SAX & DOM

CPS 116
Introduction to Database Systems

Announcements (Thu. Oct. 27)
- Homework #3 due in 1 week
- Project milestone #2 due in 2 weeks

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++, etc.
- JAXP (Java API for XML Processing)
  - Bundled with standard JDK
  - Includes SAX, DOM parsers and XSLT transformers

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

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

A simple SAX example
- Print out text contents of `title` elements

```java
import java.io.*;
import org.xml.sax.*;
import org.xml.sax.helpers.XMLReaderFactory;
import org.xml.sax.helpers.DefaultHandler;

public class SaxExample extends DefaultHandler {
    public static void main(String[] argv) throws Exception {
        String fileName = argv[0];
        // Create a SAX parser:
        XMLReader xr = XMLReaderFactory.createXMLReader();
        // Parse the document with this event handler:
        xr.setContentHandler(new SaxExample());
        xr.parse(new InputSource(new FileReader(fileName)));
    }
}
```
A simple SAX example (cont'd)

```java
private StringBuffer titleStringBuffer = null;
public void startElement(String uri, String localName,
String qName, Attributes attributes) {
if (qName.equals("title")) {
    titleStringBuffer = new StringBuffer();
}
public void endElement(String uri, String localName,
String qName) {
    if (qName.equals("title")) {
        System.out.println(titleStringBuffer.toString());
        titleStringBuffer = null;
    }
}
public void characters(char[] ch, int start, int length) {
    if (titleStringBuffer != null)
        titleStringBuffer.append(ch, start, length);
}
```

Warning: This code does not handle data with
//title[/title]
pattern

Only relevant when
namespace is involved

A common mistake

What is wrong with the following?
```
private String titleString = null;
public void endElement(String uri, String localName,
String qName) {
    // Print the last chunk of characters seen before </title>
    if (qName.equals("title")) {
        System.out.println(titleString);
    }
    public void characters(char[] ch, int start, int length) {
        titleString = new String(ch, start, length);
    }
```

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

```java
private ArrayList path = new ArrayList();
private int pathLengthWhenOutputIsActivated;
```

A more complex SAX example (cont'd)
```
public void startElement(String uri, String localName,
String qName, Attributes attributes) {
    path.add(qName); // Maintain the path.
    if (path.size() >= 3 &&
        (String)(path.get(path.size()-1)).equals("title") &&
        (String)(path.get(path.size()-2)).equals("section") &&
        (String)(path.get(path.size()-3)).equals("book") ) {
        // path matches //book/section/title:
        if (titleStringBuffer == null) {
            pathLengthWhenOutputIsActivated = path.size();
            titleStringBuffer = new StringBuffer();
        }
    }
}
```

A more complex SAX example (cont'd)
```
public void endElement(String uri, String localName,
String qName) {
    if (titleStringBuffer != null &&
        path.size() == pathLengthWhenOutputIsActivated) {
        // Closing the element that activated output buffering:
        System.out.println(titleStringBuffer.toString());
        titleStringBuffer = null;
    }
    path.remove(path.size()-1); // Maintain the path.
}
public void characters(char[] ch, int start, int length) {
    if (titleStringBuffer != null)
        titleStringBuffer.append(ch, start, length);
}
```

This check prevents premature output
in case that title has subelements

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Would it work if we change this check to qName.equals("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

DOM example

```xml
<?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>
```

Node interface

```java
n.getNodeType() returns the type of Node n
d.childNodes() returns a NodeList containing Node n's children
  - For example, subelements are children of an Element; DocumentType is a child of the Document
d.getDocumentElement() returns the root Element of Document d
e.getAttributes() returns a NamedNodeMap (hash table) containing
  the attributes of Element e
  - Attributes are not considered children!
a.getNodeName() returns the name of Attr a
a.getNodeValue() returns the value of Attr a
t.getNodeValue() returns the content of Text t
For convenience: n.getParentNode(), n.getPreviousSibling(), n.getNextSibling(), n.getOwnerDocument(), etc.
```

Constructing DOM from XML

```java
import java.io.*;
import javax.xml.parsers.*;
import org.xml.sax.*;
import org.w3c.dom.*;
import javax.xml.transform.*;
import javax.xml.transform.dom.*;
import javax.xml.transform.stream.*;
public class DomExample {
  public static void main(String[] argv) throws Exception {
    // Parse input XML into a DOM Document:
    DocumentBuilderFactory factory=DocumentBuilderFactory.newInstance();
    DocumentBuilder builder=factory.newDocumentBuilder();
    Document document=builder.parse(new File(argv[0]));
    // Use the default (identity) Transformer to print the DOM Document:
    TransformerFactory tFactory=TransformerFactory.newInstance();
    Transformer transformer=tFactory.newTransformer();
    transformer.transform(new DOMSource(document),
                         new StreamResult(System.out));
  }
}
```

Traversing DOM

- Compute the string value of an XML node

```java
public static String convertNodeToString(Node n) {
  // String value of a Text Node is just its content:
  if (n.getNodeType() == Node.TEXT_NODE)
    return n.getNodeValue();
  // String value of a Node of another type is the concatenation
  // of its children's string values:
  String text = "";
  NodeList children = n.getChildNodes();
  for (int i=0; i<children.getLength(); i++) {
    Node child = children.item(i);
    text = text + convertNodeToString(child);
  }
  return text;
}
```

Traversing DOM (cont'd)

- Print out text contents of title elements

```java
public static void outputTitle(Node n) {
  if (n.getNodeType() == Node.ELEMENT_NODE &&
      n.getNodeName().equals("title")) {
    System.out.println(convertNodeToString(n));
  } else {
    // Recurse down the tree and look for titles to output:
    NodeList children = n.getChildNodes();
    for (int i=0; i<children.getLength(); i++) {
      Node child = children.item(i);
      outputTitle(child);
    }
  }
}
```

- How would you print out just //book/section/title?
  - Use getParentNode() 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>
```

```java
public static Document newDocWithTitles(Document inputDoc) throws Exception {
    // Create a new Document:
    DocumentBuilderFactory factory=DocumentBuilderFactory.newInstance();
    DocumentBuilder builder=factory.newDocumentBuilder();
    Document newDoc=builder.newDocument();
    // Create the root Element:
    Element newElement=newDoc.createElement("result");
    newDoc.appendChild(newElement);
    // Add titles:
    addTitlesToNewDoc(newDoc, inputDoc);
    return newDoc;
}
```

Copying subtrees in DOM

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

```java
public static Document newDocWithTitles2(Document inputDoc) throws Exception {
    // Add titles:
    addTitlesToNewDoc2(newDoc, inputDoc);
}
```

```java
public static void addTitlesToNewDoc2(Document newDoc, Node n) throws Exception {
    if (n.getNodeType() == Node.ELEMENT_NODE &&
    n.getNodeName().equals("title")) {
        Node newNode = newDoc.importNode(n, true);
        newDoc.getDocumentElement().appendChild(newNode);
    } else {
        // Recurse down the tree and look for titles to add:
        NodeList children = n.getChildNodes();
        for (int i=0; i<children.getLength(); i++) {
            Node child = children.item(i);
            addTitlesToNewDoc2(newDoc, child);
        }
    }
}
```

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?