Semi-structured Data: Programming

Introduction to Databases
CompSci 316 Fall 2021
Announcements (Tue., Nov. 2)

• Homework 3 due tonight
• Project Milestone 3 due date extended one week
  • Now due NEXT Thu., Nov. 11
  • For this Thu., submit weekly project progress update
APIs for working with JSON/XML

If data live in a database, use a “database API,” e.g.:
- `pymongo`: MongoDB
- `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

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

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

text = xml.sax.parse(sys.stdin, PathHandler())
```
SAX events

Most frequently used events:

- **startDocument**

- **endDocument**

- **startElement**

- **endElement**

- **characters**

  - 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)
A common mistake

What is wrong with the following?

```python
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
```

- Cannot handle the case where other tags appear within a `title` element
- It is possible that `characters()` are called multiple times for one piece of text; this code only prints out the last part
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

```python
def startDocument(self):
    self.path = list()
    self.pathLenWhenOutputStarts = None
    self.outBuffer = None
```
A more complex SAX example (cont’d)

```python
def startElement(self, name, attrs):
    self.path.append(name)  # maintain the path
    if len(self.path) >= 3 and\n        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\n        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 another etc.
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
<?xml version="1.0"?>
<!DOCTYPE ...>
<bibliography>
  <book ISBN="ISBN-10" price="80.00">
    <title>Foundations of Databases</title>
    <author>Abiteboul</author>
    <author>Hull</author>
    <author>Vianu</author>
    ...
  </book>
    ...
  </book>
  ...
</bibliography>

Whitespace in between elements is also parsed as Text (unless DTD or parsing option specify otherwise)
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

```python
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

```python
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(
        nodeToString(child)
        for child in n.childNodes
    )
```
Traversing DOM

• Print out text contents of `title` elements

```python
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`?
  • Use `parentNode` to check for section parent and book grandparent
Constructing DOM from scratch

• Construct a DOM Document showing all titles as follows:

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

```python
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

```python
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?