

Semi-structured Data: Programming

Introduction to Databases

CompSci 316 Fall 2018



DUKE
COMPUTER SCIENCE

Announcements (Thu., Nov. 1)

- Homework #3 due next Tuesday
- Project milestone #2 due next Thursday
 - But remember your brief weekly update on Piazza today!

APIs for working with JSON/XML

If data live in a database, use a “database API,” e.g.:

- `pymongo` : MongoDB \approx `psycopg2` : PostgreSQL

If data live in files or messages, then parse data into a representation in your application programming language and use APIs to access/query data:

- Low-level XML APIs: SAX, DOM
- XML APIs with query functionality
 - JavaScript DOM Level 3 (supports XPath)
 - Python `lxml` (supports XPath/XSLT)
 - Java Saxon (supports XPath/XQuery/XSLT)

SAX & DOM

Both are basic API's for XML processing

- **SAX (Simple API for XML)**
 - Started out as a Java API, but now exists for other languages too
- **DOM (Document Object Model)**
 - Language-neutral API with implementations in Java, C++, python, etc.

SAX processing model

- Serial access
 - XML document is processed as a stream
 - Only one look at the data
 - Cannot go back to an early portion of the document
- Event-driven
 - A parser generates **events** as it goes through the document (e.g., start of the document, end of an element, etc.)
 - Application defines **event handlers** that get invoked when events are generated

A simple SAX example

- Print out text contents of `title` elements

```
import sys
import xml.sax
from io import StringIO

class PathHandler(xml.sax.ContentHandler):
    def startDocument(self):
        .....
    def startElement(self, name, attrs):
        .....
    .....

xml.sax.parse(sys.stdin, PathHandler())
```

SAX events

Most frequently used events:

- `startDocument`
- `endDocument`
- `startElement`
- `endElement`
- `characters`

```

<?xml version="1.0"?> → startDocument
<bibliography> → startElement
  <book ISBN="ISBN-10" price="80.00">
    <title>Foundations of Databases</title>
    ...
  </book> → endElement
  ...
</bibliography> → endElement
                ↳ endDocument
  
```

- Whenever the parser has processed a chunk of character data (without generating other kinds of events)
- Warning: The parser may generate multiple `characters` events for one piece of text

Whitespace may come up as `characters` or `ignorableWhitespace`, depending on whether a DTD is present

A simple SAX example (cont'd)

```
def startDocument(self):
    self.outBuffer = None

def startElement(self, name, attrs):
    if name == 'title':
        self.outBuffer = StringIO()

def endElement(self, name):
    if name == 'title':
        print(self.outBuffer.getvalue())
        self.outBuffer = None

def characters(self, content):
    if self.outBuffer is not None:
        self.outBuffer.write(content)
```

Tag name

A map from attribute names to values

Characters read

A common mistake

What is wrong with the following?

```
def endElement(self, name):  
    # print the last chunk of chars before </title>:  
    if name == 'title':  
        print(self.chars)  
  
def characters(self, content):  
    self.chars = content
```

A more complex SAX example

- Print out the text contents of top-level section titles in books, i.e., `//book/section/title`
 - Old code would print out all titles, e.g., `//book/title`, `//book//section/title`
 - For simplicity, assume that if we have the pattern `//book/section/title//book/section/title`, we print the higher-level `title` element
- Idea: maintain as state the path from the root

```
def startDocument(self):  
    self.path = list()  
    self.pathLenWhenOutputStarts = None  
    self.outBuffer = None
```

A more complex SAX example (cont'd)


```

def startElement(self, name, attrs):
    self.path.append(name) # maintain the path
    if len(self.path) >= 3 and\
        self.path[-3:] == ['book', 'section', 'title']:
        # path matches //book/section/title:
        if self.outBuffer is None:
            self.pathLenWhenOutputStarts = len(self.path)
            self.outBuffer = StringIO()

def endElement(self, name):
    if self.outBuffer is not None and\
        len(self.path) == self.pathLenWhenOutputStarts:
        print(self.outBuffer.getvalue())
        self.outBuffer = None
    self.path.pop() # maintain the path

def characters(self, content):
    if self.outBuffer is not None:
        self.outBuffer.write(content)

```


 Would it work if we remove this check?

Would it work if we change this check to name == "title"?

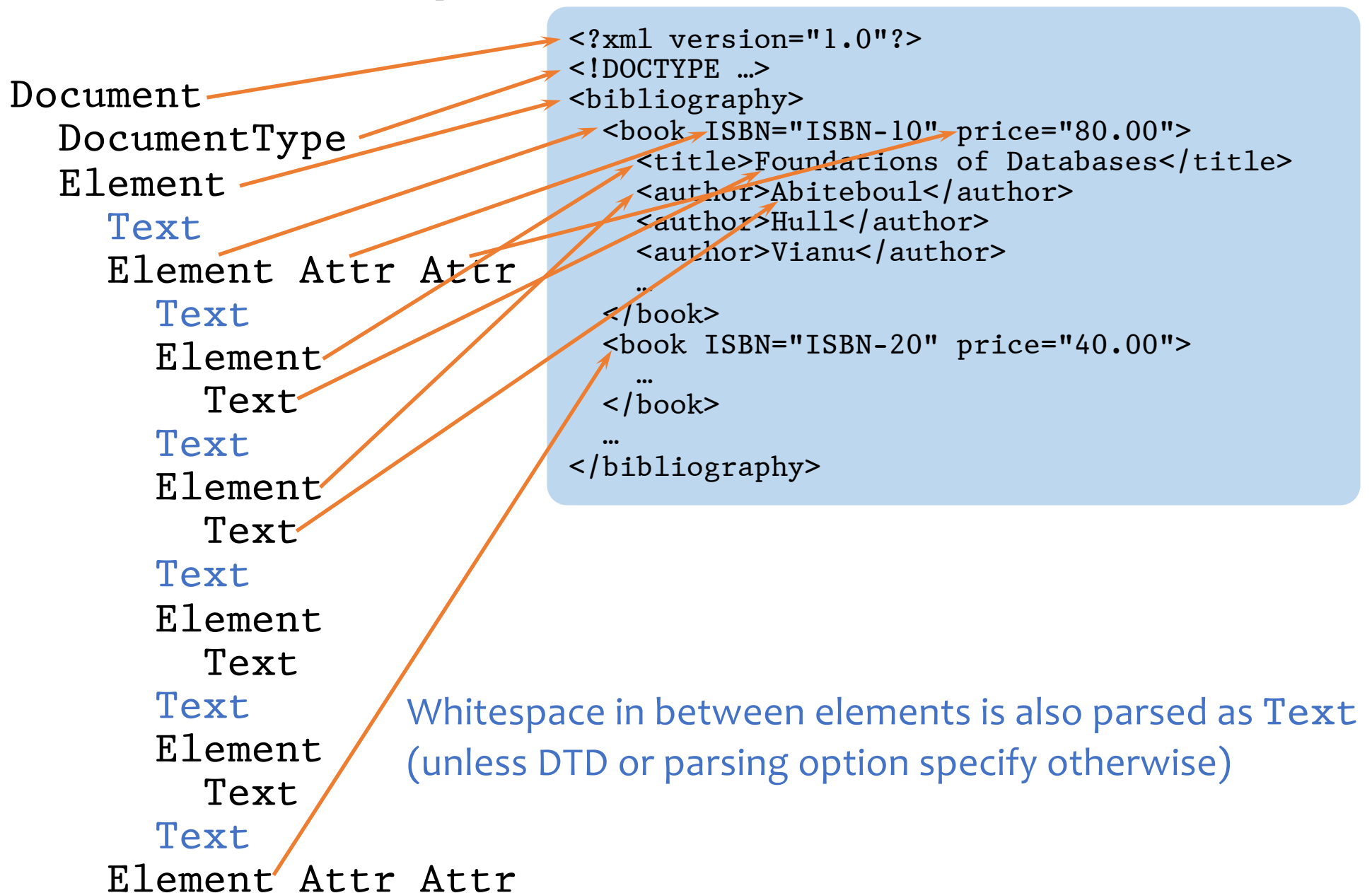
DOM processing model

- XML is parsed by a parser and converted into an in-memory DOM tree
- DOM API allows an application to
 - Construct a DOM tree from an XML document
 - Traverse and read a DOM tree
 - Construct a new, empty DOM tree from scratch
 - Modify an existing DOM tree
 - Copy subtrees from one DOM tree to anotheretc.

DOM Node's

- A DOM tree is made up of Node's
- Most frequently used types of Node's:
 - **Document**: root of the DOM tree
 - Not the same as the root element of XML
 - **DocumentType**: corresponds to the DOCTYPE declaration in an XML document
 - **Element**: corresponds to an XML element
 - **Attr**: corresponds to an attribute of an XML element
 - **Text**: corresponds to chunk of text

DOM example



Node interface

`n.nodeType` returns the type of Node `n`

`n.childNodes` returns a list containing `n`'s children

- E.g., subelements are children of an Element; DocumentType is a child of the Document
- `n.appendChild(c)` adds Node `c` as the last child of `n`

`d.documentElement` returns the root Element of Document `d`

`e.nodeName` returns the tag name of Element `e`

`e.attributes` returns a NamedNodeMap containing `e`'s attributes

- Attributes are not considered children!
- Loop through attributes using

```
for i in range(e.attributes.length):
    a = e.attributes.item(i)
```

 - `a.nodeName` returns the attribute name
 - `a.nodeValue` returns the attribute value
- Given `e`, `e.hasAttribute(name)`, `e.getAttribute(name)`, `e.setAttribute(name, value)` are also available

`t.nodeValue` returns the content of Text `t`

For convenience: `n.parentNode`, `n.previousSibling`, `n.nextSibling`, `n.ownerDocument`, etc.

Constructing DOM from XML

```
import sys
from xml.dom.minidom import parse

dom = parse(sys.stdin)

# now print it back out:
print(dom.toprettyxml(indent=' '*4, encoding='utf-8'))
```


Traversing DOM

- Compute the string value of an XML node

```
def nodeToString(n):  
    # string value of a Text node is just its content:  
    if n.nodeType == n.TEXT_NODE:  
        return n.nodeValue;  
    # string value of a Node of another type is the  
    # concatenation of its children's string values:  
    return ''.join(\n        nodeToString(child) \  
        for child in n.childNodes \  
    )  
}
```

Traversing DOM

- Print out text contents of `title` elements

```
def outputTitle(n):  
    if n.nodeType == n.ELEMENT_NODE and\  
        n.nodeName == 'title':  
        print(nodeToString(n))  
    else:  
        for child in n.childNodes:  
            outputTitle(child)
```

- How do you print out just `//book/section/title`?

Constructing DOM from scratch

- Construct a DOM Document showing all titles as follows:

```
<result>
  <title text="title1"/>
  <title text="title2"/>...
</result>
```

```
from xml.dom.minidom import getDOMImplementation

def addTitles(n, newdoc):
    if n.nodeType == input.ELEMENT_NODE and \
        n.nodeName == 'title':
        e = newdoc.createElement('title')
        e.setAttribute('text', nodeToString(n))
        newdoc.documentElement.appendChild(e)
    else:
        for child in n.childNodes:
            addTitles(child, newdoc)

newdom = getDOMImplementation().\
    createDocument(None, 'result', None)
addTitles(dom, newdom)
```

Copying subtrees in DOM

- Construct a DOM Document showing all title elements from the input XML

```
from xml.dom.minidom import getDOMImplementation
```

```
def addTitles2(n, newdoc):  
    if n.nodeType == input.ELEMENT_NODE and\  
        n.nodeName == 'title':  
        e = newdoc.importNode(n, True)  
        newdoc.documentElement.appendChild(e)  
    else:  
        for child in n.childNodes:  
            addTitles2(child, newdoc)
```

```
newdom = getDOMImplementation().\  
    createDocument(None, 'result', None)  
addTitles2(dom, newdom)
```

—————→ A Document can import (copy) a Node from another element; the second argument specifies whether to copy recursively or not

Summary: SAX versus DOM

- SAX
 - Because of one-pass processing, a SAX parser is fast, consumes very little memory
 - Applications are responsible for keeping necessary state in memory, and are therefore more difficult to code
- DOM
 - Because the input XML needs to be converted to an in-memory DOM-tree representation, a DOM parser consumes more memory
 - Lazy materialization of DOM tree helps alleviate this problem
 - Applications are easier to develop because of the powerful DOM interface
- Which one scales better for huge XML input?