Java & XML

Objectives

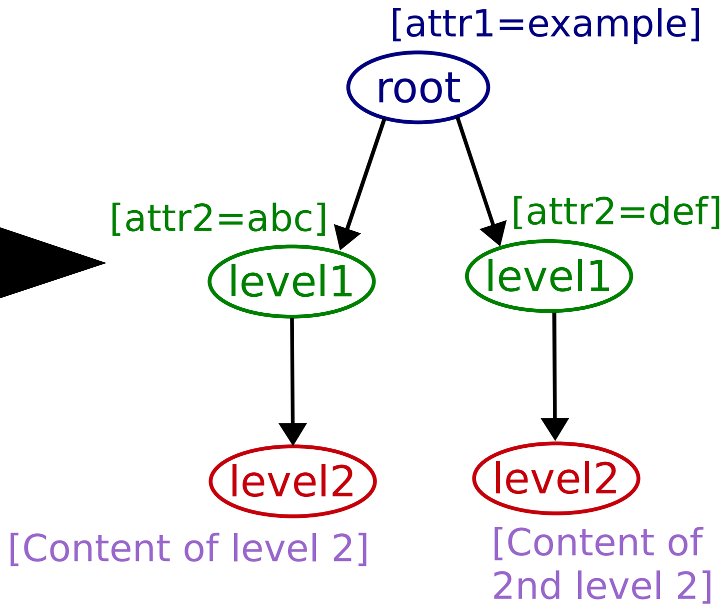
Learn the basics of processing XML with Java
- How to read XML documents
- How to write XML documents

Get familiar with the three common techniques used for processing XML docs with Java
- SAX (Simple API for XML)
- StAX (Streaming API for XML)
- DOM (Document Object Model)

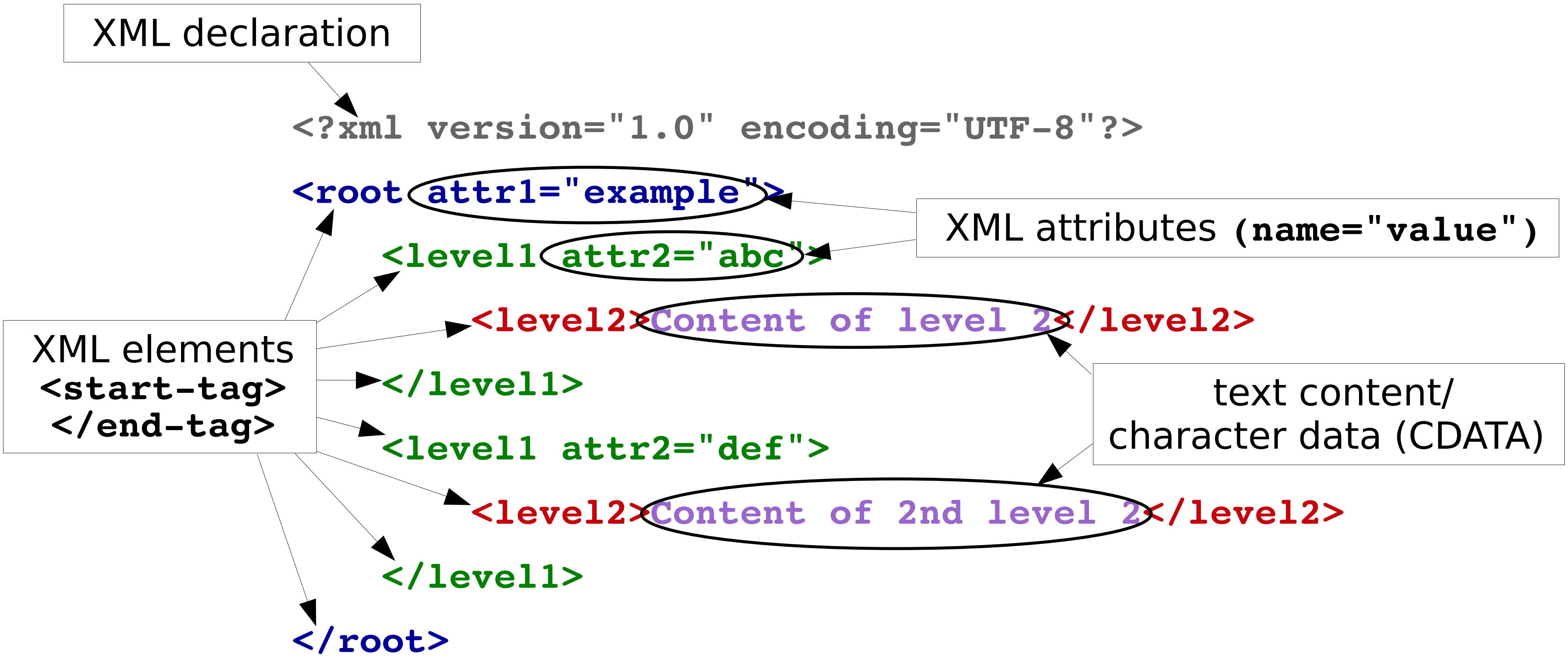
Reminder: XML

- XML data (not necessarily stored in files) is organized as a hierarchical tree, with optional attributes for the nodes:

```
<?xml version="1.0" encoding="UTF-8"?>
<root attr1="example">
    <level1 attr2="abc">
        <level2>Content of level 2</level2>
    </level1>
    <level1 attr2="def">
        <level2>Content of 2nd level 2</level2>
    </level1>
</root>
```



Reminder: XML Terminology



XML declaration

```
<?xml version="1.0" encoding="UTF-8"?>
<root attr1="example">
    <level1 attr2="abc">
        <level2>Content of level 2</level2>
    </level1>
    <level1 attr2="def">
        <level2>Content of 2nd level 2</level2>
    </level1>
</root>
```

XML attributes **(name="value")**

XML elements
<start-tag>
</end-tag>

text content/
character data (CDATA)

Reminder: XML Terminology

- **Parsing** XML data means reading an XML document into the application's memomy
- Parsing XML resembles *traversing* a tree
- **Serialize** XML is the opposite of parsing XML, i.e., XML data is written to a document
- **Well-formedness** of an XML document means that:
  - the document has exactly one root element and
  - all begin- and end-tags of elements are correctly nested, with none missing and none overlapping

Java and XML

- Java provides a broad functionality for dealing with XML data
- Two main mechanisms to parse XML:
  - To parse your data sequentially as a stream of events
  - To build an object representation of it
- Several XML toolkits are available for Java, e.g.:
  - JAXP is part of the Java platform
  - JDOM is open source

Java API for XML Processing (JAXP)

- JAXP is a Java API for processing XML data
- Independent of a particular XML processor implementation
- Provides the capability of parsing, validating, transforming, and querying XML documents
- Implements common XML techniques such as:
  - SAX (Simple API for XML)
  - DOM (Document Object Model)
  - StAX (Streaming API for XML)

Java Factories

- A **Factory** (or virtual constructor) is an object which can be used to create another object
- The **Factory** object has a static method to create the new **Factory** object (**Factory.newInstance()**)
- This **Factory** object offers static methods for creating new objects (e.g., **newDocument()**)

```
Factory factory = Factory.newInstance();
Builder builder = factory.newDocument();
```

- **Factories** are often used in APIs that have more than one possible implementation
- JAXP provides several **Factories** for creating objects that can be used for processing XML

SAX Parsing

- SAX (Simple API for XML) allows you to parse your XML data as a stream of events
- Traverses the XML document from the beginning to the end (serial) while interpreting the XML syntax
- A SAX parser reacts on XML components while reading the XML data and creates (SAX-)events:
    - Start/end reading a document
    - Opening/closing an element
    - etc.

SAX Parsing

```
<root>
   <level1>Content of level 1</level1>
   <level1>Content of 2nd level 1</level1>
</root>
```

- SAX events that are created by the SAX parser while reading the example document:
  1. document starts
  2. start tag **`<root>`** found
  3. start tag **`<level1>`** found
  4. text **“`Content of level 1`”** found
  5. end tag **`</level1>`** found
  6. start tag **`<level1>`** found
  7. text **“`Content of 2nd level 1`”** found
  8. end tag **`</level1>`** found
  9. end tag **`</root>`** found
  10. document ends

SAX Parsing

- SAX parsing is like “waiting” for the content of an XML document which will be delivered by the parser
- We do not have to care about the flow of control, but wait for the events to *push* our class (“inversion of control”)
- This is also called *push parsing*

SAX (Dis-)Advantages

- Advantages
  - Fast (good performance), few overhead
  - Can handle big amounts of XML data

- Disadvantages
  - Linear access to the XML data (we only see that part of the document that the parser is processing at a certain moment)
  - Access to the information of one node at a time – no access to the tree context/hierarchy
  - No write support: XML data is parsed in readonly modus

拉丁语 read mode

Loading an XML File with SAX

- SAX Parsers can be used to access huge amounts of XML data in a serial way
- Your class has to be extended:

```
import org.xml.sax.helpers.DefaultHandler;
public class ParseXml extends DefaultHandler {
```

- Creating a SAX parser:

```
DefaultHandler handler = new ParseXml();
SAXParser saxParser = SAXParserFactory.newInstance().newSAXParser();
saxParser.parse(new File("file.xml"), handler);
```

→ The parsing process starts and the XML data is *pushed into your application* (push parser)

Reacting on SAX Events

- To catch the pushed in data, methods have to be written which are reacting on XML events:

```
public void startDocument()

public void startElement(String namespaceURI,
                         String localName, // local name
                         String qName, // qualified name
                         Attributes attrs)

public void endElement(String namespaceURI,
                       String localName, // local name
                       String qName)

public void characters(char[] buf, int offset, int len)

public void endDocument()
```

Reacting on SAX Events

```
public void startElement(String namespaceURI,
                        String localName, // local name
                        String qName, // qualified name
                        Attributes attrs)
                        throws SAXException {

   if(qName.equals("level1")){

      String temp = attrs.getValue(attrs.getIndex("attr2"));

      //Do something ...

   }

   ...

}
```

StAX Parsing

- StAX (Streaming API for XML) allows you to parse XML data serial, like SAX
- Our calling class has the control over the parsing process and *pulls* (reads) the data from the XML parser
- This is also called *pull parsing*
- Two variants of StAX
  - *Cursor API*
  - *Event-iterator API*
    (we take a look at this variant)

StAX Parsing

- The *event-iterator API* allows high-level access to XML events
- A parser of the event-iterator API represents an **`Iterator`** over **`XMLEvent`** objects
- This **`Iterator`** provides XML events one after the other
- Methods **`hasNext()`** and **`next()`** iterate on XML components
- Every XML component is represented by a separate Java interface that is derived from **`XMLEvent`**

StAX (Dis-)Advantages

- Advantages
  - Can handle huge amounts of XML data
  - Additionally, it can create (serialize) XML documents
- Disadvantages
  - No treeview available
  - Not possible to modify an existing XML document
  - Usually more complex than SAX

Loading an XML File with StAX

- Necessary imports:

```
import javax.xml.stream.*; //provides XMLEventReader/-factory
import javax.xml.stream.events.*; //all types of XMLEvents
```

- Creating a StAX parser:

```
XMLInputFactory inputFactory = XMLInputFactory.newInstance();
XMLEventReader eventReader = inputFactory.createXMLEventReader(
                          new StreamSource(new File("file.xml")));
```

- **`XMLInputFactory`**: Defines a factory API that enables applications to obtain a parser that represents an **`Iterator`** over **`XMLEvent`** objects from XML documents.
- **`XMLEventReader`**: Defines the API to obtain **`XMLEvents`**. Using this class, an application programmer can iterate over **`XMLEvent`** objects.

StAX Reading

- Iterating through all **`XMLEvents`** (representing XML components) in the whole XML document:

```
while (eventReader.hasNext()) {
    XMLEvent event = eventReader.nextEvent();

    // process XML event
    ...
}
```

- **`XMLEvent`**: An **`XMLEvent`** is the base interface for all the other (more specific) interfaces such as **`StartDocument`**, **`EndElement`**, **`Characters`**, **`Attribute`**, etc.

StAX Event Types

- There is a separate interface for each XML event that might occur in an XML document
- All XML event types inherit from **`XMLEvent`**
- All interfaces are in package: **`javax.xml.stream.events`**
- Some of the interfaces:

Interface name	Interface represents
`XMLEvent`	base event interface for handling markup events
`StartDocument`	start of the document
`EndDocument`	end of the document
`StartElement`	start of an element
`EndElement`	end of an element
`Attribute`	an attribute
`Characters`	content, CData, and whitespace
`Comment`	a comment

StAX Event Types

- Retrieve event type (as **int**) with method **XMLEvent.getEventType()**:

```
 1: StartElement
 2: EndElement
 4: Characters
 5: Comment
 7: StartDocument
 8: EndDocument
10: Attribute
    ...
```

- Or with individual methods (as **boolean** values):

```
XMLEvent.isStartElement()
XMLEvent.isEndElement()
XMLEvent.isAttribute()
XMLEvent.isEndDocument()
XMLEvent.isCharacters()
...
```

StAX Event Types

- In order to query the properties of a specific event, we might want to cast an **`XMLEvent`** to the subinterface that it represents
- Casting may result in a class cast exception if the event to be casted is of another type

```
if (event.isStartElement()){ //prevent class cast exception
    StartElement se = event.asStartElement(); //casting
    System.out.println(se.getName()); //access properties
}


if (event.isCharacters()) { //prevent class cast exception
    Characters c = event.asCharacters(); //casting
    System.out.println(c.getData()); //access properties
}
```

Reading the Whole Document with StAX

```
Stack<String> stack = new Stack<String>();
while (eventReader.hasNext()) {
   XMLEvent event = eventReader.nextEvent();
   if (event.isStartElement()) {
      stack.push(event.asStartElement().getName().getLocalPart());
      Iterator<Attribute> it = event.asStartElement().getAttributes();
      while (it.hasNext()) {
         Attribute a = it.next();
         System.out.println(stack + " " + a.getName().getLocalPart()
                                      + "=\"" + a.getValue() + "\"");
      }
   }
   if (event.isCharacters()) {
      String s = event.asCharacters().getData();
      if (s.trim().length() > 0) {
         System.out.println(stack + " \"" + s + "\"");
      }
   }
   if (event.isEndElement()) {
      stack.pop();
   }
}
```

Example output:

```
[root] attr1="example"
[root, level1] attr2="abc"
[root, level1, level2] "Content of level 2"
[root, level1] attr2="def"
[root, level1, level2] "Content of 2nd level 2"
```

Example taken from:
http://www.torsten-horn.de/techdocs/java-xml.htm

StAX Writing

- Necessary imports:

```
import javax.xml.stream.*; //provides XMLEventReader/-factory
```

- Creating a StAX writer:

```
XMLOutputFactory outputFactory = XMLOutputFactory.newInstance();
XMLEventWriter eventWriter = outputFactory.createXMLEventWriter(
                               new FileOutputStream("out.xml"));
XMLEventFactory eventFactory = XMLEventFactory.newInstance();
```

- **`XMLOutputFactory:`** Defines a factory API that enables applications to obtain XML writers.
- **`XMLEventWriter:`** Defines the interface to write XML documents.
- **`XMLEventFactory:`** Defines the interface for creating instances of **`XMLEvents`**.

StAX Writing

- Procedure to write an XML document with StAX:

  1. Get **`XMLEvents`**: either take **`XMLEvents`** from a parsed XML document or create new **`XMLEvents`** with the help of an **`XMLEventFactory`**.
  2. Write **`XMLEvents`**: an XML document can be written with the help of an **`XMLEventWriter`**.

- The order in which **`XMLEvents`** are written determines the structure of the resulting XML document.
- The order in which the **`XMLEvents`** are created is independent of the output.

Creating XMLEvents in StAX

- Some important methods of the **`XMLEventFactory`** for creating **`XMLEvents`**:

Method	Parameter	Return type
`newInstance`		`XMLEventFactory`
`createStartDocument`	`String encoding, String version, boolean standalone`	`StartDocument`
`createEndDocument`		`EndDocument`
`createStartElement`	`String prefix, String namespaceUri, String localName`	`StartElement`
`createEndElement`	`String prefix, String namespaceUri, String localName`	`EndElement`
`createAttribute`	`String localName, String value`	`Attribute`
`createCharacters`	`String content`	`Characters`
`createComment`	`String text`	`Comment`

Creating XMLEvents in StAX

- Some examples of creating XMLEvents:

```
StartDocument startDocument = eventFactory.createStartDocument();
StartElement startRoot = eventFactory.createStartElement(
                                                       "", "", "root");
Attribute attr1 = eventFactory.createAttribute("attr1", "example");
EndElement endRoot = eventFactory.createEndElement("", "", "root");
StartElement startLevel1 = eventFactory.createStartElement(
                                                     "", "", "level1");
Attribute attr2 = eventFactory.createAttribute("attr2", "abc");
StartElement startLevel2 = eventFactory.createStartElement(
                                                      "", "", "level2");
Characters contentLevel2 = eventFactory.createCharacters(
                                                 "Content of level 2");
EndElement endLevel2 = eventFactory.createEndElement("", "", "level2");
EndElement endLevel1 = eventFactory.createEndElement("", "", "level1");
EndDocument endDocument = eventFactory.createEndDocument();
```

Writing XMLEvents in StAX

- Assuming we have created an **XMLEventWriter** and all the **XMLEvents** from the last slides, we can write the data to an XML document:

```
writer.add(startDocument);
writer.add(startRoot);
writer.add(attr1);
writer.add(startLevel1);
writer.add(attr2);
writer.add(startLevel2);
writer.add(contentLevel2);
writer.add(endLevel2);
writer.add(endLevel1);
writer.add(endRoot);
writer.add(endDocument);
writer.close(); //do not forget to close the writer
```

- This output is not well formatted: it will produce a file with all content on one line and without spaces.

Writing XMLEvents in StAX

- It is better to create further **Characters** events in order to adjust line breaks and indentation. For example:

```
Characters indent = eventFactory.createCharacters("    ");
Characters newLine = eventFactory.createCharacters("\n");

writer.add(startDocument);
writer.add(newLine);
writer.add(startRoot);
writer.add(attr1);
writer.add(newLine);
writer.add(indent);
writer.add(startLevel1);
writer.add(attr2);
writer.add(newLine);
writer.add(indent);
writer.add(indent);
writer.add(startLevel2);
writer.add(contentLevel2);
writer.add(endLevel2);
writer.add(newLine);
writer.add(indent);
writer.add(endLevel1);
writer.add(newLine);
writer.add(endRoot);
writer.add(newLine);
writer.add(endDocument);
```

Example output file "out.xml":

```
<?xml version="1.0" encoding="UTF-8"?>
<root attr1="example">
    <level1 attr2="abc">
        <level2>Content of level 2</level2>
    </level1>
</root>
```

DOM Parsing

- DOM (Document Object Model) is an official standard of the W3C
- Allows you to build an object representation of your XML data
- The data is represented as a tree:
  - The tree resists *completely* in the memory
- DOM is not restricted to XML data/files

DOM (Dis-)Advantages

- Advantages
  - It is possible to navigate the tree (back and forth)
  - Nodes can be modified, added, or removed
  - XML documents can be created (serialized)
- Disadvantages
  - DOM parsing needs huge resources of computer memory and performance
  - → DOM parsing is only possible for relative small amounts of XML data (~ 10 MB)

Loading an XML File into a DOM Object

```
import javax.xml.parsers.*; //provides DocumentBuilder/-factory
import org.w3c.dom.*; //the Document and many more tools

DocumentBuilderFactory fac = DocumentBuilderFactory.newInstance();
DocumentBuilder builder = fac.newDocumentBuilder();
Document document = builder.parse(new File("file.xml"));
```

- **DocumentBuilderFactory:** Defines a factory API that enables applications to obtain a parser that produces DOM object trees from XML documents.
- **DocumentBuilder:** Defines the API to obtain DOM **Document** instances from an XML document. Using this class, an application programmer can obtain a **Document** from XML.
- **Document:** The **Document** interface represents the entire HTML or XML document. Conceptually, it is the root of the document tree, and provides the primary access to the document's data.

Handling an (XML) String as a DOM Object

```
import java.io.StringReader;
import org.xml.sax.InputSource;
//rest as above

//variable “xml” contains the XML data
String xml = “<root><element>Hello world</element></root>”;

DocumentBuilderFactory fac = DocumentBuilderFactory.newInstance();
DocumentBuilder builder = fac.newDocumentBuilder();
StringReader stringReader = new StringReader(xml);
InputSource inputSource = new InputSource(stringReader);
Document document = builder.parse(inputSource);
```

DOM Reading

- Visit all child **Nodes** of a **Node**:

```
private void visitNode(Node node) {
   // process node...

   // iterate over all children of a node
   for (int i = 0; i < node.getChildNodes().getLength(); i++) {
      // recursively visit all child nodes
      visitNode(node.getChildNodes().item(i));
   }
}
```

- Go through all **Nodes** in the whole XML document by calling the **visitNode** method with the root node of an XML DOM tree: **visitNode(document.getDocumentElement());**

- **org.w3c.dom.Node:** The **Node** interface is the primary datatype for the entire Document Object Model. It represents a single node in the document tree and is the base interface for all the other (more specific) nodes such as **Document**, **Element**, **Text**, **Attr**, etc.

DOM Node Types

- There is a separate interface for each node type that might occur in an XML document
- All node types inherit from class **`Node`**
- All interfaces are in package **`org.w3c.dom`**
- Some of the interfaces:

Interface name	Interface represents
`Node`	base node interface for handling nodes in an XML document
`Document`	the document
`Element`	an element
`Attr`	an attribute of an element
`Text`	textual content
`CDATASection`	CDATA content

DOM Node Types

Retrieve node type with method **`short Node.getNodeType()`**:

1: element node

2: attribute node

3: text node

4: cdata

8: comment

...

Important Methods of the **Node** Object (reading)

Method	Return type	Explanation
getChildNodes	**NodeList**	A list of all child nodes
getAttributes	**NamedNodeMap**	The attributes of the node
getNodeName	**String**	Name of the node
getParentNode	**Node**	The parent of the node
getNodeType	**short**	Type of the node
getNodeValue		The value of the node
getElementsByName	**NodeList**	*All* nodes of a given name

Iterating over all children of a **Node**:

```
for (int i=0; i< node.getChildNodes().getLength(); i++) {
    // the actual child:
    Node aChild = node.getChildNodes().item(i);

    // process child node
    ...
}
```

DOM Nodes & Elements

- Differences between a **Node** and an **Element**:

  The **Element** can query its properties (for example, attributes) by name, while the **Node** has just an anonymous Iterator-view on them.

- Example 1: Extract root node as a **Node** object and extract attribute **attr1**:

```
Node rootNode = document.getDocumentElement();
NamedNodeMap nnm = rootNode.getAttributes();
Node attr1Node = nnm.getNamedItem("attr1");
String attr1 = ((Attr) attr1Node).getValue();
```

- Example 2: Extract root node as an **Element** object and extract attribute **attr1**:

```
Element rootElement = document.getDocumentElement();
String attr1 = rootElement.getAttribute("attr1");
```

DOM Nodes & Elements

- **`org.w3c.dom.NodeList:`** The **`NodeList`** interface provides the abstraction of an ordered collection of **`Nodes`** (for example: the children of a **`Node`**).
- **`org.w3c.dom.NamedNodeMap:`** Objects implementing the **`NamedNodeMap`** interface are used to represent collections of **`Nodes`** that can be accessed by name (for example: attributes).
- **`org.w3c.dom.Element:`** The **`Element`** interface represents an element in an HTML or XML document (inherits from **`Node`**).

Reading the Whole Document with DOM

```
private static void visitNode(Node node) {
   if (node.getNodeType() == 1) {
      System.out.print("\n" + node.getNodeName() + ": ");
      NamedNodeMap attributes = node.getAttributes();
      if (attributes != null) {
         for (int i = 0; i < attributes.getLength(); i++) {
            System.out.print(attributes.item(i) + " ");
         }
      }
   }

   if (node.getNodeType() == 3 && !node.getTextContent().trim().isEmpty()) {
      System.out.print("\"" + node.getTextContent().trim() + "\"");
   }

   NodeList nodeList = node.getChildNodes();
   for (int i = 0; i < nodeList.getLength(); i++) {
      visitNode(nodeList.item(i));
   }
}
```

Example output:

```
root: attr1="example"
level1: attr2="abc"
level2: "Content of level 2"
level1: attr2="def"
level2: "Content of second level 2"
```

Initial call:

```
visitNode(document.getDocumentElement());
```

Important Methods of the **Node** Object (writing)

Method	Return type	Explanation
`createElement`	`Element`	Create a new node
`createTextNode`	`Text`	Text-content of a node
`appendChild`	`void`	Add a child to a node
`createAttribute`	`Attr`	Creates an attribute

In general, creating XML trees with DOM is a bottom-up procedure:

1. create a **Node**
2. create the content of the **Node** (text, attributes, ...) and add it to the **Node**
3. add the **Node** to its parent **Node**

Creating Nodes with DOM

```
DocumentBuilder documentBuilder =
          DocumentBuilderFactory.newInstance().newDocumentBuilder();
Document document = documentBuilder.newDocument();

// First, we create all the necessary elements:

Element root = document.createElement("root");
root.setAttribute("attr1", "example");

Element level1 = document.createElement("level1");
level1.setAttribute("attr2", "abc");

Element level2 = document.createElement("level2");
level2.setTextContent("Content of level 2");

// Appending the children in bottom-up-order:

level1.appendChild(level2);
root.appendChild(level1);
document.appendChild(root);
```

Resulting XML:

```
<root attr1="example">
    <level1 attr2="abc">
        <level2>Content of level 2</level2>
    </level1>
</root>
```

Modifying Nodes with DOM

- It is also possible to modify existing elements with DOM.
- Adding new elements to existing **Nodes**:

```
Element level1 = doc.createElement("level1");
level1.setAttributes("attr1", "content");
root.addChild(level1); // "root" already existed
```

- Existing attributes will be overwritten:

```
// "level1" already had an attribute "attr1"
level1.setAttributes("attr1", "newattr");
```

Transformers

- Transformers are generic APIs for processing transformation instructions and performing a transformation from a source (DOM tree) to another output format.
- Examples: transforming a DOM tree to a String, transforming DOM trees with XSL

Transforming a DOM Tree to a String

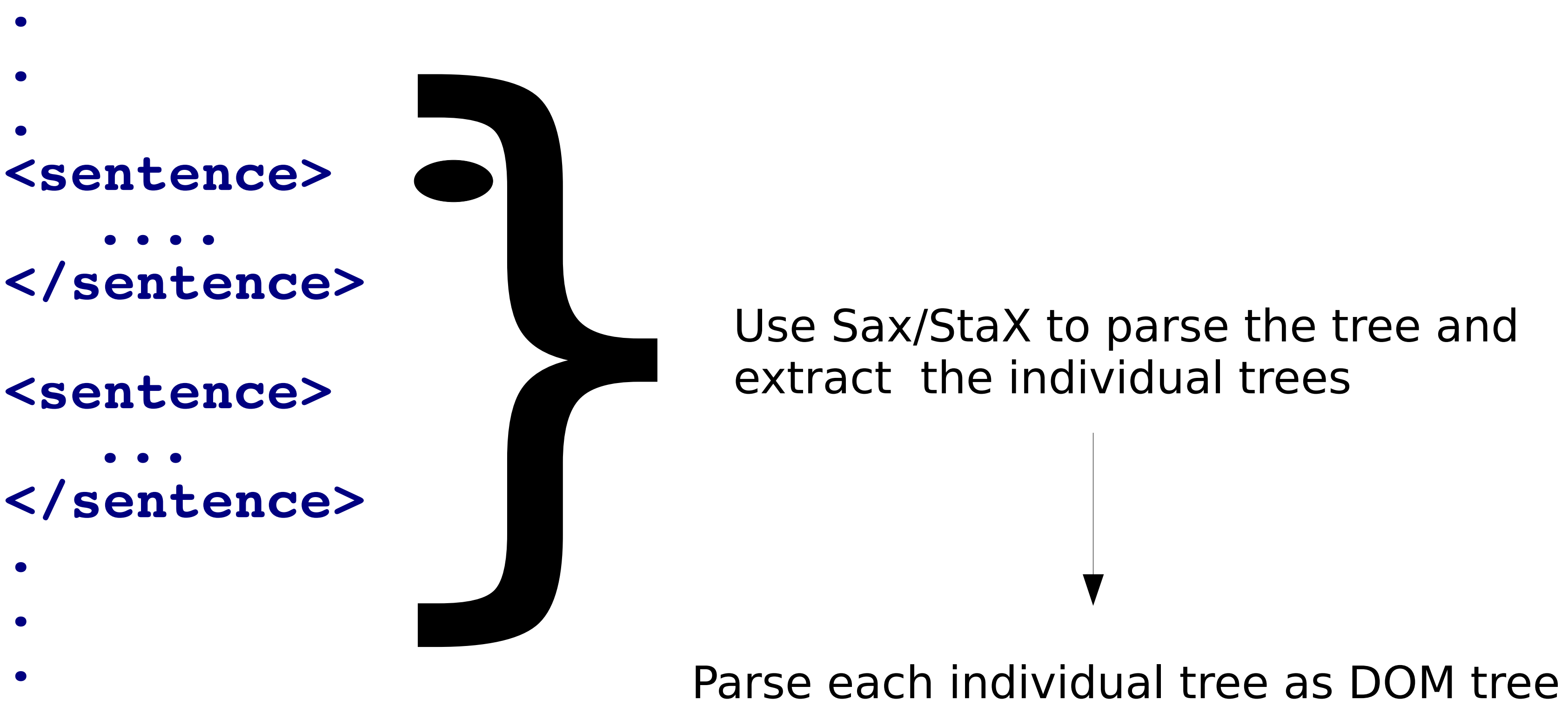
```
Import java.io.*;
import javax.xml.transform.Transformer;
import javax.xml.transform.TransformerFactory;
import javax.xml.transform.OutputKeys;
import javax.xml.transform.stream.StreamResult;
import javax.xml.transform.dom.DOMSource;

TransformerFactory transformerFactory = TransformerFactory.newInstance();
transformerFactory.setAttribute("indent-number", 4);

Transformer transformer = transformerFactory.newTransformer();
transformer.setOutputProperty(OutputKeys.OMIT_XML_DECLARATION, "no");
transformer.setOutputProperty(OutputKeys.INDENT, "yes");

StringWriter stringWriter = new StringWriter();

StreamResult result = new StreamResult(stringWriter);
DOMSource source = new DOMSource(document);
transformer.transform(source, result);
String xml = writer.toString();

Writer writer = new BufferedWriter(new OutputStreamWriter(new
FileOutputStream(new File("out.xml"))));
writer.write(xml);
writer.close();
```

Which Technology is Better?

- There is no one answer to that question
- All three technologies – SAX, StAX, and DOM – have their advantages and disadvantages
- It always depends on the concrete application which technology to choose
  - Stream-based processing is e.g. preferred if the documents are huge, but their structure is rather simple
  - Model-based processing is e.g. preferred if the documents are complex and much navigation (back and forth) is required

Combinig S(t)AX & DOM

- Sometimes, huge amounts of XML data are a *serial collection* of trees:



```
.
.
.
<sentence>
   ....
</sentence>

<sentence>
   ...
</sentence>
.
.
.
```

Use Sax/StaX to parse the tree and extract the individual trees

Parse each individual tree as DOM tree

Reading Material

- For this topic of XML processing with Java, there is no single book chapter that you have to read.
- Please find all information in one of the following books and internet sources or google for further information:
  - “Java und XML – Grundlagen, Einsatz, Referenz” by Michael Scholz & Stephan Niedermeier (chs. 2.1, 2.3, 2.4.1 + appropriate subchapters of chs. 3, 4, 6)
  - “Java ist auch eine Insel” by Christian Ullenboom (ch. 13): http://openbook.galileocomputing.de/javainsel/javainsel_16_001.html#dodtp411227dd-8e3b-4ef7-9be3-33b57be542fe
  - “Java 7 - Mehr als eine Insel” by Christian Ullenboom (ch. 7): http://openbook.galileocomputing.de/java7/1507_07_001.html#dodtp4f411983-98d0-4afd-bfac-b60f6ec2991a
  - “Java & XML” by Brett D. McLaughlin & Justin Edelson
  - http://www.torsten-horn.de/techdocs/java-xml.htm