

Chapter 11

Algorithms and APIs

- XML as a data structure:
 - *abstract datatype* with API: DOM
 - (mainly main-memory) implementations; used e.g. in Java applications
 - low-level API with variable-based access
- Databases?
 - high-level API: XPath, XQuery
 - mapping to relational model (Oracle, IBM DB2) or ObjectTypes (Oracle, DB2)
 - “Native” storage: Software AG-Tamino
 - classical database functionality: multiuser, transactions, recovery

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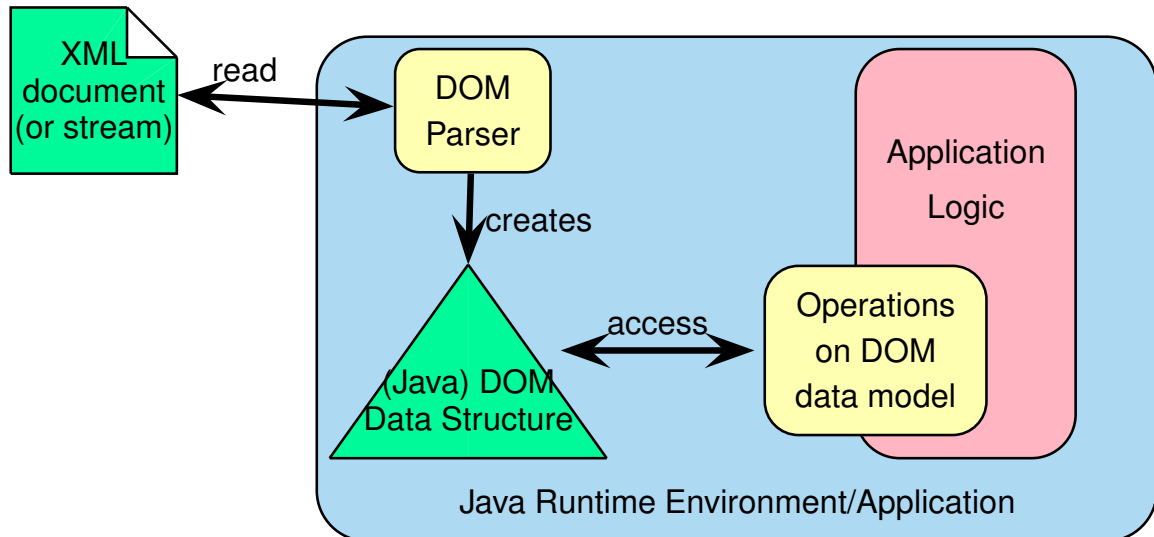
Algorithms and APIs (Cont'd)

- Stream Processing:
 - XML data transfer as sequence of events
 - SAX (Simple Application Interface for XML), StAX (Streaming API for XML)
- XML as Data Exchange Format in Web Services
 - serialize application objects as XML
 - SOAP: generic [not discussed in this course]
 - JAXB: "model-aware" infrastructure
- an intermediate rule-based concept:
 - `apache.commons.digester`

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11.1 DOM

- DOM (Document Object Model) defines a platform- and language-independent object-oriented *interface* (i.e., an *abstract datatype*) for generating, processing and manipulating XML data.



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DOM

- DOM is a specification of an interface/abstract datatype for the XML data model, *not a* data model and *not a* programming language!
- implementations in Java, C++, etc; usually main-memory-based; specialized Java interface definitions:
 - recommended for this course: JDOM2: `org.jdom2.*`, `jdom2.jar`,
 - original jdom (=jdom1) deprecated (mainly XPath handling changed; 2013),
 - another alternative: `dom4j`,
 - not recommended: `org.w3c.dom.*` (the plain dom is an implementation that exists in nearly all programming languages and does not make use of Java's advantages);
- language base of the DOM specification: OMG-IDL
- Main-memory-based:
 - handling *small* XML fragments for data exchange

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DOM: PRINCIPLES

- only one document in a single DOM instance
- step-by-step-access to the data:
based on variable assignments in the surrounding imperative/object-oriented programming language and on iterators (cf. proceeding in the [network data model](#)):
 - class “Document”: represents the complete document,
 - * doctype declaration, `getRootElement()`
 - class “Node”: `getNodeTypes()`, `getChildren()`, `getFirstChild()`, `getNextSibling()`, `getParentNode()`, ...
 - class “Element”: `getName()`, `getAttributes()`, `getContent()`, ...
 - class “Attribute”: `getName()`, `getValue()`, ...
 - corresponding methods for generating and changing nodes.
- additionally, XPath and XSLT can be applied to instances of Document and Element;
- based on DOM, XPath and XQuery can be implemented (cf. Apache Xerces (XML/DOM)/Xalan (C++/Java; XPath 1.0/XSLT 1.0 [in 2016])
- XPath/XSLT often inefficient (no indexes, query optimization), restricted functionality

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JDOM – sample code fragment

```
// apt-get install libjdom2-java; add jdom2.jar to the classpath
import java.io.File;
import java.util.List;
import org.jdom2.Document;
import org.jdom2.Element;
import org.jdom2.input.SAXBuilder;

public class MondialJDOMSimple {
    public static void main(String[] args) {
        try {
            SAXBuilder builder = new SAXBuilder();
            Document doc = (Document) builder.build(new File("../mondial.xml"));
            Element mondial = doc.getRootElement();
            List<Element> countries = mondial.getChildren("country");
            String firstcode = countries.get(0).getAttributeValue("car_code");
            System.out.println(firstcode);
        } catch (Exception e) { e.printStackTrace(); }
    }
}
```

[Filename: java/JDOM/MondialJDOMSimple.java]

- SAXBuilder can be set on any input stream.
- XMLOutputter([Format])/SAXOutputter

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JDOM2: XPath

- similar to JDBC/SQLJ statement concept for SQL in Java:
- Basic: compile Strings into XPath expressions, evaluate to Object or List<Object>,
- Optional: add (type) Filter for result node type,
- Advanced: XPath expression contains variables
 - must be declared as a map of variables (optionally with preset values)
 - call then requires also namespace blabla, see doc,
- XPath handling changed severely from jdom to jdom2 (2013).
- id(), number(), and thus also max(), sum() etc. not supported.

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JDOM2: XPath example

```
import java.io.File;
import java.util.List;
import java.util.Map;
import java.util.HashMap;
import org.jdom2.Document;
import org.jdom2.Element;
import org.jdom2.Attribute;
import org.jdom2.Namespace;
import org.jdom2.input.SAXBuilder;
import org.jdom2.xpath.XPathFactory;
import org.jdom2.xpath.XPathExpression;
import org.jdom2.filter.Filters;

public class MondialJDOMXPath {
    public static void main(String[] args) {
        try {
            SAXBuilder builder = new SAXBuilder();
            Document doc = (Document) builder.build(new File("../mondial.xml"));
            Element mondial = doc.getRootElement();
            XPathFactory xpf = XPathFactory.instance();
```

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```

XPathExpression xpath = xpf.compile("//country[@car_code='R']/@area");
Attribute a = (Attribute) xpath.evaluateFirst(doc);    // -> casting
int area = Integer.valueOf(a.getValue());
System.out.println(area);

xpath = xpf.compile("//country[@area > 7000000]/name");
List<Object> names = xpath.evaluate(doc);    // <Object> -> casting
for (Object n : names) System.out.println(((Element) n).getTextTrim());

Map<String, Object> vars = new HashMap<String, Object>();
vars.put("code", "D");
XPathExpression<Element>    // due to filter: result type guaranteed
    xp2 = xpf.compile("//country[@car_code=$code]/population[last()]",
        Filters.element(), vars, (Namespace[]) null);
Element res = xp2.evaluateFirst(doc);    // no casting necessary
int pop = Integer.valueOf(((Element)res).getTextTrim());
System.out.println(pop);
xp2.setVariable("code", "F");
res = (Element) xp2.evaluateFirst(doc);
pop = Integer.valueOf(((Element)res).getTextTrim());
System.out.println(pop);
} catch (Exception e) { e.printStackTrace(); }
}}                                     [Filename: java/JDOM/MondialJDOMXPath.java]

```

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Deprecated: JDOM1 – sample code fragment: XPath

```

public Element getCity(Element country, String provname, String cityname)
{
    Element city = null;
    XPath xpath;
    try
    { if (provname != null) {
        xpath = XPath.newInstance("./province[name=$pn]/city[name=$cn]");
        xpath.setVariable("pn", provname); }
        else
        xpath = XPath.newInstance("./city[name=$cn]");
        xpath.setVariable("cn", cityname);
        // xpath.addNamespace(... an instance of Namespace ...);
        city = (Element) xpath.selectSingleNode(country);
    }
    catch (Exception e) {...}
    return city;
}

```

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JDOM and XSLT

XSLT: $xsl(xml) \times xml \rightarrow xml$

- Simple: class `org.jdom2.transform.XSLTransformer` (XSLT 1.0 only?)
- More complex: JAXP TrAX classes
 - `JDOMSource/JDOMResult` as generic interfaces to XML representations
- `saxon` can/could also be combined with JDOM2 (via a JDOM wrapper class provided by Saxon)

JDOM Output etc

- `XMLOutputter`
- predefined formats available
- for adding a DTD reference:
`document.setDocType(new DocType("elementname", "dtdfilename"));`

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```
import java.io.File;
import org.jdom2.input.SAXBuilder;
import org.jdom2.Document;
import org.jdom2.transform.XSLTransformer;
import org.jdom2.output.XMLOutputter;
import org.jdom2.output.Format;

public class MondialJDOMXSL {
    public static void main(String[] args) {
        try {
            SAXBuilder builder = new SAXBuilder();
            Document doc = (Document) builder.build(new File("mondial.xml"));
            XSLTransformer xsltr = new XSLTransformer("../..XSLT/mondial-simple.xsl");
            Document result = xsltr.transform(doc);
            Format fmt = Format.getPrettyFormat();
            fmt.setLineSeparator(System.getProperty("line.separator"));
            // default would be DOS/windows style \r\n
            XMLOutputter outputter = new XMLOutputter(fmt);
            outputter.output(result, System.out);
        } catch (Exception e) { e.printStackTrace(); }
    }
}
```

[Filename: java/JDOM/MondialJDOMXSL.java]

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```

import java.io.File;
import org.jdom2.input.SAXBuilder;
import org.jdom2.Document;
import org.jdom2.transform.JDOMSource;
import javax.xml.transform.*;
import javax.xml.transform.Transformer;
import javax.xml.transform.TransformerFactory;
import javax.xml.transform.stream.StreamResult;
import javax.xml.transform.stream.StreamSource;

public class MondialJDOMXSL2 {
    public static void main(String[] args) {
        try {
            SAXBuilder builder = new SAXBuilder();
            Document doc = (Document) builder.build(new File("mondial.xml"));
            TransformerFactory factory = TransformerFactory.newInstance();
            Source xsltSource = new StreamSource("../XSLT/mondial-simple.xsl");
            Transformer transformer = factory.newTransformer(xsltSource);
            StreamResult result = new StreamResult("bla.xml");
            JDOMSource src = new JDOMSource(doc);
            transformer.transform(src, result);
        } catch (Exception e) { e.printStackTrace(); }
    } }

```

[Filename: java/JDOM/MondialJDOMXSL2.java]

11.2 HTML vs XHTML in Java

- HTML/XHTML has a DTD that restricts the element types, nesting, and attributes,
- HTML applications know+use a fixed DTD,
- sloppyness/tolerance can exploit that the DTD is known, allow to omit “obvious” things.
- HTML *usage* is less strict than XHTML (cf. parser exercise to the lecture)
 - mainly concerned: HTML parsers in the browsers that should accept handwritten dirty/sloppy HTML.
 - data model [tree](#): intermediate levels (e.g. table: thead, tbody) may be missing
browsers “know” how to render it (best-effort)
 - parsing the [input character stream](#):
 - * closing tags may be missing, e.g.,
<tr><td>bla <td>blubb </tr>
 - * empty elements like
 instead of
 (HTML tools know that br-elements are empty)
- **XML tools must not accept any sloppyness**

HTML to XHTML

- tidy: <https://www.html-tidy.org/>
console application (→ can be used in shell scripts) C library libtidy
- JSoup: Java HTML DOM Parser and API: <https://jsoup.org/>
 - uses an own (HTML) DOM implementation
`Document doc = Jsoup.parse(string s; [baseUri for hrefs]);`
`Document doc = Jsoup.connect("http://en.wikipedia.org/").get();`
`Document doc = Jsoup.parse(File in, String charsetName, String baseUri);`
 - stepwise navigation in the DOM
 - allows simple XPath style selects
`doc.select("selector pattern");`
 - set/modify content, attributes and text contents
 - serialization: `toString()` (obviously!)
 - document properties (DTD, output mode, ...) can be set:
charset, syntax (html/xml), indentAmount, escapeMode (how to handle HTML entities), e.g.
`document.outputSettings().syntax(Document.OutputSettings.Syntax.xml);`
 - note: JSoup materializes the whole document tree

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JSoup example

```
import org.jsoup.Jsoup;
import org.jsoup.nodes.Document;
import java.io.*;
public class JSoupTest {
    public static void main(String[] args) {
        try {
            Document doc = Jsoup.connect("http://en.wikipedia.org/wiki/Ball's_Pyramid").get();
            // File input = new File("bla.html");
            // Document doc = Jsoup.parse(input, "iso-8859-1", "");
            doc.outputSettings().syntax(Document.OutputSettings.Syntax.xml);
            String xml = doc.toString();
            BufferedWriter writer = new BufferedWriter(new FileWriter("jsoupoutput.xml"));
            writer.write(xml);
            writer.close();
        } catch (Exception e) { e.printStackTrace(); }
    } }
[Filename: java/JSoupTest.java]
```

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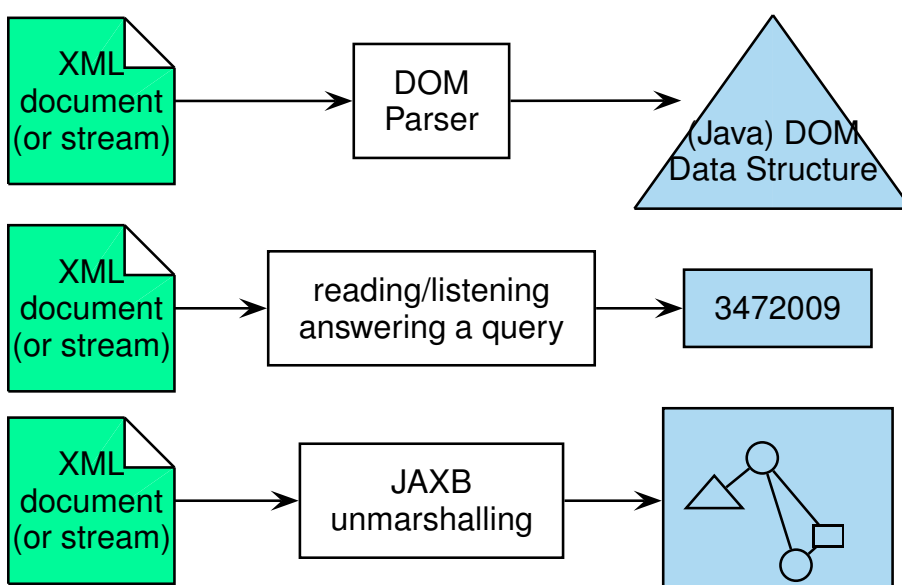
11.3 XQJ: XQuery API for Java

- similar to JDBC for “SQL in Java”
- access to a remote XML DB: open a connection, send an XQuery query, receive an iterable set of results.
- Tutorial: <https://www.progress.com/tutorials/xquery/api-for-java-xqj>
- saxonEE (commercial version) implements XQJ (although it's not a remote XML DB server then)

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11.4 XML Stream Processing

- reading from a file or from an HTTP connection both is actually reading char by char from a stream
- the stream is parsed, resulting in something that can be used by application:



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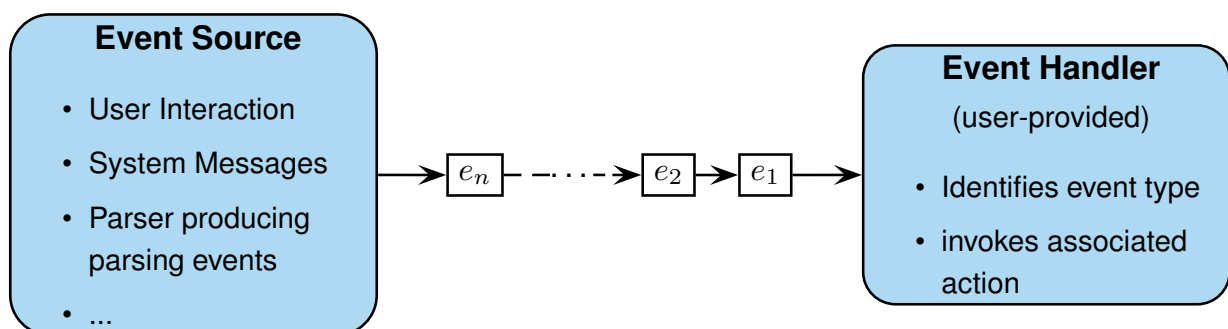
PARSING: GENERAL CONCEPTS

- **Compiler Construction in general:**
 1. input: a sequence of characters
 2. lexical analysis ("lexer") extracts the keywords (e.g. "begin", "end", "for") and outputs a sequence of *tokens*
 3. syntactical (grammar) analysis: check grammatical structure and generate the *parse tree* (e.g. via automaton)
 4. tools: lex & yacc/bison
 5. interpreter, optimizer, compiler, visualizer etc. process the parse tree
 - **XML:**
 1. lexical: split unicode input sequence into opening tags, closing tags, attributes, PCDATA, processing instructions, etc.
 2. syntactical and structural: is it well-formed XML? (if not: "debug" it?)
 3. processing: build DOM tree, build JAXB structure, visualize, ...
 - the above DOM and JAXB are actually parser+specific processing
- ⇒ **XML Stream Processing: works on the tokens sequence!**

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EVENT-BASED PROCESSING AS A *General Design Pattern*

- A stream of (high-level) items that carry some inherent semantics can be seen as a stream of "events"
(in contrast to a simple 0-1-stream, a byte stream or similar low-level streams)

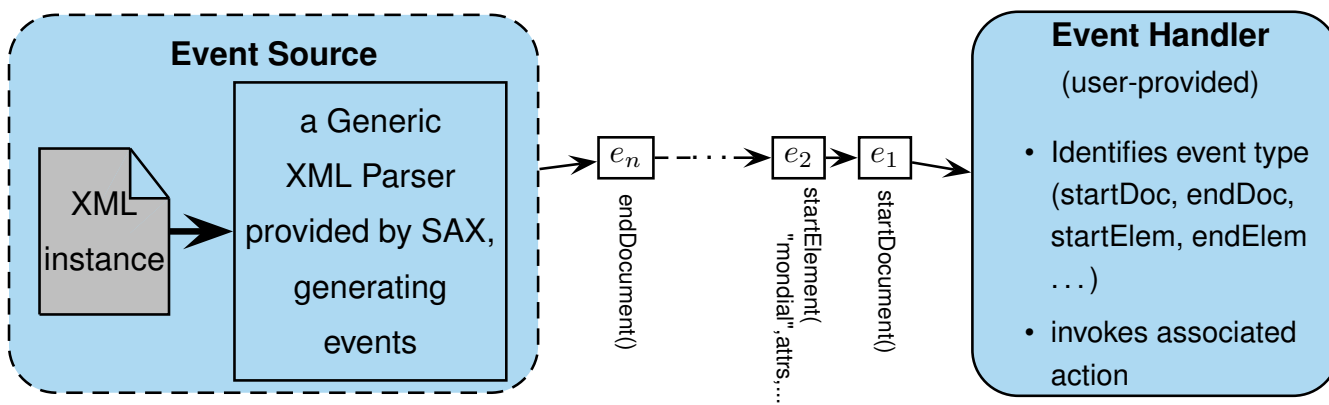


- The application programmer provides the Event Handler implementation, containing actions for each type of event;
- kind of *rule-based*;
- programmer is *not* in charge of the control flow

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11.5 Event-based XML Parsing with SAX

- SAX (“The Simple API for XML”) is an *event-based interface/model*



Represents/processes an XML document as a sequence of events (depth-first traversal), e.g.

- startDocument(), endDocument()
- startElement(Name, attributesList) – attributes not split
- endElement(Name)
- characters(string)

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XML PARSING WITH SAX

SAX: parse XML tokens from a character stream (e.g., a file)

- import classes: `javax.xml.parsers.*`, `org.xml.sax.*`
- a generic XML Parser is parameterized with a *Content Handler* (plus *Error Handler*, *DTD Handler*, and *EntityResolver*) implementation.
- The most trivial Content Handler is the *DefaultHandler* that does nothing: the document is parsed, events are detected, but no action is performed (DTD / XML Schema validation can be switched on).
- Event handler programmed wrt. a “push API”.
- Normally, the user-provided Content Handler extends the *DefaultHandler*, overwriting (some of) its event methods.
- With the content handler implementation, the user provides “actions” in form of Java code, associated with specific events (and even dependent on context information).
- If during parsing of the XML document, a specific event occurs, the code of the associated action from the content handler is invoked (“callback”).

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SAX (AND STAX): APPLICATIONS

Only events are signaled: linear processing based on incoming sequence of events (=tokens).

- ... among many other things, one can generate a DOM tree structure,
- validation according to a DTD (using an automaton as given on Slide 176) in linear time,
 - SAX (and StAX) are only on an intermediate level between character streams and XML
 - * have lower requirements on input syntax and structure
 - * input must be allowed XML tokens incl. text
 - * closing tags may be missing, entities may be undeclared
 - ⇒ allows e.g. for fault-tolerant parsing of sloppy HTML.
- stream-processing of XML input
 - start processing already when input document is not yet complete,
 - filtering for elements that are relevant for a given application,
 - linear search for something, e.g., names of countries,
 - stop evaluation when finished before reading the whole document.
- if necessary: application needs to maintain context.

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SAX EXAMPLE CODE

Consider a very simple application that

- detects all elements with attributes,
- for each element, output the element's name,
- for each element, output the name-value pairs of its attributes,
- end the evaluation when "Göttingen" is found.

```
element: country
- attribute: 'car_code' value: 'AL' type: 'ID'
- attribute: 'area' value: '28750' type: 'CDATA'
- attribute: 'capital' value: 'cty-cid-cia-Albania-Tirane' type: 'IDREF'
- attribute: 'memberships' value: 'org-BSEC org-CE org-CCC org-ECE org-EU ...' type: 'IDREFS'
element: encompassed
- attribute: 'continent' value: 'europe' type: 'IDREF'
- attribute: 'percentage' value: '100' type: 'CDATA'
element: ethnicgroups
- attribute: 'percentage' value: '3' type: 'CDATA'
element: ethnicgroups
- attribute: 'percentage' value: '95' type: 'CDATA'

... Göttingen found - ready.
```

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```

import java.io.IOException;
import javax.xml.parsers.*;
import org.xml.sax.SAXException;
import org.xml.sax.helpers.DefaultHandler;
public class PrintAttributes {

    public static void main(String[] args) {
        DefaultHandler handler = new ContentHandlerPrintAttributes();
        SAXParserFactory factory = SAXParserFactory.newInstance();
        try {
            SAXParser parser = factory.newSAXParser();
            parser.parse("file:../mondial.xml", handler); // <<<<<<<< and now it runs
        } catch (ContentHandlerPrintAttributes.MySAXTerminatorException e) {
            // exception for smoothly stopping the processing: <<<<<<<<<<<<<<<<<
            System.out.println(" ... Göttingen found - ready."); }
        catch (IOException e1) { e1.printStackTrace(); }
        catch (ParserConfigurationException e) { e.printStackTrace(); }
        catch (SAXException e) { e.printStackTrace(); }
    } }

```

[Filename: java/SAX/PrintAttributes.java]

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```

import org.xml.sax.Attributes;
import org.xml.sax.SAXException;
import org.xml.sax.helpers.DefaultHandler;

public class ContentHandlerPrintAttributes extends DefaultHandler {
    // react on opening elements:
    public void startElement(String url, String localName, String qName,
        Attributes attrs) throws SAXException {
        if (attrs.getLength() > 0) {
            String elementName;
            if (qName == null || qName.equals("")) elementName = localName;
            else elementName = qName;
            System.out.println("element: " + elementName);
            for (int i = 0; i < attrs.getLength(); i++) {
                System.out.println(" - attribute: '" + attrs.getQName(i)
                    + "' value: '" + attrs.getValue(i) + "' type: '"
                    + attrs.getType(i)+"'");
            }
            System.out.println();
        } }
    // methods for endElement(), startDocument(), endDocument() omitted

```

// continue next page

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```

// continue next page

public void characters(char[] text, int from, int length)
    throws SAXException {
    // stop evaluation by throwing an exception:
    String textString = (new String(text)).substring(from, from + length);
    if (textString.contains("Göttingen"))
        throw new MySAXTerminatorException();
}
// the exception stub:
public class MySAXTerminatorException extends SAXException { ; }
}

```

[Filename: java/SAX/ContentHandlerPrintAttributes.java]

- evaluation can only be stopped by raising an exception;
- the events are on the level of structural XML parsing, an XML element/subtree consists of several (often: many) events.
- all PCDATA/CDATA values are strings
→ numeric computations require conversion to Java literals or class instances.

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SAX: APPLICATIONS TO XPATH QUERY ANSWERING

Forward queries

XPath-queries like `//country[@car_code='D']/population[last()]` can be answered very (time- and memory-)efficient,

- use the sequence of events (linear)
- maintain some context (often LOGSPACE/additional LOGTIME sufficient)

... works only for queries, that contain only forward steps,

General queries

which XPath expressions can be *transformed* in equivalent forward-expressions (and with what efforts)?

- “XPath: Looking forward”; F. Bry et al ; 2002; LMU München
- [theory: complexity, connections to linear temporal logic](#)
For every linear temporal logic formula that uses past and future operators, there is an equivalent formula that uses only future operators
... but in general of exponential size.

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11.6 XML Streams/StAX - The Streaming API for XML

Higher abstraction level (than character-based XML) for XML data exchange:

javax.xml.stream (rt.jar)

Reconsider SAX

- on-the fly processing, no in-memory representation for good performance
- idea of “XML Event Stream”: a char stream (File, HTTP) can be converted into an XML Event Stream by an XML parser; see example’s main() method.
- SAX does not make the XML Event Stream accessible, but only via calls of methods of the Event Handler.

Generalization and Abstraction: XML Streams

- XMLEvent types: StartDocument, DTD, StartElement, Characters, EndElement, EndDocument, (Attribute), (Namespace) ...
- XMLStreamReader, XMLStreamWriter, XMLEventReader, XMLEventWriter,
- XML Streams also can be connected *directly* as an *abstract* means to exchange XML

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XML Streams: Application Scenarios

- READ: usage analogous to SAX: process an XML file input as an XML Event Input Stream:
control flow is not passed to the parser (**unlike SAX**), but XML events are accessed using an *iterator*, controlled by the Java program using the StAX API (*Pull-API*).
[Note: iterators are a common design pattern, not only applied to collections, but as we see here also to streams: init(), next(), ...]
⇒ application code: same as for SAX, only operational embedding done differently.
- WRITE and READ: streamed data exchange between processed on the XML level.
- Two variants exist:
 - XMLStreamReader, XMLStreamWriter (“Cursor”)
 - XMLEventReader, XMLEventWriter (“Iterator”)
- XML-S/E-Readers/Writers can be put on any input/output stream (FileInput/OutputStream, BufferedInput/OutputStream, System.out, HTTP stuff (see Web Services) or directly connected to each other:
XMLS/EWriter->PipedOutputStream->PipedInputStream->XMLS/EReader of the next application)

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INTERFACES XMLSTREAMREADER, XMLSTREAMWRITER

XMLStreamReader

- `int eventtype = r.next()` and then switch based on eventtype
javax.xml.stream.XMLStreamConstants.XX:
START_DOCUMENT, START_ELEMENT, CHARACTERS, END_ELEMENT, ...
- access methods when on START_DOCUMENT: `getEncoding()` etc.
- goal-driven access methods on the reader when on START_ELEMENT:
`r.getLocalName()`, `r.getAttributeValue(name)`,
`r.getAttributeCount()`, `r.getAttributeLocalName(n)`, `r.getAttributeValue(n)` for iteration,
`r.getElementText()` (reads also the next EndElement from the stream!),
`r.getName()` (as QName),
namespace handling: `r.getPrefix()`, `r.getNamespaceURI()` (default NS),
`r.getNamespaceURI(prefix)`,
- goal-driven access method when on CHARACTERS: `r.getText()`, `r.isWhiteSpace()`;
- goal-driven access methods on the reader when on END_ELEMENT:
`r.getLocalName()` + namespace handling
- note again: all PCDATA/CDATA values are strings.

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XMLStreamWriter

- `w.writeStartDocument()`
- `w.writeStartElement(name)`,
- `w.writeEmptyElement(name)`,
Note: there is `w.writeEmptyElement(name)`, although for the Reader, there is no event type
EMPTY_ELEMENT; instead also for empty Elements, START_ELEMENT and
END_ELEMENT are separately read
⇒ copying straightly to output will create an non-empty element with ""-content!
- `w.writeAttribute(name, value)`, (and all three also with namespace handling)
- `w.writeCharacters(text)`;
- `w.writeEndElement()`: closes the innermost open element;
- `w.writeEndDocument()`: closes all open elements.
- `w.flush()`: force write any data to the underlying output mechanism.

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StAX StreamReader Example

```
import javax.xml.stream.XMLInputFactory;
import javax.xml.stream.XMLStreamConstants;
import javax.xml.stream.XMLStreamReader;
import java.io.FileInputStream;

public class StAXPrintAttributes {
    public static void main(String[] args) {

        try {
            FileInputStream inputStream = new FileInputStream("../mondial.xml");
            XMLInputFactory inputFactory = XMLInputFactory.newInstance();
            XMLStreamReader parser = inputFactory.createXMLStreamReader(inputStream);
            boolean goOn = true;

            while (goOn) {
                int eventtype = parser.next();
                switch(eventtype) {
                    case XMLStreamConstants.END_DOCUMENT:
                        goOn = false;
                        break;    // << break after each case!

                        // continue next page                515

                        // continue next page

                    case XMLStreamConstants.START_ELEMENT:
                        if (parser.getAttributeCount() > 0) {
                            System.out.println(parser.getLocalName());
                            for (int i = 0; i < parser.getAttributeCount(); i++) {
                                System.out.println(" - attribute: '" + parser.getAttributeLocalName(i)
                                    + "' value: '" + parser.getAttributeValue(i)
                                    + "' type: '" + parser.getAttributeType(i));
                            }
                        }
                        break;
                        // cases for endElement(), startDocument(), endDocument() omitted
                    case XMLStreamConstants.CHARACTERS:
                        String textString = parser.getText();
                        if (textString.contains("Göttingen"))
                            goOn = false;
                }
            }
            System.out.println(" ... Göttingen found - ready.");
            parser.close();
        } catch (Exception e) { e.printStackTrace(); }
    }
}
```

[Filename: java/StAX/StAXPrintAttributes.java]

XMLeventReader/XMLeventWriter

- above: [XMLStreamReader/Writer](#):
 - XML-parsing level “events” like in SAX
 - the reader is the central object (`r.next()→int`, `r.getLocalName()`, ...)
- alternative: [XMLeventReader/Writer](#):
 - consider (empty or CDATA) XML Elements as *events* on the application level,
 - XMLeventReader as an *Iterator* over a sequence of events (actually, XMLeventReader extends `Iterator { ...}`), applicable to pure XML files, but also to incoming HTTP-XML streams (→ Web Services)
 - * `hasNext()` → boolean: check if there are more events.
 - * `nextEvent()` → XMLevent: get the next XMLevent
 - * `getElementText()` → String: reads the content of a text-only element.
 - * `nextTag()` → XMLevent: skips any insignificant space events until a `START_ELEMENT` or `END_ELEMENT` is reached. [what about CHARACTERS?]
 - * `peek()`→ XMLevent: check the next XMLevent without reading it from the stream.

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StAX Event Example: Exam Registration

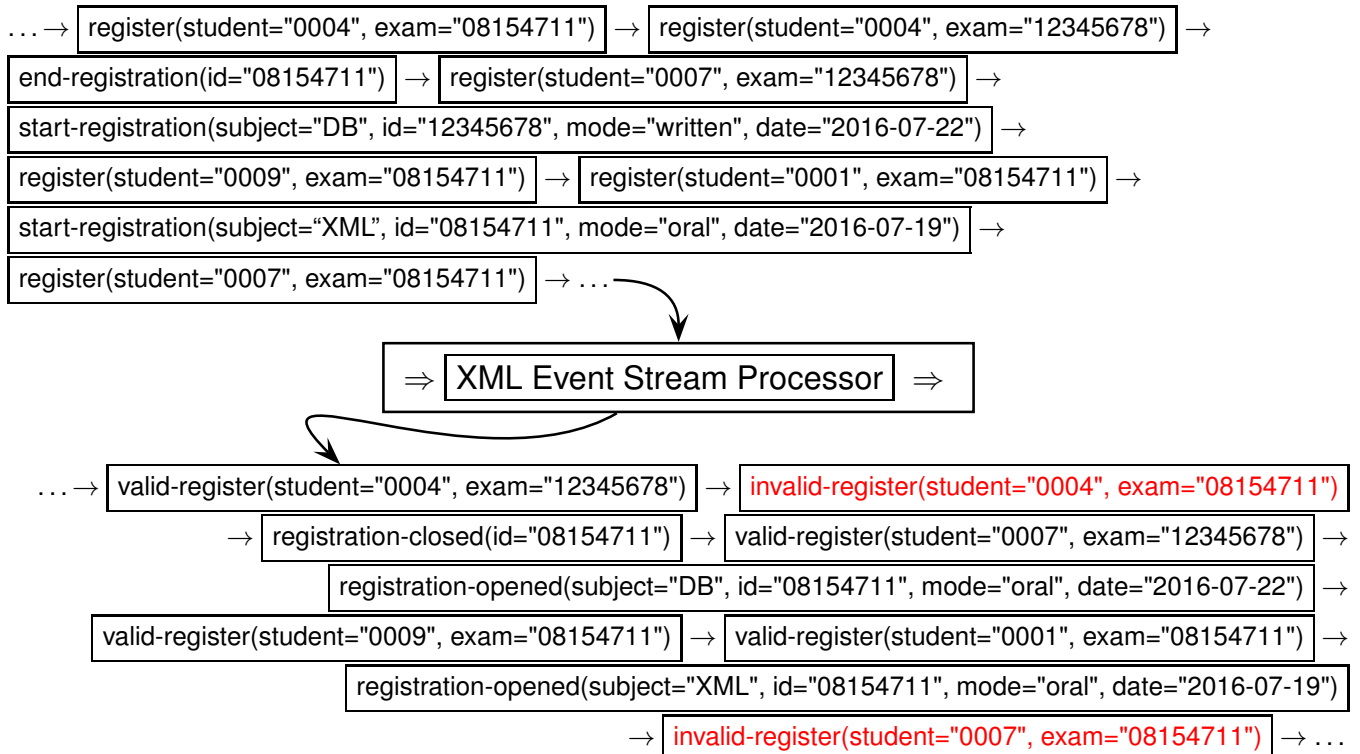
Assume the administration of exams in a student’s office (“Prüfungsamt”):

- The *subject* (e.g., “Semi-Structured Data and XML”) and ID of lectures/exams,
- whether the exam is *written* or *oral*,
- for written exams, the date of the exam,
- for oral exams, a number of dates is given when the single exams are held.
- the registration period *starts* when receiving an incoming XML message
`start-registration`
- the registration period *ends* when receiving an incoming XML message
`end-registration`
- for all students that did (`register`) correctly, the student’s relevant details are extracted and written to an `XMLOutputStream` stream (`valid-register`; in the example, we pipe it to `stdout`.)
- students that register before beginning or after the end of registration, are not accounted for the exam; an error message/event `invalid-register` goes to the `XMLOutputStream`.

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StAX Example: Exam Registration

- the program should allow the management of registrations for multiple exams at one time (all incoming over the same continuous input stream).



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StAX Example Cont'd:

Consider the following XML sequence as input stream:

```
<?xml version="1.0" encoding="UTF-8"?>
<stream>
  <register student="0007" exam="08154711"/>
  <start-registration id="08154711" subject="Semistructured Data and XML"
    date="2016-07-19" mode="oral"/>
  <register student="0001" exam="08154711"/>
  <register student="0009" exam="08154711"/>
  <start-registration id="12345678" subject="Databases"
    date="2016-07-22" mode="written"/>
  <register student="0007" exam="12345678"/>
  <end-registration id="08154711"/>
  <register student="0004" exam="08154711"/>
  <register student="0004" exam="12345678"/>
</stream>
```

[Filename: java/StAX/exams.xml]

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StAX Example Cont'd:

Code for the Exam bean, containing the exam's properties and some constants):

```
import java.util.Date;
import java.text.SimpleDateFormat;
import javax.xml.namespace.QName;
import javax.xml.stream.events.StartElement;

public class Exam {
    private String id;      private String subject;
    private String date;   private boolean oral;
    private boolean registeringClosed = false;
    private String startOfReg; private String endOfReg;

    public Exam(StartElement ev) { // the <start-registration> element "event"
        this.id = ev.getAttributeByName(new QName("id")).getValue();
        this.subject = ev.getAttributeByName(new QName("subject")).getValue();
        this.oral = "oral".equals(ev.getAttributeByName(new QName("mode")).getValue());
        this.date = ev.getAttributeByName(new QName("date")).getValue();
        this.setStartOfReg(getTodayDate());
    }

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    public String getId() { return id; }
    public String getDate() { return date; }
    public String getSubject() { return subject; }
    public boolean isOral() { return oral; }
    public boolean isWritten() { return (!oral); }
    public String getMode() { if (oral) return "oral"; else return "written"; }
    public boolean isRegisteringClosed() { return registeringClosed; }
    public void setRegisteringClosed(boolean registeringClosed) {
        this.registeringClosed = registeringClosed; }
    public String getEndOfReg() { return endOfReg; }
    public String getStartOfReg() { return startOfReg; }
    public void setStartOfReg(String startOfReg) { this.startOfReg = startOfReg; }
    public void setEndOfReg(String endOfReg) { this.endOfReg = endOfReg; }

    public static String getTodayDate() {
        return new SimpleDateFormat().format(new Date()); }
    /* private String getTodayDate() {
        DateFormat format = new SimpleDateFormat().;
        return format.format(new Date()); }
    */
}
```

[Filename: java/StAX/Exam.java]

StAX Example Cont'd:

Code for the main parser class, containing the main method:

```
import java.io.File;           import java.io.FileInputStream;
import java.io.OutputStream;
import java.text.DateFormat;   import java.text.SimpleDateFormat;
import java.util.HashMap;      import java.util.Map;
import java.util.Iterator;

import javax.xml.namespace.QName;
import javax.xml.stream.XMLInputFactory;
import javax.xml.stream.XMLOutputFactory;
import javax.xml.stream.XMLStreamConstants;
import javax.xml.stream.events.XMLEvent;
import javax.xml.stream.XMLEventFactory;
import javax.xml.stream.events.StartElement;
import javax.xml.stream.events.EndElement;
import javax.xml.stream.events.Attribute;
import javax.xml.stream.events.Characters;
import javax.xml.stream.XMLEventReader;
import javax.xml.stream.XMLEventWriter;

// continue next page           523
import javax.xml.stream.XMLEventWriter;

// continue next page

public class ExamStreamParser {
    public static void main(String[] args) {
        try{
            FileInputStream in = new FileInputStream("exams.xml");
            OutputStream out = System.out;
            XMLInputFactory inputFactory = XMLInputFactory.newInstance();
            XMLOutputFactory outputFactory = XMLOutputFactory.newInstance();
            XMLEventReader parser = inputFactory.createXMLEventReader(in);
            XMLEventWriter writer = outputFactory.createXMLEventWriter(out);
            XMLEventFactory eventFactory = XMLEventFactory.newInstance();
            Map<String,Exam> exams = new HashMap<String,Exam>();
            boolean goOn = true;

            while (goOn) {
                XMLEvent event = parser.nextEvent();
                int eventtype = event.getEventType();
                switch(eventtype) {

                    // continue next page
```

```
// continue next page
```

```
case XMLStreamConstants.START_ELEMENT:
    StartElement ev = (StartElement)(event.asStartElement());
    if("start-registration".equals(ev.getName().getLocalPart())) {
        Exam exam = new Exam(ev);
        exams.put(exam.getId(), exam);
        Iterator<Attribute> attrs = ev.getAttributes();
        StartElement se = eventFactory.createStartElement("", null, "registration-opened",
        writer.add(se);
        writer.add(eventFactory.createEndElement("", null, "registration-opened"));
        writer.add(eventFactory.createCharacters("\n"));
    }
    else if("end-registration".equals(ev.getName().getLocalPart())) {
        String examId = ev.getAttributeByName(new QName("id")).getValue();
        Exam exam = exams.get(examId);
        if(exam == null) {
            System.err.println("no such exam with id '"+examId+"' open for registration!");
            break;
        }
        exam.setEndOfReg(Exam.getTodayDate());
        exam.setRegisteringClosed(true);
    }
    // continue next page
```

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```
// continue next page
```

```
else if("register".equals(ev.getName().getLocalPart())) {
    String studentId = ev.getAttributeByName(new QName("student")).getValue();
    String examId = ev.getAttributeByName(new QName("exam")).getValue();
    if(exams.containsKey(examId)) {
        Exam exam = exams.get(examId);
        if(! exam.isRegisteringClosed()) {
            StartElement se = eventFactory.createStartElement(
                "", null, "valid-register", ev.getAttributes(), null);
            writer.add(se);
            writer.add(eventFactory.createEndElement("", null, "valid-register"));
            writer.add(eventFactory.createCharacters("\n"));
        }
        else { // exam.isRegisteringClosed()
            StartElement se = eventFactory.createStartElement(
                "", null, "invalid-register", ev.getAttributes(), null);
            writer.add(se);
            writer.add(eventFactory.createCharacters("reg. ended on " + exam.getEndOfReg()));
            writer.add(eventFactory.createEndElement(
                "", null, "invalid-register"));
            writer.add(eventFactory.createCharacters("\n"));
        }
    }
    // continue next page
```

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```
else { // not (exams.containsKey(examId))
```

```

    // continue next page

    else { // not (exams.containsKey(examId))
        StartElement se = eventFactory.createStartElement(
            "", null, "invalid-register", ev.getAttributes(), null);
        writer.add(se);
        writer.add(eventFactory.createCharacters("reg. for exam '"+examId+"' not open"));
        writer.add(eventFactory.createEndElement("", null, "invalid-register"));
        writer.add(eventFactory.createCharacters("\n"));
    }
}
break;
case XMLStreamConstants.END_DOCUMENT:
    parser.close();
    writer.flush();
    writer.close();
    goOn = false;
    break;
}
}} catch (Exception e) { e.printStackTrace(); }
}
}

```

[Filename: java/StAX/ExamStreamParser.java]

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Some comments on XMLEventReader/Writer

- XMLEventReader/Writer
 - no simple getLocalName()/getAttributeByName(), but only via qnames or getAttributes() as Iterator<Attribute>.
 - Note: real event-based applications usually use namespaces.
 - no getAttributeValue(...), but only via getAttribute(...).getValue().
 - generates instances of Event class
 - * memory-intensive, garbage-collector-intensive
 - * instances can be given away to threads for processing
 - For output, also event instances have to be created (use EventFactory).
 - No EmptyElement class - neither for Reader nor Writer.
 - EndElement explicitly needs element name again.

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Some notes for both XMLStreamReader and XMLEventReader

- Only XMLStreamWriter has a notion of empty elements:
 - XMLStream/EventReader: empty elements also have an EndElement event;
 - XMLEventWriter: empty elements require to write an explicit EndElement!
- The accessors to attributes differ between XMLStreamReader on START_ELEMENT and XMLEventReader→StartElement.

StAX COMPARISON WITH SAX

SAX: • “Push” API

- feeds a single event handler that is given “away” to the parser
- Common pattern: methods for each event type, where startElement() and endElement() contain large ifs.

StAX: ... next page ...

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StAX Comparison with SAX (Cont'd)

StAX: • “Pull” API

- Common pattern: huge switch command whose cases again contain large ifs.
- the design as a “pull-interface” where the user has control allows to use Reader.next()/Reader.nextEvent() whenever the programmer wants it:
 - in the “case”-code for StartElement, one can call next() to read the text content immediately for further processing. This saves some booleans.
- Modularization:
the while(...){... parser.next() ...} loop is parameterized with the parser. For “subtasks”, other procedures can be called that have specific implementation of the cases:

```
case XMLStreamConstants.START_ELEMENT:  
    if parser.getLocalName.equals("country") {  
        Country country = processCountry(parser); // run another while-loop  
        // (that first must process the attributes of the START_ELEMENT)  
        mondial.add(country);    }
```

Note that such methods can be wrapped as constructor calls like

```
prov = new Province(parser, country)  
to parse a province into an object of class Province that belongs to an object of class  
Country. (e.g. to implement JAXB; see Slide 535 ff.)
```

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StAX Comparison with SAX (Cont'd)

- Performance: no difference.
The underlying XMLStream is the same.
- both can easily produce XML output via XMLStreamWriter/XMLEventWriter (e.g. to another SAX/StAX appl.)
- The actual code to be written is not much different in both cases.
- SAX maps a unicode input stream directly to the EventHandler calls.
- StAX makes the [intermediate abstraction level](#) of XML event streams accessible.