COMP60411
Modelling Data on the Web
XPath, XML Schema, and XQuery

Week 3

Bijan Parsia
Uli Sattler
University of Manchester
Week 1 coursework

• All graded!
  – Q1, SE1, M1, CW1

• In general,
  – Pay attention to the feedback
    • check the rubrics
    • Try to regenerate
    • Try on other people’s
  – If you don’t understand
    • Come talk to us!
    • We’re happy to explain further
  – Remember, you’ll get essays (and MCQs) on the exam
    • Practice and learn now!
    • It will help!
SE1 General Feedback

• Check the personalised feedback given via BB
• Use a good spell checker, and check grammar
• No need to repeat the question or to explain terms introduced or discussed in the lecture, e.g., “conceptual model”
• Structure your essay: either
  – point out ways in which a CM can be useful, make each of these points as clear as possible, e.g., with an example; think whether this is ‘universally true’ or only in certain situations
  – explain why a designing a CM is a waste of time.
• You could have made your statement in 150 words
  – We would appreciate that
• Long conclusions are unnecessary
  – (At most, 1 sentence for summary suffices)
  – (And if you stick to 150 words, that shouldn’t be needed)
M1 & CW1 General Feedback

- Read the specification
  - carefully
  - ask if you’re unsure
  - ask if something is unclear
  - don’t assume

- Work on basic, spec-conform solution first
  - then extend functionality
Last Week

We have encountered many things:

Tree data models:

1. Data Structure formalisms: XML (including name spaces)
2. Schema Language: RelaxNG
3. Data Manipulation: DOM (and Java)

General concepts:
• Semi-structured data
• Self-Describing
• Trees
• Regular Expressions
• Internal & External Representation, Parsing & Serialising
• Validation, valid, …
• Format

Any Questions?
This Week

• Two new interaction mechanisms:
  – XPath
  – XQuery, extends XPath

• Your second schema language:
  – XML Schema, also known as XSD or WXS

• XSD and XQuery:
  – PSVI and typed queries

• More on Namespaces:
  – Extensibility!
XPath
XML documents...

There are various standards, tools, APIs, data models for XML:

• to **describe** XML documents & **validate** XML document against:
  – we have seen: RelaxNG
  – today: XML Schema

• to parse & **manipulate** XML documents programmatically:
  – we have seen & worked with: DOM (there’s also SAX, etc.)
  – today, we will learn about **XPath** and **XQuery**

• transform an XML document into another XML document or into an instance of another formats, e.g., html, excel, relational tables
  – ....another form of **manipulation**
Manipulation of XML documents

• **XPath** for navigating through and querying of XML documents

• **XQuery**
  – more expressive than XPath, uses XPath
  – for querying and data manipulation
  – Turing complete
  – designed to access large amounts of data, to interface with relational systems

• **XSLT**
  – similar to XQuery in that it uses XPath, ....
  – designed for “styling”, together with XSL-FO or CSS

• contrast this with **DOM** and **SAX**:
  – a collection of APIs for programmatic manipulation
  – includes data model and parser
  – to build your own applications
XPath

• designed to navigate to/select parts in a well-formed XML document
• no transformational capabilities (as in XQuery and XSLT)
• is a W3C standard:
  – XPath 1.0 is a 1999 W3C standard
  – XPath 2.0 is a 2007 W3C standard that extends/is a superset of XPath 1.0
    • richer set of WXS types & schema sensitive queries
  – XPath 3.0 is a 2014 W3C standard
• allows to select/define parts of an XML document: sequence of nodes
• uses path expressions
  – to navigate in XML documents
  – to select node-lists in an XML document
  – similar to expressions in a traditional computer file system
• provides numerous built-in functions
  – e.g., for string values, numeric values, date and time comparison, node and QName manipulation, sequence manipulation, Boolean values, etc.
• Contrast with SQL!

XML Schema later more

sequence vs set?

rm *//*.pdf
XPath: Datamodel

- remember how an XML document can be seen as a node-labelled tree
  - with element names as labels: *its DOM tree*

- XPath operates on the abstract, logical tree structure of an XML document, rather than its surface, text syntax
  - *but not on its DOM tree!*

- XPath uses **XQuery/XPath Datamodel**
  - there is a translation at [http://www.w3.org/TR/xpath20/#datamodel](http://www.w3.org/TR/xpath20/#datamod)el
    - see XPath process model…
  - it is similar to the DOM tree
    - easier
<table>
<thead>
<tr>
<th>Level</th>
<th>Data unit examples</th>
<th>Information or Property required</th>
</tr>
</thead>
<tbody>
<tr>
<td>cognitive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>application</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tree adorned with DOM tree, Infoset, XPath</td>
<td>nothing</td>
<td>a schema</td>
</tr>
<tr>
<td>complex</td>
<td><code>&lt;foo:Name t=&quot;8&quot;&gt;Bob</code></td>
<td>well-formedness</td>
</tr>
<tr>
<td>simple</td>
<td><code>&lt;foo:Name t=&quot;8&quot;&gt;Bob</code></td>
<td></td>
</tr>
<tr>
<td>character</td>
<td><code>&lt;foo:Name t=&quot;8&quot;&gt;Bob</code></td>
<td>which encoding (e.g., UTF-8)</td>
</tr>
<tr>
<td>bit</td>
<td><code>10011010</code></td>
<td></td>
</tr>
</tbody>
</table>
XPath processing - a simplified view

Flowchart:
- **Input/Output**
- **Generic tools**
- **XPath expression** → **XPath parser** → **XPath tree** → **XPath Execution Engine**
- **Schema** → **(Schema-aware) Parser** → **Standard Datamodel** (e.g., DOM or XPath)
- **XML document**
- **Node Sequence**
XPath processing - a more detailed view
XPath: Datamodel

- the XPath DM uses the following concepts
- **nodes**:
  - element
  - attribute
  - text
  - namespace
  - processing-instruction
  - comment
  - document (root)

- **atomic value**:
  - behave like nodes without children or parents
  - is an atomic value, e.g., xsd:string

- **item**: atomic values or nodes

```xml
<?xml version="1.0" encoding="ISO-8859-1"?>
<bookstore>
  <book>
    <title lang="en">Harry Potter</title>
    <author>J K. Rowling</author>
    <year>2005</year>
    <price>29.99</price>
  </book>
</bookstore>
```
XPath Data Model

```xml
<?xml version="1.0" encoding="UTF-8"?>
<network>
<description name="Boston">
This is the configuration of our network.
</description>
<host name="agatha" type="server" os="linux">
<interface name="eth0" type="Ethernet">
<arec>agatha.example.edu</arec>
<cname>mail.example.edu</cname>
<addr>192.168.0.4</addr>
</interface>
<service>SMTP</service>
<service>POP3</service>
<service>IMAP4</service>
</host>
<host name="gil" type="server" os="linux">
<interface name="eth0" type="Ethernet">
<arec>gil.example.edu</arec>
<cname>mail.example.edu</cname>
<addr>192.168.0.4</addr>
<service>SMTP</service>
</interface>
<service>POP3</service>
<service>IMAP4</service>
</host>
</network>
```

From:
Comparison XPath DM and DOM datamodel

- XPath DM and DOM DM are similar, but different
  - most importantly regarding names and values of nodes but also structurally (see ★)
  - in XPath, only attributes, elements, processing instructions, and namespace nodes have names, of form (local part, namespace URI)
  - whereas DOM uses pseudo-names like #document, #comment, #text
  - In XPath, the value of an element or root node is the concatenation of the values of all its text node descendants, not null as it is in DOM:
    - e.g, XPath value of <a>A<b>B</b></a> is “AB”
  
★ XPath does not have separate nodes for CDATA sections (they are merged with their surrounding text)

- XPath has no representation of the DTD
  - or any schema

```
<N>here is some text and <![CDATA[some CDATA < >]]> </N>
```
XPath: core terms — relation between nodes

• We know trees already:
  – each node has at most one parent
    • each node but the root node has exactly one parent
    • the root node has no parent
  – each node has zero or more children
  – ancestor is the transitive closure of parent, i.e., a node’s parent, its parent, its parent, ...
  – descendant is the transitive closure of child, i.e., a node’s children, their children, their children, ...

• when evaluating an XPath expression $p$, we assume that we know
  – which document and
  – which context we are evaluating $p$ over
  – … we see later how they are chosen/given

• an XPath expression evaluates to a node sequence,
  – a node is a document/element/attribute node or an atomic value
  – document order is preserved among items
XPath - by example

```xml
<?xml version="1.0" encoding="UTF-8"?>
<network>
<description name="Boston">
  This is the configuration of our network.
</description>
<host name="agatha" type="server" os="linux">
  <interface name="eth0" type="Ethernet">
    <arec>agatha.example.edu</arec>
    <cname>mail.example.edu</cname>
    <addr>192.168.0.4</addr>
  </interface>
  <service>SMTP</service>
  <service>POP3</service>
  <service>IMAP4</service>
</host>
<host name="gil" type="server" os="linux">
  <service>SMTP</service>
</host>
</network>
```
XPath - abbreviated syntax by example

XPath expression: `//*[2]`
XPath - abbreviated syntax by example

XPath expression: */*[2]/*[1]/*[3]
XPath - abbreviated syntax
know your context node

XPath expression: */*[2]
This is the configuration of our network in the Boston office.

XPath expression: `/*/*[1]`
XPath - abbreviated syntax local globally

XPath expression: //service

```xml
<?xml version="1.0" encoding="UTF-8"?>
<network>
  <description name="Boston">
    This is the configuration of our network.
  </description>
  <host name="agatha" type="server" os="linux">
    <interface name="eth0" type="Ethernet">
      <arec>agatha.example.edu</arec>
      <cname>mail.example.edu</ifcname>
      <addr>192.168.0.4</addr>
    </interface>
    <service>SMTP</service>
    <service>POP3</service>
    <service>IMAP4</service>
  </host>
  <host name="gil" type="server" os="linux">...<host>
```
XPath - abbreviated syntax
local globally

XPath expression: //*
XPath - abbreviated syntax attributes in filters

XPath expression:
//[@name="agatha"]
Find more about XPath: read up and play with examples, e.g., in
Contrast with SQL
(Just with what you’ve seen!)
XML Schema
another schema language for XML
There is more than 1 schema language

- RelaxNG schemas
  - S
  - S1
  - S2
  - docs valid wrt S, S1
docs valid wrt S2, S3

- XML Schema schemas
  - S3
  - S4
  - docs valid wrt S, S1

docs valid wrt S, S1

all well-formed XML docs

all XML docs
A more correct picture:

XML Schema is an XML schema language with an XML syntax (unlike for RelaxNG, there is no compact syntax).

RelaxNG schemas

S
S1
S2

docs valid wrt S, S1
docs valid wrt S2, S3

docs valid wrt S, S1

docs valid wrt S, S1

all well-formatted XML docs

all XML docs

XML Schema schemas

S3
S4
Schema languages for XML

provide means to define the legal structure of an XML document

cartoon.rnc, a RelaxNG Schema for cartoon descriptions
A variety of schema languages have been developed for XML; they vary w.r.t.

- **their expressive power:**
  - “do I have a means to express foo?”
  - “how hard is it to describe foo?”

- **ease of use/understanding:**
  - “how easy it is to write a schema?”
  - “how easy is it to understand a schema written by somebody else?”

- **the complexity of validating** a document w.r.t. a schema:
  - “how much space/time does it take to verify whether a document is valid w.r.t. a schema (in the size of document and schema)?”
  - (Mostly for implementors!)
Schema languages for XML

provide means to define the legal structure of an XML document

cartoon.xsd, an **XML Schema** schema for cartoon descriptions

```xml
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
  elementFormDefault="qualified">
  <xs:element name="cartoon">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="prolog"/>
        <xs:element ref="panels"/>
      </xs:sequence>
      <xs:attributeGroup ref="attlist.cartoon"/>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

```xml
<?xml version="1.0" encoding="UTF-8"?>
<cartoon copyright="United Feature Syndicate"
  year="2000">
  <prolog>
    <series>Dilbert</series>
    <author>Scott Adams</author>
    <characters>
      <character>The Pointy-Haired Boss</character>
      <character>Dilbert</character>
    </characters>
  </prolog>
  ...
</cartoon>
```

```xml
<?xml version="1.0" encoding="UTF-8"?>
<cartoon copyright="Bill Watterson"
  year="1994">
  <prolog>
    <series>Calvin and Hobbs</series>
    <author>Bill Watterson</author>
    <characters>
      <character>Calvin</character>
      <character>Hobbs</character>
      <character>Snowman</character>
    </characters>
  </prolog>
  ...
</cartoon>
```
XML Schema

- XML Schema is also referred to as XML Schema Definition, abbr. XSD
- is a W3C standard, see http://www.w3.org/XML/Schema

- a RNG in compact syntax (or DTD) is **not** a well-formed XML document
  - though you can use the RelaxNG XML format
- an XML Schema schema **is** a well-formed XML document
  - no human oriented syntax
- XML Schema
  - is *mostly* more expressive than DTDs
  - but *overlaps* with RelaxNG: each has non-shared features
- in contrast to DTDs, XML Schema supports
  - **namespaces**, so we can combine several documents: for schema validation, universal names are used (rather than qualified names)
  - **datatypes**, including simple datatypes for parsed character data and for attribute values, e.g., for *date* (when was 11/10/2006?)
  - more features for describing the (element & mixed) content of elements
XML Schema: a first example

Example with RNG:

```xml
<?xml version="1.0"?>

<note>
  <to>Tove</to>
  <from>Jani</from>
  <sentOn>2007-01-29</sentOn>
  <body>
    Have a nice weekend!
  </body>
</note>
```

```
default namespace = "http://www.w3schools.com"

element note {
  element to { text },
  element from { text },
  element sentOn { text },
  element body { text }
}
```
XML Schema: a first example

<?xml version="1.0"?>
<note
xmlns="http://www.w3schools.com"
xmlns:xs="http://www.w3.org/2001/XMLSchema"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <to>Tove</to>
  <from>Jani</from>
  <sentOn>2007-01-29</sentOn>
  <body>
    Have a nice weekend!
  </body>
</note>

<!DOCTYPE note SYSTEM "note.xsd">

note.xsd:

<?xml version="1.0"?>
<xs:schema
  xmlns:xs="http://www.w3.org/2001/XMLSchema"
  targetNamespace="http://www.w3schools.com"
  xmlns="http://www.w3schools.com"
  elementFormDefault="qualified">
  <xs:element name="note">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="to" type="xs:string"/>
        <xs:element name="from" type="xs:string"/>
        <xs:element name="sentOn" type="xs:date"/>
        <xs:element name="body" type="xs:string"/>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:schema>
XML Schema: some remarks

- to validate an XML document against an XML schema,
  – we use a **validating XML parser** that supports **XML Schema**
  – e.g., DOM level 2, SAX2
XML Schema: some remarks

- to validate an XML document against an XML schema,
  - we use a **validating XML parser** that supports **XML Schema**
  - e.g., DOM level 2, SAX2
- in an XSD schema,
  - each element and type can only be declared once
  - almost all elements can contain an element
    `<xs:annotation>...<xs:annotation>` as their first child: useful, e.g., for
    ```xml
    <xs:simpleType name="northwestStates">
      <xs:annotation>
        <xs:documentation>States in the Pacific Northwest of US</xs:documentation>
      </xs:annotation>
      <xs:restriction base="xs:string"></xs:restriction>
    </xs:simpleType>
    ```
- **XML Schema** provides support for modularity & re-use through
  - `xs:import`
  - `xs:include`
  - `xs:redefine`
XML Schema & Namespaces

• most XML Schema schemas start like this, in note.xsd

```xml
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
  targetNamespace="http://www.w3schools.com"
  xmlns="http://www.w3schools.com"
  elementFormDefault="qualified" >
  ...
</xs:schema>
```

• and a document using such a schema looks like this:

```xml
<?xml version="1.0"?>
<note xmlns="http://www.w3schools.com"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  “This document uses an XSD schema”
</note>
```
XML Schema & Namespaces

- XSD supports (and uses) **namespaces**
- an XSD schema typically has 2 namespaces:
  - `targetNamespace` for those **elements defined in schema** and
    - which also might need a separate declaration
  - XMLSchema namespace `http://www.w3.org/2001/XMLSchema`
  - (and may involve many more!)

```xml
<?xml version="1.0"?>
<p:note
    xmlns:p="http://www.w3schools.com"
    xmlns:xs="http://www.w3.org/2001/XMLSchema"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
    <p:to>Paul</p:to>
</note>
```

```xml
<?xml version="1.0"?>
<note
    xmlns="http://www.w3schools.com"
    xmlns:xs="http://www.w3.org/2001/XMLSchema"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
    <to>
        Paul
    </to>
</note>
```
XML Schema core concepts: datatypes

- in the previous examples, we used 2 Built-in datatypes:
  - xs:string
  - xs:date

- many more:
  - built-in/atomic/primitive e.g., xs:dateTime
  - composite/user-defined e.g., xs:lists, xs:union
  - through restrictions/user-defined e.g., ints < 10
XML Schema core concepts: datatypes

Each XSD datatype comes with a

- **value space**, e.g., for xs:boolean, this is {true, false}.
- **lexical space**, e.g., for xs:boolean, this is {true, false, 1, 0}, and
- **lexical-to-value** mapping \(\mapsto\) that has to be neither injective nor surjective
  - for xs:boolean, it’s surjective, but not injective
e.g., true \(\mapsto\) true and 1 \(\mapsto\) true
  - for xs:integer 1 \(\mapsto\) 1 and 01 \(\mapsto\) 1 and 001 \(\mapsto\) 1,…
- **constraining facets** that can be used in restrictions of that datatype
  - e.g., for xs:integer: maxInclusive, maxExclusive, minInclusive, …
  - e.g., for defining “SmallInteger” or “ShortString”
XML Schema: types

We can define **types** in an XSD schema, in two ways:

- **xs:simpleType** for simple types, to be used for
  - **attribute values** and
  - **elements** without element child nodes and without attributes
- **xs:complexType** for complex types, to be used for
  - **elements** with
    - element content or
    - mixed element content or
    - text content and attributes
XML Schema: type declarations

- can be **anonymous**, e.g., in the definition of age or person below:

  ```xml
  <xs:element name="age">
    <xs:simpleType>
      <xs:restriction base="xs:integer">
        <xs:minInclusive value="3"/>
        <xs:maxInclusive value="7"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:element>
  <age>4</age>
  
  <xs:element name="person">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="Name" type="Nametype"/>
        <xs:element name="DoB" type="xs:date"/>
      </xs:sequence>
      <xs:attribute name="friend" type="xs:boolean"/>
    </xs:complexType>
  </xs:element>
  <person friend="1">
    <Name>...</Name>
    <DoB>...</DoB>
  </person>
  ```

- can be **named**, e.g., Agetype or PersonType

  ```xml
  <xs:element name="age" type="AgeType"/>
  <xs:simpleType name="AgeType">
    <xs:restriction base="xs:integer">
      <xs:minInclusive value="3"/>
      <xs:maxInclusive value="7"/>
    </xs:restriction>
  </xs:simpleType>
  
  <xs:element name="person" type="PersonType"/>
  <xs:complexType name="PersonType">
    <xs:sequence>
      <xs:element name="Name" type="Nametype"/>
      <xs:element name="DoB" type="xs:date"/>
    </xs:sequence>
    <xs:attribute name="friend" type="xs:boolean"/>
  </xs:complexType>
  ```
XML Schema: atomic simple types

- are based on the numerous built-in datatypes
- that can be restricted using `xs:restriction facets`, e.g.,

| enumeration   | `<xs:simpleType name="bikeType">`  
|               | `  <xs:restriction base="xs:string">`  
|               | `    <xs:enumeration value="MTB"/>`  
|               | `    <xs:enumeration value="Race"/>`  
|               | `    <xs:enumeration value="Hybrid"/>`  
|               | `  </xs:restriction>`  
|               | `</xs:simpleType>`  

| length        | `<xs:simpleType name="eightChar">`  
|               | `  <xs:restriction base="xs:string">`  
|               | `    <xs:length value="8"/>`  
|               | `  </xs:restriction>`  
|               | `</xs:simpleType>`  

XML Schema: atomic simple types

- are based on the numerous built-in datatypes
- that can be restricted using `xs:restriction` facets, e.g.,

<table>
<thead>
<tr>
<th></th>
<th>XML Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>maxLength, minLength</td>
<td>`&lt;xs:simpleType name=&quot;medStr&quot;&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;xs:restriction base=&quot;xs:string&quot;&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;xs:minLength value=&quot;5&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;xs:maxLength value=&quot;8&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:restriction&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:simpleType&gt;</td>
</tr>
<tr>
<td>maxExclusive/maxInclusive</td>
<td>`&lt;xs:simpleType name=&quot;age&quot;&gt;</td>
</tr>
<tr>
<td>minExclusive/minInclusive</td>
<td>&lt;xs:restriction base=&quot;xs:integer&quot;&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;xs:minInclusive value=&quot;0&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;xs:maxInclusive value=&quot;120&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:restriction&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:simpleType&gt;</td>
</tr>
<tr>
<td>patterns (using regular</td>
<td>`&lt;xs:simpleType name=&quot;simpleStr&quot;&gt;</td>
</tr>
<tr>
<td>expressions close to Perl’s)</td>
<td>&lt;xs:restriction base=&quot;xs:string&quot;&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;xs:pattern value=&quot;([a-z][A-Z]+)=&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:restriction&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:simpleType&gt;</td>
</tr>
</tbody>
</table>
XML Schema: composite simple types

- we can use built-in datatypes not only in **restrictions**, but also in **compositions** to:
  - `xs:list`
  - `xs:union`

```xml
<xs:simpleType name='IntList'>
  <xs:list itemType='xs:integer'/>
</xs:simpleType>

<xs:simpleType name='ShortList'>
  <xs:restriction base='IntList'>
    <xs:maxLength value='8'/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name='ColourListOrDate'>
  <xs:union memberTypes="ColourList xs:date"/>
</xs:simpleType>

<xs:simpleType name='ColourList'>
  <xs:list>
    <xs:restriction base='xs:string'>
      <xs:enumeration value='red'/>
      <xs:enumeration value='green'/>
      <xs:enumeration value='blue'/>
    </xs:restriction>
  </xs:list>
</xs:simpleType>
```
XML Schema: simple types

• can be used in
  – element declarations, for elements without element child nodes
  – attribute declarations

• we can specify fixed or default values

```xml
<xs:complexType name="PersonType">
  <xs:sequence>
    <xs:element name="Name" type="xs:string"/>
    <xs:element name="DoB" type="xs:date"/>
  </xs:sequence>
  <xs:attribute name="friend" type="xs:boolean" default="true"/>
  <xs:attribute name="phone" type="xs:string"/>
</xs:complexType>
```
XML Schema: simple content

- for elements
  - where we cannot use xs:simpleType because of attribute declarations
  - but that have simple (e.g., text) content only,
  ➪ we can use xs:simpleContent, e.g.

```xml
<xs:element name="size">
  <xs:complexType>
    <xs:simpleContent>
      <xs:extension base="xs:integer">
        <xs:attribute name="country" type="xs:string"/>
      </xs:extension>
    </xs:simpleContent>
  </xs:complexType>
</xs:element>
```

```xml
<size country="UK">4</size>
```
XML Schema: complex types

- **element order enforcement constructs:**
  - **sequence**: order preserving
  - **all**: like sequence, but not order preserving
  - **choice**: choose exactly one

- these constructs can be combined with `minOccurs` and `maxOccurs`,
  - by default, both are set to 1,
  - but they can be set to any non-negative integer or “unbounded”, e.g.

```xml
<xs:complexType name="nametype">
  <xs:sequence>
    <xs:element name="fname" type="xs:string"/>
    <xs:element name="mname" type="xs:string">
      <minOccurs="0" maxOccurs="7"/>
    </xs:element>
    <xs:element name="lname" type="xs:string"/>
  </xs:sequence>
</xs:complexType>
```
XML Schema: mixed content

- to allow for mixed content, set attribute mixed="true", e.g.,

```xml
<xs:complexType name="PersonType" mixed="true">
  <xs:sequence>
    <xs:element name="Name" type="xs:string"/>
    <xs:element name="DoB" type="xs:date"/>
  </xs:sequence>
  <xs:attribute name="friend" type="xs:boolean" default="true"/>
  <xs:attribute name="phone" type="xs:string"/>
</xs:complexType>
```

- but we
  - cannot constrain where the text occurs between elements,
  - can only say that content can be mixed
XML Schema: restriction and extension

- we have already used `xs:extension` and `xs:restriction` both for
  - simple types and
  - complex types
- they are XML Schema’s mechanisms for **inheritance**
- **extension**: specifying a new type X by extending Y
  - this “appends” X’s definition to Y’s, e.g.,

```xml
<xs:simpleType name="AgeType">
  <xs:restriction base="xs:integer">
    <xs:minInclusive value="3"/>
    <xs:maxInclusive value="7"/>
  </xs:restriction>
</xs:simpleType>

<xs:complexType name="NewAgeType">
  <xs:simpleContent>
    <xs:extension base="AgeType">
      <xs:attribute name="range" type="xs:string"/>
    </xs:extension>
  </xs:simpleContent>
</xs:complexType>

<xs:complexType name="PersonType">
  <xs:sequence>
    <xs:element name="Name" type="xs:string"/>
    <xs:element name="DoB" type="xs:date"/>
  </xs:sequence>
  <xs:attribute name="friend" type="xs:boolean" default="true"/>
  <xs:attribute name="phone" type="xs:string"/>
</xs:complexType>

<xs:complexType name="LongPersonType">
  <xs:complexContent>
    <xs:extension base="PersonType">
      <xs:sequence>
        <xs:element name="address" type="xs:string"/>
      </xs:sequence>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>
```
XML Schema: restriction and extension

- **restriction**: easy for simple types we have seen it several times

```xml
<xs:simpleType name="AgeType">
  <xs:restriction base="xs:integer">
    <xs:minInclusive value="3"/>
    <xs:maxInclusive value="7"/>
  </xs:restriction>
</xs:simpleType>
```

- **restriction**: “cumbersome” for complex types: specifying a new type X by restricting a complex type Y requires the reproduction of Y’s definition, e.g.,

```xml
<xs:complexType name="PersonType">
  <xs:sequence>
    <xs:element name="Name" type="xs:string"/>
    <xs:element name="DoB" type="xs:date"/>
  </xs:sequence>
  <xs:attribute name="friend" type="xs:boolean"/>
  <xs:attribute name="phone" type="xs:string"/>
</xs:complexType>
```

```xml
<xs:complexType name="StrictPersonType">
  <xs:complexContent>
    <xs:restriction base="PersonType">
      <xs:sequence>
        <xs:element name="Name">
          <xs:simpleType>
            <xs:restriction base="xs:string">
              <xs:pattern value="^[A-Z][a-z]+"/>
            </xs:restriction>
          </xs:simpleType>
        </xs:element>
        <xs:element name="DoB" type="xs:date"/>
      </xs:sequence>
      <xs:attribute name="friend" type="xs:boolean"/>
      <xs:attribute name="phone" type="xs:string"/>
    </xs:restriction>
  </xs:complexContent>
</xs:complexType>
```
XML Schema: restriction and extension

- **usage**: in a document, an element of a type derived by restriction or extension from Y can be used in place of an element of type Y…
  - provided you say so explicitly, e.g., in

  ```xml
  <person phone="2">
    <Name>Peter</Name>
    <DoB>1966-05-04</DoB>
  </person>
  <person xsi:type="LongPersonType" phone="5432" friend="0">
    <Name>Paul</Name>
    <DoB>1967-05-04</DoB>
    <address>Manchester</address>
  </person>
  ```

  - this means that a XSD-aware parser has to **manage** a schema’s **type hierarchy**
    - to ensure that `LongPersonType` was really derived by restriction or extension from the type expected for `person`

- but XSD-aware parser does NOT have to “guess” an element’s type from its properties
- In SE3: compare they “pain & gain” of using types to “pain & gain” of using other features like substitution groups!
XML Schema: restriction and extension

- to prevent a type from being instantiated directly, use e.g.,
  
  `<xs:complexType name="StrictPersonType" abstract="true">`

- to prevent a type from being further extended and/or restricted use e.g.,
  
  `<xs:complexType name="StrictPersonType" final="#all">`

- closely related to the mechanism of restriction/extension are substitution groups, i.e., a mechanism to allow to replace one element with a group of others
XML Schema: summary of complex types

- we have simple and complex **types**:
  - simple types for attribute values and text in elements
  - complex types for elements with child elements or attributes
- we have simple and complex **content** of elements:
  - simple content:
    - elements with only text between tags and possibly attributes
  - complex content:
    - element content (elements only)
    - mixed content (elements and text)
    - empty content (at most attributes)
- a complex content type can be specified in 3 ways: using
  - element order enforcement constructs (all, sequence, choice)
  - a single child of simpleContent:
    derive a complex type from a simple or complex type with simple content
  - a single child of complexContent:
    derive a complex type from another complex type using restriction or extension
Comparing XML Schema & RelaxNG

- You know one better than the other…one is simpler than the other…
- in RNG, no mechanism for manipulating datatypes, lists, unions,…
  - but you can borrow this from XSD!
- in RNG, no restrictions & extension, no (non-atomic) types
  - in a document, an element of a type derived by restriction from Y can be used in place of an element of type Y
  - this can make writing complex schemas easier!
  - but this means that a validating XML parser has to manage a schema’s type hierarchy
- XML Schema has restrictions on expressing constraints on content models
  - so that matching a node’s child node sequence against the corresponding content model is “easier”
  - e.g., XML Element Declarations Consistent constraint
- is there a set of XML documents (e.g., your cartoon descriptions)
  - for which we can formulate a RNG
  - but not an XML schema?
  - or the other way round?
Extensibility

is a systemic measure of the ability to extend a system/XML format/XML schema and the level of effort required to implement the extension.

RNGs and extensibility

- **Multiple** RNGs

- Given a **single** RNG, we can easily
  - loosen features
    - Choice
    - Repetition (regular expressions!)
    - ANY - for elements of any kind!
    - #IMPLIED and #DEFAULT
  - tighten features
    - naturally: every name must have a declaration!
    - No namespace sensitivity
Example

- **Two RNGs**
  - One describing a **superset** of the other
  - Safe for generation
    - Not as safe for consumption
    - But perhaps safe in the right way?

- **Multiple RNGs vs. Well-formedness**
  - Finding a fit
  - Finding a “best” fit
    - Too tight a fit is pointless
    - Too loose can be pointless too!

\[
\text{start} = \text{element problem} \ ((\text{declaration},\text{declaration})+)>
\]

\[
\text{start} = \text{element problem} \ \{\text{declaration},\text{declaration}+\}>
\]
XSD and Extensibility

- Multiple WXS
  - As with RNGs
  - WXS can relate
    - I.e., A WXS can extend or refine another WXS
    - ...see include and import
    - Just as a type can extend another
      - Inter-schema refinement can do more
  - with namespace support!
- In a single WXS
  - Choice and repetition
  - Wildcards!
    - Strictly more expressive
    - Namespace aware
- (RelaxNG also has modularity and extension features)

```xml
<xs:any namespace="##other" processContents="lax"/>
<xs:any namespace="http://www.w3.org/1999/XSL"/>
<xs:any namespace="##targetNamespace"/>
<xs:anyAttribute namespace="http://www.w3.org/XML"/>
```
Namespaces

- Their fundamental goal:
  - to manage names...
  - provide "Decentralised extensibility"
    - What does this mean?

- Their fundamental limitation:
  - Name extensibility only!
  - Clash prevention only!
    - At least at the technical level...

- Schemas need to be namespace sensitive
  - And to enable more elaborate behavior
XML Schema: Namespaces

- **targetNamespace**
  - Every WXS has a `targetNamespace`
    - At least implicitly
    - for those elements defined in schema
    - It also has a lot of symbol spaces
  - But any `<ws:schema>` has only **one** targetNamespace!
    - We need to relate documents (i.e., DOMs!)
    - a `ws:schema` component can have more namespaces!
Some Namespace Patterns

For example

- Contained NS Pattern
- Global Attributes NS Pattern
  - Attributes are weird
- General Extension NS Pattern
- Version
- Abuse

Be sure you understand the difference between
- namespace declarations
- namespaces,
- expanded names,
- namespace scope, etc.
Remember Namespaces?!

- **Namespace declarations**, e.g., `xmlns:calc="http://bjp.org/calc/"`
  - looks like/can be treated as a normal attributes (CW2)
- **Qualified names** (“QNames”), e.g., `calc:plus`
  - Prefix, e.g., `calc`
  - Local name, e.g., `plus`
- **Expanded name**, e.g., `{http://bjp.org/calc/}plus`
- **Namespace name**, e.g., `http://bjp.org/calc/`
- **The scope** of a declaration is:
  - The element where the declaration **appears** together with
  - **the descendants** of that element...
    - ...except those descendants which have a conflicting declaration
      - (and their descendants, etc.)
    - I.e., a declaration with the same prefix
- **Scopes nest and shadow**
  - Deeper nested declarations redefine/overwrite outer declarations
The Contained Namespace Patterns

- a very common pattern
- a form of composition where a “context” is shared by subtrees
  - Think SVG in HTML
- where an element with all its attributes and “relevant” descendants share the same namespace and processing
  - a descendant may be the root of a new “context” subtree
  - but then is in a new namespace with its own processing instruction
  - which will also apply to all its descendants, apart from ...
The Contained Namespace Patterns

another example:

```xml
<xsl:stylesheet xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
    xmlns:xs="http://www.w3.org/2001/XMLSchema" exclude-result-prefixes="xs" version="2.0">
    <xsl:import-schema schema-location="http://ex.org/minischema.xsd"/>
    <xsl:template match="/">
        ...
    </xsl:template>
</xsl:stylesheet>
```

```xml
<xsl:stylesheet xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
    xmlns:xs="http://www.w3.org/2001/XMLSchema" exclude-result-prefixes="xs" version="2.0">
    <xsl:import-schema>
        <xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
            <xs:element name="a" type="Union"/>
            <xs:complexType name="Union">
                <xs:union memberTypes="xs:integer xs:boolean"/>
            </xs:complexType>
        </xs:schema>
    </xsl:import-schema>
    <xsl:template match="/">
        ...
    </xsl:template>
</xsl:stylesheet>
```
How to Capture in XML Schema?

- **xs:import**
  - Declares a foreign namespace
    - and associated schema (but no prefix for it: the schema does this!)

```xml
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
           xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
           targetNamespace="http://www.w3.org/1999/XSL/Transform" elementFormDefault="qualified">


  ...<xs:element name="import-schema" substitutionGroup="xsl:declaration">
     <xs:complexType>
       <xs:complexContent>
         <xs:extension base="xsl:element-only-versioned-element-type">
           <xs:sequence>
             <xs:element ref="xs:schema" minOccurs="0" maxOccurs="1"/>
           </xs:sequence>
           <xs:attribute name="namespace" type="xs:anyURI"/>
           <xs:attribute name="schema-location" type="xs:anyURI"/>
         </xs:extension>
       </xs:complexContent>
     </xs:complexType>
  </xs:element>

  ...</xs:schema>
```

Brings in the foreign namespace and its declarations

And we can now use elements declared
How to Capture in XML Schema?

- **xs:import**
  - Declares a foreign namespace
  - and associated schema

```xml
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
            xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
            targetNamespace="http://www.w3.org/1999/XSL/Transform" elementFormDefault="qualified">


  <xs:element name="import-schema" substitutionGroup="xsl:declaration">
    <xs:complexType>
      <xs:complexContent>
        <xs:extension base="xsl:element-only-versioned-element-type">
          <xs:sequence>
            <xs:element ref="xs:schema" minOccurs="0" maxOccurs="1"/>
          </xs:sequence>
          <xs:attribute name="namespace" type="xs:anyURI"/>
          <xs:attribute name="schema-location" type="xs:anyURI"/>
        </xs:extension>
      </xs:complexContent>
    </xs:complexType>
  </xs:element>

  ...
</xs:schema>
```

If you delete this

then this breaks

but this is still ok
How to Capture in XML Schema?

- Strange:
  - xmlns declares the namespace binding
  - xs:import makes that namespace “schema active”

```xml
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
           xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
           targetNamespace="http://www.w3.org/1999/XSL/Transform"
           elementFormDefault="qualified">

  <xs:import namespace="http://www.w3.org/2001/XMLSchema"
              schemaLocation="http://www.w3.org/2001/XMLSchema.xsd"/>

  <xs:element name="import-schema" substitutionGroup="xsl:declaration">
    <xs:complexType>
      <xs:complexContent>
        <xs:extension base="xsl:element-only-versioned-element-type">
          <xs:sequence>
            <xs:element ref="xs:schema" minOccurs="0" maxOccurs="1"/>
          </xs:sequence>
          <xs:attribute name="namespace" type="xs:anyURI"/>
          <xs:attribute name="schema-location" type="xs:anyURI"/>
        </xs:extension>
      </xs:complexContent>
    </xs:complexType>
  </xs:element>

</xs:schema>
```

If you delete this, then this breaks.
Attributes & Namespaces

• **Why** do we have attributes?
  – Attributes aren’t **ordered**
  – Attributes don’t **repeat**
  – Attributes don’t **contain markup**
    • They can’t contain **structured data**
  – Require a **special** node type, axes, syntax, etc.
  – **Prefixless** attribute name weirdness:

A default namespace declaration applies to all **unprefixed element** names within its scope. Default namespace declarations do **not** apply directly to **attribute** names; the interpretation of unprefixed attributes is determined by the **element** on which they appear.
“Local” vs. “Global” Attributes

Another namespace pattern

- Attributes in the null namespace
  - Null namespace attributes are contextually processed
    - Thus “local”

A default namespace declaration applies to all unprefixed element names within its scope. Default namespace declarations do not apply directly to attribute names; the interpretation of unprefixed attributes is determined by the element on which they appear.

```xml
<a xmlns:ex1="http://ex.org/1"
   xmlns:ex2="http://ex.org/2">
  <ex1:b name="..."/>
  <ex2:b name="..."/>
  <ex1:c ex1:name="..." ex2:name="..."/>
  <ex1:c ex1:name="..." ex1:name="..."/>
</a>
```

- Same name, but (perhaps) processed differently
- Different names, no connection
- Same names and illegal
Global Attributes Example

- Language extensions
  - xml:lang
  - xml:base
  - xml:space
  - xml:id

```xml
<xs:attributeGroup name="specialAttrs">
  <xs:attribute ref="xml:base"/>
  <xs:attribute ref="xml:lang"/>
  <xs:attribute ref="xml:space"/>
  <xs:attribute ref="xml:id"/>
</xs:attributeGroup>
```
Consider queries

```xml
<a type="a" xmlns:ex1="bla" xmlns:ex2="bla2" xmlns="bla3">
   <ex1:b name="1"/>
   <ex2:b name="2"/>
   <ex1:c ex1:name="3" ex2:name="4"/>
   <ex1:c ex1:name="5"/>
   <b name="6"/>
</a>
```

- `//@*` (all 6 attribute nodes)
- `//@name` (only 3 unprefixed attribute nodes)
- `//@ex1:name` (3,5)
- `//@*[namespace-uri()="bla2"]` (4)
- `//@*[namespace-uri()=""]` (1,2,6)
What to do with new version of format?

- Make it live in **new namespace**!
  - For what sorts of change?
    - Any change?
    - Extensions?
    - Revisions?
    - Just the “meaning”?
    - “Sufficient” change?

- Changing the namespace breaks stuff
  - So, perhaps do this when a change should break things?
  - [http://www.w3.org/2001/tag/doc/namespaceState.html](http://www.w3.org/2001/tag/doc/namespaceState.html)
  - [http://www.w3.org/TR/xmlschema-guide2versioning/](http://www.w3.org/TR/xmlschema-guide2versioning/)
Extension within a Namespace?

- Alternative Schema!
  - Just make a separate, unrelated document

- Use xs:include
  - Like xs:import but for “same namespace”
  - Use xs:redefine to redefine components
    - But not elements!
      - (Anonymous/unnamed types bite you)
    - Can only refine not completely redefine

```xml
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
  targetNamespace="http://MyCompositeSchema">
  <xs:include schemaLocation="http://www.cs.man.ac.uk/~sattler/myFirstSchema.xsd"/>
  <xs:include schemaLocation="http://www.cs.man.ac.uk/~sattler/myOtherSchema.xsd"/>

  .....  
</xs:schema>
```
Wildcards

• **xs:any**
  - Allows *any element (etc)* from *any namespace*!
  - With or *without* a definition
    - That is, can allow for any *well formed XML*
    - Sometimes known as an *open content model*

• **Consider** *comment*
  - What if we want structured comments?
    - With *any XML whatsoever*!

```xml
<xs:element name="comment">
  <xs:complexType mixed="true">
    <xs:sequence>
      <xs:any minOccurs="0" maxOccurs="unbounded" processContents="skip"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>

<el:comment xmlns:el="http://owl.cs.manchester.ac.uk/2010/comp/ssd-60372/day2/el">
  <h>What's this element? </h> Oo, mixed content! <a xmlns="http://ex.org" b="?"/>
  <el:foo>Junk!</el:foo>
</el:comment>
```
Tighter Wildcards

- **We can control**
  - *Which* namespaces
    - Name any specific number of namespaces
    - Explicitly forbid a namespace (e.g., not http://ex.org/)
    - Allow all, only non-targetNS, the targetNS, etc.
  - **Degree of validation**
    - strict: must be valid against a declaration
    - skip: anything well-formed!
    - lax: validate what you can figure out to validate, ignore the rest

```xml
<xs:any namespace="http://MyTrusted" minOccurs="0" maxOccurs="unbounded" processContents="lax" />
```
Rules of Thumb:

- For **multiple** WXS documents over **one** NS
  - Use `xs:include`
  - Can mix content models on existing elements!
  - Modularize development
    - With a bit of version hacking

- For making **one** schema over **multiple** NSs
  - Use `xs:import`
  - “Required” for multi-NS formats
    - since there is only 1 targetNameSpace per WXS
    - encourages NS centered development modularization

- For dealing with NSs not in your control
  - Use wildcards

- For relaxing parts of a document toward well-formed
  - Use wildcards
Empirical Interlude
Schemas?

• In SQL, schema before all
  – CREATE TABLE or nothing happens
  – Can’t INSERT INTO
  – Can’t SELECT FROM
  – So every SQL database has a schema
    • And the data conform

• XML, never need a schema
  – Except the minimal schema of well-formed-ness
    • Which is more mere minimal syntax
  – So why?
    • To communicate
    • To error check
    • To guide tools

• Given these advantages
  – How often used?
Consider....

It was a bit disappointing to notice that a relatively large fraction of the XSDs we retrieved did not pass a conformance test by SQC. As mentioned in Section 2, only 30 out of a total of 93 XSDs were found to be adhering to the current specifications of the W3C [17].

Often, lack of conformance can be attributed to growing pains of an emerging technology: the SQC validates according to the 2001 specification and 19 out of the 93 XSDs have been designed according to a previous specification. Some simple types have been omitted or added from one version from one version of the specs to another causing the SQC to report errors.
Today’s XML

Figure 1: Summary of the Quality of the XML Web.
Today’s XML

• Weird facts:
  – 18% are not well formed
    • 66.4% of non-well formed documents have a DOCTYPE!
      – WHY!?
• “Validity is rare on the web. Just over 10% of the well-formed documents are also valid.”
  – Is there a difference between DTDs and WXS?
Invalid with DOCTYPE/DTD

docs that claim to be valid against X (X is ok) but aren’t

Figure 2: Distribution of causes for non-validation: DTD.
Invalid with “schemaLocation”/XSD

docs that claim to be valid against X (X is ok) but aren’t

Figure 3: Distribution of causes for non-validation: XSD.
XQuery
XQuery

• is a language for **querying** XML data
  – one aspect of data **manipulation**
• it is built on/heavily uses/extends XPath expressions
  – smooth syntactic extensions: every XPath is an XQuery
• a W3C standard since 2007, see [http://www.w3.org/TR/xquery/](http://www.w3.org/TR/xquery/)
• is supported by major database engines (IBM, Oracle, Microsoft, etc.)
• it can be used to
  – extract information to use in a Web Service
  – generate summary reports
  – transform XML data to HTML
  – search Web documents for relevant information
  – ...and to answer queries
XQuery: some basics

- XQuery provides support for datatypes, i.e., we have variables and can declare their type, yet the query processor may be strict: no attempt at a conversion to the correct type needs to be made!
  - e.g., if I try to add an integer with a decimal or write an integer into a decimal variable, the query processor may stop with an error

- like XPath, XQuery is based on node sequences
  - a sequence is a (poss. empty) list of nodes
  - as usual, nodes are of one of 7 kinds: element, attribute, text, namespace, processing-instruction, comment, or document (root)
  - if $mySeq is a sequence, $mySeq[3] is its third item

- all variable names start with “$” as in $mySeq
- comments are between “(:” and “:)” as in “(: this is a comment:)”
- a central, SQL-like part are FLOWR expressions
FLWOR expressions

- “FLWOR” is pronounced “flower”
- A FLWOR expression has 5 possibly overlapping parts:
  - **For** e.g., `for $x` in `doc("people.xml").contactList/person`
  - **Let** e.g., `let $i := 3` `let $n := $x/name/firstname`
  - **Where** e.g., `where $x/@categ = “friend”`
  - **Order by** e.g., `order by $x/name/lastname` ascending
  - **Return** e.g., `return concat($x/name/lastname, “, “$x/name/firstname)`

**F** and **L** can appear any (!) number of times in any order.
**W** and **O** are optional, but must appear in the order given.
**R** has always to be there...depending on who you ask...

```
people.xml
<?xml version="1.0" encoding="UTF-8"?>
<contactlist>
  <person categ="friend" age="25">
    <name>
      <lastname>Doe</lastname>
      <firstname>John</firstname>
    </name>
    <phone>0044 161 1234 5667</phone>
    <address>123 Main Street</address>
    <city>Manchester</city>
  </person>
  ...
</contactlist>
```
FLWOR expressions

• a **for expression** determines what to iterate through
• is basically of the form

```
for variable (as datatype)? (at position)? in expression
```

• where **expression** is
  – any XPath location path or
  – a FLWOR expression (nesting!) or
  – a logic expression (if-then-else, etc.), later more

• e.g., for $b$ in doc("people.xml")/contactList/person[@categ = "friend"]
  – query processor goes through the sequence of all (element) nodes
    selected by the XPath location path

• e.g., for $b$ at $p$ in doc("contactlist.xml")/contactList/person
  where $p = 3$
  return $b$
  – query processor goes through (the singleton sequence containing)
    the third element node of the node set selected by the XPath location

```xml
<?xml version="1.0" encoding="UTF-8"?>
<contactlist>
  <person categ="friend" age="25">
    <name>
      <lastname>Doe</lastname>
      <firstname>John</firstname>
    </name>
    <phone>0044 161 1234 5667</phone>
    <address>123 Main Street</address>
    <city>Manchester</city>
  </person>
  ...
</contactlist>
```
FLWOR expressions

- a **let expression** binds a variable to a value
- is basically of the form

  ```
  let variable (as datatype)? := expression
  ```

- where *expression* is
  - any XPath location path or
  - a FLOWR expression or
  - a logic expression (if-then-else, etc.), later more

- e.g.,

  ```xml
  for $b in
    doc("people.xml")/contactlist/person
  let $name as element() := $b/name/firstname
  return $name
  ```

  ```xml
  for $b in
    doc("people.xml")/contactlist/person
  let $name as text() :=
    if (xs:integer($b/@age) < xs:integer(16))
      then ($b/name/firstname/text())
    else ($b/name/lastname/text())
  return $name
  ```
FLWOR expressions

• we can repeat and mix for and let expressions
• a FLOWR expression
  – has at least one \texttt{for} or one \texttt{let} expression,
  – but can have any number of them in any order
• careful: the order plays a crucial role for their meaning
• make sure to bind variables to the right values before using them in \texttt{for} expression:

```plaintext
let $doc := \texttt{doc("people.xml")}$
for $p$ in $doc/contactlist/person$
let $n := p/name/lastname/text()$
let $a := p/@age$
for $double$ in $doc/contactlist/person[@age = $a][name/lastname/text() = $n]$
....
```

\texttt{people.xml}
```xml
<?xml version="1.0" encoding="UTF-8"?>
<contactlist>
  <person categ="friend" age="25">
    <name>
      <lastname>Doe</lastname>
      <firstname>John</firstname>
    </name>
    <phone>0044 161 1234 5667</phone>
    <address>123 Main Street</address>
    <city>Manchester</city>
  </person>
  ...
</contactlist>
```
FLWOR expressions

- **return expression** determines output
- is basically of the form

\[
\text{return expression}
\]

- where *expression* is one of the logical expressions to be defined later
- it returns elements as *they are*, i.e., with attributes and descendants
- e.g.,

```
<MyFriendList>
  for $b$ in doc("people.xml")/contactlist/person[@categ="friend"]
  return $b/name/firstname/text()
</MyFriendList>
```

returns `<MyFriendList>John Millie...</MyFriendList>`

- careful: we needed "{", "}" to distinguish between text and instructions
FLWOR expressions

- as mentioned before, we can make use of logical expressions including
  - if-then-else
  - some/every
  - Boolean expressions
- e.g.,

```xml
<?xml version="1.0" encoding="UTF-8"?>
<contactlist>
  <person categ="friend" age="25">
    <name>
      <lastname>Doe</lastname>
      <firstname>John</firstname>
    </name>
    <phone>0044 161 1234 5667</phone>
    <address>123 Main Street</address>
    <city>Manchester</city>
  </person>
  ...
</contactlist>
```

```javascript
let $doc := doc("people.xml")
return
<MyFriendList>
{
  for $b in $doc/contactlist/person[@categ="friend"]
  return
  <friend>
  { (if (xs:integer($b/@age) < xs:integer(16))
    then $b/name/firstname/text()
    else $b/name/lastname/text()) }
  </friend>
}
</MyFriendList>
```
XQuery: constructors

- as we have seen, we can use text in the return part
- to return a more complex XML document, we can make use of constructors
  – e.g., direct element constructors as in the previous example
  – or direct element constructors with attributes
- we use “{“ and “}” to delimit expressions that are evaluated, e.g.,

```
let $doc := doc("contactlist-john-doe.xml")
for $p in $doc/contactlist/person
return
  <example>
  <p> Here is a query. </p>
  <eg> $p/name </eg>
  <p> Here is the result of the query. </p>
  <eg> { $p/name } </eg>
  </example>
```

- if we want to construct elements with attributes, we can do this easily: e.g.,
  return <friend phone = "{ xs:string($p/phone) }">{ (if (...
FLOWR expressions

- **where** is used to filter the node sets selected through let and for
- like in SQL, we can use **where** for **joins** of several trees or documents
- e.g.,

```xml
cities.xml
<?xml version="1.0" encoding="UTF-8"?>
<citylist>
  <city>
    <name>Manchester</name>
    <club>Manchester United</club>
  </city>
  <city>
    <name>Munich</name>
    <club>Die Loewen</club>
  </city>
  ...
</citylist>
```

```xml
people.xml
<?xml version="1.0" encoding="UTF-8"?>
<contactlist>
  <person categ="friend" age="25">
    <name>
      <lastname>Doe</lastname>
      <firstname>John</firstname>
    </name>
    <phone>0044 161 1234 5667</phone>
    <address>123 Main Street</address>
    <city>Manchester</city>
  </person>
  ...
</contactlist>
```

- for $p$ in doc("contactlist-john-doe.xml")/contactlist/person
  - for $c$ in doc("cities.xml")/citylist/city
    - where $p/city/text() = $c/name/text()
  - return concat("Dear ", $p/name/firstname, ", do you like ", $c/club ,"? ")
FLOWR expressions

- a more realistic, SQL-like example
  (from <oXygen/>):

```xml
product.xml
<?xml version="1.0" encoding="UTF-8"?>
<products>
    <product>
        <productId>1</productId>
        <productName>Wave Runner</productName>
        <productSpec>120 HP blaa</productSpec>
    </product>
    ...
</products>

sale.xml
<?xml version="1.0" encoding="UTF-8"?>
<sales>
    <sale productId="1">
        <mrq>180$</mrq>
        <ytd>18.87% up</ytd>
        <margin>5%</margin>
    </sale>
    ...
</sales>
```

```
<sales>
    {  
        for $product in doc("products.xml")/products/product,  
            $sale in doc("sales.xml")/sales/sale  
            where $product/productId = $sale/@productId  
        return <product id="{$product/productId}">
            { $product/productName, $product/productSpec,  
              $sale/mrq, $sale/ytd, $sale/margin }  
        </product>
    }
</sales>
```
FLOWR expressions

• like in SQL, we can nest expressions
• e.g., the previous example does not work in case a city has several clubs:

```
people.xml
<?xml version="1.0" encoding="UTF-8"?>
<contactlist>
  <person categ="friend" age="25">
    <name>
      <lastname>Doe</lastname>
      <firstname>John</firstname>
    </name>
    <phone>0044 161 1234 5667</phone>
    <address>123 Main Street</address>
  </person>
</contactlist>
```

```
cities.xml
<?xml version="1.0" encoding="UTF-8"?>
<citylist>
  <city>
    <name>Manchester</name>
    <club>Manchester United</club>
    <club>Manchester City</club>
  </city>
  <city>
    <name>Munich</name>
    <club>Die Loewen</club>
    <club>Bayern-Muenchen</club>
  </city>
  ...
</citylist>
```

```
<sales>
  {for $p in doc("contactlist-john-doe.xml")/contactlist/person
   for $c in doc("cities.xml")/citylist/city
   where $p/city/text() = $c/name/text()
   return concat("Dear ", $p/name/firstname,
   ", do you like ", $c/club[$i], " ?"))}
</sales>
```
XQuery FLOWR expressions

- **order by** allows us to order sequences before we return them
- we can combine several orderings into new ones *lexicographically*
- e.g., for $nr$ in 1 to 5
  for $letter$ in ("a", "b", "c")
  order by $nr$ descending, $letter$ descending
  return concat($nr, $letter)

  yields 5c 5b 5a 4c 4b ....

- e.g., for $nr$ in 1 to 5
  for $letter$ in ("a", "b", "c")
  order by $letter$ descending, $nr$ descending
  return concat($nr, $letter)

  yields 5c 4c 3c 2c 1c 5b...
XQuery: grouping

- like SQL, XQuery provides **aggregation functions**
  - max and min
  - average
  - count, etc
- like in SQL, when we want to use them, we need to *group*:
- but this comes natural, e.g.,

```xml
for $an in fn:distinct-values(doc("orders.xml")/orderlist/order/artNr)
let $arts := doc("orders.xml")/orderlist/order[artNr = $an]
where fn:count($arts) >= 3
return
  <high-demand-item>
    <articleNr> { $an } </articleNr>
    <maxPrice> { fn:max($arts/price) } </maxPrice>
    <avgPrice> { fn:avg($arts/price) } </avgPrice>
  </high-demand-item>
```
Examples

contactlist.xml

```xml
<?xml version="1.0" encoding="UTF-8"?>
<contactList>
    <person categ="friend" age="25">
        <name>
            <lastname>Doe</lastname>
            <firstname>John</firstname>
        </name>
        <phone>0044 161 1234 5661</phone>
        <address>123 Main Street</address>
        <city>Manchester</city>
    </person>
    <person categ="friend" age="14">
        <name>
            <lastname>Doen</lastname>
            <firstname>Jane</firstname>
        </name>
        <phone>0049 89 1234 5662</phone>
        <address>25 King Street</address>
        <city>Munich</city>
    </person>
    <person categ="foe" age="45">
        <name>
            <lastname>Do</lastname>
            <firstname>Jonathan</firstname>
        </name>
        <phone>0044 161 1234 5663</phone>
        <address>12 Queen Street</address>
        <city>Manchester</city>
    </person>
    <person categ="foe" age="13">
        <name>
            <lastname>Dove</lastname>
            <firstname>Jamie</firstname>
        </name>
        <phone>0049 89 1234 5664</phone>
        <address>23 Main Street</address>
        <city>Munich</city>
    </person>
</contactList>
```
Example queries

- **Q1:** for $b$ in doc("contactlist.xml")/contactList/person[@categ = "friend"][position() = 1]
  
  return $b$

- **Q2:** for $b$ at $p$ in doc("contactlist.xml")/contactList/person[@categ = "foe"]
  
  where $p = 2$
  
  return $b$

- **Q3:** for $b$ at $p$ in doc("contactlist.xml")/contactList/person[@categ = "foe"]
  
  where $p = 3$
  
  return $b$

- **Q4:**
  
  for $p$ in doc("contactlist.xml")/contactList/person[@age > 16]
  
  return $p$/name
Example queries (cont.)

- Q5: for $p$ in doc("contactlist.xml")/contactList/person
  return $p/phone

- Q6: let $doc := doc("contactlist.xml")
  for $p$ in $doc/contactList/person
  let $a := xs:integer($p/@age)
  let $c := xs:string($p/@categ)
  where $a < xs:integer(16)
  and $c = "foe"
  return $p

- Q7: for $c$ in fn:distinct-values(doc("contactlist.xml")/contactList/person/city)
  let $p := doc("contactlist.xml")/contactList/person[city = $c]
  order by fn:avg($p/@age)
  return
  <city name = "{$c}"
    <avg_age>{fn:avg($p/@age)}</avg_age>
  </city>
XQuery: functions

• XQuery is more than FLWOR expression
• it provides more than 100 built-in functions, we have already seen some, plus
  – e.g., <name>{uppercase($p/lastname)}</name>
  – e.g., let $nickname := (substring($p/firstname,1,4))
• it allows the user to define functions
  
  declare function
  
  declare function local:minPrice($price as xs:decimal, $discount as xs:decimal )
  as xs:decimal 
  { let $disc := ($price * $discount) div 100 
  return ($price - $disc) } 
  
  To summarize the departments from Manchester, use:

  declare function pr
  
  declare function local:summary($emps as element(employee)*)
  as element(dept) *
  {
    for $d in fn:distinct-values($emps/deptno)
    let $e := $emps[deptno = $d]
    return
    <dept>
      <deptno>{$d}</deptno>
      <headcount>{fn:count($e)}
      <payroll>{fn:sum($e/salary)}</payroll>
    </dept> 
  } 

  to be used e.g., in

  <minPrice>
    { local:minPrice($book/price, $book/discount) } 
  </minPrice>
XQuery Functions: Closure

- XQuery is compositional
  - a query returns a node sequence
  - a functions return node sequence
    - A single node is a singleton node sequence and vice versa
  - So we can write queries with functions at key steps
    - Not just in predicate tests!

```xml
<returns>a sequence of nodes</returns>
```

XQuery query!!
result sequence!
XQuery Functions: Closure

```
declare function local:header() as node() {
    <div class="web-page-header">
        <img src="images/mylogo.jpg" alt="Our Logo"/>
        <h1>Acme Widgets Inc.</h1>
    </div>
};
local:header()//h1
```

```
(1, 2, 3, 4, 5)[.>3]
```

```
declare function local:numbers() {
    (1, 2, 3, 4, 5)
};
local:numbers()[.>3]
```

```
declare function local:gt3($nodes) {
    $nodes[.>3]
};
local:gt3(local:numbers())
```

```
<h1>Acme Widgets Inc.</h1>
```
XQuery, schemas, and types

- if you query documents that are associated with a schema, you can exploit schema-aware query answering:
  - XSD has default values, e.g., answer to this query may vary depending on your schema!

```xml
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified">
  <xs:element name="person"/>
  <xs:attributeGroup name="attlist.person">
    <xs:attribute name="id" use="required" type="xs:ID"/>
    <xs:attribute name="isFriend" default="true"/>
    <xs:simpleType>
      <xs:restriction base="xs:token">
        <xs:enumeration value="true"/>
        <xs:enumeration value="false"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:attributeGroup>
</xs:schema>
```

for $m in doc('personal.xml')//*[:@isFriend = 'true']
return $m/name/family/text()
XQuery, schemas, and types

- if you query documents that are associated with a schema, you can exploit schema-aware query answering, e.g., XML Schema aware like SAXON-EE:
  - careful if you use <oXygen>: it sometimes confuses SAXON-HE/SAXON-EE
  - XSD has default values, e.g., answer to this query may vary depending on your schema

```xquery
import schema namespace uli="www.uli.org" at "test4.xsd";
for $m in doc('Untitled7.xml')//uli:nEl
return data($m/@attr)
```

```xml
<?xml version="1.0" encoding="UTF-8"?>
<uli:nlist xmlns:uli="www.uli.org"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="www.uli.org file:test4.xsd">
    <uli:nEl>3</uli:nEl>
    <uli:nEl attr="4">4</uli:nEl>
    <uli:nEl>5</uli:nEl>
</uli:nlist>
```
XQuery, schemas, and types

- if you query documents that are associated with a schema, you can exploit schema-aware query answering, eg XML Schema aware like Saxon-SA:
  - WXS has types, e.g., answer to this query may vary depending on your schema

```xml
<?xml version="1.0" encoding="UTF-8"?>
<uli:list xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="www.uli.org test4.xsd"
  xmlns:uli="www.uli.org">
  <uli:friend>Paul</uli:friend>
  <uli:friend>Peter</uli:friend>
  <uli:friend>Mary</uli:friend>
  <uli:friend>Joanne</uli:friend>
  <uli:friend>Lucy</uli:friend>
</uli:list>
```

```xml
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
  targetNamespace="www.uli.org"
  xmlns:uliS="www.uli.org"
  elementFormDefault="qualified">
  <xs:element name="list" type="uliS:B">
    <xs:complexType>
      <xs:complexContent>
        <xs:restriction base="uliS:A">
          <xs:sequence>
            <xs:element name="friend" type='xs:string' minOccurs='4' maxOccurs='5'/>
          </xs:sequence>
        </xs:restriction>
      </xs:complexContent>
    </xs:complexType>
  </xs:element>
</xs:schema>
```
XQuery, schemas, and types: the PSVI

Post-schema-validation infoset:
Internal Rep. adorned with schema information
e.g., a tree adorned with default values & types
Quick Note on PSVI

- Post Schema-Validation Infoset
  - First approximation: DOM + Schema Information
    - What kind of information?
      - Default attribute (and other) values
      - Type information
  - Remember node types in the DOM
    - Atomic values are all *text* (string)
    - But WXS lets us have loads of atomic types!
      - As well as simple and complex types!
    - XQuery (and XPath &gt;=2.0) can be sensitive to those types
    - Thus, that type information has to get into the queried data

- PSVIs are known to be valid!
  - Thus we can make some assumptions about their structure
SQL intuition on PSVI

(SCHEMA) CREATE TABLE

CSV

Program

Populated Database

Schema

Validation

PSVI

Well Formed XML
Namespace, schemas, and queries

- schemas and queries can be used together in a powerful way
  - e.g., to retrieve values and default values
  - e.g., by exploiting type hierarchy in query: this can have various advantage:
    - we can safe big ‘unions’ of queries through querying for instances of super types
    - should we change our schema/want to work with documents with new kind of elements (see XML/OWL coursework), it may suffice to adapt the schema to new types; queries may remain unchanged!

- usage of namespace, schemas, and queries is a bit tricky:
  - when to use/declare which namespace/prefix where
  - tool support required

- more in coursework and later
Coursework: SEs

• As you (should) know by now, we use rubrics to mark
  – for SEs and others
  – for coursework and exam

• For you to understand these better, you are going to apply
  – SE2 rubric to
  – SE2 essay of a friend
  – …we printed rubrics for you:
    • find a friend (or 2)
    • take a rubric each
    • swap your SE2 essays (e.g. via email)
    • mark each other’s essays
    • discuss the outcome
    • submit a guess for your own mark for SE2 on BB as GuessSE2
  • …keep this in mind when you write
    • SE3, SE4, SE5
    • exam
    • your thesis
Coursework this week

• Get to know tools/oxygen better:
  – use it to test your understanding of XPath
  – collect a fine sample of XML docs, XSDs, RNGs, …

• Q3:
  – use tools to answer questions

• CW3:
  – XQuery for arithmetic learning site

• M3: XPath, XQueries, and XSD
  – do this before SE3

• SE3: robustness, schemas, and different query styles
  – think/read about robustness
  – do M3 before you do this