SAX & DOM

CPS 116

Introduction to Database Systems

Announcements (October 26)

- ❖ Homework #3 due next Tuesday
  - Help session next Monday; see email for details
  - Deadline for Problem X1 (only) extended to Thursday
- ❖ Project milestone #2 due November 9

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

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

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

```
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)));
    return;
  }
  … …
```

A simple SAX example (cont'd)

Only relevant when namespace is involved

```
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);
}
```

Assuming no namespace processing, `qname` is tag name

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

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);
}
```

- ❖ 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

```
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

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

DOM processing model

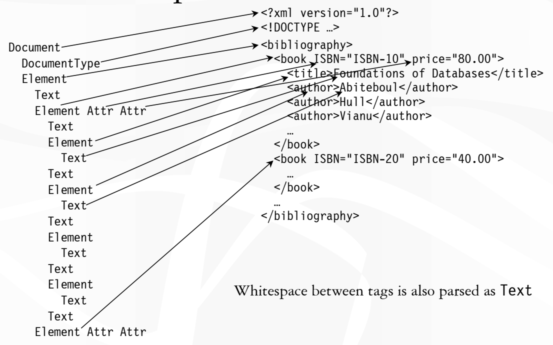
- ❖ XML is parsed by a parser and converted into an in-memory DOM tree
- ❖ DOM API allows an application to
  - ▪ Construct a DOM tree from an XML document
  - ▪ Traverse and read a DOM tree
  - ▪ Construct a new, empty DOM tree from scratch
  - ▪ Modify an existing DOM tree
  - ▪ Copy subtrees from 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 sames 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
    Element Attr Attr
      Text
      Element
        Text
      Text
      Element
        Text
      Text
      Element
        Text
      Text
    Element Attr Attr
```

```
<?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 ISBN="ISBN-20" price="40.00">
    …
  </book>
  …
</bibliography>
```

Whitespace between tags is also parsed as Text

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

```
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));
 }
}
```

In general, you can use an XSLT Transformer instead

Traversing DOM

- ❖ Compute the string value of an XML node

```
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

```
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?
  - Use getParentNode() to check for section parent and book grandparent

Constructing DOM from scratch

- Construct a DOM `Document` showing all titles as follows:

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

```
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;
}
```

Constructing DOM from scratch (cont'd)

```
public static void addTitlesToNewDoc(Document newDoc, Node n)
throws Exception {
 if (n.getNodeType() == Node.ELEMENT_NODE &&
     n.getNodeName().equals("title")) {
    // This is a title Element; add it:
    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);
    }
  }
}
```

You can only create an `Element` within a `Document`

Copying subtrees in DOM

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

```
public static Document newDocWithTitles2(Document inputDoc)
throws Exception {
  … …
  // Add titles:
  addTitlesToNewDoc2(newDoc, inputDoc);
  … …
}
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
  - Applications are easier to develop because of the powerful DOM interface
- Which one scales better for huge XML input?