Querying and Storing XML

Week 1
Introduction & course overview, XML basics
January 15-18, 2013

Key information

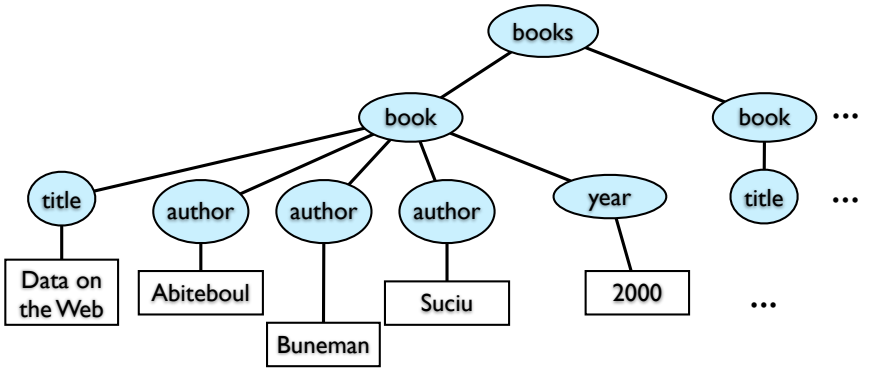
- Instructor: James Cheney, jcheney@inf.ed.ac.uk
- Lectures: 11:10-12:00, Tuesday/Friday
  - LT4, 7 Bristo Square
- Office Hours: (IF 5.29)
- TA: Clare Llewellyn, s1053147@sms.ed.ac.uk
- Webpage:
  - http://www.inf.ed.ac.uk/teaching/courses/qsx/
  - Weekly readings, project ideas/suggested readings

What is XML?

- eXtensible Markup Language [W3C 1998]
- Ask five different people, get five different answers...
  - a self-describing data format?
  - a generalization of HTML?
  - the future/past?
  - best thing since sliced bread/clunky and evil?
  - a metalanguage?
    - http://en.wikipedia.org/wiki/List_of_XML_markup_languages

In a nutshell:

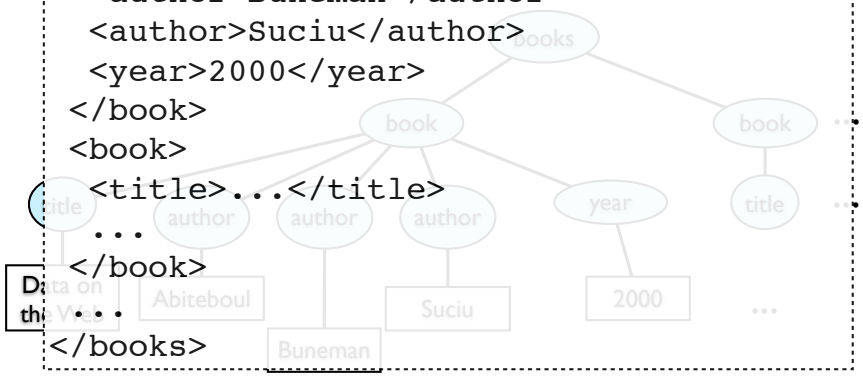
- A (meta)language for *semi-structured data* (trees)



In a nutshell:

- A (meta) language for *semi-structured data* (trees)

```
<?xml version="1.0"?>
<books>
 <book>
  <title>Data on the Web</title>
  <author>Abiteboul</author>
  <author>Buneman</author>
  <author>Suciu</author>
  <year>2000</year>
 </book>
 <book>
  <title>...</title>
  ...
 </book>
 ...
</books>
```



XML for markup/ documents

- SGML
- HTML - hypertext markup language
- TEI - Text markup, language technology
- DocBook - documents -> html, pdf, ...
- SMIL - Multimedia
- SVG - Vector graphics
- MathML - Mathematical formulas

XML for (semi-)structured data

- MusicXML
- NewsML
- iTunes
- DBLP http://dblp.uni-trier.de
- CIA World Factbook
- IMDB http://www.imdb.com/
- XBEL - bookmark files (in your browser)
- KML - geographical annotation (Google Maps)
- XACML - XML Access Control Markup Language

XML as an abstract syntax

- Many systems now use XML as a general-purpose syntax for other programming languages or configuration files...
  - Java servlet config (web.xml)
    - Apache Tomcat, Google App Engine, ...
  - Web Services - WSDL, SOAP, XML-RPC
  - XUL - XML User Interface Language (Mozilla/Firefox)
  - BPEL - Business process execution language
  - Other Web standards:
    - XSLT, XML Schema, XQueryX
    - RDF/XML
    - OWL - Web Ontology Language
    - MMI - Multimodal interaction (phone + car + PC)

XML tools

- Standalone:
  - xsltproc, mxquery, calabash (XProc)
- Most PLs have XML parsers; many have XSLT engines/ libraries also
  - SAX (streaming), DOM (in-memory) interfaces
  - libxml2, expat, libxslt (C)
  - Xerces, Xalan (Java)

- XPath (path expressions) used in many languages
  - JavaScript/JQuery
  - XSLT, XQuery

Native XML databases

- Offer native support for XML data & query languages (not building on existing RDBMS)
  - Galax
  - MarkLogic
  - eXist
  - BaseX
  - among others...

- Suitable for new or lightweight applications
  - but some lack features like transactions, views, updates

XML support in industry

- Most commercial RDBMSs now provide some XML support

  - Oracle 11g - XML DB

  - IBM DB2 pureXML

  - Microsoft SQL Server - XML support since 2005
    - Language Integrated Query (LINQ) targets SQL & XML in .NET programs
- Data publishing, exchange, integration problems are very important
  - big 3 have products for all of these
  - SQL/XML standard for defining XML views of relational data

The wonderful thing about standards...

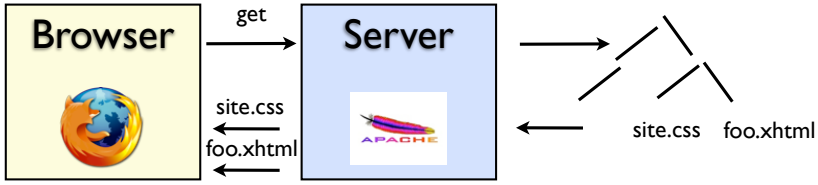
- There are **so many** to choose from!
  - XPath 1.0, 2.0, XSLT 1.0, 2.0, XQuery, XProc
  - RDF, RDFS, OWL 1.0, 2.0, SPARQL 1.0, 1.1, ...
- W3C process moves quickly
  - and is hit-or-miss
  - often driven by nontechnical/industrial issues
- Standards reflect compromises between needs of different communities
  - XML standards often compromise between "data" and "document" views of world
  - and it shows!

Beyond the hype (Google "I hate XML")

- XML "wave" (1999-200?): may have crested
- XML can be and has been (justifiably) criticized
  - bloat, ad hoc features, too many standards
  - wheel reinvention: why not LISP S-Expressions [McCarthy 1960]
- New semistructured formats/syntaxes now in vogue
  - RDF, JSON, YAML, Google Protocol Buffers
  - many XML vendors re-branding as "NoSQL"
- Nevertheless, the basic issues are pretty much the same
  - and XML is definitely not going away
- Our goal: rise above fray, understand essential issues in CS terms

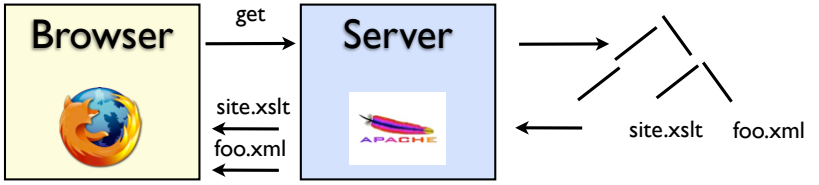
Where is XML used?

Static Web site



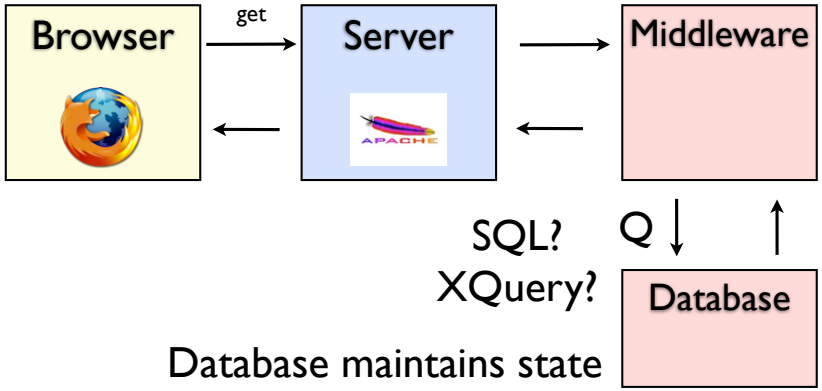
(X)HTML + CSS
(+ SVG + MathML)

Static Web site (XML + XSLT)

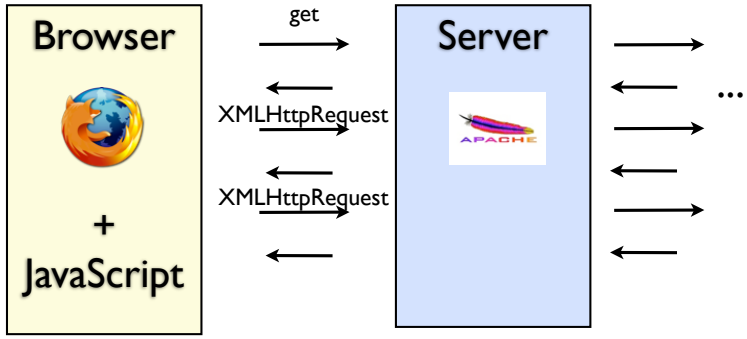


allows better factoring
into data + presentation

Dynamic Web site

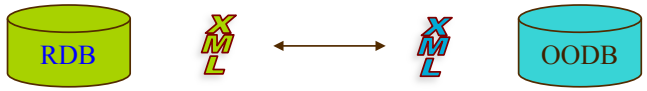


Web 2.0: Asynchronous Java and XML



Data exchange

- Massive demand
  - across platforms/DBs
  - across enterprises



- XML has become the prime standard for data interchange on the Web

Data integration (warehousing)

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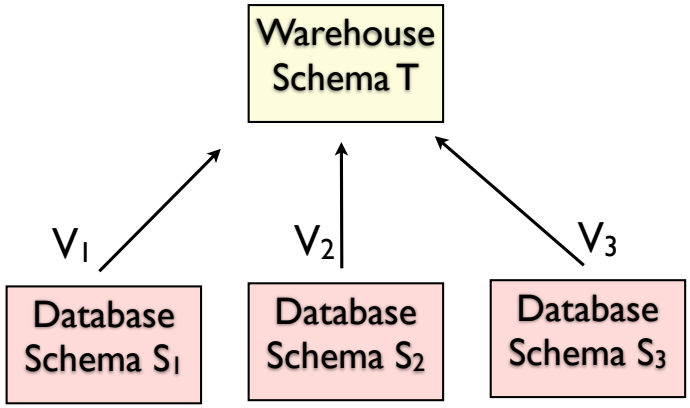
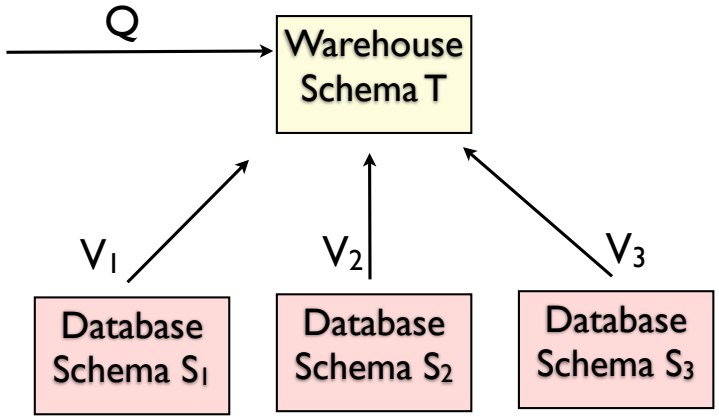


Data integration (warehousing)



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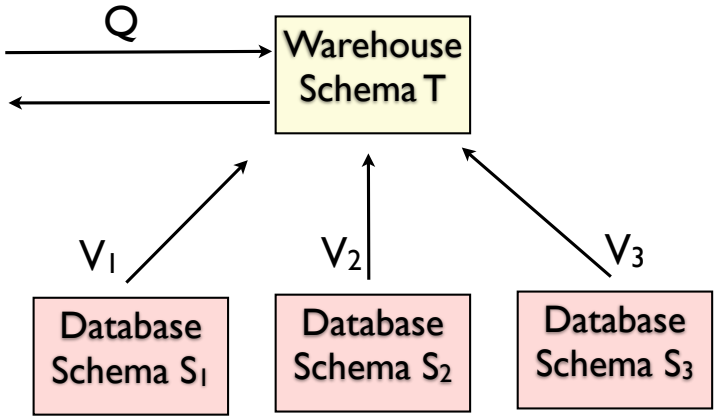
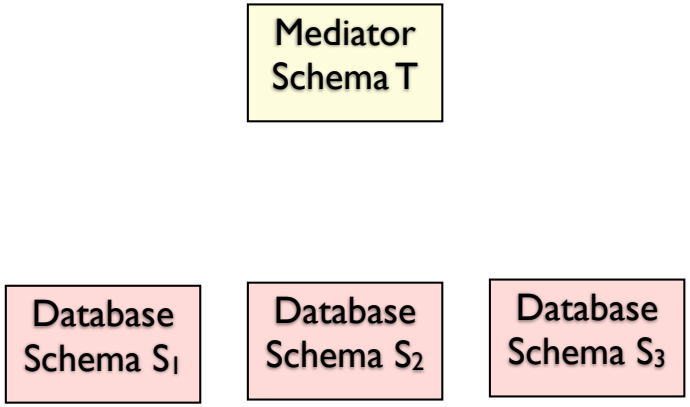


Data integration (mediation)



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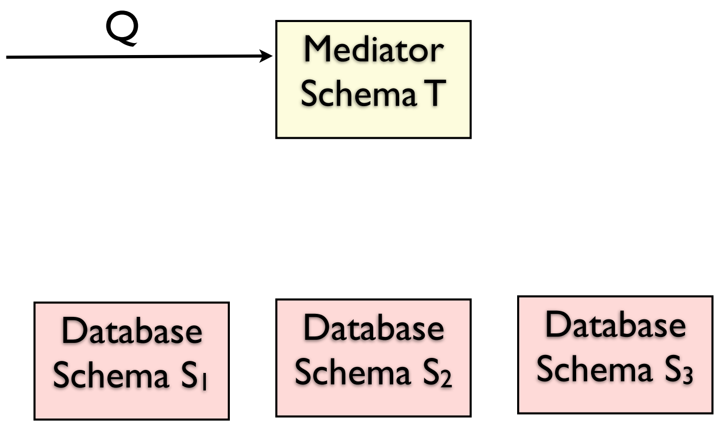

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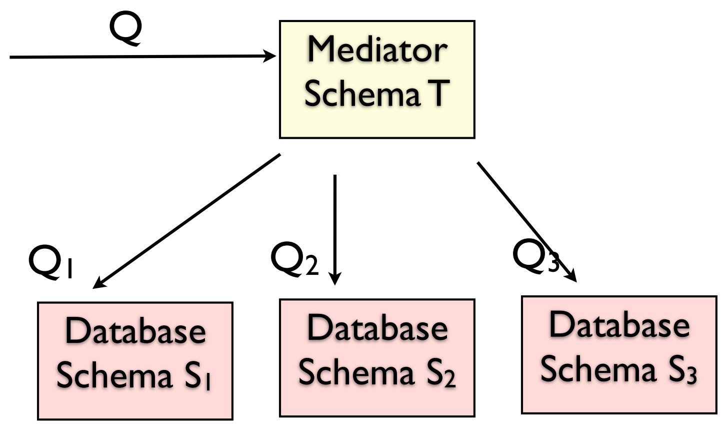

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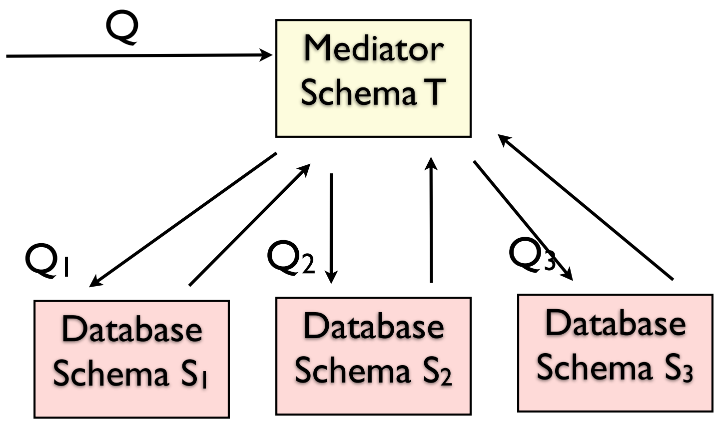

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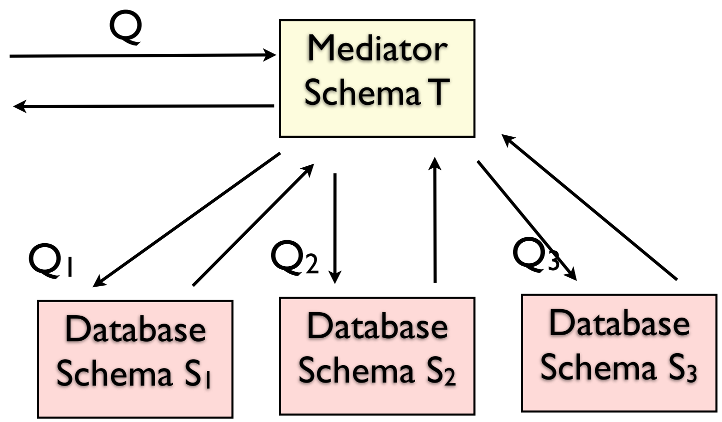


Course overview

What you need for this course

- Prerequisites:
  - *Language Semantics & Implementation* (PL)
  - or *Computers & Intractability* (Algorithms/complexity)
  - or permission
- *Database Systems* or *ADBS* wouldn't hurt
  - good if you have at least heard of SQL
- *Data Integration & Exchange*, *Extreme Computing* or *Natural Language Technologies* may complement

Evaluation

- 35%: Reviews (7 assignments)
  - Due **each Monday at 4pm until week 8**
  - Week 2-3: read/review **all 3 tutorials**
  - Week 4-8: read/review **2 out of 3 papers**
- 50%: Course project report
  - due **Monday, March 25, 4pm**
- 15%: Project presentation
  - during week 10-11 (**after** report due!)

Reviews

- Hand in reviews on **Monday at 4pm before** of the week in which the papers are to be discussed.
  - Online handin, details TBA soon
- Each review should be about **half a page**
  - summary, key ideas, questions you have, flaws you have found, and suggestions for improvement.
- Marked on "+/✓/-" scale.
  - + = 2 pts (outstanding)
  - ✓ = 1 pt (pass)
  - - = 0 pts (incomplete)

Projects

- The project is the main assessed component of the course.
- Projects can take two forms:
  - **Design and development projects**
    - (2-3 students) implement or improve upon an algorithm or system.
  - **Survey/benchmarking projects**
    - (1 student) surveying 5-10 research papers on a particular topic, or using several systems for the same task and comparing them
- **Project report**: 15-30 pages (typically longer for group projects)

Suggested timetable

- Week 3: select project, form groups
  - project ideas: http://www.inf.ed.ac.uk/teaching/courses/qsx/project.html
  - contact me or use qsx-students@inf.ed.ac.uk list
- Week 5: literature review/identify related work
- Week 7: Draft report/preliminary results
- Week 10-11: Final report & presentation
- **It is up to you to ensure that your project stays on track!**

Presentations

- Each group member must participate in presentation
- ~5 min per group member (e.g. 3-person group gets 15 minutes)
- Summarize background
- Present research question
- Summarize progress and next steps

Introductions

- Who you are
- What you want to get out of the course
- ...Start thinking about project groups early
  - Use mailing list qsx-students@inf.ed.ac.uk

What you should get from this course

- Skills/knowledge in demand in industry ($$)
  - **NOT:** Specific language/tool/system/protocol/API
  - you should be able to pick it up on your own.
- Research / team / project experience
- Background useful for working with other XML or Web standards/tools
- Chance to put diverse CS concepts into practice

Syllabus/topics

- Weeks 1-3: Foundations
- Weeks 4-5: Storage & publishing
- Weeks 6-8: Additional topics (updates, static analysis, provenance)
- Week 9: Break
- Week 10-11: Project presentations

Next time

- XML background

Foundations of XML

- XML itself
- Query and transformation languages
  - XPath: a path-based language for navigating / selecting parts of XML trees
  - XQuery: a "SQL for XML" query language
  - XSLT: a pattern-matching, recursive transformation language
- Schemas (DTDs, XML Schema)
  - validation, automata
  - Constraints (keys)

XML and databases

- XML "shredding": Storing/querying XML in relational databases
  - Shredding XML trees into relations (with or without schema)
  - Translating XML queries/updates to SQL over shredded representation
- XML "publishing": Providing XML views of legacy relational data
  - Translating XML queries over views to SQL
  - Schema-directed publishing

XML updates

- Beyond DOM: Updating XML stored as relations
- XQuery Update Facility
  - extending XQuery to support updates
- Updating XML views of relations
  - how to translate updates to XML views to SQL

Typechecking and static analysis

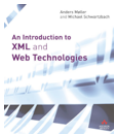
- Typed programming with XML
  - regular expression types and inference
- Predicting structure of result of queries
  - application: finding "path errors" in queries
- Using this to improve performance
  - e.g. detecting when a query and update do (or don't) "overlap"
  - can save time recomputing views

Provenance for semi-structured data

- Provenance: Understanding where data came from, how it has been produced
  - Increasingly important for scientific data
- Why and where provenance
- Annotation and XML query languages
- Provenance for curated (evolving) data

Reading

- Web Data Management (Abiteboul et al. 2011)
  - ch. 1-5 provide excellent overview of XML, Schemas, XPath, XQuery and shredding
  - also good coverage of RDF/OWL/SPARQL and cloud computing/ MapReduce
  - webdam.inria.fr/Jorge/



- Introduction to XML and Web Technologies (Moller, Schwartzach 2006)
  - now a bit dated but good coverage of XML and Java-based Web programming
  - slides, ch. 4 online
- Research papers - listed week-by-week on course web page

XML background

Some history

- SGML - (Charles Goldfarb, ISO 8879, 1986)
  - widely used for document management
  - but complex & hard to implement
- HTML - (Tim Berners-Lee, 1991)
  - most successful application of SGML
- XML - (W3C, 1998)
  - simplify SGML, for Web data/content
  - still pretty complicated, though

HTML: limitations

- HTML was intended as a declarative markup language
  - emphasizing structure over presentation
- But with success of Web, intense pressure for more presentation features
  - CSS helps separate content from structure, a little
- nevertheless, while great for human consumption, HTML is not suitable for representing general data
  - fixed set of tags
  - describe display format, not structure of data

Good things about XML

- Tags can be defined for specific applications other than HTML
- The structure of the data can be defined more precisely
  - DTDs, XML Schemas
- Structures can be arbitrarily nested
  - even including recursion
- XML standard does not define how data should be displayed
  - Style sheets (XSLT) can transform XML to HTML or other forms

Scraping data from HTML

```
<h2>Some data</h2>
<table border="2">
  <tr><th>A</th><th>B</th>
  <tr><td>1<td>2</td>
  <tr><td>3</td><td>4
</table>
```


Scraping data from HTML

```
<h2>Some data</h2>
<table border="2">
  <tr><th>A</th><th>B</th>
  <tr><td>1<td>2</td>
  <tr><td>3</td><td>4
</table>
```

Optional closing tags - hard to parse

Data as XML

```
<?xml version="1.0"?>
<root title="Some data">
 <table>
  <row><A>1</A><B>2</B></row>
  <row><A>3</A><B>4</B></row>
 </table>
</row>
```

Data as XML

Header

```
<?xml version="1.0"?>
<root title="Some data">
 <table>
  <row><A>1</A><B>2</B></row>
  <row><A>3</A><B>4</B></row>
 </table>
</row>
```


Data as XML

Attribute

```
<?xml version="1.0"?>
<root title="Some data">
 <table>
  <row><A>1</A><B>2</B></row>
  <row><A>3</A><B>4</B></row>
 </table>
</row>
```


Data as XML

Element

```
<?xml version="1.0"?>
<root tit                ta">
 <table>
  <row><A>1</A><B>2</B></row>
  <row><A>3</A><B>4</B></row>
 </table>
</row>
```


Data as XML

Text

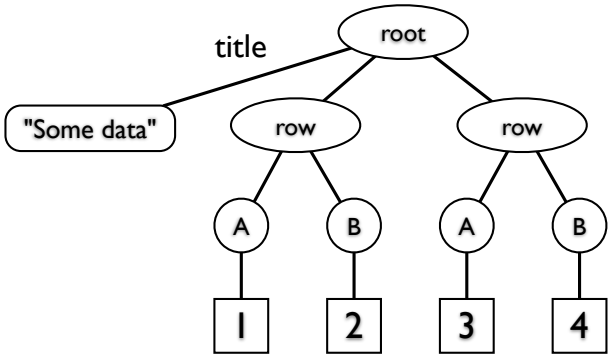
```
<?xml version="1.0"?>
<root title="Some data">
 <table>
  <row><A>1</A><B>2</B></row>
  <row><A>3</A><B>4</B></row>
 </table>
</row>
```

Data as XML

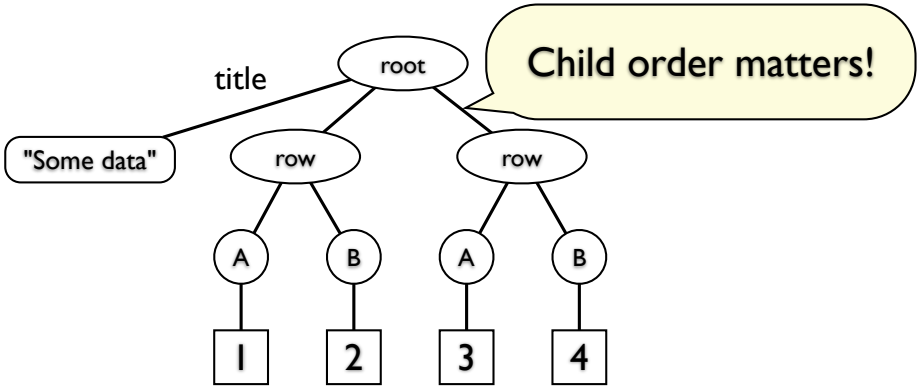
```
<?xml version="1.0"?>
<root title="Some data">
 <table>
  <row><A>1</A><B>2</B><
  <row><A>3</A><B>4</B></row>
 </table>
</row>
```

NOTE: Tag names have NO pre-defined meaning!

XML Data as trees



XML Data as trees



Basics

- An XML document consists of
- elements - `<a>...</a>`
  - tags come in pairs
  - tags must be properly nested (can't skip closing tag!)
- attributes - `<a b="x" c="y">`
  - key-value pairs associated with elements
- text values - `<a>foo<b>123</b></a>`
  - unquoted text inside elements

Elements

- Element: the segment between an start and its corresponding end tag
  - **Unique root element**
- subelement: the relation between an element and its component elements.

```
<person>
    <name> James Cheney </name>
    <tel> 0131 651 5658 </tel>
    <email> jcheney@inf.ed.ac.uk </email>
    <email> cheneyj@acm.org </email>
</person>
```


Nested structure

- nested tags can be used to express various structures, e.g., "records":

```
<person>
    <name> James Cheney </name>
    <tel> 0131 651 5658 </tel>
    <email> jcheney@inf.ed.ac.uk </email>
    <email> cheneyj@acm.org </email>
</person>
```

- a list: represented by using the same tags repeatedly:

```
<person> … </person>
<person> … </person>
...
```


Ordering

- XML elements are ordered!
  - How to represent sets in XML?
  - How to represent an unordered pair (a, b) in XML?
- Can one directly represent the following in a relational database?

```
<person> … </person>
<person> … </person>   …
    <person>
        <name> James Cheney </name>
        <tel> 0131 651 5658 </tel>
        <email> jcheney@inf.ed.ac.uk </email>
        <email> cheneyj@acm.org </email>
    </person>
```


Attributes

- A start tag may contain attributes describing certain "properties" of the element (e.g., dimension or type)

```
<picture>
    <height dim="cm"> 2400</height>
    <width dim="in"> 96 </width>
    <data encoding="gif"> M05-+C$ … </data>
</picture>
```

- References (meaningful only when a DTD is present):

```
<person id = "011"   pal="012">
    <name> George Bush</name>
</person>
<person id = "012"   pal="011">
    <name> Saddam Hussein </name>
</person>
```

Attribute structure

- XML attributes cannot be nested -- flat
  - the names of XML attributes of an element must be unique.
  - one can't write `<person pal="Blair" pal="Saddam"> ...`
- XML attributes are not ordered:

```
<person id = "011" pal="012">
    <name> George Bush</name>
</person>
```

is the same as

```
<person pal="012" id = "011">
    <name> George Bush</name>
</person>
```

- Attributes vs. subelements: unordered vs. ordered, and
  - attributes cannot be nested (flat structure)
  - subelements cannot represent references

Extras

- *entity references*: `& &quot; >`
  - textual substitution; allows escaping special characters
  - you can define your own if you want
- *processing instructions*: `<? foo : bar ?>`
  - can be used to pass information to processors
- *comments*: `<!-- foo -->`
- *CDATA sections:* - `<![CDATA[ I <3 XML ]]>`
  - allows including raw text (<, >, &, etc. uninterpreted)
- Luckily, these are mostly irrelevant to use of XML **for data**
  - but you need to know about them when writing reading/writing XML as text

Quiz

- Groups of 2-3: Find as many errors in this XML document as you can

```
<?xml version="1.0">
<books>
 <book id="1'>
  <title>Data on the Web</title>
  <authors>
    <author id="a1">Abiteboul
    <author id=a2>Buneman & </author>
    <author id='a3'>Suciu</authors>
  </author>
  <year>2000/year>
  <publisher>Addison-Wesley</publisher>
</books>
<foo>bar</foo>
```


Quiz

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  <publisher>Addison-Wesley</publisher>
</books>
<foo>bar</foo>
```

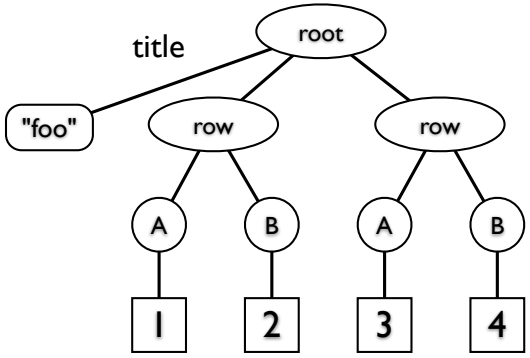
Processing XML

- Most programming languages have XML libraries
  - parsers (SAX, DOM)
  - in-memory manipulation (DOM)
  - validation (schemas)
- Thus, usually don't need to worry about all the fiddly details of character sets
  - XML supports UNICODE, many other encodings

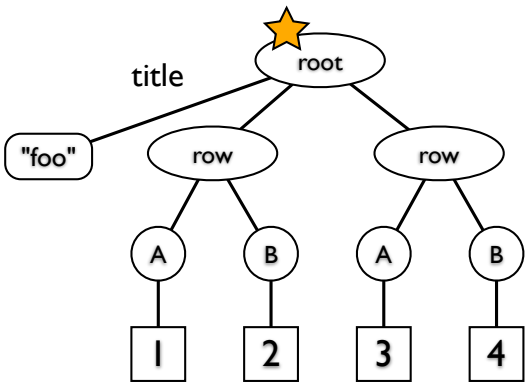
SAX: Basic idea

- SAX: Streaming API for XML (de facto standard)
  - reads XML document incrementally
  - generates calls to event handlers
  - you write code that handles these events

SAX: Example

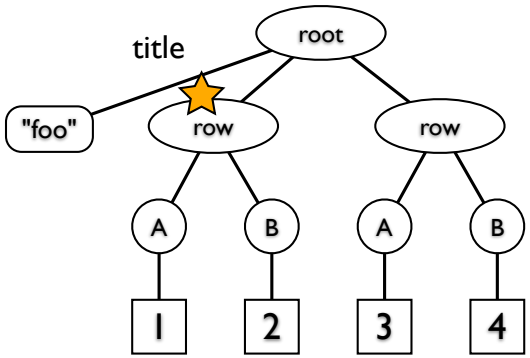


SAX: Example



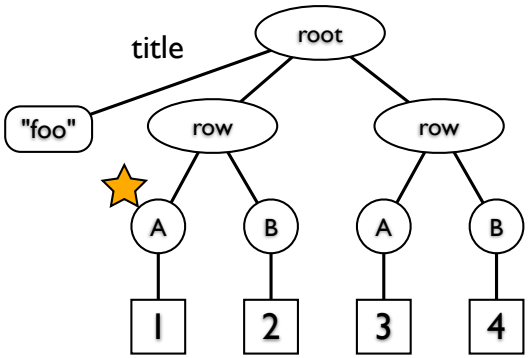

```
beginElt("root",[title="foo"])
```

SAX: Example



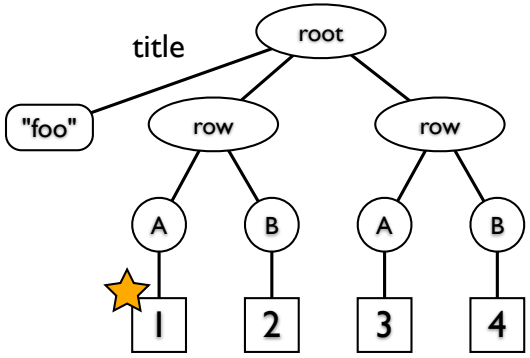

```
beginElt("root",[title="foo"])
 beginElt("row")
```


SAX: Example



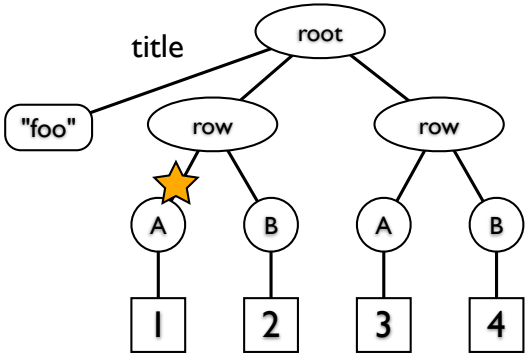

```
beginElt("root",[title="foo"])
 beginElt("row")
  beginElt("A")
```


SAX: Example



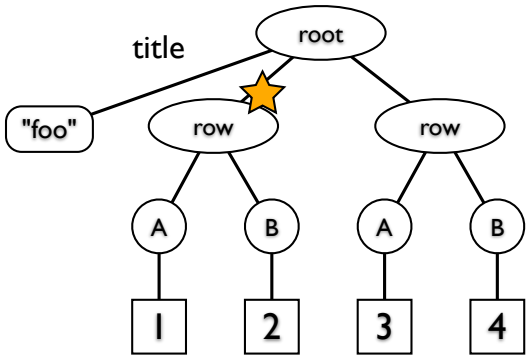

```
beginElt("root",[title="foo"])
 beginElt("row")
  beginElt("A")
   text("1")
```


SAX: Example



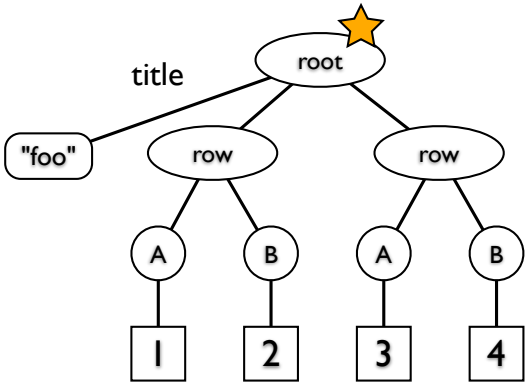

```
beginElt("root",[title="foo"])
 beginElt("row")
  beginElt("A")
   text("1")
  endElt("A")
```

SAX: Example




```
beginElt("root",[title="foo"])
 beginElt("row")
  beginElt("A")
   text("1")
  endElt("A")
  beginElt("B")
   text("2")
  endElt("B")
 endElt("row")
```


SAX: Example




```
beginElt("root",[title="foo"])
 beginElt("row")
  beginElt("A")
   text("1")
  endElt("A")
  beginElt("B")
   text("2")
  endElt("B")
 endElt("row")
 beginElt("row")
  beginElt("A")
   text("1")
  endElt("A")
  beginElt("B")
   text("2")
  endElt("B")
 endElt("row")
endElt("root")
```


SAX: Advantages

- Very widely supported
- Can be very efficient
  - for operations that are streaming-friendly
  - only realistic option for documents too large for memory
- Can easily ignore parts of the document
  - comments, etc.
  - these are still processed, however (SAX reads in whole XML file whether or not it is all needed)

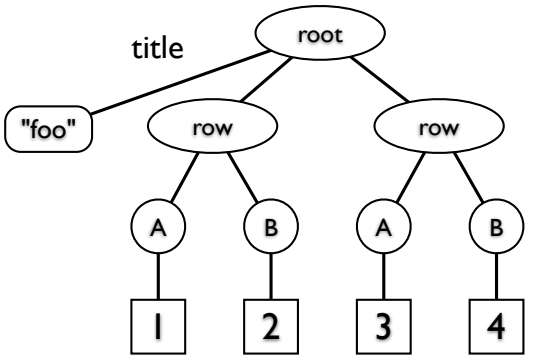
SAX: Disadvantages

- Non-starter if random access needed
- Not suitable for transformations to persistent or large data
  - e.g. in-browser or database updates
- Can be tricky to program
  - due to need to handle atomic events
  - need to figure out how to incrementalize processing & maintain state

DOM: Basic idea

- DOM: Document Object Model (W3C)
  - reads XML document all at once
  - allocates tree structure in memory
  - provides standard methods for traversing, modifying doc
  - widely used in JavaScript to dynamically update HTML page
- parses/loads document into memory

DOM: Example

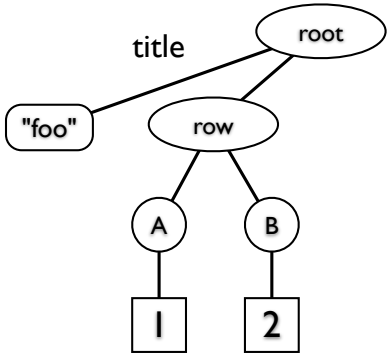


root = document.body

c1 = root.getFirstChild()

c2 = root.getLastChild()

DOM: Example



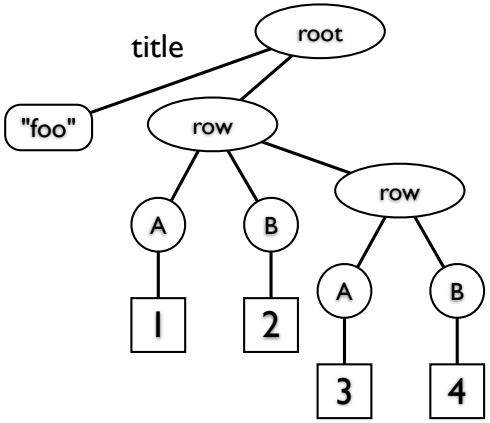
root = document.body

c1 = root.getFirstChild()

c2 = root.getLastChild()

root.deleteChild(c2)

DOM: Example



root = document.body

c1 = root.getFirstChild()

c2 = root.getLastChild()

root.deleteChild(c2)

c1.appendChild(c2)

DOM: Advantages

- Much easier to program
- Offers random access & dynamic updates
- Best if scalability to large data not a concern
- Library support for path queries can be very convenient (e.g. JQuery)
  - though naive implementations of queries can be very slow

DOM: Disadvantages

- Memory footprint can be several times that of XML text
  - which is already bloated!
- Thus, cannot be used for data > size of memory (gigabytes)
- At a programming level, side-effecting updates can be tricky to get right
  - but no realistic alternatives yet to JavaScript for browser interactivity

Next week

- XPath: Navigating through XML trees
- XQuery: SQL-like queries for constructing new XML trees from existing data