Introduction to Semistructured Data and XML

Chapter 27, Part D
Based on slides by Dan Suciu
University of Washington

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

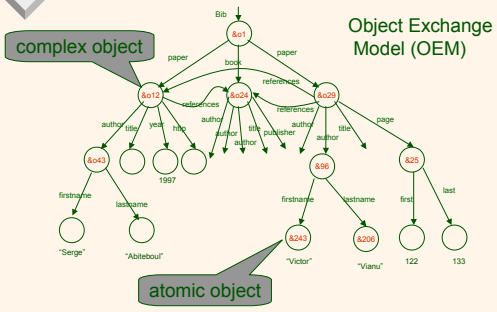
- From documents (HTML) to data (XML)
- From information retrieval to data management
- For databases, also a paradigm shift:
  - from relational model to semistructured data
  - from data processing to data/query translation
  - from storage to transport

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 }
         }
}
```

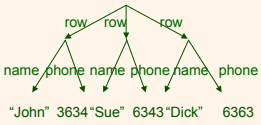

Characteristics of Semistructured Data

- 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 }
}

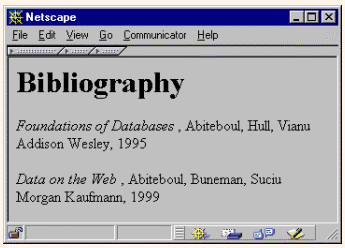
XML

- A W3C standard to complement HTML
- Origins: Structured text SGML
  - Large-scale electronic publishing
  - Data exchange on the web
- Motivation:
  - HTML describes presentation
  - XML describes content

HTML 4.0 ∈ XML ⊂ SGML

- http://www.w3.org/TR/2000/REC-xml-20001006 (version 2, 10/2000)

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
Abiteboul, 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

Why are we DB'ers interested?

- It's data, stupid. That's us.
- Proof by Google:
  - database+XML – 1,940,000 pages.
- Database issues:
  - How are we going to model XML? (graphs).
  - How are we going to query XML? (XQuery)
  - How are we going to store XML (in a relational database? object-oriented? native?)
  - How are we going to process XML efficiently? (many interesting research questions!)

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

Shortcomings of DTDs

Useful for documents, but not so good for data:

- Element name and type are associated globally
- 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
- Element names and types associated locally
- 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

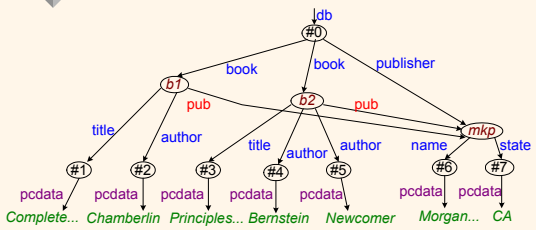
Sample XML Schema

```
<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
- XQuery: query language

XML Data Model (Graph)



Issues:

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

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
- Valid XML document: conforms to a schema

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

XML-Query Data Model

- Describes XML data as a tree
- Node ::= DocNode |
  ElemNode |
  ValueNode |
  AttrNode |
  NSNode |
  PINode |
  CommentNode |
  InfoItemNode |
  RefNode

http://www.w3.org/TR/query-datamodel/2/2001

XML-Query Data Model

Element node (simplified definition):

- elemNode : (QNameValue,
  {AttrNode },
  [ElemNode | ValueNode])
  → ElemNode
- QNameValue = means "a tag name"

Reads: "Give me a tag, a set of attributes, a list of elements/values, and I will return an element"

XML Query Data Model

Example:

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

```
book1= elemNode(book,
  {price2, currency3},
  [title4,
   author5,
   author6,
   author7,
   year8])
price2 = attrNode(…)   /* next */
currency3 = attrNode(…)
title4 = elemNode(title, string9)
…
```

XML Query Data Model

Attribute node:

- attrNode : (QNameValue, ValueNode) → AttrNode

XML Query Data Model

Example:

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

```
price2 = attrNode(price,string10)
string10 = valueNode(…)  /* next */
currency3 = attrNode(currency,
                     string11)
string11 = valueNode(…)
```


XML Query Data Model

Value node:

- ValueNode = StringValue | BoolValue | FloatValue …

- stringValue : string → StringValue
- boolValue : boolean → BoolValue
- floatValue : float → FloatValue

XML Query Data Model

Example:

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

```
price2 = attrNode(price,string10)
string10 = valueNode(stringValue("55"))
currency3 = attrNode(currency, string11)
string11 = valueNode(stringValue("USD"))

title4 = elemNode(title, string9)
string9 =
valueNode(stringValue("Foundations…"))
```


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: attributes, entities, processing instructions, comments