

SAX & DOM

CompSci 316
Introduction to Database Systems

Announcements (Thu. Oct. 31)

- ❖ Homework #3 non-Gradiance deadline extended to next Thursday
 - Gradiance deadline remains next Tuesday
- ❖ Project milestone #2 due in two weeks
- ❖ Data+Journalism talk next Monday before noon
 - RSVP

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 other goodies

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>
 ...
</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)

```
private StringBuffer titleStringBuffer = null; Only relevant when namespace is involved
public void startElement(String uri, String localName, String qName,
 Attributes attributes) { Assuming no namespace processing, qname is tag name
 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?

```
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.

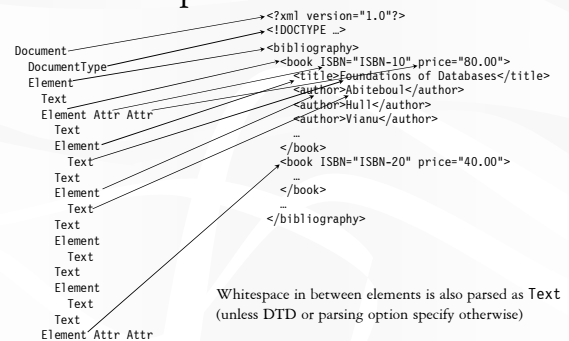
## DOM Node's

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- ❖ 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

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## Node interface

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- 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

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```
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

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- ❖ 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)

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- ❖ 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

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- ❖ 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)

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

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- ❖ 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

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- ❖ 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?

## XPath, XQuery, and XSLT APIs

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- ❖ `javax.xml.xpath`: evaluate XPath on DOM objects
  - Specify an input source or a node (context), and get a list of nodes back
- ❖ `java.xml.xquery`: send XQuery to XML data sources (local or remote) and get XML answers back
  - Just like what JDBC does for SQL
  - Vendors supply drivers
- ❖ `javax.xml.transform`: transform input XML documents using an XSLT specification