Introduction to Semistructured Data and XML

Based on slides by Dan Suciu
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Overview

- From HTML to XML
- DTDs
- Querying XML: XPath
- Transforming XML: XSLT

How the Web is Today

- HTML documents
  - often generated by applications
  - consumed by humans only
  - easy access: across platforms, across organizations
- No application interoperability:
  - HTML not understood by applications
    - screen scraping brittle
  - Database technology: client-server
    - still vendor specific

New Universal Data Exchange Format: XML

A recommendation from the W3C

- XML = data
- XML generated by applications
- XML consumed by applications
- Easy access: across platforms, organizations

Paradigm Shift on the Web

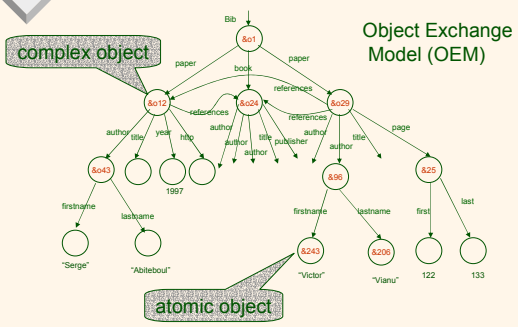
- From documents (HTML) to data (XML)
- From information retrieval to data management
- For databases, also a paradigm shift:
  - from relational model to semistructured data
  - from data processing to data/query translation
  - from storage to transport

Semistructured Data

Origins:

- Integration of heterogeneous sources
- Data sources with non-rigid structure
  - Biological data
  - *Web data*

The Semistructured Data Model



Syntax for Semistructured Data

```
Bib: &o1 { paper: &o12 { … },
           book:  &o24 { … },
           paper: &o29
                { author: &o52 "Abiteboul",
                  author: &o96 { firstname: &243 "Victor",
                                 lastname: &o206 "Vianu"},
                  title: &o93 "Regular path queries with constraints",
                  references: &o12,
                  references: &o24,
                  pages: &o25 { first: &o64 122, last: &o92 133}
                }
         }
```

Observe: Nested tuples, set-values, oids!

Syntax for Semistructured Data

May omit oids:

```
 { paper: { author: "Abiteboul",
            author: { firstname: "Victor",
                      lastname: "Vianu"},
            title: "Regular path queries …",
            page: { first: 122, last: 133 }
          }
 }
```

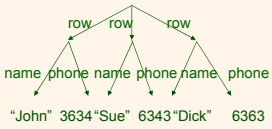
Characteristics of Semistructured Data

- Missing or additional attributes
- Multiple attributes
- Different types in different objects
- Heterogeneous collections

Self-describing, irregular data, no a priori structure

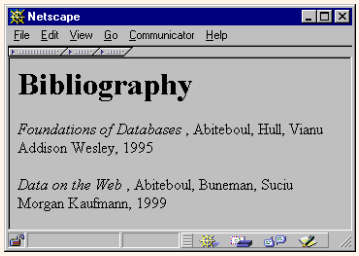
Comparison with Relational Data

name	phone
John	3634
Sue	6343
Dick	6363



{ row: { name: "John", phone: 3634 },
  row: { name: "Sue", phone: 6343 },
  row: { name: "Dick", phone: 6363 }
}

From HTML to XML



HTML describes the presentation

HTML

<h1> Bibliography </h1>
<p> Foundations of Databases
Abiteboul, Hull, Vianu

 Addison Wesley, 1995
<p> Data on the Web
Abiteoul, Buneman, Suciu

 Morgan Kaufmann, 1999

XML

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

XML describes the content

XML

- A W3C standard to complement HTML
- Origins: Structured text SGML
- Motivation:
  - HTML describes presentation
  - XML describes content
- http://www.w3.org/TR/2000/REC-xml-20001006 (version 2, 10/2000)

$$\text{HTML4.0} \in \text{XML} \subset \text{SGML}$$

XML Terminology

- Tags: book, title, author, …
  - start tag: <book>, end tag: </book>
- Elements:
  <book>…<book>,<author>…</author>
  - elements can be nested
  - empty element: <red></red> (Can be abbrv. <red/>)
- XML document: Has a single root element
- Well-formed XML document: Has matching tags

More XML: Attributes

```
<book price = "55" currency = "USD">
  <title> Foundations of Databases </title>
  <author> Abiteboul </author>
  …
  <year> 1995 </year>
</book>
```

Attributes are alternative ways to represent data

More XML: Oids and References

```
<person id="o555"> <name> Jane </name> </person>

<person id="o456"> <name> Mary </name>
                   <children idref="o123 o555"/>
</person>

<person id="o123" mother="o456"><name>John</name>
</person>
```

oids and references in XML are just syntax

More XML: CDATA Section

- Syntax: <![CDATA[.....any text here...]]>
- Example:

```
<example>
   <![CDATA[ some text here </notAtag> <>]]>
</example>
```


More XML: Entity References

- Syntax: &entityname;
- Example:
  <element> this is less than < </element>
- Some entities:

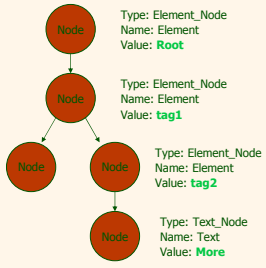
<	<
>	>
&	&
'	'
"	"
&	Unicode char

Xml – Storage

- Storage is done just like an n-ary tree (DOM)

```
<root>
   <tag1>
      Some Text
      <tag2>More</tag2>
   </tag1>
</root>
```

Type: Text_Node
Name: Text
Value: **Some Text**



Xml vs. Relational Model

Computer Table

Id	*Speed*	*RAM*	*HD*
101	800Mhz	256MB	40GB
102	933Mhz	512MB	40GB

```
<Table>
  <Computer Id='101'>
    <Speed>800Mhz</Speed>
    <RAM>256MB</RAM>
    <HD>40GB</HD>
  </Computer>
  <Computer Id='102'>
    <Speed>933Mhz</Speed>
    <RAM>512MB</RAM>
    <HD>40GB</HD>
  </Computer>
</Table>
```


Overview

- From HTML to XML
- DTDs

Document Type Descriptors

- Sort of like a schema but not really.

```
<!ELEMENT Book (title, author*) >

<!ELEMENT title #PCDATA>
<!ELEMENT author (name, address,age?)>

<!ATTLIST Book id ID #REQUIRED>
<!ATTLIST Book pub IDREF #IMPLIED>
```

- Inherited from SGML DTD standard
- BNF grammar establishing constraints on element structure and content
- Definitions of entities

DTD – An Example

```
<?xml version='1.0'?>
<!ELEMENT Basket (Cherry+, (Apple | Orange)*) >
    <!ELEMENT Cherry EMPTY>
        <!ATTLIST Cherry flavor CDATA #REQUIRED>
    <!ELEMENT Apple EMPTY>
        <!ATTLIST Apple color CDATA #REQUIRED>
    <!ELEMENT Orange EMPTY>
        <!ATTLIST Orange location 'Florida'>
```

```
<Basket>
  <Cherry flavor='good'/>
  <Apple color='red'/>
  <Apple color='green'/>
</Basket>
```

```
<Basket>
  <Apple/>
  <Cherry flavor='good'/>
  <Orange/>
</Basket>
```


DTD - !ELEMENT

```
<!ELEMENT Basket (Cherry+, (Apple | Orange)*) >
```

Name — Children

- !ELEMENT declares an element name, and what children elements it should have
- Wildcards:
  - * Zero or more
  - + One or more

DTD - !ATTLIST

```
<!ATTLIST Cherry flavor CDATA #REQUIRED>
<!ATTLIST Orange location CDATA #REQUIRED
                color 'orange'>
```

Element — Attribute — Type — Flag

- !ATTLIST defines a list of attributes for an element
- Attributes can be of different types, can be required or not required, and they can have default values.

Attributes in DTDs

Types:

- CDATA = string
- ID = key
- IDREF = foreign key
- IDREFS = foreign keys separated by space
- (Monday | Wednesday | Friday) = enumeration
- NMTOKEN = must be a valid XML name
- NMTOKENS = multiple valid XML names
- ENTITY = you don't want to know this

Attributes in DTDs

Kind:

- #REQUIRED
- #IMPLIED = optional
- value = default value
- value #FIXED = the only value allowed

Using DTDs

- Must include in the XML document
- Either include the entire DTD:
  - <!DOCTYPE rootElement [.....]>
- Or include a reference to it:
  - <!DOCTYPE rootElement SYSTEM "http://www.mydtd.org">
- Or mix the two... (e.g. to override the external definition)

DTD –Well-Formed and Valid

```
<?xml version='1.0'?>
<!ELEMENT Basket (Cherry+)>
    <!ELEMENT Cherry EMPTY>
        <!ATTLIST Cherry flavor CDATA #REQUIRED>
```

Not Well-Formed

```
<basket>
  <Cherry flavor=good>
</Basket>
```

Well-Formed but Invalid

```
<Job>
  <Location>Home</Location>
</Job>
```

Well-Formed and Valid

```
<Basket>
  <Cherry flavor='good'/>
</Basket>
```


DTDs as Grammars

```
<!DOCTYPE paper [
  <!ELEMENT paper   (section*)>
  <!ELEMENT section ((title,section*) | text)>
  <!ELEMENT title     (#PCDATA)>
  <!ELEMENT text      (#PCDATA)>
]>
```

```
<paper> <section> <text> </text> </section>
        <section> <title> </title> <section> … </section>
                                   <section> … </section>
        </section>
</paper>
```


DTDs as Grammars

- A DTD = a grammar
- A valid XML document = a parse tree for that grammar

DTDs as Schemas

Not so well suited:

- impose unwanted constraints on order
  <!ELEMENT person (name,phone)>
- references cannot be constrained
- can be too vague:
  <!ELEMENT person ((name | phone | email)*)>

like an upper bound schema

Shortcomings of DTDs

Useful for documents, but not so good for data:

- No support for structural re-use
  - Object-oriented-like structures aren't supported
- No support for data types
  - Can't do data validation
- Can have a *single* key item (ID), but:
  - No support for multi-attribute keys
  - No support for foreign keys (references to other keys)
  - No constraints on IDREFs (reference *only* a Section)

XML Schema

- In XML format
- Includes primitive data types (integers, strings, dates, etc.)
- Supports value-based constraints (integers > 100)
- User-definable structured types
- Inheritance (extension or restriction)
- Foreign keys
- Element-type reference constraints

Sample XML Schema

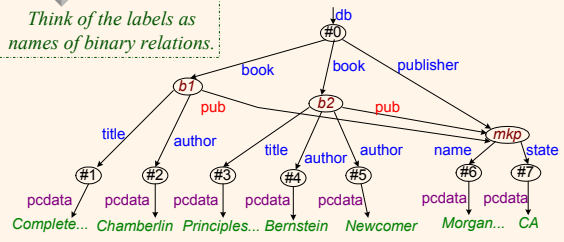
```
<schema version="1.0" xmlns="http://www.w3.org/1999/XMLSchema">
<element name="author" type="string" />
<element name="date" type = "date" />
<element name="abstract">
  <type>
    …
  </type>
</element>
<element name="paper">
  <type>
    <attribute name="keywords" type="string"/>
    <element ref="author" minOccurs="0" maxOccurs="*" />
    <element ref="date" />
    <element ref="abstract" minOccurs="0" maxOccurs="1" />
    <element ref="body" />
  </type>
</element>
</schema>
```


Important XML Standards

- XSL/XSLT: presentation and transformation standards
- RDF: resource description framework (meta info such as ratings, categorizations, etc.)
- Xpath/Xpointer/Xlink: standard for linking to documents and elements within
- Namespaces: for resolving name clashes
- DOM: Document Object Model for manipulating XML documents
- SAX: Simple API for XML parsing

XML Data Model (Graph)

Think of the labels as names of binary relations.



Issues:

- Distinguish between attributes and sub-elements?
- Should we conserve order?

XML vs. Semistructured Data

- Both described best by a graph
- Both are schema-less, self-describing
- XML is ordered, ssd is not
- XML can mix text and elements:

```
<talk> Making Java easier to type and easier to type
        <speaker> Phil Wadler </speaker>
</talk>
```

- XML has lots of other stuff: entities, processing instructions, comments

What about XML queries?

- Xpath
  - A single-document language for "path expressions"
    - Not unlike regular expressions on tags
    - E.g. /Contract/*/UnitPrice, /Contract//UnitPrice, etc.
- XSLT
  - XPath plus a language for formatting output
- XQuery (next lecture)