SAX and DOM

Introduction to Databases
CompSci 316 Fall 2016

Announcements (Tue., Nov. 1)

- Homework #3 due next Tuesday
- Project milestone #2 due next Thursday

SAX & DOM

Both are 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.

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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

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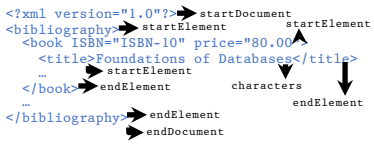
SAX events

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

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A simple SAX example

- Print out text contents of `title` elements

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

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

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

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
```

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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"`?

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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.

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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

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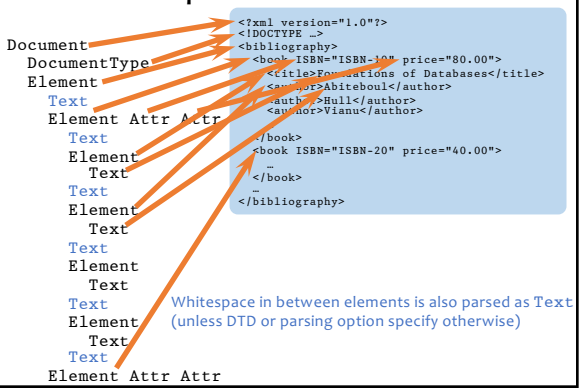
DOM example



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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.

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Constructing DOM from XML

```
import sys
reload(sys)
sys.setdefaultencoding('utf-8')
from xml.dom.minidom import parse


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

} Hack to ensure Unicode I/O

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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(\
     nodeToString(child)\
     for child in n.childNodes\
   )
}
```

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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`?
  - Use `parentNode` to check for `section` parent and `book` grandparend

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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)
```

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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

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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?