SAX & DOM

CPS 116
Introduction to Database Systems

Announcements (October 15)

- Homework #3 due in 1½ weeks
- Help session next Monday 4-5:30pm?
  - Not only for Homework #3 but also for project
    - Walkthrough of the web-db-beers JSP/Servlet setup
- Project milestone #2 due in 3 weeks
  - Feedback on milestone #1 will be emailed to you this weekend

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

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

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

A common mistake

What is wrong with the following?

```java
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);
}
```

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)

```java
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();
        }
    }
}
```

This check prevents premature output in case that title has subelements.

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

A more complex SAX example (cont’d)

```java
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);
}
```

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
  
```
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

Document
  DocumentType
    Element
      Text
      Attr
    Element
      Text
      Element
        Text
        Attr
      Element
        Text
      Element
    Element
      Text
      Element
      Attr
    Text
  Element
    Text
    Element
    Text
  Text

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

Node interface

- `n.getNodeType()` returns the type of Node `n`
- `n.getChildNodes()` 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.getNodeName()` returns the tag name of Element `e`
- `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.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));
    }
}
```

In general, you can use an XSLT Transformer instead.

Traversing DOM

 Computes 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)

 Prints out text contents of title elements

```java
public static void outputTitle(Node n) {
    if (n.getNodeType() == Node.ELEMENT_NODE &&
        n.getNodeName().equals("title")) {
        // This is a title Element; output it:
        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?
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 {
    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;
}
```

Constructing DOM from scratch (cont’d)

```java
public static void addTitlesToNewDoc(Document newDoc, Node n)
throws Exception {
    if (n.getNodeType() == Node.ELEMENT_NODE &&
        n.getNodeName().equals("title")) {
        Element newElement = newDoc.createElement("title");
        newElement.setAttribute("text", convertNodeToString(n));
        newDoc.getDocumentElement().appendChild(newElement);
    } 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);
            addTitlesToNewDoc(newDoc, child);
        }
    }
}
```

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 {
        // 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?