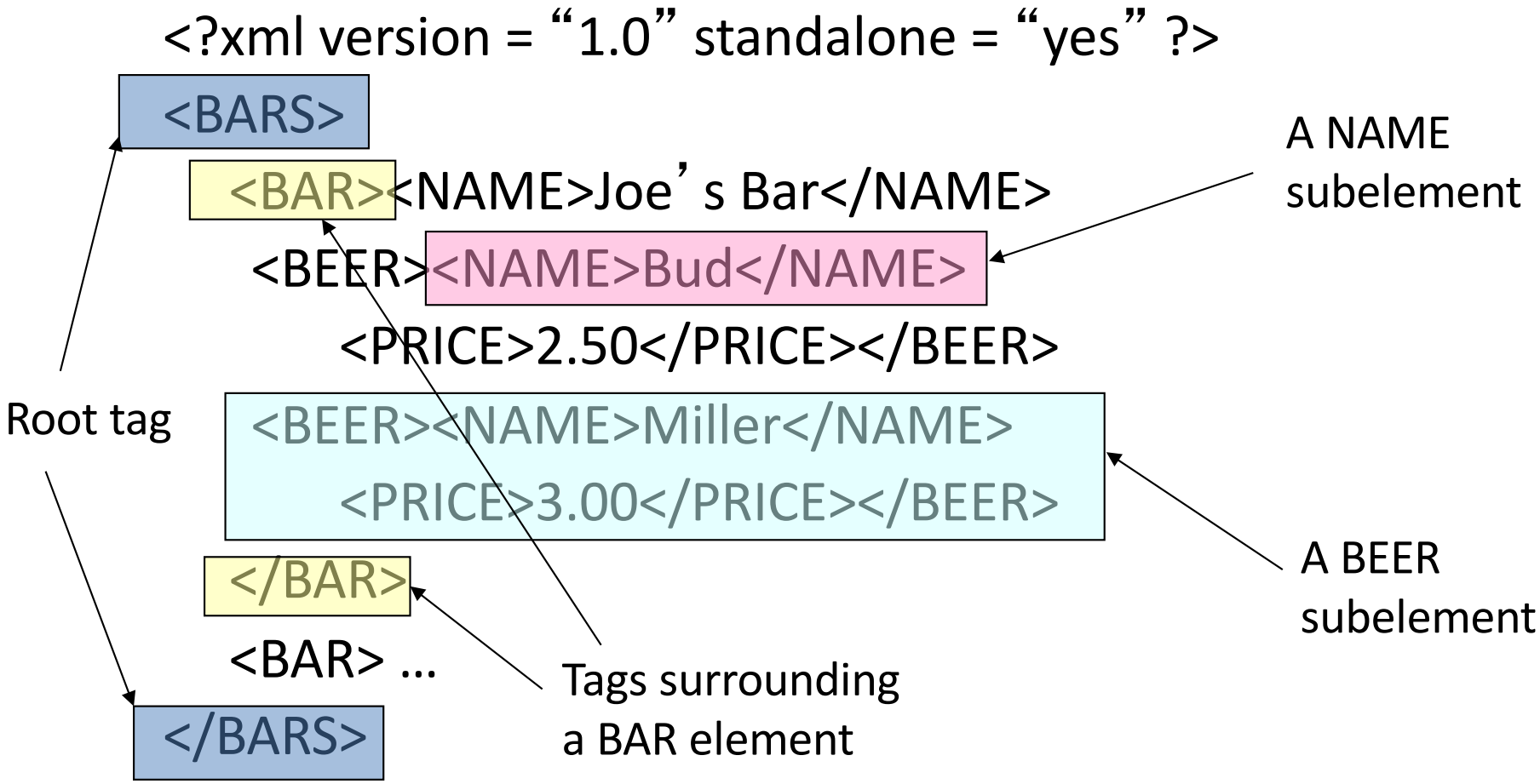
- Start the document with a *declaration*, surrounded by
  <?xml … ?> .
- Normal declaration is:
  <?xml version = ”1.0” standalone = ”yes” ?>
  - “standalone” = “no Data Type Definition (DTD) provided”

- The document starts with a *root tag* that surrounds nested tags.

<Tags>

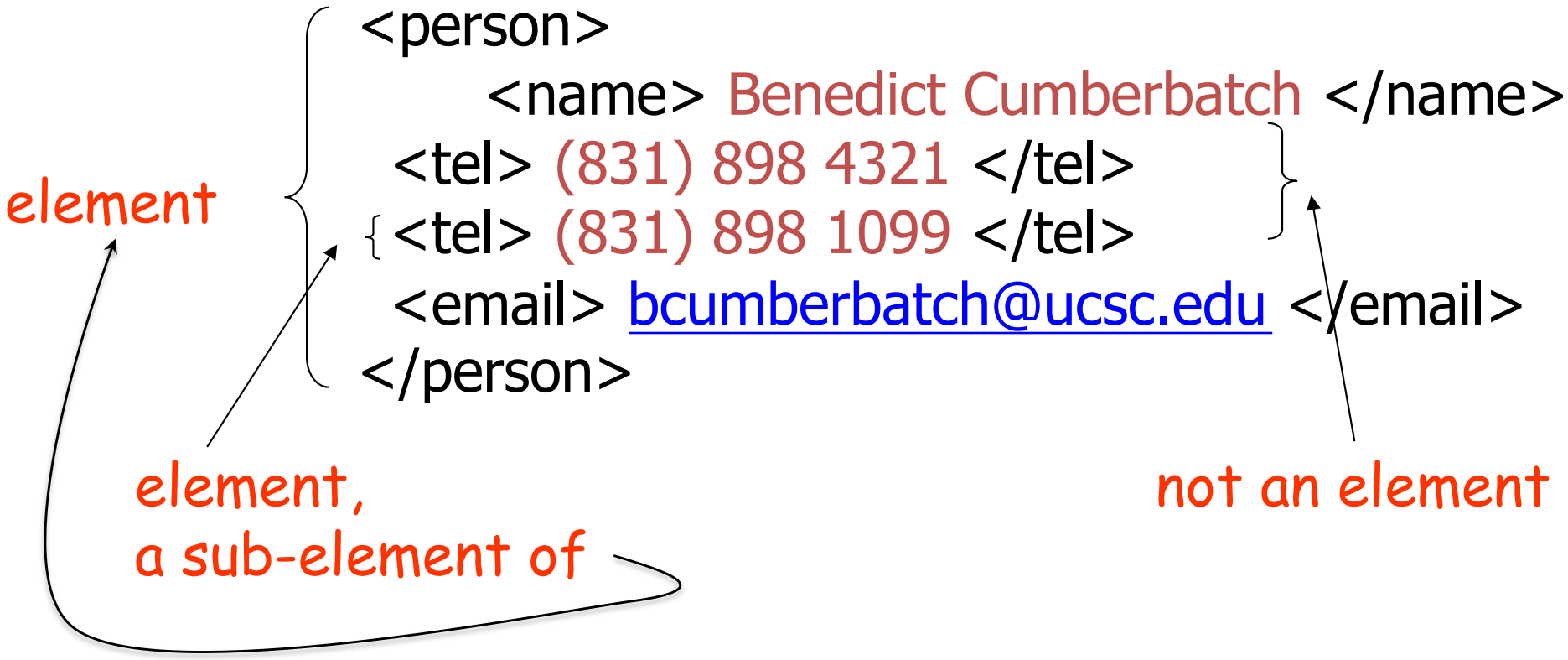
- Tags are normally matched pairs, as <FOO> … </FOO>.
- XML tags are case-sensitive.
  - E.g., <FOO> … </foo> does not match.
- Tags may be nested arbitrarily.
- XML has only one basic type, which is text.

Example: Well-Formed XML



More Terminology

- The segment of an XML document between an opening and a corresponding closing tag is called an *element*.



Using XML to Specify a Tuple

```
<person>
  <name> Benedict Cumberbatch</name>
  <tel> (831) 898 4321 </tel>
  <email> bcumberbatch@ucsc.edu </email>
</person>
```

Using XML to Specify a List

- We can represent a list by using the *same* tag repeatedly:

```
<addresses>
   <person> ... </person>
   <person> ... </person>
   <person> ... </person>
   ...
</addresses>
```

Example:
Two Ways of Representing a DB

projects:

title	budget	managedBy

employees:

name	ssn	age

Project and Employee Relations in XML

```
<db>
  <project>
    <title> Pattern recognition </title>
    <budget> 10000 </budget>
    <managedBy> Joe </managedBy>
  </project>
  <employee>
    <name> Joe </name>
    <ssn> 344556 </ssn>
    <age> 34 < /age>
  </employee>
  <employee>
    <name> Sandra </name>
    <ssn> 2234 </ssn>
    <age> 35 </age>
  </employee>
  <project>
    <title> Auto guided vehicle </title>
    <budget> 70000 </budget>
    <managedBy> Sandra </managedBy>
  </project>
  :
</db>
```

Way 1: Projects and employees are intermixed.

Project and Employee Relations in XML (cont'd)

```
<db>
   <projects>
     <project>
          <title> Pattern recognition </title>
          <budget> 10000 </budget>
          <managedBy> Joe </managedBy>
     </project>
     <project>
          <title> Auto guided vehicles </title>
          <budget> 70000 </budget>
          <managedBy> Sandra </managedBy>
     </project>
    :
   </projects>
```

```
<employees>
  <employee>
     <name> Joe </name>
     <ssn> 344556 </ssn>
     <age> 34 </age>
  </employee>
  <employee>
     <name> Sandra </name>
     <ssn> 2234 </ssn>
     <age>35 </age>
  </employee>
 :
  </employees>
</db>
```

Way 2: Employees follow projects.

Attributes

- An (opening) tag may contain *attributes*. These are typically used to describe the content of an element.
- Attributes cannot be repeated within a tag.

```
<entry>
   <word language = “en”> cheese </word>
   <word language = “fr”> fromage </word>
   <word language = “ro”> branza </word>
   <meaning> A food made … </meaning>
</entry>
```

Attributes (cont'd)

- Another common use for attributes is to express dimension or type.

```
<picture>
   <height dim= "cm"> 2400 </height>
   <width dim= "in"> 96 </width>
   <data encoding = "gif" compression = "zip">
      M05-.+C$@02!G96YEFEC ...
   </data>
</picture>
```

- A document that obeys the "nested tags" rule and does not repeat an attribute within a tag is said to be *well-formed* .

Using IDs and IDRefs

```
<family>
    <person  id="jane" mother="mary" father="john">
        <name> Jane Doe </name>
    </person>
    <person id="john" children="jane jack">
        <name> John Doe </name>
    </person>
    <person id="mary" children="jane jack">
        <name> Mary Doe </name>
    </person>
        <person  id="jack" mother="mary" father="john">
        <name> Jack Doe </name>
    </person>
</family>
```

An Example

```
<db>
  <movie id="m1">
    <title>Waking Ned Divine</title>
    <director>Kirk Jones III</director>
    <cast idrefs="a1 a3"></cast>
    <budget>100,000</budget>
  </movie>
  <movie id="m2">
    <title>Dragonheart</title>
    <director>Rob Cohen</director>
    <cast idrefs="a2 a9 a21"></cast>
    <budget>110,000</budget>
  </movie>
  <movie id="m3">
    <title>Moondance</title>
    <director>Dagmar Hirtz</director>
    <cast idrefs="a1 a8"></cast>
    <budget>90,000</budget>
  </movie>
  :
  <actor id="a1">
    <name>David Kelly</name>
    <acted_In idrefs="m1 m3 m78" >
    </acted_In>
  </actor>
  <actor id="a2">
     <name>Sean Connery</name>
     <acted_In idrefs="m2 m9 m11">
     </acted_In>
     <age>68</age>
  </actor>
  <actor id="a3">
      <name>Ian Bannen</name>
      <acted_In idrefs="m1 m35">
      </acted_In>
  </actor>
   :
</db>
```

DTD Structure

<!DOCTYPE <root tag> [

    <!ELEMENT <name>(<components>)>

    . . . more elements . . .

]>

Document Type Descriptors

- Document Type Descriptors (DTDs) impose structure on an XML document, much like relation schemas impose a structure on relations.
- The DTD is just a *syntactic* specification.
  - Not a semantic specification

Example: Address Book

```
<person>
    <name> MacNiel, John </name>
    <greet> Dr. John MacNiel </greet>
    <addr>1234 Huron Street </addr>
    <addr> Rome, OH 98765 </addr>
    <tel> (321) 786 2543 </tel>
    <fax> (321) 786 2543 </fax>
    <tel> (321) 786 2543 </tel>
    <email> jm@abc.com </email>
</person>
```

Exactly one name

At most one greeting

As many address lines as needed (in order)

Mixed telephones and faxes

As many emails as needed

Specifying the Structure

The structure of a person entry can be specified by:

name, greet?, addr*, (tel | fax)*, email*

XML uses a form of Regular Expression (described later).

A DTD for Address Book

```
<!DOCTYPE addressbook [
  <!ELEMENT addressbook (person*)>
  <!ELEMENT person
      (name, greet?, address*, (fax | tel)*, email*)>
  <!ELEMENT name      (#PCDATA)>
  <!ELEMENT greet     (#PCDATA)>
  <!ELEMENT address   (#PCDATA)>
  <!ELEMENT tel       (#PCDATA)>
  <!ELEMENT fax       (#PCDATA)>
  <!ELEMENT email     (#PCDATA)>
]>
```

"Parsed Character Data" (i.e., text)

Our Relational DB Revisited

projects:

title	budget	managedBy

employees:

name	ssn	age

Two Potential DTDs for that Relational DB

```
<!DOCTYPE db [
   <!ELEMENT db           (projects, employees)>
   <!ELEMENT projects     (project*)>
   <!ELEMENT employees (employee*)>
  <!ELEMENT  project      (title, budget, managedBy)>
   <!ELEMENT employee   (name, ssn, age)>
   ...
]>
```

```
 <!DOCTYPE db [
    <!ELEMENT db          (project | employee)*>
    <!ELEMENT project     (title, budget, managedBy)>
    <!ELEMENT employee (name, ssn, age)>
    ...
 ]>
```

Summary of XML Regular Expressions

- A The tag A occurs
- e1,e2 The expression e1 followed by e2
- e* 0 or more occurrences of e
- e? Optional -- 0 or 1 occurrences
- e+ 1 or more occurrences
- e1 | e2 either e1 or e2
- (e) grouping, e.g.,
  <!ELEMENT Address Street, (City | Zip)>

Specifying Attributes in the DTD

- Bars can have an attribute `kind`, a character string describing the bar.

```
<!ELEMENT BAR (NAME, BEER*)>
   <!ATTLIST BAR kind CDATA #IMPLIED>
```

Character string type; no tags

Attribute is optional, as opposed to: #REQUIRED

Example of Attribute Use

- In a document that allows BAR tags, we might see:

```
<BAR kind = ”sushi”>
   <NAME>Homma’s</NAME>
   <BEER><NAME>Sapporo</NAME>
       <PRICE>5.00</PRICE></BEER>
   ...
</BAR>
```

Specifying ID and IDREF Attributes in a DTD

```
<!DOCTYPE family [
  <!ELEMENT family   (person)*>
  <!ELEMENT person  (name)>
  <!ELEMENT name    (#PCDATA)>
  <!ATTLIST person
            id          ID       #REQUIRED
            mother   IDREF   #IMPLIED
            father    IDREF   #IMPLIED
            children  IDREFS  #IMPLIED>
]>
```

id is an ID attribute

An XML Document That Conforms to the DTD

```
<family>
    <person  id="jane"  mother="mary" father="john">
        <name> Jane Doe </name>
    </person>
    <person id="john" children="jane jack">
        <name> John Doe </name>
    </person>
    <person id="mary" children="jane  jack">
        <name> Mary Doe </name>
    </person>
        <person  id="jack"  mother=”mary" father="john">
        <name> Jack Doe </name>
    </person>
</family>
```

Consistency of ID and IDREF Attribute Values

- ID stands for identifier. The values across all IDs must be distinct.
- IDREF stands for identifier reference. If an attribute is declared as IDREF, then …
  - the associated value must exist as the value of some ID attribute (i.e., no dangling "pointers").
- IDREFS specifies "several" (0 or more) identifiers.
- IDREFs are a lot like Foreign Keys … except that IDREFs don't have data types!

movieschema.dtd

```
<!DOCTYPE db [
  <!ELEMENT   db       (movie+, actor+)>
  <!ELEMENT   movie    (title, director, cast, budget)>
    <!ATTLIST          movie  id  ID  #REQUIRED>
  <!ELEMENT   title    (#PCDATA)>
  <!ELEMENT   director (#PCDATA)>
  <!ELEMENT   cast     EMPTY>
    <!ATTLIST cast     idrefs  IDREFS  #REQUIRED>
  <!ELEMENT   budget   (#PCDATA)>
```

movieschema.dtd (cont'd)

```
  <!ELEMENT   actor      (name, acted_In, age?, directed*)>
  <!ATTLIST   actor      id      ID       #REQUIRED>
  <!ELEMENT   name       (#PCDATA)>
  <!ELEMENT   acted_In   EMPTY>
     <!ATTLIST  acted_In        idrefs   IDREFS  #REQUIRED>
  <!ELEMENT   age        (#PCDATA)>
  <!ELEMENT   directed   (#PCDATA)>
]>
```

Connecting the Document with its DTD

- In line:

```
<?xml version="1.0"?>
<!DOCTYPE db [<!ELEMENT ...> … ]>
<db> ... </db>
```

Includes everything from movieschema.dtd

- Another file:

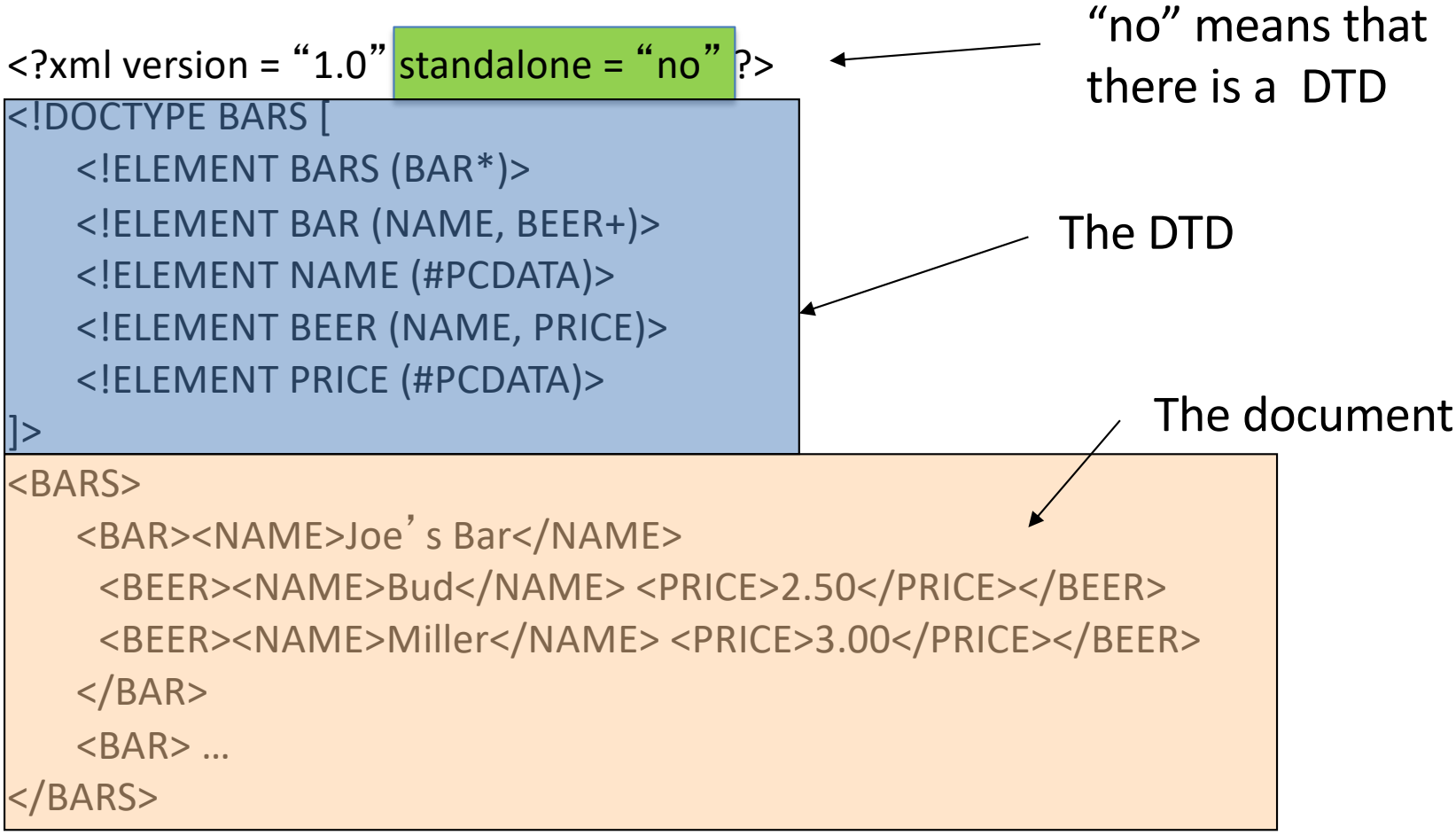
```
<!DOCTYPE db SYSTEM ”movieschema.dtd">
```

Note word SYSTEM

- A URL:

```
<!DOCTYPE db SYSTEM
        "http://www.schemaauthority.com/movieschema.dtd">
```

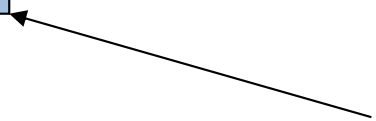
First Example



Second Example

- Assume the BARS DTD is in file bar.dtd.

```
<?xml version = "1.0" standalone = "no" ?>
<!DOCTYPE BARS SYSTEM "bar.dtd">
<BARS>
    <BAR><NAME>Joe's Bar</NAME>
     <BEER><NAME>Bud</NAME>
          <PRICE>2.50</PRICE></BEER>
     <BEER><NAME>Miller</NAME>
          <PRICE>3.00</PRICE></BEER>
    </BAR>
    <BAR> …
</BARS>
```



Get the DTD from the file bar.dtd

Well-Formed and Valid Documents

- We say that an XML document is *well-formed* if the document (with or without an associated DTD) has proper nesting of tags and the attributes of every element are all unique.

- We say that an XML document x is *valid* with respect to a DTD D if x conforms to D. That is, if the document x conforms to the regular expression grammar and constraints given by D.

DTDs versus Schemas (or Types)

- By database (or programming language) standards DTDs are rather weak specifications.
  - Only one base type -- PCDATA
  - No useful "abstractions" e.g., no sets
  - IDREFs are untyped. They allow you to reference something, but you don't know what!
  - Few constraints. E.g., "Local keys" as opposed to global IDs.
  - Tag definitions are *global.*

- XML Schema:
  - An extension of DTDs that allows one to impose a schema or type on an XML document.

XML Schema

- A more powerful way to describe the structure of XML documents.

- XML-Schema declarations are themselves XML documents.
  - They describe “elements” and the things doing the describing are also “elements”.

- See Chapter 30 of Silberschatz (online) for more information.

Query Languages for XML

- XPath: Language for navigating through an XML document.
- XQuery: Query language for XML, similar in power to SQL.
- XSLT: Language for extracting information from an XML document and transforming it.
- See Chapter 30 of Silberschatz (online) for more information.

SQL Extension to Support XML

- SQL extensions to support XML
  - Store XML data
  - Generate XML data from relational data
  - Extract data from XML data types
    - Path expressions
- See Chapter 30 of Silberschatz (online) for more information

JSON: The Basics

Jeff Fox
@jfox015

Built in Fairfield County:
Front End Developers Meetup
Tues. May 14, 2013

What is JSON?

JSON is…

- A lightweight text based data-interchange format
- Completely language independent
- Based on a subset of the JavaScript Programming Language
- Easy to understand, manipulate and generate

JSON is NOT…

- Overly Complex
- A “document” format
- A markup language
- A programming language

Why use JSON?

- Straightforward syntax
- Easy to create and manipulate
- Can be natively parsed in JavaScript using **eval()**
- Supported by all major JavaScript frameworks
- Supported by most backend technologies

JSON vs. XML

Much Like XML

- Plain text formats
- “Self-describing“ (human readable)
- Hierarchical (Values can contain lists of objects or values)

Not Like XML

- Lighter and faster than XML
- JSON uses typed objects. All XML values are type-less strings and must be parsed at runtime.
- Less syntax, no semantics
- Properties are immediately accessible to JavaScript code

Knocks against JSON

- Lack of namespaces
- No inherent validation (XML has DTD and templates, but there is JSONlint)
- Not extensible
- It’s basically just ***not*** XML

Syntax

JSON Object Syntax

- Unordered sets of name/value pairs
- Begins with **{** (left brace)
- Ends with **}** (right brace)
- Each name is followed by **:** (colon)
- Name/value pairs are separated by **,** (comma)

JSON Example

```
var employeeData = {
  "employee_id": 1234567,
  "name": "Jeff Fox",
  "hire_date": "1/1/2013",
  "location": "Norwalk, CT",
  "consultant": false
};
```

Arrays in JSON

- An ordered collection of values
- Begins with [(left bracket)
- Ends with] (right bracket)
- Name/value pairs are separated by , (comma)

JSON Array Example

```
var employeeData = {
  "employee_id": 1236937,
  "name": "Jeff Fox",
  "hire_date": "1/1/2013",
  "location": "Norwalk, CT",
  "consultant": false,
   "random_nums": [ 24,65,12,94 ]
};
```

Data Types

Data Types: Strings

- Sequence of zero or more Unicode characters
- Wrapped in "double quotes"
- Backslash escapement

Data Types: Numbers

- Integer
- Real
- Scientific
- No octal or hex
- No NaN (Not a Number) or Infinity – Use **null** instead.

Let's end with an example JSON

```
{     "firstName": "John",
      "lastName": "Smith",
      "age": 25,
      "address":     {
             "streetAddress": "21 2nd Street",
             "city": "New York",
             "state": "NY",
             "postalCode": "10021"
             },
      "phoneNumber": [
                 {
                 "type": "home",
                 "number": "212 555-1234"
                 },
                 {
                 "type": "fax",
                 "number": "646 555-4567"
                 }
             ]
}
```

The same Example in XML

```
<Object>
<Property><Key>firstName</Key> <String>John</String></Property>
<Property><Key>lastName</Key> <String>Smith</String></Property>
<Property><Key>age</Key> <Number>25</Number></Property>
<Property><Key>address</Key> <Object> <Property><Key>streetAddress</Key>
<String>21 2nd Street</String></Property>
<Property><Key>city</Key> <String>New York</String></Property>
<Property><Key>state</Key> <String>NY</String></Property>
<Property><Key>postalCode</Key> <String>10021</String></Property>
</Object>
</Property> <Property><Key>phoneNumber</Key>
<Array> <Object> <Property><Key>type</Key> <String>home</String></Property>
<Property><Key>number</Key> <String>212 555-1234</String></Property></Object>
<Object>
<Property><Key>type</Key> <String>fax</String></Property> <Property><Key>number</
Key> <String>646 555-4567</String></Property> </Object> </Array>
</Property>
</Object>
```

Where is JSON used today?

- Anywhere and everywhere **(even in 2013, much more now)**!








And many, many more!

Some Resources

- Simple Demo on Github: https://github.com/jfox015/BIFC-Simple-JSON-Demo
- Another JSON Tutorial: http://iviewsource.com/codingtutorials/getting-started-with-javascript-object-notation-json-for-absolute-beginners/
- JSON.org: http://www.json.org/

JSON

- JSON is ubiquitous in data exchange today
  - Widely used for web services
  - Most modern applications are architected around on web services
- SQL extensions for
  - JSON types for storing JSON data
  - Extracting data from JSON objects using path expressions
    - E.g. *V-> ID*, or *v.ID*
  - Generating JSON from relational data
    - E.g. json.build_object('ID', 12345, 'name', 'Einstein')
  - Creation of JSON collections using aggregation
    - E.g. json_agg aggregate function in PostgreSQL
  - Syntax varies greatly across databases
- JSON is verbose
  - Compressed representations such as BSON (Binary JSON) used for efficient data storage

Web Services

- Allow data on Web to be accessed using remote procedure call mechanism.
- Two approaches are widely used:
  - **Representation State Transfer (REST)**: allows use of standard HTTP request to a URL to execute a request and return data.
    - Returned data is encoded either in XML, or in **JavaScript Object Notation (JSON).**
  - **Big Web Services**:
    - Uses XML representation for sending request data, as well as for returning results.
    - Standard protocol layer built on top of HTTP.
    - See Section 23.7.3