Chapter 11
Algorithms and APIs

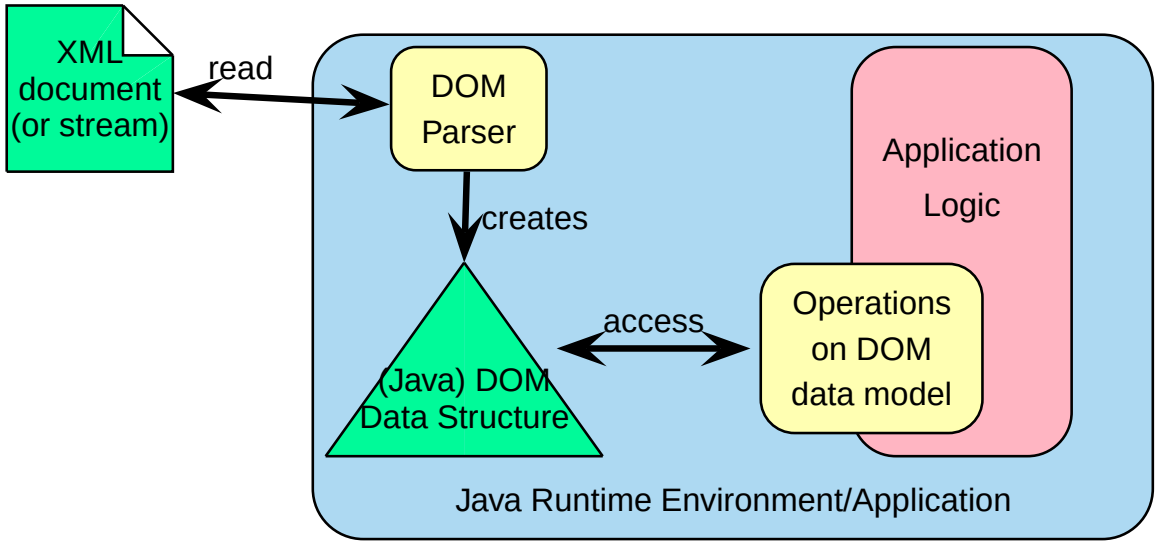
- XML as a data structure:
  - *abstract datatype* with API: DOM
  - (mainly main-memory) implementations; used e.g. in Java applications
  - low-level API with variable-based access
- Databases?
  - high-level API: XPath, XQuery
  - mapping to relational model (Oracle, IBM DB2) or ObjectTypes (Oracle,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

Algorithms and APIs (Cont’d)

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

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.



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:
  - this course: JDOM jdom.jar, org.jdom.*
  - 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: only for relatively small application programs
  (most of the "lightweight"-tools used in the course are internally based on DOM)

DOM: Principles

- only one document in a DOM
- 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):
  - document: represents the complete document,
    - Query-Methods, e.g. NodeList getElementsByName(string)
  - class “Node”: getNodeType(), 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 (XSLT)/Xindice (DB))
- often inefficient (no indexes, query optimization)

DOM – sample code fragment: Stepwise access

(taken from LanguageElement.java from MARS, using JDOM)

```
// given: Element element;

protected Set<InputVariableDefinition> getInputVariableDefinitions(
          boolean includeJoinVariables)
{ Set<InputVariableDefinition> definitions = new HashSet<InputVariableDefinition>();

  @SuppressWarnings("unchecked")
  List<Element> elements = element.getChildren();
  for (Element e : elements)
  { String elementName = e.getName();
    if (!elementName.equals("Opaque"))
    { String name = e.getAttributeValue("name", "");
      InputVariableDefinition variable = null;
      if (elementName.equals("has-input-variable"))
        variable = new InputVariableDefinition(name, InputVariableDefinition.INPUT);
      else if (elementName.equals("uses-variable") && includeJoinVariables)
        variable = new InputVariableDefinition(name, InputVariableDefinition.USE);
      if (variable != null)
      { String use = e.getAttributeValue("use", "");
        if (use.length() > 0) variable.setUse(use);
        definitions.add(variable);
      }
    }
  }
  return definitions;
}
```

DOM – sample code fragment: XPath

(taken from ServiceRegistry.java from MARS)

- similar to the JDBC statement concept for SQL in Java:

```
public Element getTaskDescr(Element serviceDescr, String task)
{
  Element taskDescr = null;
  try
  {  XPath xpath = XPath.newInstance(
        "./lsr:has-task-description/lsr:TaskDescription[" +
        "contains(lsr:describes-task/@rdf:resource,$task)]");
     xpath.addNamespace(Namespaces.RDF_NS);
     xpath.addNamespace(Namespaces.MARS_NS);
     xpath.addNamespace(Namespaces.LSR_NS);
     xpath.setVariable("task", task);
     taskDescr = (Element) xpath.selectSingleNode(serviceDescr);
  }
  catch (Exception e) {...}
}
```

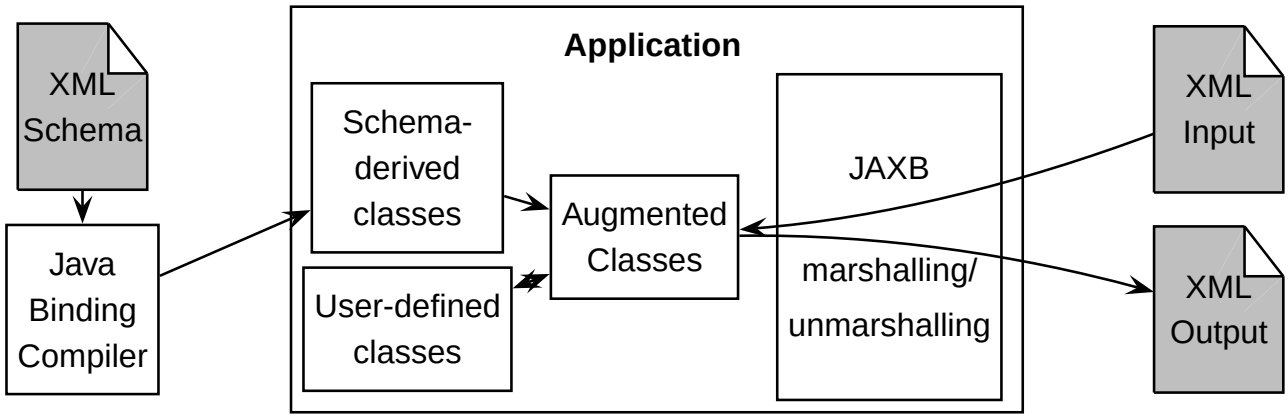

11.2 JAXB - The Java API for XML Binding

- Part of the Java Web Services Developer Pack
- SUN's "Java Web Service Tutorial"
  http://java.sun.com/webservices/tutorial.html
- XML elements describe objects with properties,
- correspond to classes of an application,
- derive interface with setX/getX methods (= Java Beans) as skeletons for these classes (automatically generated from an XML Schema description),
- user derives classes from these interfaces by adding behavior,
- application logics implemented by using these classes,
- import/export of XML instances of these classes via generic mappings (derived from the XSD).

JAXB Architecture

- map XML Schemas to Java classes (get/set methods),
- methods for *unmarshalling* XML instance documents into Java objects,
- methods for *marshalling* Java objects back into XML instance documents.

Architecture



JAXB - Example

[Filename: java/JAXB/books.xml]

```
<?xml version="1.0"?>
<Collection>
  <books>
    <book isbn="111-1234">
      <name>Learning JAXB</name>
      <price>34</price>
      <authors>
        <authorName>Jane Doe</authorName>
      </authors>
      <language>English</language>
      <language>French</language>
      <promotion>
        <Discount>10% until March 2003</Discount>
      </promotion>
      <publicationDate>2003-01-01</publicationDate>
    </book>

    <book isbn="112-0815">
      <name>Java Web Services Today and Beyond</name>
      <price>29</price>
      <authors>
        <authorName>John Brown</authorName>
        <authorName>Peter T.</authorName>
      </authors>
      <language>English</language>
      <promotion>
        <Discount>Buy one get Web Services Part 1 free</Discount>
      </promotion>
      <publicationDate>2002-11-01</publicationDate>
    </book>
  </books>
</Collection>
```

- values for xd:date and xs:time must conform to the syntax required for these XML types (cf. Slide 275)

JAXB - Example: XSD

[Filename: java/JAXB/books.xsd]

```
<?xml version="1.0"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:jaxb="http://java.sun.com/xml/ns/jaxb" jaxb:version="2.0">

<xs:element name="Collection">
 <xs:complexType>
  <xs:sequence>
   <xs:element name ="books">
    <xs:complexType>
     <xs:sequence>
      <xs:element name="book" type="bookType"
                  minOccurs="0" maxOccurs="unbounded"/>
     </xs:sequence>
    </xs:complexType>
   </xs:element>
  </xs:sequence>
 </xs:complexType>
</xs:element>



  <!-- continue next page -->
```



```
<xs:complexType name="bookType">
 <xs:sequence>
  <xs:element name="name" type="xs:string"/>
  <xs:element name="price" type="xs:long"/>
  <xs:element name="authors" >
   <xs:complexType>
    <xs:sequence>
     <xs:element name="authorName" type="xs:string" minOccurs="1"
                 maxOccurs="unbounded"/>
    </xs:sequence>
   </xs:complexType>
  </xs:element>
  <xs:element name="language" type="xs:string" minOccurs="1"
                maxOccurs="unbounded"/>
  <xs:element name="promotion">
   <xs:complexType>
    <xs:choice>
     <xs:element name="Discount" type="xs:string" />
     <xs:element name="None" type="xs:string"/>
    </xs:choice>
   </xs:complexType>
  </xs:element>
  <xs:element name="publicationDate" type="xs:date"/>
 </xs:sequence>
  <xs:attribute name="isbn" type="xs:string" />
</xs:complexType>
</xs:schema>
```

JAXB HowTo

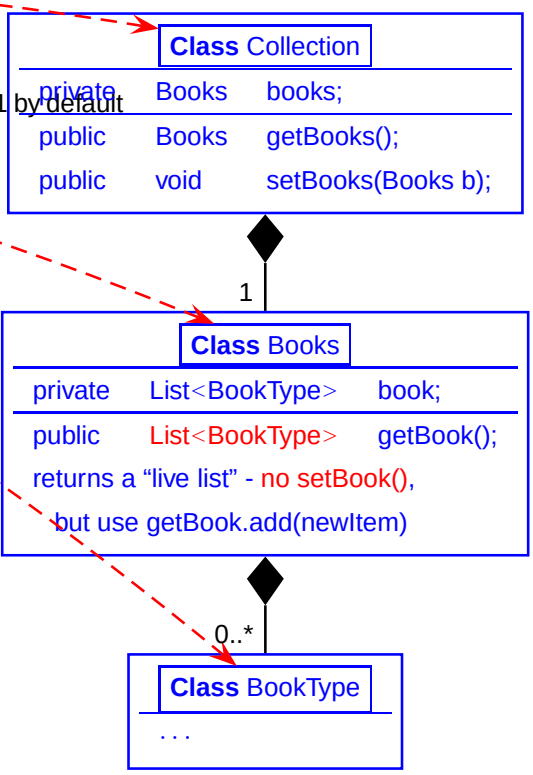
- README file in java/JAXB/JAXB-README.txt:

```
## Java Architecture for XML Binding (JAXB)

 mkdir myjaxb
 cd myjaxb
 mkdir classes gen-src
 ## java6: included in JDK
 ## earlier java: download jaxb and adjust below HOME:
 java -jar JAXB2_20070122.jar
 export JAXB_HOME=whereeveritis/jaxb20
 export JAXB_LIB=$JAXB_HOME/lib
 export JAXB_JAR=$JAXB_LIB/jaxb-api.jar:$JAXB_LIB/jaxb-libs.jar:$JAXB_LIB/jaxb-xjc.jar

 $JAXB_HOME/bin/xjc.sh -p JAXBbooks books.xsd -d gen-src
 # created classes can the be found in gen-src/JAXBbooks
 javac -d classes `find gen-src -name '*.java'`
 javac -d classes -classpath classes JAXBbooks.java
 java -classpath classes JAXBbooks books.xml

 # Syntax for old Java (with jaxb.jar in classpath)
 $JAXB_HOME/bin/xjc.sh -p JAXBmondial mondial-jaxb.xsd -d gen-src
 javac -d classes -classpath $JAXB_JAR `find gen-src -name '*.java'`
 javac -d classes -classpath $JAXB_JAR:classes JAXBmondial.java
 java -classpath classes:$JAXB_JAR JAXBmondial mondial-jaxb.xml
```


JAXB: Binding XML Schema to Java Classes

```
<xs:element name="Collection">
  <xs:complexType>
    <xs:sequence>
      <xs:element name ="books">
        <xs:complexType>
          <xs:sequence>
            <xs:element name="book" type="bookType"
                minOccurs="0" maxOccurs="unbounded"/>
          </xs:sequence>
        </xs:complexType>
      </xs:element>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

minOccurs = maxOccurs = 1 by default



- elements that have complexTypes are mapped to classes (for local type declarations: local classes like Collection.Books),
- elements of simpleTypes and attributes are mapped to instance properties
- multivalued properties are handled by lists; updates not via setXXX(), but via list modifications

JAXB: Binding XML Schema to Java Classes (2)

```
<xs:complexType name="bookType">
  <xs:sequence>
    <xs:element name="name" type="xs:string"/>
    <xs:element name="price" type="xs:string"/>
    <xs:element name="authors" >
      <xs:complexType>
        <xs:sequence>
          <xs:element name="authorName" type="xs:string"
            minOccurs="1" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="language" type="xs:string"
    minOccurs="1" maxOccurs="unbounded"/>
    <xs:element name="promotion">
      <xs:complexType>
        <xs:choice>
          <xs:element name="Discount" type="xs:string" />
          <xs:element name="None" type="xs:string"/>
        </xs:choice>
      </xs:complexType>
    </xs:element>
    <xs:element name="publicationDate" type="xs:date"/>
  </xs:sequence>
  <xs:attribute name="isbn" type="xs:string"/>
</xs:complexType>
```

Class BookType

```
private String       name;
private String       isbn;
private long         price;
private XMLGregorianCalendar publicationDate;
private Authors      authors;
private List         language
private Promotion    promotion;
public  String       getName();    void setName(String s);
public  String       getIsbn();    void setIsbn(String s);
public  long         getPrice();   void setPrice(long x);
public  XML-G-C.     getPublicationDate();   void set(...)
public  Authors      getAuthors();   void setAuthors(Authors as);
public  List         getLanguage();   no setLanguage()
public  Promotion    getPromotion();   void setPromotion();
```

1 — 1

Class Authors

```
private List<String> authorName;
public  List<String> getAuthorName();
live list - no setAuthorName()
```

Classes Promotion

```
private String discount;
private String none;
public get/set methods
```


JAXB - Example Usage

[Filename: java/JAXB/JAXBbooks.java]

```
import javax.xml.bind.JAXBContext;
import javax.xml.bind.Unmarshaller;
import javax.xml.bind.Marshaller;
import java.util.List;
import javax.xml.datatype.XMLGregorianCalendar;

import java.io.File;
import org.w3c.dom.*;
import javax.xml.transform.dom.*;
import javax.xml.transform.*;
import javax.xml.transform.stream.*;

// import java content classes generated by binding compiler
import JAXBbooks.*;

/**
  * This shows how to use JAXB to unmarshal an xml file
  * Then display the information from the content tree
  */

public class JAXBbooks {

  public static void main (String args[]) {
    try
    {
      JAXBContext jc = JAXBContext.newInstance("JAXBbooks");
      Unmarshaller unmarshaller = jc.createUnmarshaller();

      Collection collection= (Collection)
             unmarshaller.unmarshal(new File( "books.xml"));

      Collection.Books books = collection.getBooks();
      List bookList = books.getBook();
```

```
    for( int i = 0; i < bookList.size();i++ )
    {
      System.out.println("Book  details "   );
      BookType book =(BookType) bookList.get(i);
      System.out.println("Book Name: " +  book.getName().trim());
      System.out.println("Book ISBN: " +  book.getIsbn().trim());
      System.out.println("Book Price: " +  book.getPrice());
      System.out.println("Book promotion: " +
         book.getPromotion().getDiscount().trim());
      System.out.println("No of Authors " +
         book.getAuthors().getAuthorName().size());

      BookType.Authors authors = book.getAuthors();
      for (int j = 0; j < authors.getAuthorName().size();j++)
      {
        String authorName = (String) authors.getAuthorName().get(j);
        System.out.println("Author Name " + authorName.trim());
      }
      XMLGregorianCalendar date = book.getPublicationDate();
      System.out.println("Date " + date);
      for (int j = 0; j < book.getLanguage().size();j++)
      {
        String language = (String) book.getLanguage().get(j);
        System.out.println("Language " + language.trim());
      }
      // add an element to a live list:
      book.getLanguage().add("Kisuaheli");
      System.out.println();
    }

    // write the result to an XML file:
    Marshaller m = jc.createMarshaller();
    DOMResult domResult = new DOMResult();
    m.marshal(collection, domResult);
    Document doc = (Document) domResult.getNode();
    // transformer stuff is only for writing DOM tree to file/stdout
    TransformerFactory factory = TransformerFactory.newInstance();
    Source docSource = new DOMSource(doc);
    StreamResult result = new StreamResult("foo.xml");
    Transformer transformer = factory.newTransformer();
    transformer.transform(docSource, result);
  }catch (Exception e ) {
       e.printStackTrace();
  }
 }
}
```


JAXB - Another Example

[Filename: java/JAXB/mondial-jaxb.xml]

```
<?xml version="1.0"?>
<mondial>
 <country name="Austria" area="83850" indep_date="1918-11-12"  capital="cty-Austria-
  <population>8023244</population>
  <province name="Styria" area="16386">
   <population>1203000</population>
   <city name="Graz">
    <population year="1994-01-01">238000</population>
   </city>
  </province>
  <province name="Salzburg" area="7154">
   <population>501000</population>
   <city name="Salzburg">
    <population year="1994-01-01">144000</population>
   </city>
  </province>
  <province name="Vienna" area="415">
   <population>1583000</population>
    <city name="Vienna" id="cty-Austria-Vienna">
     <population year="1994-01-01">1583000</population>
    </city>
  </province>
 </country>
</mondial>
```

JAXB - Example: XSD

[Filename: java/JAXB/mondial-jaxb.xsd]

```
<?xml version="1.0"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
   xmlns:jaxb="http://java.sun.com/xml/ns/jaxb" jaxb:version="2.0">
 <xs:element name="mondial">
  <xs:complexType>
   <xs:sequence>
    <xs:element name="country" type="country"
                minOccurs="0" maxOccurs="unbounded"/>
   </xs:sequence>
  </xs:complexType>
 </xs:element>

 <xs:complexType name="country">
  <xs:sequence>
   <xs:element name="population" type="populationtype"
               minOccurs="0" maxOccurs="1" />
   <xs:element name="province" type="province"
               minOccurs="0" maxOccurs="unbounded" />
  </xs:sequence>
  <xs:attribute name="name" type="xs:string" use="required"/>
  <xs:attribute name="area" type="xs:integer" use="optional"/>
  <xs:attribute name="car_code" type="xs:ID" use="optional"/>
  <xs:attribute name="indep_date" type="xs:date" use="optional"/>
  <xs:attribute name="capital" type="xs:IDREF" use="optional">
   <xs:annotation>  <!-- annotation of the target type  <<<<<<<< -->
    <xs:appinfo>
     <jaxb:property>
      <jaxb:baseType name="City"/>
     </jaxb:property>
    </xs:appinfo>
   </xs:annotation>
  </xs:attribute>
 </xs:complexType>
```



```
 <xs:complexType name="province">
  <xs:sequence>
   <xs:element name="population" type="populationtype"
       minOccurs="0" maxOccurs="1" />
   <xs:element name="city" type="city"
       minOccurs="0" maxOccurs="unbounded" />
  </xs:sequence>
  <xs:attribute name="name" type="xs:string" use="required"/>
  <xs:attribute name="area" type="xs:integer" use="optional"/>
 </xs:complexType>

 <xs:complexType name="city">
  <xs:sequence>
   <xs:element name="population" type="populationtype"
       minOccurs="0" maxOccurs="unbounded"/>
  </xs:sequence>
  <xs:attribute name="name" type="xs:string" use="required"/>
  <xs:attribute name="id" type="xs:ID"/>
 </xs:complexType>

 <xs:complexType name="populationtype">
  <xs:simpleContent>
   <xs:extension base="xs:decimal">
    <xs:attribute name="year" type="xs:date" use="optional"/>
   </xs:extension>
  </xs:simpleContent>
 </xs:complexType>
</xs:schema>
```

- annotation of the country/@capital IDREFS attribute:
  $\Rightarrow$ public City getCapital()
- countries have at most one population subelement, cities may have several ones.

JAXB - Example Usage

[Filename: java/JAXB/JAXBmondial.java]

```
import javax.xml.bind.JAXBContext;
import javax.xml.bind.Unmarshaller;
import java.io.File;
import java.util.List;

// import java content classes generated by binding compiler
import JAXBmondial.*;

/**
 * This shows how to use JAXB to unmarshal an xml file
 * Then display the information from the content tree
 */

public class JAXBmondial {

 public static void main (String args[]) {
 try {
  JAXBContext jc = JAXBContext.newInstance("JAXBmondial");
  Unmarshaller unmarshaller = jc.createUnmarshaller();

  Mondial mondial =
    (Mondial) unmarshaller.unmarshal(new File("mondial-jaxb.xml"));
  List countryList  = mondial.getCountry();
  Province prov;
  City city;

  for ( int i = 0; i < countryList.size();i++ )
  {
    Country country  = (Country) countryList.get(i);
    System.out.println("Country: " + country.getName()  );
    System.out.println("   pop: " +
        country.getPopulation().getValue());

    // Java knows from the annotation of the IDREF attribute
    // that this is a city

    City c = country.getCapital();
    System.out.println("   cap: " +  c.getName());

    List provList = country.getProvince();
    for (int j = 0; j < provList.size() ; j++)
    {
      prov = (Province) provList.get(j);
```


JAXB Mapping: Summary

- allows for easy and lightweighted unmarshalling, bean-based manipulation and marshalling of XML data,
- higher level of abstraction from XML representation, compared with DOM and SAX,
- but still actually just a way to manipulate XML data without having to know the specific notions of the XML data model.

Minor Comments

- naming (getBook() for a list etc.) not always intuitive;
  can be customized by annotations to the XSD;
- intermediate elements (example: Books, Authors) lead to unnecessary classes;
  can often be omitted (example: Language elements)

$\Rightarrow$ to get a better “modeling”, do not use structures like

Country-hasProvince-Province-hasCity-City

(as in Striped RDF/XML [Semantic Web lecture]; this would generate intermediate classes), but

Country-Province-City.

JAXB Integration with Java Application?

A comfortable usage of the generated classes into an application program is not yet supported:

- means: add application-specific methods
  (and properties that would be local to the Java existence of the object)
- define a subclass: java_xxx extends xxx
  - after unmarshalling, the objects are only instances of xxx

  $\Rightarrow$ methods of java_xxx not applicable
- define class java_xxx where xxx is a subclass of:
  - useful from the java point of view: extend application class with bean functionality and marshalling
  - cannot be communicated to the JAXB generation of the classes (annotation with xjc:superClass c in the xsd does only allow to make all classes subclasses of c)

JAXB Integration with Java Application

Delegation

- (manually) write application classes that delegate to the JAXB-generated classes and extend them with application functionality,
- after unmarshalling, traverse the tree and create the “real” objects

$\Rightarrow$ application classes must be manually adapted after schema changes.

Manual editing of generated classes themselves

- edit the generated xxx.java files
- if instance attributes are added, they must also be added either to propOrder, or get an anntotation as @XmlAttribute – and then they will be exported when marshalling them

$\Rightarrow$ must be manually redone/adapted after schema changes.

Using Helper Classes

- encode behavior in separate helper classes that provide static methods:
  mondialHelper.addProvince(Country,Province)

JAXB - Example Usage with extended class definition

put the following into the generated JAXB/gen-src/JAXBmondial/Country.java and then recompile:

```
    // a method for more comfortable manipulation:
    public void addProvince(Province p) {
        getProvince().add(p);
    }
    // a "useful" method:
    public void printCityNames() {
        List provList = getProvince();
        for (int j = 0; j < provList.size() ; j++)
            {
                Province prov = (Province) provList.get(j);
                List cityList = prov.getCity();
                for (int k = 0; k < cityList.size() ; k++)
                    {
                        City city = (City) cityList.get(k);
                        System.out.println(city.getName().trim());
                    }
            }
    }
```

[Filename: java/JAXB/put-into-Country.java]

JAXB - Example Usage with extended class definition

```
import javax.xml.bind.JAXBContext;
import javax.xml.bind.Unmarshaller;
import java.io.File;
import java.util.List;

// import java content classes generated by binding compiler
import JAXBmondial.*;

public class JAXBmondial2 {

 public static void main (String args[]) {
 try {
  JAXBContext jc = JAXBContext.newInstance("JAXBmondial");
  Unmarshaller unmarshaller = jc.createUnmarshaller();
  Mondial mondial =
    (Mondial) unmarshaller.unmarshal(new File("mondial-jaxb.xml"));
  List countryList  = mondial.getCountry();

  for ( int i = 0; i < countryList.size();i++ )
  {
    Country country  = (Country) countryList.get(i);
    System.out.println("Country: " + country.getName()  );
    country.printCityNames();  // <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
  }
 }catch (Exception e ) { e.printStackTrace(); }
}
}
```

[Filename: java/JAXB/JAXBmondial2.java]

ASIDE: SOAP (SIMPLE OBJECT ACCESS PROTOCOL)

- Generic “protocol” (nevertheless, HTTP-based)
- Any object can be serialized in XML, sent, and deserialized
  (only having the Java class code, without having an XSD).
  So far similar to the OIF (Object Interchange Format) of ODMG (cf. Slide 53 ff.).
- The XML representation is not intended to be processed on the XML level, but only by soap-unpacking it.
- Bad experience: correct packing/unpacking only between same SOAP implementations.
- Note: Instances of Java XML (DOM) are not serialized as plain XML, but as SOAP serialization of an instance of the underlying DOM implementation class.
  (not intended *for* exchanging XML, but for exchanging objects *by* XML).

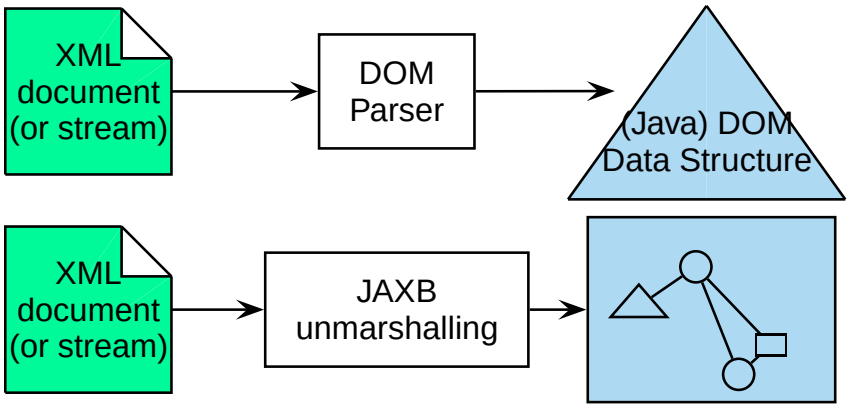
⇒ when messages are designed to be XML, SOAP is not the right way, but use simple, plain HTTP!

- One does not need to have any knowledge of XML to use soap (actually, knowledge of XML doesn’t help).

⇒ so it does not fit in this course.

11.3 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:



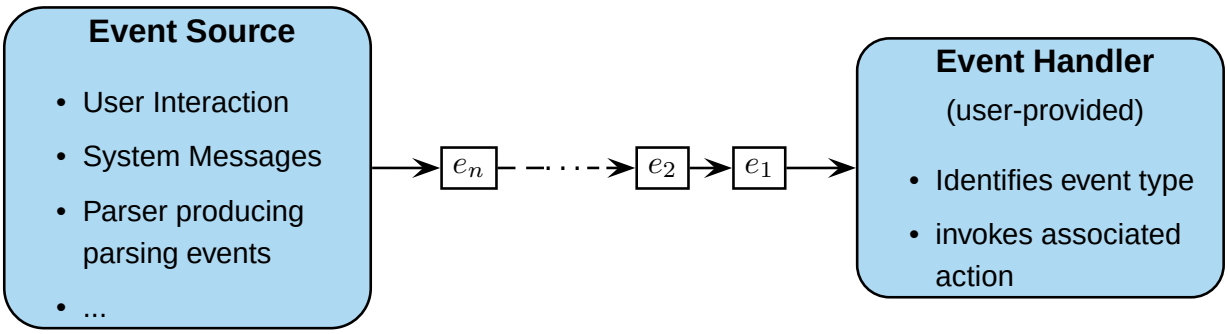
PARSING: GENERAL CONCEPTS

- 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?
  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!

EVENT-BASED PROCESSING AS A *general Design Pattern*

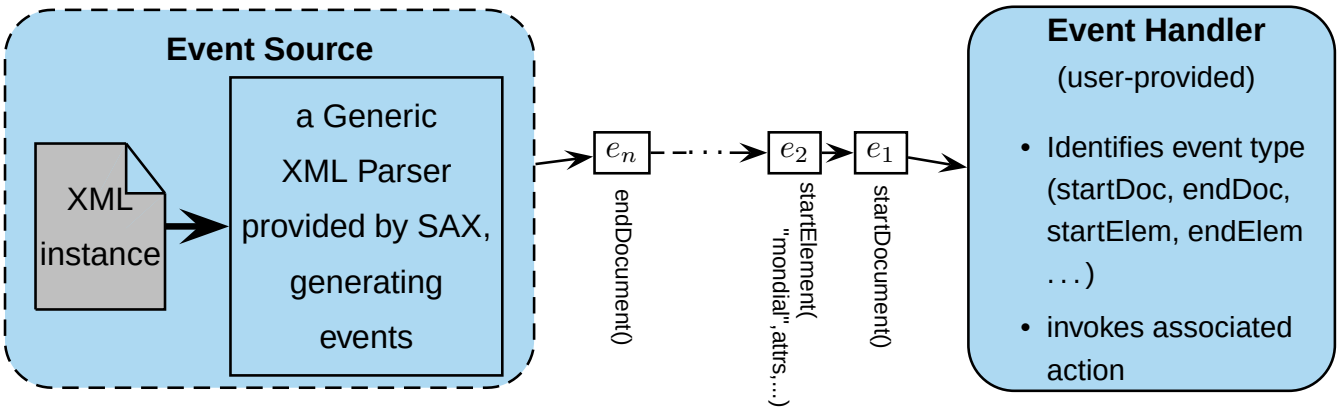
- A stream of (high-level) items that carry some inherent semantics can be seen as a stream of “events”
  (in contrast to a simple 0-1-stream, a byte stream or similar low-level streams)



- 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

11.4 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)

XML Parsing with SAX

SAX: parse XML from a file (in general: char stream).

- 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”*).

SAX: Applications

Only events are signaled: linear processing based on incoming sequence of events.

- ... among many other things, one can generate a DOM tree structure,
- validation according to a DTD (using the automaton as given on Slide 176) in linear time,
- 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
    (Exercise: sketch the behavior of the event handler on relevant events)
  - if the stream is a list of elements of the same structure:
    generate a database entry for each element (use JDBC)
- if necessary: application needs to maintain context.

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

```
>java PrintAttributes mondial.xml > bla.out
>less bla.out
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-EBRD 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'
element: religions
 - attribute: 'percentage' value: '70' type: 'CDATA'
...
```

Class “PrintAttributes.java”:

```
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) {
        if (args.length != 1) {
            System.err.println("usage: PrintAttributes <url>");
            System.exit(1);
        }
        String url = args[0];    // ... prepare a contentHandler:
        DefaultHandler handler = new ContentHandlerPrintAttributes(
                "printing attributes of document at url '" + url + "'");
        SAXParserFactory factory = SAXParserFactory.newInstance();
        try {
            SAXParser parser = factory.newSAXParser();
            parser.parse(url, handler);  // <<<<<<<<< and now it runs ...
        } catch (IOException e1) {
            e1.printStackTrace();
        } catch (ParserConfigurationException e) {
            e.printStackTrace();
        } catch (SAXException e) {
            e.printStackTrace();
        }
    }
}
```

[see java/SAX/PrintAttributes.java]

Class “ContentHandlerPrintAttributes.java”:

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

public class ContentHandlerPrintAttributes extends DefaultHandler {
    public ContentHandlerPrintAttributes(String message) {
        System.out.println(message);
    }

    // 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(), characters() omitted
    // all other "parsing events" are ignored in this case
}
```

[see java/SAX/ContentHandlerPrintAttributes.java]

SAX: Applications to XPath Query Answering

Forward queries

XPath-queries like //country[@car_code='D']/population 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.

11.5 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 the Event Handler.

Generalization and Abstraction: XML Streams

- XMLEvents: StartDocument, StartElement, Character, EndElement,
- XMLStreamWriter, XMLStreamReader,
- XML Streams also can be connected *directly* as an *abstract* means to exchange XML

SAX and StAX: Applications

Stream-based processing can be applied to XML data on multiple levels:

- low-level applications:
  SAX is often used for building a DOM from ASCII XML input: “opening tag with attributes”, “text”, “closing tag” can immediately be translated into the DOM constructors.
- low-level streaming of an XML instance:
  answering XPath (forward-axes only) queries; optionally maintaining some context (e.g., stack).
- higher level “application-level events”:
  the XML stream is not seen as the traversal of a large instance, but as a sequence of (independent) XML fragments that are seen as application-level events
  [RFID applications, time series of stock quotes, RSS feeds]

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(), ...]
  $\Rightarrow$ application code: same as for SAX, only operational embedding done differently.
- WRITE AND READ: streamed data exchange between processed on the XML level

Interfaces XMLStreamWriter, XMLStreamReader

(only some comments; see also following examples)

Reader

- int event = r.next() and then switch based on event type javax.xml.stream.XMLStreamConstants.XX: START_DOCUMENT, START_ELEMENT, ATTRIBUTE, CHARACTERS, END_ELEMENT, ...
- goal-driven access methods when on START_ELEMENT: r.getLocalName(), r.getAttributeValue(*name*), r.getAttributeCount(), getAttributeValue(*n*) for iteration, r.getElementText() (reads also the next EndElement from the stream!)
- goal-driven access method when on CHARACTERS: r.getText()

Writer

- Writer: w.writeStartDocument(), w.writeStartElement(*name*),a w.writeAttribute(*name*,*value*), w.writeCharacters(*text*): obvious;
- w.writeEndElement(): closes the innermost open element;
- w.writeEndDocument(): closes all open elements.
- w.flush(): force write any data to the underlying output mechanism.

StAX Example: Exam Registration

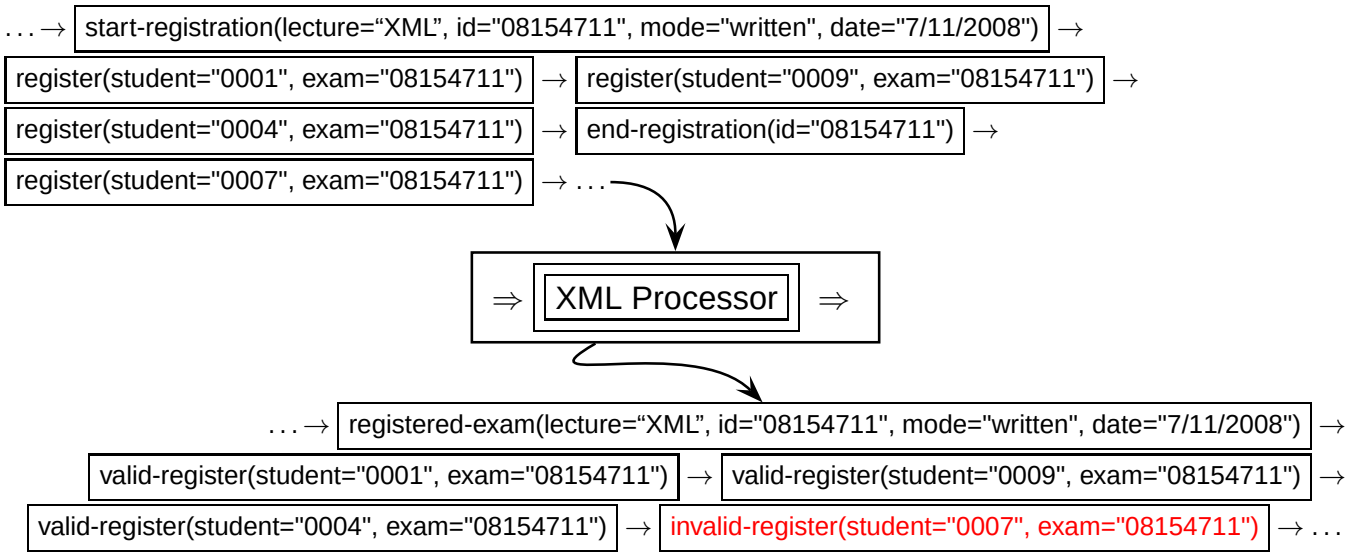
Assume the administration of exams in a student's office ("Prüfungsamt"):

- 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 some output stream (`valid-register`; in the example, we use `STDOUT`.)
- students that register before beginning or after the end of registration, are not accounted for the exam; an XML message `invalid-register` goes to `STDOUT`,

StAX Example: Exam Registration (Cont'd)

- the registration data of the students comes in via a continuous input stream;
- the program should allow the management of registrations for multiple exams at one time (all incoming over the same input stream).

Example stream:



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" mode="written">
    <subject>Semistructured Data and XML</subject>
    <date>07/11/2008</date>
  </start-registration>
  <register student="0001" exam="08154711"/>
  <register student="0009" exam="08154711"/>
  <start-registration id="12345678" mode="oral">
    <subject>Dental Hygiene</subject>
    <dates>
      <date>17/9/2008</date>
      <date>18/9/2008</date>
    </dates>
  </start-registration>
  <end-registration id="12345678"/>
  <register student="0004" exam="08154711"/>
  <register student="0004" exam="12345678"/>
  <register student="0007" exam="12345678"/>
  <end-registration id="08154711"/>
  <register student="0007" exam="08154711"/>
</stream>
```

[Filename: java/StAX/exam.xml]

StAX Example Cont'd (2):

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

```
import java.util.ArrayList;
import java.util.List;

public class Exam {
  public static final String DATE = "date";
  public static final String SUBJECT = "subject";
  public static final String ID = "id";
  public static final String MODE = "mode";
  public static final String DATES = "dates";
  public static final String STARTOFREG = "start-of-registering";
  public static final String ENDOFREG = "end-of-registering";

  private String id;
  private boolean oral;
  private String subject;
  private String date;
  private List<String> dates;
  private boolean registeringClosed = false;
  private String startOfReg;
  private String endOfReg;

  public Exam(String id, String mode) {
    this.id = id;
    this.oral = "oral".equals(mode);
    this.dates = new ArrayList();
  }
```



```
  public String getId() { return id; }
  public void setDate(String date) { this.date = date; }
  public String getDate() { return date; }
  public void setDates(List<String> dates) {this.dates = dates; }
  public List<String> getDates() { return dates; }
  public void setSubject(String subject) { this.subject = subject; }
  public String getSubject() { return subject; }
  public boolean isOral() { return oral; }
  public boolean isWritten() { return (!oral); }

  public String getMode() {
    if (oral) return "oral";
    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;
  }
}
```

[Filename: java/StAX/Exam.java]

StAX Example Cont'd (3):

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

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

import javax.xml.stream.XMLInputFactory;
import javax.xml.stream.XMLOutputFactory;
import javax.xml.stream.XMLStreamConstants;
import javax.xml.stream.XMLStreamException;
import javax.xml.stream.XMLStreamReader;
import javax.xml.stream.XMLStreamWriter;


public class ExamStreamParser {

  FileInputStream inputStream;
  OutputStream outputStream;

  public ExamStreamParser(FileInputStream in, OutputStream out) {
    this.inputStream = in;
    this.outputStream = out;
  }

  public void startParsing() {
    try {
      XMLInputFactory inputFactory = XMLInputFactory.newInstance();
      XMLOutputFactory outputFactory = XMLOutputFactory.newInstance();
      XMLStreamReader parser = inputFactory.createXMLStreamReader(inputStream);
      XMLStreamWriter writer = outputFactory.createXMLStreamWriter(outputStream);
      Exam currentExam = null;
      Map<String,Exam> exams = new HashMap<String,Exam>();
          boolean goOn = true;
```



```
          while (goOn) {
          int event = parser.next();
          switch(event) {
          case XMLStreamConstants.END_DOCUMENT:
             parser.close();
             writer.flush();
             writer.close();
             goOn = false;
             break;
          case XMLStreamConstants.START_ELEMENT:
            // start-registration and its subelelements
            if("start-registration".equals(parser.getLocalName())) {
                currentExam = new Exam(parser.getAttributeValue(null, Exam.ID),parser.getAttributeValue(null, Exam.MOD
                currentExam.setStartOfReg(getDate());
                break;
              }
            if(Exam.SUBJECT.equals(parser.getLocalName())) {
                currentExam.setSubject(parser.getElementText()); break;
              }
            if(Exam.DATE.equals(parser.getLocalName())) {
                if(currentExam.isWritten()) currentExam.setDate(parser.getElementText());
                else currentExam.getDates().add(parser.getElementText());
                break;
              }
            if("end-registration".equals(parser.getLocalName())) {
                String examId = parser.getAttributeValue(null,Exam.ID);
              Exam exam = exams.get(examId);
              if(exam == null) {
                System.err.println("no such exam with id '"+examId+"' open for registration!");
                break;
              }
                exam.setEndOfReg(getDate());
                exam.setRegisteringClosed(true);
                break;   // no output is generated.
              }
            // register and its subelements
            if("register".equals(parser.getLocalName())) {
                String studentId = parser.getAttributeValue(null, "student");
                String examId = parser.getAttributeValue(null, "exam");
                if(exams.containsKey(examId)) {
                  Exam exam = exams.get(examId);
                  if(! exam.isRegisteringClosed()) {
                    writer.writeStartElement("valid-register");
                  writer.writeAttribute("student", studentId);
                  writer.writeAttribute("exam", examId);
                  writer.writeEndElement();
                } else {
                    writer.writeStartElement("invalid-register");
                    writer.writeAttribute("student", studentId);
                  writer.writeAttribute("exam", examId);
                  writer.writeStartElement("message");
                  writer.writeCharacters("invalid registration! registration for exam '" + exam.getId()
                    + "' (" + exam.getSubject() + ") has ended on " + exam.getEndOfReg());
                  writer.writeEndElement();
                }
                } else {
                  writer.writeStartElement("invalid-register");
                  writer.writeAttribute("student", studentId);
                writer.writeAttribute("exam", examId);
                writer.writeStartElement("message");
                writer.writeCharacters("invalid registration! exam '"+examId+"' is not (yet?) open for registration.")
                writer.writeEndElement();writer.writeEndElement();
                }
                writer.writeCharacters("\n");
                break;
              }
              break;
```

```
        case XMLStreamConstants.END_ELEMENT:
          if("start-registration".equals(parser.getLocalName())) {
            exams.put(currentExam.getId(),currentExam);
            writer.writeStartElement("registered-exam");
            writer.writeAttribute(Exam.ID, currentExam.getId());
            writer.writeAttribute(Exam.MODE, currentExam.getMode());
            writer.writeCharacters("\n  ");
              writer.writeStartElement(Exam.SUBJECT);
            writer.writeCharacters(currentExam.getSubject());
            writer.writeEndElement();
            writer.writeCharacters("\n  ");
              writer.writeStartElement(Exam.STARTOFREG);
            writer.writeCharacters(currentExam.getStartOfReg());
            writer.writeEndElement();
            writer.writeCharacters("\n  ");
              if(currentExam.isWritten()) {
              writer.writeStartElement(Exam.DATE);
              writer.writeCharacters(currentExam.getDate());
              writer.writeEndElement();
            } else {
              writer.writeStartElement(Exam.DATES);
              for(Iterator<String> i=currentExam.getDates().iterator();i.hasNext();) {
                writer.writeStartElement(Exam.DATE);
                writer.writeCharacters(i.next());
                writer.writeEndElement();
              }
              writer.writeEndElement();
            }
              writer.writeCharacters("\n");
              writer.writeEndElement();writer.writeCharacters("\n");
            currentExam = null; // it's better to provoke
            // a nullpointer exception than to edit the wrong exam object
            break;
          }
        }
      }
    } catch (XMLStreamException e) {
      e.printStackTrace();
    }
  }

  private String getDate() {
    DateFormat format = new SimpleDateFormat();
    Date date = new Date();
    return format.format(date);
  }

  public static void main(String[] args) {
    try {
      ExamStreamParser examStreamParser = new ExamStreamParser(new FileInputStream(args[0]), System.out);
      examStreamParser.startParsing();
    } catch (FileNotFoundException e) {
      e.printStackTrace();
    }
  }
}
```

[Filename: java/StAX/ExamStreamParser.java]

StAX Comparison with SAX

SAX:
- "Push" API
- Common pattern: methods for each event type, where startElement() and endElement() contain large `if`s.

StAX:
- "Pull" API
- Common pattern: huge `switch` command whose cases again contain large `if`.

- Performance: no difference
  (inside, StAX's next() does the same as the SAX builtin stream reader algorithm that call the EventHandler)
- 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
  - can easily produce XML output via `XMLStreamWriter` (e.g. to another StAX appl.)
    (programmatically, the same feature can be provided by a SAX Event Handler as well using StAX's xml.stream classes)

Example: XML Stream Communication

```
import java.io.PipedInputStream;
import java.io.PipedOutputStream;
import java.io.OutputStream;
import javax.xml.stream.XMLOutputFactory;
import javax.xml.stream.XMLStreamWriter;

public class XMLStreamTestWriter implements Runnable
{
  OutputStream outputStream;

  public XMLStreamTestWriter(OutputStream out) {
    this.outputStream = out;
  }

  public void run() {
    try {
      XMLOutputFactory outputFactory = XMLOutputFactory.newInstance();
      XMLStreamWriter writer = outputFactory.createXMLStreamWriter(outputStream);
      writer.writeStartElement("foo");
      int i=1;
      while (i<100) {
        writer.writeStartElement("bla");
        writer.writeCharacters(" " + i);
        writer.writeEndElement();
        System.out.print("Write <bla>" + i + "</bla> ");
        //writer.flush(); // if not uncommented: strictly alternating
        // comment out flush: sleep < 700 causes alternating after blocks of 2...5 elements
        try{ java.lang.Thread.sleep(50); }
          catch (Exception e) { e.printStackTrace(); }
        i++;
      }
      // writer.writeEndElement();  // close </foo> is done by the next line:
      writer.writeEndDocument(); // docu: closes all tags, but does not send anything else
      writer.flush();
      writer.close();
    } catch (Exception e) { e.printStackTrace(); }
    System.out.println("Writer finished");
  }

  public static void main(String[] args) throws Exception{
    PipedOutputStream pos = new PipedOutputStream();
    PipedInputStream pis = new PipedInputStream();
    pis.connect(pos);
    new Thread (new XMLStreamTestWriter(pos)).start();
    new Thread (new XMLStreamTestReader(pis)).start();
  }
}
```

[Filename: java/StAX/XMLStreamTestWriter.java]

- underlying: connected PipedOutput/InputStream

Example: XML Stream Communication (Cont'd)

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

public class XMLStreamTestReader implements Runnable {

  InputStream inputStream;

  public XMLStreamTestReader(PipedInputStream in) {
    this.inputStream = in;
  }

  public void run() {
    try {
      XMLInputFactory inputFactory = XMLInputFactory.newInstance();
      XMLStreamReader parser = inputFactory.createXMLStreamReader(inputStream);
      boolean goOn = true;
      while (goOn) {
        int event = 0;
        try {
          event = parser.next();
          switch(event) {
            case XMLStreamConstants.START_ELEMENT:
              System.out.println("Read start element " + parser.getLocalName());
              break;
            case XMLStreamConstants.CHARACTERS:
              System.out.println("Read " + parser.getText());
              break;
            case XMLStreamConstants.END_ELEMENT:
              System.out.println("Read end element " + parser.getLocalName());
              break;
              case XMLStreamConstants.END_DOCUMENT: // never happens!
              System.out.println("Read end document");
              goOn = false;
            default: System.out.println("Read something else. event: " + event);
          }}
          catch(Exception e) { parser.close(); goOn = false; }
      }
      parser.close();
      System.out.println("Reader finished");
    }
    catch (Exception e) { e.printStackTrace(); }
  }
}
```

[Filename: java/StAX/XMLStreamTestReader.java]

11.6 Aside: Use of Date and Time Datatypes

- XML Schema: simple datatypes for dateTime
- represented by String literals in attribute values or text contents
  - xs:dateTime: *yyyy-mm-dd* T*hh:mm:ss*[.*xx*][{+|-}*hh:mm*]
  - xs:time: *hh:mm:ss* [{+|-}*hh:mm*]
  - xs:duration: P [*n* Y][*n* M][*n* D][T[*n* H][*n* M][*n* [.*n*] S]], where *n* can be any natural number
  - xs:dayTimeDuration, xs:yearMonthDuration: restrictions of xs:duration.
- for XQuery handling with specific operations (similar to those known from SQL) cf. Slide 275.
- map to appropriate classes for processing by Java (and by this e.g. with JDBC from and to SQL databases).

Aside: Date and Time in Java

Java provides several classes for handling date and time:

- Datatype: import java.util.GregorianCalendar;

Create from string representation:

- import java.text.DateFormat; import java.text.SimpleDateFormat;

```
public static String datedefaultpattern = "yyyy-MM-dd'T'HH:mm:ss";
// input: string s (following the XML Schema pattern)
DateFormat df = new SimpleDateFormat(datedefaultpattern);
GregorianCalendar typedvalue = df.parse(s);
// result: typedvalue as an object
```

- see java.util.GregorianCalendar for method documentation.
- TODO: check if JAXB declares automatically as date (which class in Java) and whether set-methods of JAXB-created classes automatically convert data.

11.7 Web Services (Overview)

- History: RPC (Remote Procedure Call)
  - call a specific procedure at a specific server
    (client stub→marshalling→message→unmarshalling→ server stub→ server).
- History: OMG Standard (Object Management Group) CORBA (1989, “Common Object Request Broker Architecture”; cf. Slides 38 ff.):
  - Middleware, usually applied in an Intranet,
  - central ORB bus where services can connect,
  - service registry (predecessor of WSDL and UDDI ideas)
  - description of service interfaces in object-oriented style
    (IDL - interface description language, similar to C++ declarations)
  - exchanging objects between services via OIF (Object Interchange Format)

  ⇒ RPC abstraction (call abstract functionality) by the ORB as a broker.
- XML-RPC and SOAP+WSDL+UDDI) are XML-based variants of RPC+Corba.
- SOA (“Service-Oriented Architecture”).

HTTP: Hypertext Transfer Protocol (Overview)

- HTTP 0.9 (1991), HTTP 1.0 (1995), HTTP 1.1 (1996).
- Application Layer Protocol, based on a (reliable) transport protocol (usually TCP “Transmission Control Protocol” that belongs to the “Internet Protocol Suite” (IP)) [see Telematics lecture].
- Request-Response Protocol: open connection, send something, receive response (upon completion), close connection
- usually associated with Web Browsing and HTML:
  send (HTTP GET) URL, get URL (=resource) contents
  ⇒ this is already a (very basic) Web Service
  also: send HTTP POST URL+Data (Web Forms) get answer
  ⇒ this is also a (still basic) Web Service; “Hidden Web”
- common protocol used for communication with and between Web Services ...

(Java) Servlet

- a piece of software that should be made available as a Web Service
- implements the methods of the Servlet interface
  (Java: `javax.Servlet`, subclasses `GenericServlet`, `HttpServlet`)

Web (Service|Servlet) Container

- a piece of software that extends a Web Server with infrastructure to provide the runtime environment to run servlets as Web Services,
- hosts one or more Web Services that extend the container's base URL,
- the servlets' code must be accessible to the Web Service Container, usually located in a specific directory,
- controls the lifecycle of the servlets: (`init()`, `destroy()`)
- maps the incoming communication from ports via the URLs to the appropriate servlet invocation
  Method `service(`*`httpContents`*`)`, mapped to `doGet(`*`httpContents`*`)`, `doPut(`*`httpContents`*`)`.

Abstraction Levels

- a Web Services Container contains several "projects" (eclipse terminology) or "applications":
  - from the programmer's view, a "project" is an eclipse project, as a package it is a single .war file, at the end, it is a subdirectory in the container.
    Each project has an (internal) name (its directory name in the container), e.g. `project1` or `mondial`.
- Each project consists of one or more servlets:
  - each servlet has an (internal) name (relative to its directory name in the container), e.g. `project1` contains servlets `servlet1a` and `servlet1b`.
  - each servlet's code is a class that extends javax.HttpServlet;

ABSTRACTION LEVELS: URL MAPPING

HTTP connections (GET, POST) received by the server are transparently forwarded to the servlets.

URLs are e.g.

```
http://www.example.org/services/2011/oneservice/handle1
http://www.example.org/mondial/sqlonline
```

- the Web Service Container has a base url;
  `http://www.example.org`.
- the Web Service Container maps *relative paths* to projects (later: by tomcat's server.xml), e.g.
  `/services/2011/oneservice` to `project1`,
  `/mondial` to `mondial`.
- each project's configuration (later: web.xml) maps path tails to servlet ids, and servlet ids to servlet classes, e.g.
  `/handle1` and `/` to `servlet1a` to `Project1.MyServletA`,
  `/handle2` to `servlet1b` to `Project1.MyServletB`.

TOMCAT BASIC INSTALLATION

- Web Server with Web Service Container: Download and install Apache Tomcat
  - can *optionally, but not necessarily* be combined with the Apache Webserver
  - can be installed in the CIP Pool
- set environment variable (catalina is tomcat's Web Service Container)

```
export CATALINA_HOME=~/apache-tomcat-x.x.x
```

- configure server: edit

```
$CATALINA_HOME/conf/server.xml:
<!-- Define a non-SSL HTTP/1.1 Connector on port 8080 -->
<Connector port="8080" .../>
```

- start/stop tomcat:

```
$CATALINA_HOME/bin/startup.sh
$CATALINA_HOME/bin/shutdown.sh
```

- logging goes to

```
$CATALINA_HOME/logs/catalina.out
```

General Servlet Preparation Directory Structure

MyProject project directory (anywhere outside tomcat)

MyProject/build.xml the ant file for compiling and deploying – see later.

MyProject/src the .java (and other) sources

MyProject/lib jars that are needed for building, but should not be copied to the Web Service Container.
Put javax.servlet.jar there (tomcat has own classes for servlets, this would create conflicts).

MyProject/WebRoot roughly, all this content is copied later to the Web Service Container.

MyProject/WebRoot/WEB-INF

the whole content of MyProject/WebRoot except WEB-INF is visible later (e.g., HTML pages can be placed here); the contents of WEB-INF is used by the Web Service Container.

MyProject/WebRoot/WEB-INF/web.xml web application configuration – see later.

MyProject/WebRoot/WEB-INF/classes compiled binary stuff,

MyProject/WebRoot/WEB-INF/lib used jars.

HTTP methods GET and POST

HTTP GET and POST: request-response

HTTP GET should be used only if invocation does *not* change

- Request consists only of URL+parameters:

  `http://www.example.org/mondial?type=city&code=D&name=Berlin&province=Berlin`

HTTP POST should be used if it has side effects or changes the state of the Web Service

- Request URL consists only of the plain URL,
- parameters (e.g. queries using forms) or any other information is sent via a stream

$\Rightarrow$ often also queries use POST

Response: always as a stream.

- other HTTP methods PUT (resource), DELETE (resource) are used in REST (Representational State Transfer) “architectures”
  (e.g. the eXist XML database and document management system uses REST)

SERVLET PROGRAMMING

- servlets handle *incoming* HTTP connections via doGet() (=react-on-get) and doPost() (=react-on-post) methods:

```
public class MyServletA extends HttpServlet
{ public void init(ServletConfig cfg) throws ServletException
    {  ... initialization ... }
  protected void doGet(HttpServletRequest request,
            HttpServletResponse response) throws ServletException
    { ... }
  protected void doPost(HttpServletRequest request,
            HttpServletResponse response) throws ServletException
    { ... }
}
```

- doGet() and doPost() both read the HttpServletRequest and write the HttpServletResponse object.
- the HttpServletRequest is different between GET (simpler) and POST (including a stream).

SERVLET PROGRAMMING - SOME METHODS

```
doGet/doPost(HttpServletRequest req, HttpServletResponse resp) throws ...
{ String path = req.getPathInfo();
```

tail of the URL path, e.g. do

```
if (path.equals("/handle1")) { ... }
```

```
java.util.Map<java.lang.String,java.lang.String[]> req.getParameterMap();
```

(doGet) returns a java.util.Map of the parameters of this request.

```
ServletInputStream   req.getInputStream();   or
java.io.BufferedReader req.getReader();
```

(doPost) retrieves the body of the request as binary data using a ServletInputStream.
(doPost) retrieves the body of the request as character data using a BufferedReader.

```
PrintWriter out = response.getWriter();
```

yields a Writer to the response – send character text.

```
ServletOutputStream os = response.getOutputStream();
```

yields an output stream. Don't forget os.flush().

Invoking a new HTTP Connection

Strongly stripped fragment (without try-catch etc.):

```
public static StringBuffer connectAndSend(String url, StringBuffer content) {
  HttpURLConnection.setFollowRedirects(true);
  HttpURLConnection con = (HttpURLConnection) new URL(url).openConnection();
  con.setRequestMethod("POST");
    con.setDoInput(true);
    con.setDoOutput(true);
    con.setRequestProperty("Connection", "keep-alive");
    con.setConnectTimeout(timeout);
    con.setRequestProperty("Content-type", "text/xml");
  write(con.getOutputStream(), content);
  con.getOutputStream().close();
  con.connect();
  StringBuffer response = read(con.getInputStream());
  con.getInputStream().close();
  return response;    }
```


A Note on Multithreading

- servlets can be instantiated by the container permanently or on-demand.
- if multiple requests for the same servlet come in, the servlet container can run multiple threads on the same instance of a servlet.
  - be careful with instance variables,
  - implement mutual exclusion if necessary
- the server can also create (and remove) additional instances of a servlet.

The Project's web.xml

```
<web-app>
  <!-- Define servlet names and associate them with classfiles -->

  <servlet>
    <servlet-name>servlet1a</servlet-name>
    <servlet-class>org.dbis.project1.MyServletA</servlet-class>
    <init-param> ... </init-param>
  </servlet>
  <servlet> ... </servlet>

  <!-- define mapping of path tails to servlets -->

  <servlet-mapping>
    <servlet-name>servlet1a</servlet-name>
    <url-pattern>/handle1</url-pattern>
  </servlet-mapping>
  <servlet-mapping>
    <servlet-name>servlet1a</servlet-name>
    <url-pattern>/</url-pattern>
  </servlet-mapping>
  <servlet-mapping>
    <servlet-name>servlet1b</servlet-name>
    <url-pattern>/handle2</url-pattern>
  </servlet-mapping>
</web-app>
```


Servlet Deployment

- upon startup, tomcat deploys all servlets that are available in

  `$CATALINA_HOME/webapps`

  (considering path mappings etc. in `$CATALINA_HOME/server.xml`)

Two alternatives how to make servlets available there:

- create a `project1.war` file (web archive, similar to jar) and copy it into `$CATALINA_HOME/webapps`.
  (e.g. build.xml targets "dist" and "deploy")
  (tomcat will unpack an deploy it upon startup)
- create a directory `project1`, copy the everything that is in the `WebRoot` directory there.
  (e.g. build.xml target "deploy")

TOMCAT'S CONF/SERVER.XML

The URL paths to the projects have to be defined.

This is done in the `<Host>` element:

```
<Host>
  <Context path="/services/2011/oneservice" reloadable="false" docBase="project1"/>
  :
</Host>
```

(since the standard path `mondial` for `mondial` is used, no explicit entry is needed)

- reloadable: automatically reloads the servlet if the code is changed (e.g. a new .war). Should be done only during development.
- the path attribute is key. There can be multiple paths that are mapped to the same docBase.

SOME COMMENTS

- HTTP connections are Unicode.
- exchanging XML via HTTP must be programmed via String/StringBuffer
  - out: serialize XML,
  - in: put SAX or StAX on the Unicode stream.
- exchanging StAX's XMLStream:
  - out: have an XMLStream, run StAX's next() iterator on it,
  - serialize each event, put it in the HTTP stream
  - in: create a naked StAX XMLStreamReader on the HTTP stream that just provides the XMLStream.