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Semi-structured Data

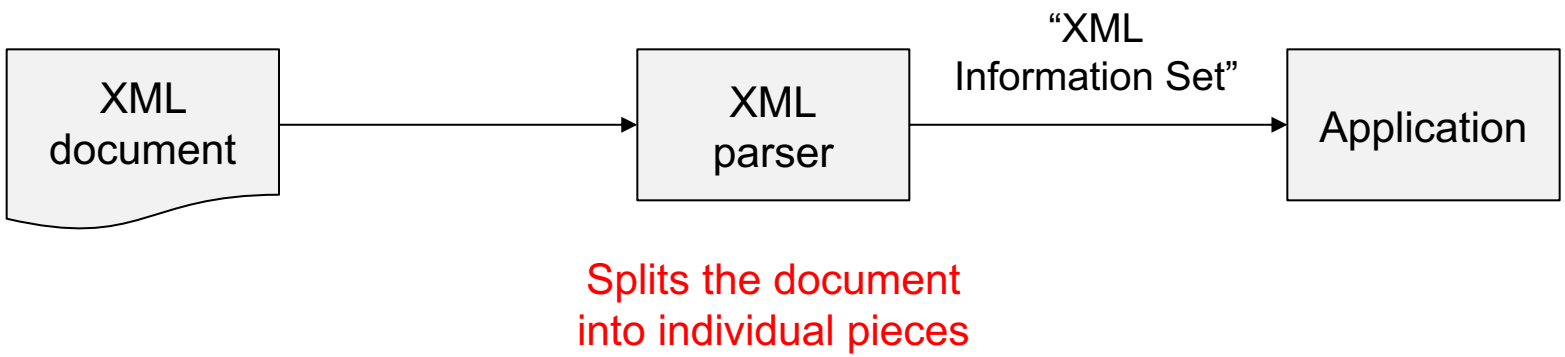
9 - Simple API for XML (SAX)

Mantas Šimkus

How XML Works

- Strict rules regarding the syntax of XML documents - allows for the development of XML parsers that can read documents

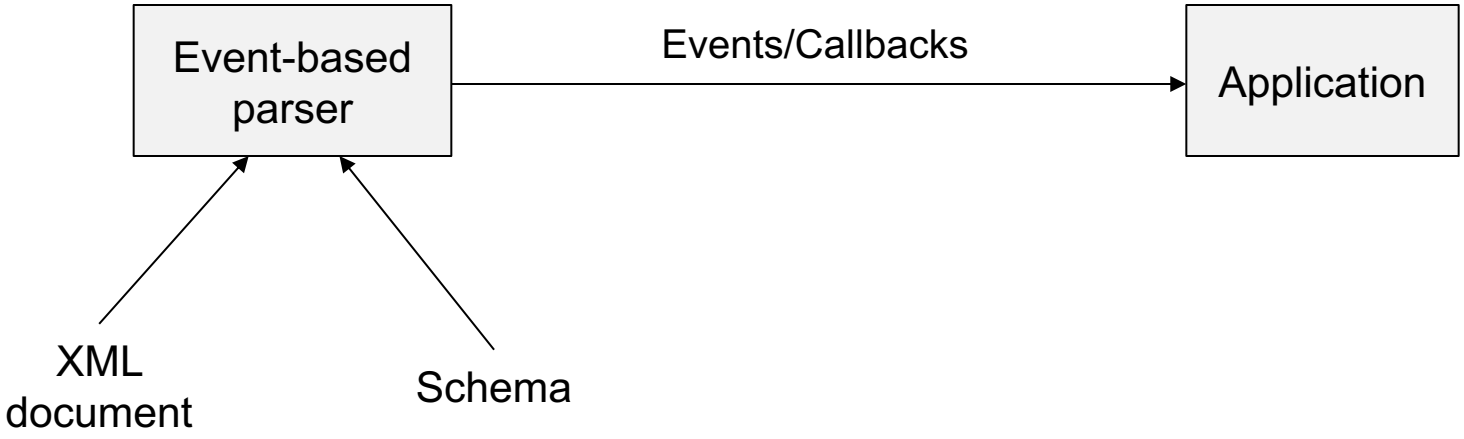
- Applications that need to understand an XML document will use a parser



Event-Based Parsers

- Report parsing events, such as the start and end of elements, directly to the application

- The application implements handlers to deal with the different events



Event-Based Parsers

parse

```
<element attr="attr-value">
    …text-1…
    <subelement>…text-2…</subelement>
</element>
```

Events/Callbacks

start document

start element: "element"

attribute name="attr" value="attr-value"

characters: "…text-1…"

start element: "subelement"

characters: "…text-2…"

end element: "subelement"

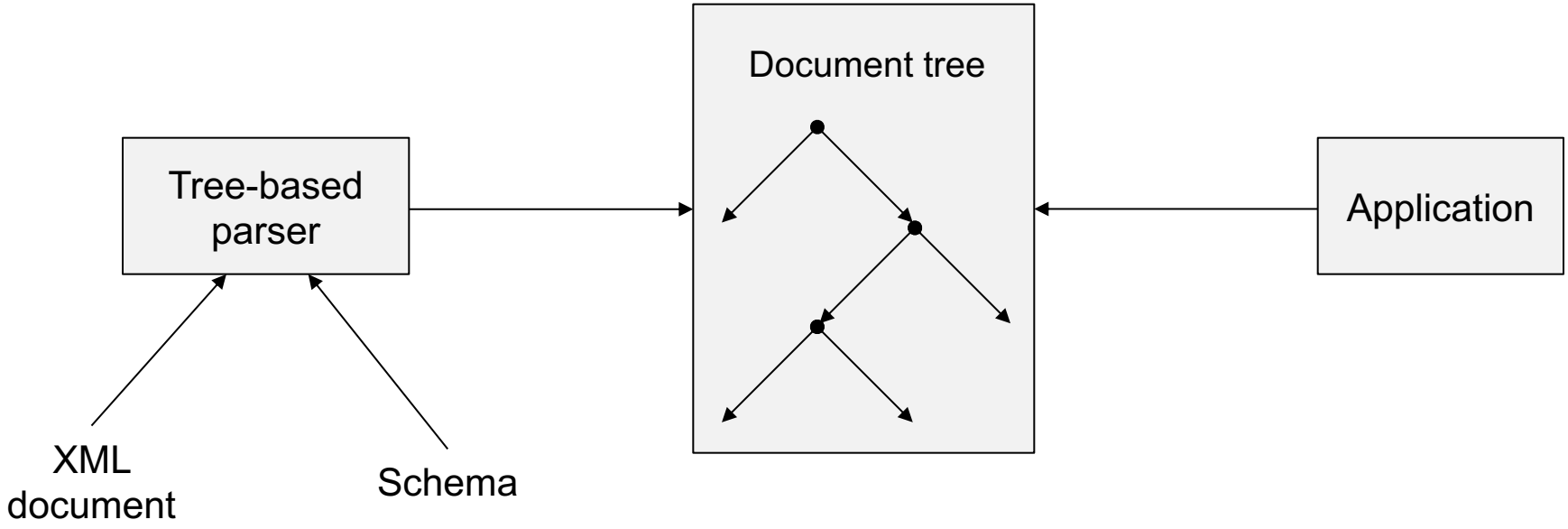
end element: "element"

end document

Tree-Based Parsers

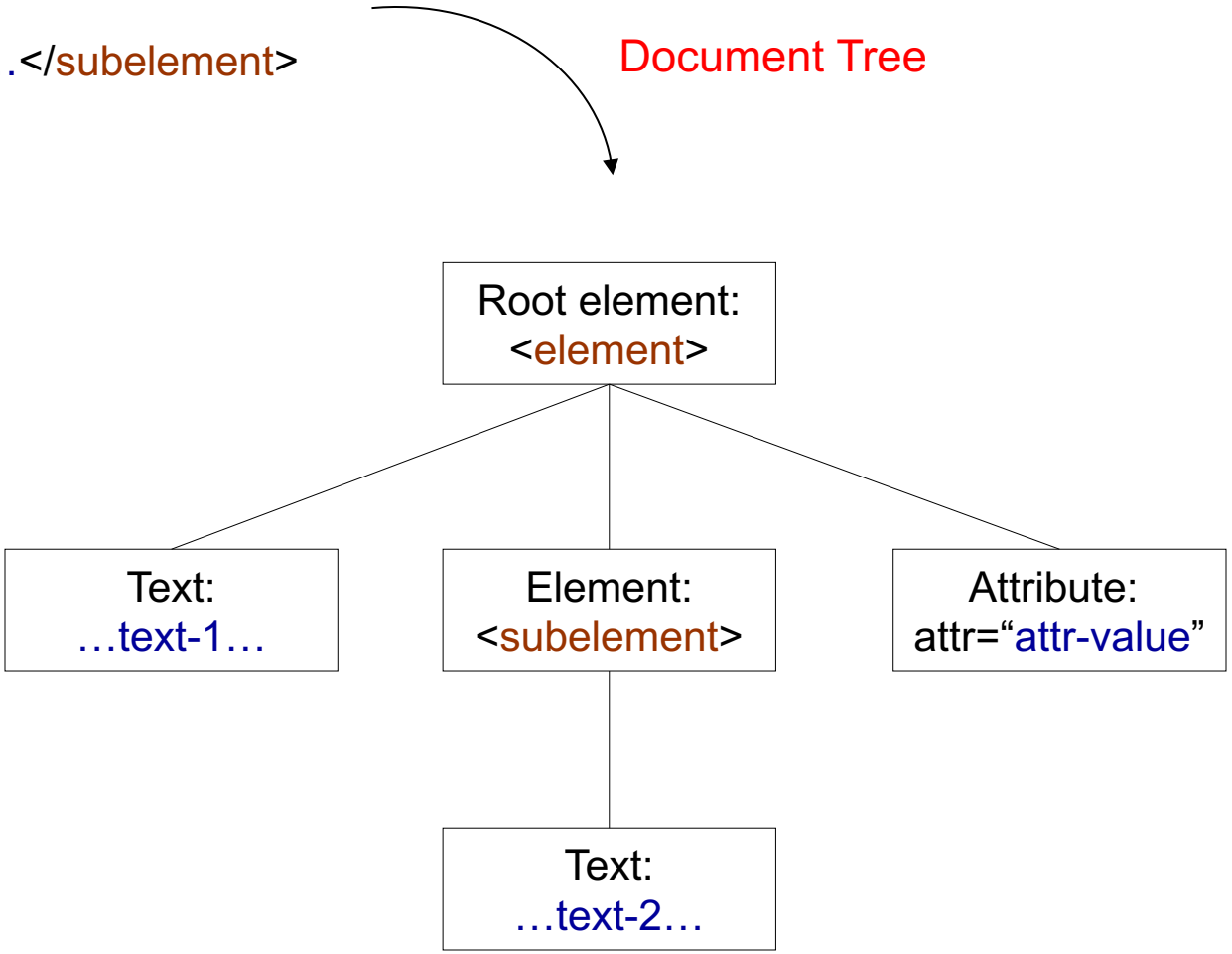
- Map an XML document into an internal tree structure stored in main memory

- The application navigates that tree



Tree-Based Parsers

```
<element attr="attr-value">
    …text-1…
    <subelement>…text-2…</subelement>
</element>
```



Event-Based vs. Tree-Based Parsers

Event-based	Tree-based
• Sequential access • Fast • Constant memory	• Random access • Slow • Proportional to the document size

+

• Large documents • Lack of data structure	• Small documents • Ready-made data structure

Standards for XML Parsers

- SAX - Simple API for XML (event-based)
  - “De facto” standard

- DOM - Document Object Model (tree-based)
  - W3C standard

… APIs to read and interpret XML documents

… we first focus on SAX

Outline

- Callbacks
- A Simple SAX Program
- Content Handling
- Error Handling
- Features

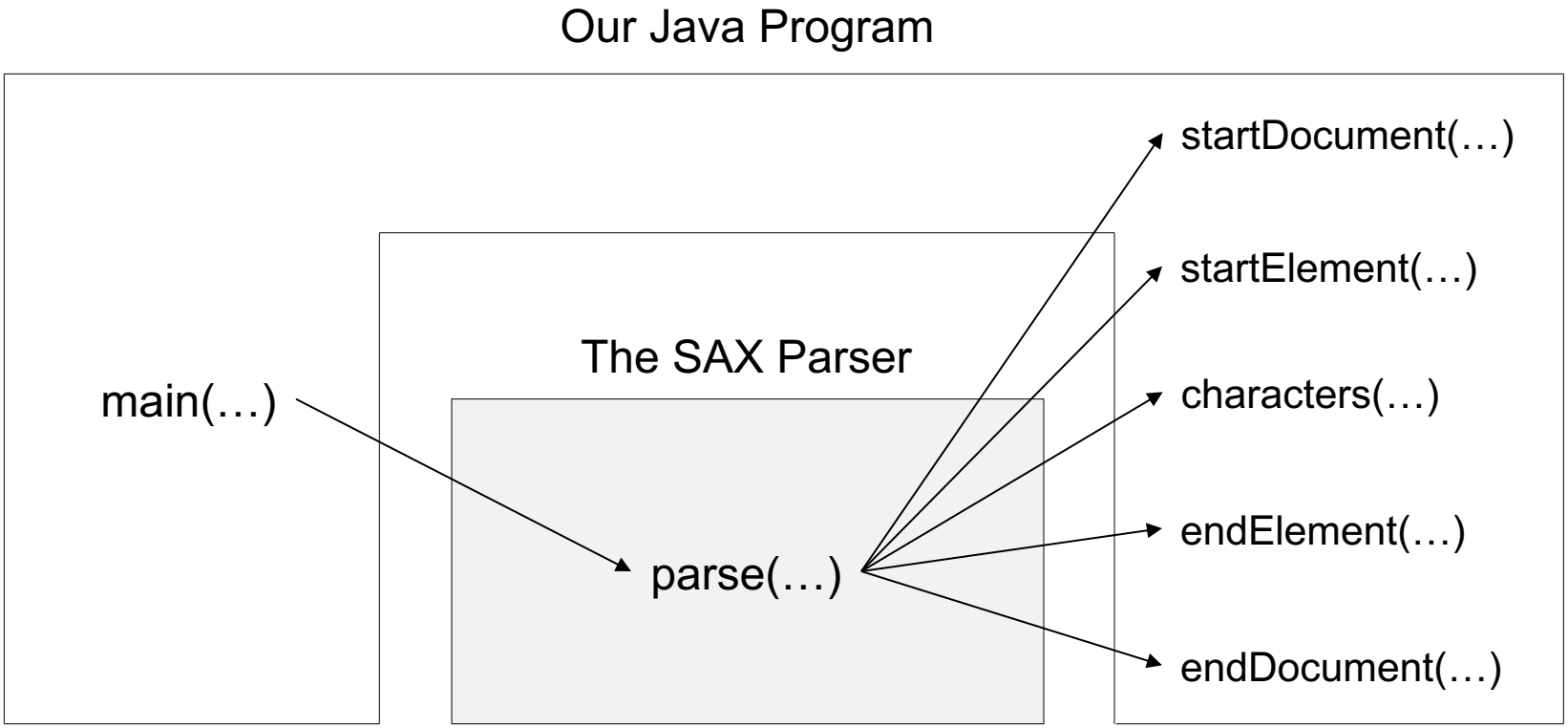
SAX - Simple API for XML

- An event-based API for reading XML documents
- No W3C standard, but a “de facto” standard - very popular
- Free and open source - http://www.saxproject.org
- Originally a Java-only API, but there are versions for several other programming languages (C++, Python, Perl, etc.)

ATTENTION: We focus on the Java version of the API

Callbacks

- SAX works through callbacks - we call the parser, it calls methods that we supply



Callbacks

- SAX works through callbacks - we call the parser, it calls methods that we supply

- Callback functions are divided into four event handlers:
  - ContentHandler - it handles basic parsing callbacks (e.g., element starts)
  - ErrorHandler - it handles parsing errors
  - DTDHandler - it handles notation and unparsed entity declarations
  - EntityResolver - customized handling for external entities

the crucial event handlers

A Simple SAX Program

course.xml

```
<?xml version="1.0"?>
<course>Semi-structured Data</course>
```

Expected Result

```
startElement: course
characters: Semi-structured Data
endElement: course
```

A Simple SAX Program

- The program consists of two classes:
  - CourseApp - it contains the main method
    - Creates an XMLReader - the actual parser that reads the XML document and calls the callbacks

```
XMLReader parser = XMLReaderFactory.createXMLReader();
```

    - Installs the content handler

```
MyHandler handler = new MyHandler();
parser.setContentHandler(handler);
```

    - Starts the parsing

```
parser.parse("course.xml");
```

A Simple SAX Program

- The program consists of two classes:
  - MyHandler - contains handlers for three kinds of callbacks
    - startElement callbacks, generated when a start tag is seen
    - endElement callbacks, generated when an end tag is seen
    - characters callbacks, generated for the content of an element

A Simple SAX Program: Class CourseApp

```
import org.xml.sax.*;
import org.xml.sax.helpers.*;

public class CourseApp {
	public static void main(String[] args) throws Exception {
		//create XMLReader
		XMLReader parser = XMLReaderFactory.createXMLReader();

		//install the content handler
		MyHandler handler = new MyHandler();
		parser.setContentHandler(handler);

		//start parsing
		for (int i =0; i < args.length; i++) {
			parser.parse(args[i]);
		}
	}
}
```

A Simple SAX Program: Class MyHandler

```
import org.xml.sax.*;

public class MyHandler implements ContentHandler {
        //SAX calls this method when it encounters a start tag
        public void startElement(String namespaceURI,
                                 String localName,
                                 String qualifiedName,
                                 Attributes atts) throws SAXException {
                System.out.println("startElement: " + qualifiedName);
        }
```

A Simple SAX Program: Class MyHandler

```
import org.xml.sax.*;

public class MyHandler implements ContentHandler {
        //SAX calls this method when it encounters a start tag
        ...

        //SAX calls this method to pass in character data
        public void characters(char[] text, int start, int length)
                        throws SAXException {
                System.out.println("characters: " + new String(text, start, length));
        }
```

A Simple SAX Program: Class MyHandler

```
import org.xml.sax.*;

public class MyHandler implements ContentHandler {
        //SAX calls this method when it encounters a start tag
        ...

        //SAX calls this method to pass in character data
        ...

        //SAX calls this method when it encounters an end tag
        public void endElement(String namespaceURI,
                               String localName,
                               String qualifiedName) throws SAXException {
                System.out.println("endElement: " + qualifiedName);
        }
} // end of MyHandler class
```

A Simple SAX Program: Class MyHandler

```
import org.xml.sax.*;

public class MyHandler implements ContentHandler {
        //SAX calls this method when it encounters a start tag
        ...

        //SAX calls this method to pass in character data
        ...

        //SAX calls this method when it encounters an end tag
        ...

        //we have to implement do-nothing methods to fulfil the interface requirements
        //for example
        public void processingInstruction(String target, String data) { }
        //and several other methods
} // end of MyHandler class
```

A Simple SAX Program

course.xml

```
<?xml version="1.0"?>
<course>Semi-structured Data</course>
```

Result

```
startElement: course
characters: Semi-structured Data
endElement: course
```

A Simple SAX Program

course.xml

```
<?xml version="1.0"?>
<course>
    <acronym>SSD</acronym>
    Semi-structured Data
</course>
```

Result

```
startElement: course
characters: \n
characters:
startElement: acronym
characters: SSD
endElement: acronym
characters:     Semi-structured Data
characters: \n
endElement: course
```

A Simple SAX Program: Class MyHandler

```
import org.xml.sax.*;

public class MyHandler implements ContentHandler {
        //SAX calls this method when it encounters a start tag
        ...

        //SAX calls this method to pass in character data
        ...

        //SAX calls this method when it encounters an end tag
        ...

        //we have to implement do-nothing methods to fulfil the interface requirements
        //for example
        public void processingInstruction(String target, String data) { }
        //and several other methods
} // end of MyHandler class
```

…is it possible to avoid this?

Class DefaultHandler

- In package org.xml.sax.helpers
- Implements all the handlers mentioned before (ContentHandler, ErrorHandler, DTDHandler, EntityResolver)
- An adapter class - it provides empty methods for every method declared in each of the four interfaces
- Extend it and override the methods that are important for the current application

http://docs.oracle.com/javase/8/docs/api/org/xml/sax/helpers/DefaultHandler.html

A Simple SAX Program: Class MyHandler Revisited

```
import org.xml.sax.*;
import org.xml.sax.helpers.*;

public class MyHandler extends DefaultHandler {
        //SAX calls this method when it encounters a start tag
        ...

        //SAX calls this method to pass in character data
        ...

        //SAX calls this method when it encounters an end tag
        ...

        //the do-nothing methods are not needed anymore
} // end of MyHandler class
```

Callbacks

- SAX works through callbacks - we call the parser, it calls methods that we supply

- Callback functions are divided into four event handlers:
  - ContentHandler - it handles basic parsing callbacks (e.g., element starts)
  - ErrorHandler - it handles parsing errors
  - DTDHandler - it handles notation and unparsed entity declarations
  - EntityResolution - customized handling for external entities

… more details for the methods of ContentHandler
can be found in the SAX-methods slides

https://docs.oracle.com/javase/8/docs/api/org/xml/sax/ContentHandler.html

Content Handling: Example

```
<products>
  <product>
    <name>Product A</name>
    <value>100</value>
    <product>
      <name>Product B</name>
      <value>200</value>
      <product>
        <name>Product E</name>
        <value>600</value>
      </product>
    </product>
    <product>
      <name>Product C</name>
      <value>400</value>
      <product>
        <name>Product E</name>
        <value>600</value>
      </product>
    </product>
  </product>
  <product>
    <name>Product D</name>
    <value>300</value>
    <product>
      <name>Product C</name>
      <value>400</value>
      <product>
        <name>
          Product E
        </name>
        <value>600</value>
      </product>
    </product>
  </product>
</products>
```

Task: Output the

- product names in product elements that are children of the root and
- the sum of the value elements of all of their descendants.

Content Handling: Example

```
<products>
  <product>
    <name>Product A</name>
    <value>100</value>
    <product>
      <name>Product B</name>
      <value>200</value>
      <product>
        <name>Product E</name>
        <value>600</value>
      </product>
    </product>
    <product>
      <name>Product C</name>
      <value>400</value>
      <product>
        <name>Product E</name>
        <value>600</value>
      </product>
    </product>
  </product>
  <product>
    <name>Product D</name>
    <value>300</value>
    <product>
      <name>Product C</name>
      <value>400</value>
      <product>
        <name>
          Product E
        </name>
        <value>600</value>
      </product>
    </product>
  </product>
</products>
```

Intended Output:

Total value of Product A: 1900

Total value of Product D: 1300

Content Handling: Example

```
import org.xml.sax.*;

public class TopProducts extends DefaultHandler {
	String eleText;
	private int level = 0;
	private int value = 0;

	[...]

}
```

Content Handling: Example

```
import org.xml.sax.*;

public class TopProducts extends DefaultHandler {
        String eleText;
        private int level = 0;
        private int value = 0;

        @Override
        /**
        *  SAX calls this method to pass in character data
        */
        public void characters(char[] text, int start, int length)
                        throws SAXException {
                eleText = new String(text, start, length);
        }
       [...]

}
```

Content Handling: Example

```
import org.xml.sax.*;

public class TopProducts extends DefaultHandler {
        String eleText;
        private int level = 0;
        private int value = 0;
        […]

       public void startElement(String namespaceURI, String localName,
                                                    String qName, Attributes atts)
                        throws SAXException {
               if ("product".equals(localName)) {
                     level++;
               }
       }
       [...]
}
```

Content Handling: Example

```
import org.xml.sax.*;

public class TopProducts extends DefaultHandler {
        […]
       public void endElement(String namespaceURI, String localName,
           String qName) throws SAXException {
               if ("name".equals(localName)) {
                      if (level == 1) System.out.print("Total value of " + eleText + ": ");
               }
              if ("value".equals(localName))  value += Integer.parseInt(eleText);

              if ("product".equals(localName)) {
                level--;
                if (level == 0)  {
                    System.out.println(value);
                    value = 0;
                }
        }
}
```

Output:

Total value of Product A: 1900
Total value of Product D: 1300

Up to Now

- **Callbacks**
- **A Simple SAX Program**
- **Content Handling**
- Error Handling
- Features

Error Handling

- We need to install an error handler
- … otherwise, most parsing errors will be ignored
- ErrorHandler - it handles parsing errors

Error Handling: Example

```
import org.xml.sax.*;
import org.xml.sax.helpers.*;

public class CourseApp {
	public static void main(String[] args) throws Exception {
		//create XMLReader
		XMLReader parser = XMLReaderFactory.createXMLReader();

		//install the content and error handler
		MyHandler handler = new MyHandler();
		parser.setContentHandler(handler);
		parser.setErrorHandler(handler);

		//start parsing
		for (int i =0; i < args.length; i++) {
			parser.parse(args[i]);
		}
	}
}
```

ErrorHandler Methods

public void fatalError(SAXParseException ex) throws SAXException

well-formedness error

public void error(SAXParseException ex) throws SAXException

validation error

public void warning(SAXParseException ex) throws SAXException

minor error

https://docs.oracle.com/javase/8/docs/api/org/xml/sax/ErrorHandler.html

Error Handling: Example

```
import org.xml.sax.*;
import org.xml.sax.helpers.*;
public class MyHandler extends DefaultHandler {
        //Content handling
        //Error handling
        public void fatalError(SAXParseException ex) throws SAXException {
                printError("FATAL ERROR", ex)
        }
        public void error(SAXParseException ex) throws SAXException {
                printError("ERROR", ex)
        }
        public void warning(SAXParseException ex) throws SAXException {
                printError("WARNING", ex)
        }

        private void printError(String err, SAXParseException ex) {
                System.out.printf("%s at %3d, %3d: %s \n", err, ex.getLineNumber(), ex.getColumnNumber(),
                                                                ex.getMessage());
        }
} // end of MyHandler class
```

Up to Now

- **Callbacks**
- **A Simple SAX Program**
- **Content Handling**
- **Error Handling**
- Features

Features

- SAX uses features to control parser's behavior
- Each feature has an absolute URI as a name
- Features are either true or false

Some Features

- http://xml.org/sax/features/validation
  - Validate the document and report validity errors
  - Default value is false

- http://xml.org/sax/features/namespaces
  - The parser is namespace-aware
  - Default value is true

see https://xerces.apache.org/xerces2-j/features.html

Example startElement Method

```
public void startElement(String namespaceURI,
                         String localName,
                         String qualifiedName,
                         Attributes atts) throws SAXException
```

is called once at the beginning of every element

- If the parser is namespace-aware
  - namespaceURI holds the prefix (prefix:localname)
  - localName holds the element name (without a prefix)
  - qualifiedName might be empty
- If the parser is not namespace-aware
  - namespaceURI, localName might be empty
  - qualifiedName holds the element's name (possibly with a prefix)

Set Feature

```
public void setFeature(java.lang.String name, boolean value)
        throws SAXNotRecognizedException
        throws SAXNotSupportedException
```

- name - the name of the feature (an absolute URI)
- value - value of the feature (true or false)
- SAXNotRecognizedException - if the feature cannot be assigned
  - Turn on validation in a non-validating parser
- SAXNotSupportedException - if the feature cannot be activated
  - Turn on validation (in a validating parser) when part of the document has been already parsed

Set Feature: Example

```
import org.xml.sax.*;
import org.xml.sax.helpers.*;
public class CourseApp {
    public static void main(String[] args) throws Exception {
        //create XMLReader
        XMLReader parser = XMLReaderFactory.createXMLReader();

        //install the content and error handler
        MyHandler handler = new MyHandler();
        parser.setContentHandler(handler);
        parser.setErrorHandler(handler);

        //turn on validation
        parser.setFeature("http://xml.org/sax/features/validation", true);

        //start parsing
        for (int i =0; i < args.length; i++) {
            parser.parse(args[i]);
        }
    }
}
```

Sum Up

- Callbacks
- A Simple SAX Program
- Content Handling
- Error Handling
- Features

Standards for XML Parsers

- SAX - Simple API for XML (event-based)
  - “De facto” standard ✓

- DOM - Document Object Model (tree-based)
  - W3C standard

… APIs to read and interpret XML documents

… next we will focus on DOM

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9 - Simple API for XML (SAX)

Methods Overview

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ContentHandler Methods

public void startDocument() throws SAXException

is called just once at the beginning of parsing

public void endDocument() throws SAXException

is called just once, and is the last method called by the parser

ContentHandler Methods

```
public void processingInstruction(String target, String data)
        throws SAXException
```

is called once for each processing instruction <?target data?>

```
<?xml-stylesheet  href="course.css"  type="text/css"?>
```

target: xml-stylesheet

data: href="course.css" type="text/css"

ContentHandler Methods

```
public void startElement(String namespaceURI,
                         String localName,
                         String qualifiedName,
                         Attributes atts) throws SAXException
```

is called once at the beginning of every element

- If the parser is namespace-aware
  - namespaceURI holds the prefix (prefix:localname)
  - localName holds the element name (without a prefix)
  - qualifiedName might be empty
- If the parser is not namespace-aware
  - namespaceURI, localName might be empty
  - qualifiedName holds the element name (possibly with a prefix)

Attributes

- When SAX calls startElement, it passes in a parameter of type Attributes

- Attributes is an interface that defines some useful methods:
  - getLength() - number of attributes
  - getLocalName(index) - attribute's local name
  - getQName(index) - attribute's qualified name
  - getValue(index) - attribute's value
  - getType(index) - attribute's type (CDATA, NMTOKEN, etc.)

ATTENTION: If local name is empty, then qualified name hold's the attribute's name

ATTENTION: SAX does not guarantee the order of the attributes

ContentHandler Methods

```
public void endElement(String namespaceURI,
                       String localName,
                       String qualifiedName) throws SAXException
```

is called once at the end of every element

- If the parser is namespace-aware
  - namespaceURI holds the prefix (prefix:localname)
  - localName holds the element name (without a prefix)
  - qualifiedName is empty
- If the parser is not namespace-aware
  - namespaceURI, localName might be empty
  - qualifiedName holds the element name (possibly with a prefix)

ContentHandler Methods

```
public void characters(char[] ch,
                       int start,
                       int length) throws SAXException
```

is called to pass in character data

```
<?xml version="1.0"?>
<course>
    <acronym>SSD</acronym>Semi-structured Data
</course>
```

ch: <?xml version="1.0"?>
<course>
    <acronym>SSD</acronym>Semi-structured Data
</course>

start: 43

SSD

length: 3

ContentHandler Methods

```
public void characters(char[] ch,
                       int start,
                       int length) throws SAXException
```

is called to pass in character data

```
<?xml version="1.0"?>
<course>
    <acronym>SSD</acronym>Semi-structured Data
</course>
```

ch: <?xml version="1.0"?>
<course>
    <acronym>SSD</acronym>Semi-structured Data
</course>

start: 56

Semi-structured Data

length: 20

ContentHandler Methods

```
public void characters(char[] ch,
                       int start,
                       int length) throws SAXException
```

is called to pass in character data

The string constructor can be used to extract the relevant characters

```
new String(ch, start, length)
```