2. XML Processor APIs

- How can (Java) applications manipulate structured (XML) documents?
  - An overview of XML processor interfaces

2.1 SAX: an event-based interface

2.2 DOM: an object-based interface

2.3 JAXP: Java API for XML Processing

Document Parser Interfaces

(See, e.g., Leventhal, Lewis & Fuchs: Designing XML Internet Applications, Chapter 10, and D. Megginson: Events vs. Trees [online])

- Every XML application contains some kind of a parser
  - editors, browsers
  - transformation/style engines, DB loaders, ...
- XML parsers have become standard tools of application development frameworks
  - JDK 1.4 contains JAXP, with its default parser (Apache Crimson)

Tasks of a Parser

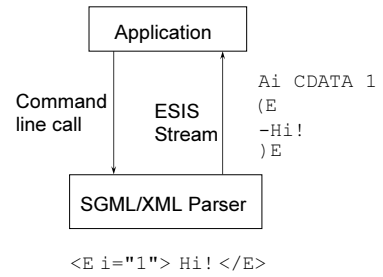
- Document instance decomposition
  - elements, attributes, text, processing instructions, entities, ...
- Verification
  - well-formedness checking
    - » syntactical correctness of XML markup
  - validation (against a DTD or Schema; optional)
- Access to contents of the DTD (if supported)
  - SAX 2.0 Extensions provide info of declarations: element type names and their content model expressions

Document Parser Interfaces

I: Event-based interfaces
- Command line and ESIS interfaces
  - » Element Structure Information Set, traditional interface to stand-alone SGML parsers
- Event call-back interfaces: SAX

II: Tree-based (object model) interfaces
- W3C DOM Recommendation
- Java-specific object models: JAXB, JDOM, dom4J

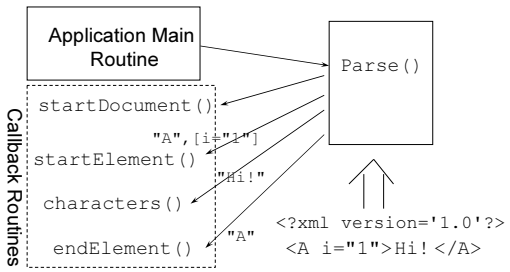
Command-line ESIS interface



Event Call-Back Interfaces

- Application implements a set of **call-back methods** for handling parse events
  - parser notifies the application by method calls
  - qualified further by parameters:
    - » element type name
    - » names and values of attributes
    - » values of content strings, …
- Idea behind ''SAX'' (Simple API for XML)
  - an industry standard API for XML parsers
  - could think as "Serial Access XML"

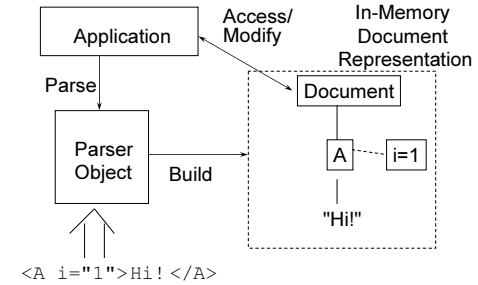
An event call-back application



Object Model Interfaces

- The parser builds ...
  - a document object consisting of sub-objects such as *document*, *elements, attributes, text*, …
- Abstraction level higher than in event based interfaces; more powerful access
  - to descendants, following siblings, …
- Drawback: Higher memory consumption
  - > used mainly in client applications (to implement document manipulation by user)

An Object-Model Based Application



2.1 The SAX Event Callback API

- A de-facto industry standard
  - Developed by members of the xml-dev mailing list
  - Version 1.0 in May 1998, Vers. 2.0 in May 2000
  - Not a parser, but a common **interface** for different parsers (like, say, JDBC is a common interface to various RDBs)
- Supported directly by major XML parsers
  - many Java based, and free; Examples: Apache Xerces, Oracle's XML Parser for Java; MSXML (in IE 5), James Clark's XP

SAX 2.0 Interfaces

- Co-operation of an application and a parser specified in terms of **interfaces** (i.e., collections of methods)
- My classification of SAX interfaces:
  - Application-to-parser interfaces
    - » to use the parser
  - Parser-to-application (or call-back) interfaces
    - » to act on various parsing events
  - Auxiliary interfaces
    - » to manipulate parser-provided information

Application-to-Parser Interfaces

- Implemented by *parser* (or a SAX driver):
  - **`XMLReader`**
    - » methods to register objects that implement call-back interfaces, and to invoke the parser
  - **`XMLFilter`** (`extends XMLReader`)
    - » to connect `XMLReader`s as a sequence of filters
    - » obtains events from an `XMLReader` and passes them further (possibly modified)

Call-Back Interfaces

- Implemented by *application* to act on parse events (A `DefaultHandler` quietly ignores most of them)
  - **`ContentHandler`**
    - » methods to process document parsing events
  - **`DTDHandler`**
    - » methods to receive notification of unparsed external entities and notations declared in the DTD
  - **`ErrorHandler`**
    - » methods for handling parsing errors and warnings
  - **`EntityResolver`**
    - » methods for customised processing of external entity references

SAX 2.0: Auxiliary Interfaces

- **`Attributes`**
  - methods to access a list of attributes, e.g:
    ```
    int getLength()
    String getValue(String attrName)
    ```
- **`Locator`**
  - methods for locating the origin of parse events (e.g. systemID, line and column numbers, say, for reporting semantic errors controlled by the application)

The `ContentHandler` Interface

- Information of general document events. (See API documentation for a complete list):
- **`setDocumentLocator(Locator locator)`**
  - Receive a locator for the origin of SAX document events
- **`startDocument(); endDocument()`**
  - notify the beginning/end of a document.
- **`startElement(String nsURI,`**
  `String localName,`
  `String rawName,`
  `Attributes atts);`
  `endElement( … );` same params, w.o. attributes

for **namespace** support

Namespaces in SAX: Example

```
<xsl:stylesheet version="1.0"
  xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
  xmlns="http://www.w3.org/TR/xhtml1/strict">
  <xsl:template match="/">
    <html>
      <xsl:value-of select="//total"/>
    </html>
  </xsl:template>
</xsl:stylesheet>
```

- `startElement` for this would pass following parameters:
  - nsURI= `http://www.w3.org/1999/XSL/Transform`
  - localname = `template`, rawName = `xsl:template`

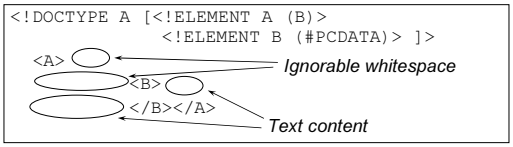
Namespaces: Example (2)

```
<xsl:stylesheet version="1.0" ...
  xmlns="http://www.w3.org/TR/xhtml1/strict">
  <xsl:template match="/">
    <html> ... </html>
  </xsl:template>
</xsl:stylesheet>
```

- `endElement` for `html` would give
  - nsURI = `http://www.w3.org/TR/xhtml1/strict` (as default namespace for element names without a prefix), localname = `html`, rawName = `html`

`ContentHandler` interface (cont.)

- **`characters(char ch[], int start, int length)`**
  - notification of character data
- **`ignorableWhitespace(char ch[], int start, int length)`**
  - notification of ignorable whitespace in element content



SAX Processing Example (1/9)

- **Input**: XML representation of a personnel database:

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<db>
  <person idnum="1234">
  <last>Kilpeläinen</last><first>Pekka</first></person>
  <person idnum="5678">
  <last>Möttönen</last><first>Matti</first></person>
  <person idnum="9012">
  <last>Möttönen</last><first>Maija</first></person>
  <person idnum="3456">
  <last>Römppänen</last><first>Maija</first></person>
</db>
```


SAX Processing Example (2/9)

- **Task**: Format the document as a list like this:

```
Pekka Kilpeläinen (1234)
Matti Möttönen (5678)
Maija Möttönen (9012)
Maija Römppänen (3456)
```

- Event-based processing strategy:
  - at the start of `person`, record the `idnum` (e.g., `1234`)
  - record starts and ends of `last` and `first` to store their contents (e.g., "`Kilpeläinen`" and "`Pekka`")
  - at the end of a `person`, output the collected data

SAX Processing Example (3/9)

- **Application**:
  First import relevant interfaces & classes:

```
import org.xml.sax.XMLReader;
import org.xml.sax.Attributes;
import org.xml.sax.ContentHandler;

//Default (no-op) implementation of
//interface ContentHandler:
import org.xml.sax.helpers.DefaultHandler;

// JAXP to instantiate a parser:
import javax.xml.parsers.*;
```


SAX Processing Example (4/9)

- Implement relevant call-back methods:

```
public class SAXDBApp extends DefaultHandler{
// Flags to remember element context:
  private boolean InFirst = false,
                  InLast = false;
// Storage for element contents and
// attribute values:
  private String FirstName, LastName, IdNum;
```


SAX Processing Example (5/9)

- Call-back methods:
  - record the start of `first` and `last` elements, and the `idnum` attribute of a `person`:

```
public void startElement (
  String nsURI, String localName,
  String rawName, Attributes atts) {
   if (rawName.equals("person"))
     IdNum = atts.getValue("idnum");
   if (rawName.equals("first"))
     InFirst = true;
   if (rawName.equals("last"))
     InLast = true;
 } // startElement
```


SAX Processing Example (6/9)

- Call-back methods continue:
  - Record the text content of elements `first` and `last`:

```
 public void characters (
     char buf[], int start, int length) {
  if (InFirst) FirstName =
         new String(buf, start, length);
  if (InLast) LastName =
     new String(buf, start, length);
 } // characters
```

SAX Processing Example (7/9)

- At the end of `person`, output the collected data:

```
public void endElement(String nsURI,
       String localName, String qName) {
   if (qName.equals("person"))
     System.out.println(FirstName + " " +
      LastName + " (" + IdNum + ")" );
//Update the context flags:
   if (qName.equals("first"))
     InFirst = false;
  //(and the same for "last" and InLast)
```


SAX Processing Example (8/9)

- Application `main` method:

```
public static void main (String args[])
  throws Exception {
// Instantiate an XMLReader (from JAXP
// SAXParserFactory):
  SAXParserFactory spf =
     SAXParserFactory.newInstance();
  try {
    SAXParser saxParser = spf.newSAXParser();
    XMLReader xmlReader =
                saxParser.getXMLReader();
```


SAX Processing Example (9/9)

- `Main` method continues:

```
// Instantiate and pass a new
// ContentHandler to xmlReader:
     ContentHandler handler = new SAXDBApp();
     xmlReader.setContentHandler(handler);
     for (int i = 0; i < args.length; i++) {
            xmlReader.parse(args[i]);
     }
  } catch (Exception e) {
     System.err.println(e.getMessage());
     System.exit(1);
  };
} // main
```


SAX: Summary

- A low-level parser-interface for XML documents
- Reports document parsing events through method call-backs
  - > efficient: does not create in-memory representation of the document
  - > used often on servers, and to process LARGE documents