<? xml ?>

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Outline

- Markup Languages and XML
- XML Structure
- XML Parsing
- Namespaces
- XML Schema
- Metadata in XML
- XPath
- XSL – XSLT
- XSL – FO
- XQuery
- XML Databases
- References

Markup Languages and XML

Markup

- Markup refers to auxiliary information (a.k.a. tags) that is interspersed with text to indicate structure and semantics.
- Examples:
  - LaTeX uses markup to specify formatting (e.g., \hspace)
  - HTML uses markup to specify structure (e.g., <p>)
- A markup language specifies the syntax and semantics of the markup tags.

Is LaTeX outdated because of its markup language

Markup Example

- Plain text
  - The brown fox jumped over the lazy dog.
- Marked up text
  - `*paragraphstart*The *subjectstart*quick brown fox*subjectend* *verbstart*jumped*verbend* over the *objectstart*lazy dog*objectend*.*paragraphend*`
- Advantages:
  - Aids semantic understanding.
  - Supports automatic translation to other formats.

Can we build a parser for this ML?

SGML

- Standard Generalised Markup Language (SGML) specifies a standard format for text markup. All SGML documents follow a Document Type Definition (DTD) that specifies the structure.

```
<!DOCTYPE uct PUBLIC "-//UCT//DTD SGML//EN">
<title>test SGML document
<author email='pat@cs.uct.ac.za' office=410 lecturer
>Pat Pukram
<version>
   <number>1.0
</version>
```

Why don't we need a closing title tag?

HTML

- HyperText Markup Language (HTML) specifies standard structure/formatting for linked documents on the WWW, as a subset of SGML.
- SGML defines general framework – HTML defines semantics for a specific application.

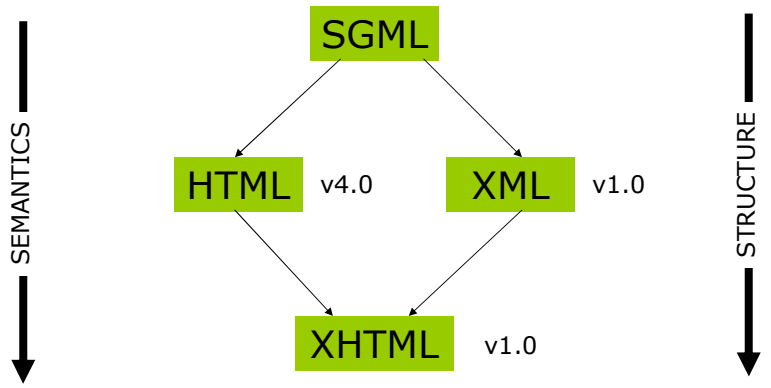
```
<html><head><title>test HTML document</title></head>
<body>
<h1>Author</h1>
<p>Pat Pukram
<br>Lecturer
<br>Email: pat@cs.uct.ac.za
<br>Office: 410
</p>
<h1>Version</h1>
<p>1.0</p>
</body>
</html>
```

XML

- eXtensible Markup Language (XML) is a subset of SGML to ease adoption, especially for WWW use.

```
<uct>
<title>test XML document</title>
<author email="pat@cs.uct.ac.za" office="410"
type="lecturer">Pat Pukram</author>
<version>
   <number>1.0</number>
</version>
</uct>
```

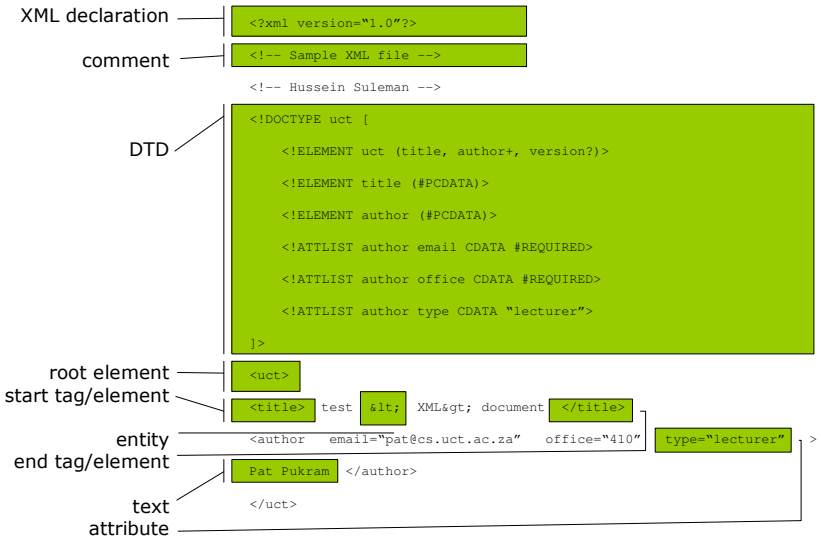
Relationship



XML Primer

- An XML document is a serialised segment of text which follows the XML standard.
  - (http://www.w3.org/TR/REC-xml)
- Documents may contain
  - XML declaration
  - DTDs
  - text
  - elements
  - processing instructions
  - comments
  - entity references

XML Sample

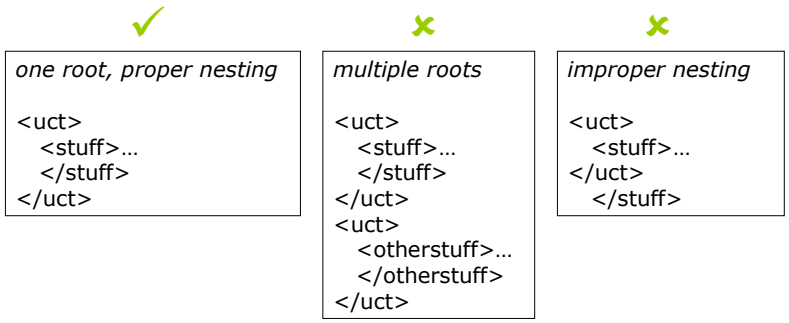


Exercise 1: View XML

- Start the Firefox WWW browser.
- Load the file `uct1.xml` from the workshop folder.
- Use the – and + buttons to collapse and expand subsections of the XML.

Well-formedness

- Well-formed XML documents have a single root element and properly nested matching start/end tags.



Validity

- Valid XML documents strictly follow a DTD (or other formal type definition language).
- Well-formedness enforces the fundamental XML structure, while validity enforces domain-specific structure!
- Why validate? Catch errors, quality assurance, allow structural assumptions …
- SGML parsers, in contrast, had no concept of well-formedness so domain-specific structure had to be incorporated into the parsing phase.

Levels of Correctness

1. Unicode encoding must not contain erroneous characters
2. XML documents **must** be well-formed
   - if there is no single root, then it is an XML fragment
   - if elements are not properly nested, it is not really XML!
3. XML **can** be valid, conforming to a DTD, Schema or other formal description

Exercise 2: View XML Error

- Start the Firefox WWW browser.
- Load the file `uct_error1.xml` from the exercise folder.
- Take note of the error and try to understand what it means.

XML Structure

XML declaration

- `<?xml encoding="UTF-8" version="1.0" standalone="yes" ?>`

- Appears (optionally) as first line of XML document.
- "encoding" indicates how the individual bits correspond to character sets.
- "version" indicates the XML version (usually 1.0).
- "standalone" indicates if external type definitions must be consulted in order to process the document correctly.

recommended for all: standalone
recommended for most European languages: UTF-8

Unicode

- Most XML is encoded in ISO 10646 Universal Character Set (UCS or Unicode).
- Unicode at first supported 16-bit characters, as opposed to ASCII's 8-bits – implying 65536 different characters from most known languages.
- This has since been expanded to 32 bits. The simplest encoding mapping this to 4 fixed bytes is called UCS-4.
- To represent these characters more efficiently, variable length encodings are used: UTF-8 and UTF-16 are standard.

Common characters should take less space to store/transmit - less common characters can take more space!

UTF-16

- Basic Multilingual Plane (characters in the range 0-65535) can be encoded using 16-bit words.
- Endianness (if there are 2 bytes, which one is stored first) is indicated by a leading Byte Order Mark (BOM) e.g., FF FE = little endian UTF-16.
- For more than 16 bits, characters can be encoded using pairs of words and the reserved D800-DFFF range.
  - `D800DC00 = Unicode 0x00010000`
    `D800DC01 = Unicode 0x00010001`
    `D801DC01 = Unicode 0x00010401`
    `DBFFDFFF = Unicode 0x0010FFFF`
- UTF-16 → UCS-4
  - D801-D7C0 = 0041, DC01 & 03FF = 0001
    (0041 << 10) + 0001 = 00010401
- UCS-4 → UTF-16 ?

Ouch!

UTF-8

- Optimal encoding for ASCII text since characters < #128 use 8 bits.
- Variable encoding thereafter
  - Unicode 7-bit = 0vvvvvvv
    Unicode 11-bit = 110vvvvv 10vvvvvv
    Unicode 16-bit = 1110vvvv 10vvvvvv 10vvvvvv
    Unicode 21-bit = 11110vvv 10vvvvvv 10vvvvvv 10vvvvvv
    etc.
- UCS-4 → UTF-8
  - 0001AB45 = 11010 101100 100101
    11110vvv 10vvvvvv 10vvvvvv 10vvvvvv
    = 11110000 10011010 10101100 10100101
    = F09AACA5
- UTF-8 → UCS-4 ?
- UTF-8, like UTF-16, is self-segregating to detect code boundaries and prevent errors.

You mean we can't actually write XML with Notepad/vi ?

Document Type Definition (DTD)

- Defines structure of XML documents.
- Optionally appears at top of document or at externally referenced location (file).

```
<!DOCTYPE uct [
    <!ELEMENT uct (title, author+, version?)>
    <!ELEMENT title (#PCDATA)>
    <!ELEMENT author (#PCDATA)>
    <!ATTLIST author email CDATA #REQUIRED>
    <!ATTLIST author office CDATA #REQUIRED>
    <!ATTLIST author type CDATA "lecturer">
    <!ELEMENT version (number)>
    <!ELEMENT number (#PCDATA)>
]>
```

- ELEMENT defines structure of elements.
  - ()=list of children, +=one or more, *=zero or more, ?=optional, PCDATA=text
- ATTLIST defines attributes for each element.
  - #REQUIRED=required, "lecturer"=default, CDATA=text

Elements / Tags

- Basic tagging or markup mechanism.
- All elements are delimited by < and >.
- Element names are case-sensitive and cannot contain spaces (full character set can be found in spec).
- Attributes can be added as space-separated name/value pairs with values enclosed in quotes (either single or double).
  - `<sometag attrname="attrvalue">`

Element Structure

- Elements may contain other elements in addition to text.
- Start tags start with "<" and end with ">".
- End tags start with "</" and end with ">".
- Empty tags start with "<" and end with "/>".
  - Empty tags are a shorthand for no content.
  - Example:
</br> is the same as
  - To convert HTML into XHTML, all
 tags must be in either of the forms above!
- Every start tag must have an end tag and must be properly nested.
- Not well-formed:
  - `<x><a>mmm<b>mmm</a>mmm</b></x>`
- Well-formed:
  - `<x><a>mmm<b>mmm</b></a><b>mmm</b></x>`
- Elements may be repeatable!

Does this work in HTML?

Special attributes

- xml:space is used to indicate if whitespace is significant or not.
  - In general, assume all whitespace outside of tag structure is significant!
- xml:lang indicates the language of the element content.
  - Example
    - `<p xml:lang="en">I don't speak</p> Zulu`
      `<p xml:lang="es">No hablo</p> Zulu`

Entities

- Entities begin with "&" and end with ";".
- Named entity references refer to (are macros for) previously defined textual content – usually defined in an external or internal DTD.
  - Example: © is assumed in HTML but in XML it can only be used if the ISOLat1 entity list is included
- Character entities correspond to Unicode characters.
  - Example: &#23; refers to decimal character number 23 A refers to hex character number 41
- Predefined escape sequence entities:
  - <(<), > (>), ' ('), " ("), &(&)

Byte Order Marker

- The Byte Order Marker is an optional code at the very beginning of the file primarily to indicate endianness of UTF-16.
  - FF FE = little endian
    - Unicode "0102 0304" stored as "02 01 04 03"
  - FE FF = big endian
    - Unicode "0102 0304" stored as "01 02 03 04"
- Since it is the first code, it also suggests the base encoding (to be used in conjunction with the more specific encoding attribute).
  - EF BB BF = UTF-8
  - FF FE 00 00 = UCS-4, little endian
- It is usually possible to use heuristics to determine encodings and endianness automatically from the first 4 bytes.

Exercise 3a: XML to store data

- Encode the following relational data in XML:

title	Markup & XML
date	2006
users	

name	machine
vusi	12
john	24
nithia	36

Exercise 3b: Handwritten XML

- Open a text editor and type in your XML document.
  - Start with an XML declaration!
  - Leave out the BOM and use UTF-8 encoding.
- Save the file in the exercise folder with a ".xml" extension.
- Open the file in Firefox to make sure it loads properly and is well-formed.

Namespaces

XML Namespaces

- Namespaces are used to partition XML elements into well-defined subsets to prevent name clashes.
- If two XML DTDs define the tag "title", which one is implied when the tag is taken out of its document context (e.g., during parsing)?
- Namespaces disambiguate the intended semantics of XML elements.

Default Namespaces

- Every element has a default namespace if none is specified.
- The default namespace for an element and all its children is defined with the special "xmlns" attribute on an element.
  - Example: `<uct xmlns="http://www.uct.ac.za">`
- Namespaces are URIs, thus maintaining uniqueness in terms of a specific scheme.

Universal Resource Locator (URL) = location-specific
Universal Resource Name (URN) = location-independent
Universal Resource Identifier (URI) = generic identifier

Explicit Namespaces

- Multiple active namespaces can be defined by using prefixes. Each namespace is declared with the attribute "xmlns:*ns*", where *ns* is the prefix to be associated with the namespace.
- The containing element and its children may then use this prefix to specify membership of namespaces other than the default.
-
```
<uct xmlns="http://www.uct.ac.za"
     xmlns:dc="http://somedcns">
   <dc:title>test XML document</dc:title>
</uct>
```

Can you rewrite the last example?

- For example
  -
```
<uct:uct xmlns:uct="http://www.uct.ac.za">
   <dc:title xmlns:dc="http://somedcns">test XML
document</dc:title>
</uct:uct>
```

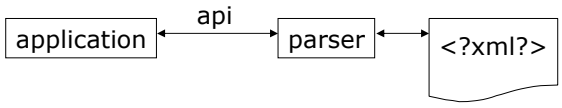
Exercise 4: Namespaces

- Edit your XML file from Exercise 3 to include namespaces as follows:
  - title and date are in the namespace `http://purl.org/dc/elements/1.1/`
  - all other date is in the namespace `http://www.cs.uct.ac.za/XMLworkshop/`
- Minimise the size of your XML by using only one definition of each namespace and shorter prefixes thereafter.
- Make sure your XML file loads into Firefox.

XML Parsing

Parsing XML

- XML parsers expose the structure as well as the content to applications, as opposed to regular file input where applications get only content or linear structure.
- Applications are written to manipulate XML documents using APIs exposed by parsers.



- Two popular APIs:
  - Simple API for XML (SAX)
  - Document Object Model (DOM)

XML, SAX, DOM … is everything a TLA?

SAX

- Simple API for XML (SAX) is event-based and uses callback routines or event handlers to process different parts of XML documents.
- To use SAX:
  - Register handlers for different events
  - Parse document
- Textual data, tag names and attributes are passed as parameters to the event handlers.

SAX Example

- Using handlers to output the content of each node, the following output can be trivially generated:
  - start document
  - start tag : uct
  - start tag : title
  - content : test XML document
  - end tag : title
  - start tag : author
  - content : Pat Pukram
  - end tag : author
  - start tag : version
  - start tag : number
  - content : 1.0
  - end tag : number
  - end tag : version
  - end tag : uct
  - end document

What happened to the attributes?

pseudo-code:

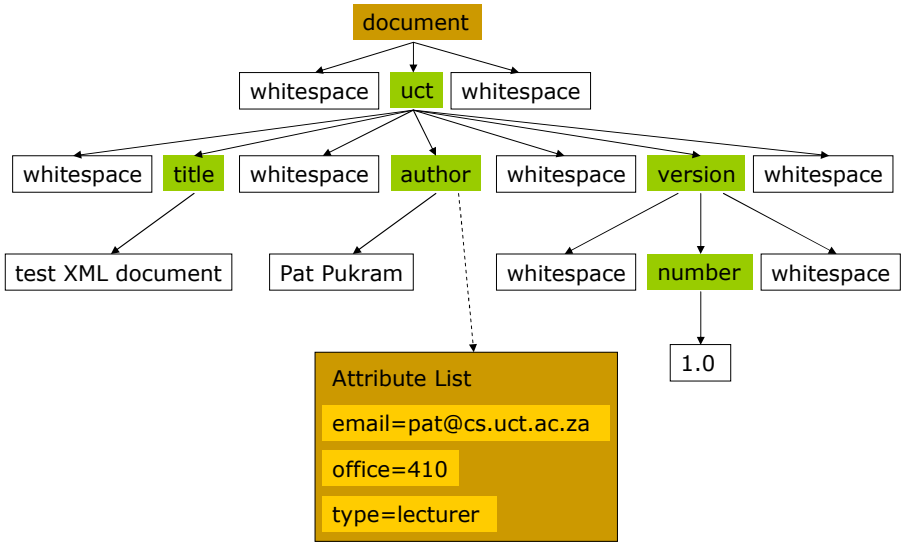
```
startCallback
{ output "start tag: ",tag }
…
main_program
{
  register_starthandler (startCallback)
  …
  do_parse
}
```

DOM

- Document Object Model (DOM) defines a standard interface to access specific parts of the XML document, based on a tree-structured model of the data.
- Each node of the XML is considered to be an object with methods that may be invoked on it to set/retrieve its contents/structure or navigate through the tree.
- DOM v1 and v2 are W3C standards. DOM3 is a (newer) standard as of April 2004.

W3C?

DOM Tree



DOM Example

- Step-by-step parsing

```
# create instance of parser
my $parser = new DOMParser;
# parse document
my $document = $parser->parsefile ('uct.xml');
# get node of root tag
my $root = $document->getDocumentElement;
# get list of title elements
my $title = $document->getElementsByTagName ('title');
# get first item in list
my $firsttitle = $title->item(0);
# get first child - text content
my $text = $firsttitle->getFirstChild;
# print actual text
print $text->getData;
```

Perl is popular for its text-processing capabilities.
Java is popular because of its libraries and servlet support.

- Quick-and-dirty approach

```
my $parser = new DOMParser;
my $document = $parser->parsefile ('uct.xml');
print $document->getDocumentElement->getElementsByTagName
('title')->item(0)->getFirstChild->getData;
```

DOM Interface subset 1/3

- Document
  - attributes
    - `documentElement` – top element in document tree
  - methods
    - `createElement (tag)` – creates and returns element 'tag'
    - `createElementNS (ns, tag)` – creates and returns element 'tag' in namespace 'ns'
    - `createTextNode (text)` – creates and returns text node with content 'text'
    - …

DOM Interface subset 2/3

- Node
  - attributes
    - `nodeName` – name of any node
    - `nodeValue` – value of text or comment node
    - `nodeType` – type of node
    - `parentNode` – node one level higher up in the tree
    - `childNodes` – list of children nodes
    - `firstChild` – first child of current node
    - `lastChild` – last child of current node
    - `previousSibling` – previous node with same parent
    - `nextSibling` – next node with same parent
    - `attributes` – list of name/value pairs
  - methods
    - `insertBefore (newchild, pos)` – inserts newchild before pos
    - `replaceChild (new, old)` – replaces child node old with new
    - `removeChild (old)` – removes child node old
    - `appendChild (new)` – adds child node new to end of list
    - `hasChildNodes` – returns whether or not there are children

DOM Interface subset 3/3

- Element (which is also a Node)
  - methods
    - `getAttribute (name)` – returns value associated with name
    - `setAttribute (name, val)` – sets value for name
    - `getElementsByTagName (tag)` – returns list of nodes from among children that match tag
- NodeList
  - attributes
    - `length` – number of nodes in list
  - methods
    - `item (pos)` – returns the node at position pos
- CharacterData (which is also a Node)
  - attributes
    - `data` – textual data

DOM Bindings

- DOM has different bindings (correspondence between abstract API and language-specific use) in different languages.
- Each binding must cater for how the document is parsed – this is not part of DOM.
- In general, method names and parameters are consistent across bindings.
- Some bindings define extensions to the DOM e.g., to serialise an XML tree.

SAX vs. DOM

- DOM is a W3C standard while SAX is a community-based "standard".
- DOM is defined in terms of a language-independent interface while SAX is specified for each implementation language (with Java being the reference).
- DOM requires reading in the whole document to create an internal tree structure while SAX can process data as it is parsed.
- In general, DOM uses more memory to provide random access.

there is another … actually, others

XML Schema

XML Schema

- XML Schema specifies the type of an XML document in terms of its structure and the data types of individuals nodes.
- It replaces DTDs – it can express everything a DTD can express plus more.
- Other similar languages are RELAX and Schematron, but XML Schema is a W3C standard so has more support.

Schema structure

- Elements are defined by
  - `<element name="…" type="…" minOccurs="…" maxOccurs="…">`
    - *name* refers to the tag.
    - *type* can be custom-defined or one of the standard types. Common predefined types include *string*, *integer* and *anyURI*.
    - *minOccurs* and *maxOccurs* specify how many occurrences of the element may appear in an XML document. *unbounded* is used to specify no upper limits.
- Example
  - `<element name="title" type="string" minOccurs="1" maxOccurs="1"/>`

Sequences

- Sequences of elements are defined using a *complexType* container.

```
<complexType>
   <sequence>
      <element name="title" type="string"/>
      <element name="author" type="string"
               maxOccurs="unbounded"/>
   </sequence>
</complexType>
```

- Note: Defaults for both *minOccurs* and *maxOccurs* are 1

Nested Elements

- Instead of specifying an atomic type for an element as an attribute, its type can be elaborated as a structure. This is used to correspond to nested elements in XML.

```
<element name="uct">
   <complexType>
      <sequence>
         <element name="title" type="string"/>
         <element name="author" type="string"
                  maxOccurs="unbounded"/>
      </sequence>
   </complexType>
</element>
```

Extensions

- Extensions are used to place additional restrictions on the content of an element.
  - Content must be a value from a given set:

```
<element name="version">
   <simpleType>
      <restriction base="string">
         <enumeration value="1.0"/>
         <enumeration value="2.0"/>
      </restriction>
   </simpleType>
</element>
```

  - Content must conform to a regular expression:

```
<element name="version">
   <simpleType>
      <restriction base="string">
         <pattern value="[1-9]\.[0-9]+"/>
      </restriction>
   </simpleType>
</element>
```

Attributes

- Attributes can be defined as part of *complexType* declarations.

```
<element name="author">
   <complexType>
      <simpleContent>
         <extension base="string">
            <attribute name="email" type="string"
                       use="required"/>
            <attribute name="office" type="integer"
                       use="required"/>
            <attribute name="type" type="string"/>
         </extension>
      </simpleContent>
   </complexType>
</element>
```

Named Types

- Types can be named and referred to by name at the top level of the XSD.
  - `<element name="author" type="uct:authorType"/>`

```
<complexType name="authorType">
   <simpleContent>
      <extension base="string">
         <attribute name="email" type="string"
                    use="required"/>
         <attribute name="office" type="integer"
                    use="required"/>
         <attribute name="type" type="string"/>
      </extension>
   </simpleContent>
</complexType>
```

Other Content Models

- Instead of *sequence,*
  - *choice* means that only one of the children may appear.
  - *all* means that each child may appear or not, but at most once each.

Many more details about content models can be found in specification!

Schema Namespaces

- Every schema should define a namespace for its elements, and for internal references to types
  - <schema xmlns="http://www.w3.org/2001/XMLSchema"
    targetNamespace="http://www.uct.ac.za"
    xmlns:uct="http://www.uct.ac.za">

    <element name="author" type="uct:authorType"/>

    <complexType name="authorType">
    <simpleContent>
    <extension base="string">
    <attribute name="email" type="string"
    use="required"/>
    <attribute name="office" type="number"
    use="required"/>
    <attribute name="type" type="string"/>
    </extension>
    </simpleContent>
    </complexType>

    </schema>

Full Schema 1/2

- <schema xmlns="http://www.w3.org/2001/XMLSchema"
  targetNamespace="http://www.uct.ac.za"
  xmlns:uct="http://www.uct.ac.za"
  elementFormDefault="qualified"
  attributeFormDefault="unqualified"
  >

  <complexType name="authorType">
  <simpleContent>
  <extension base="string">
  <attribute name="email" type="string" use="required"/>
  <attribute name="office" type="integer" use="required"/>
  <attribute name="type" type="string"/>
  </extension>
  </simpleContent>
  </complexType>

  <complexType name="versionType">
  <sequence>
  <element name="number">
  <simpleType>
  <restriction base="string">
  <pattern value="[1-9]\.[0-9]+"/>
  </restriction>
  </simpleType>
  </element>
  </sequence>
  </complexType>

Full Schema 2/2

```
<complexType name="uctType">
   <sequence>
      <element name="title" type="string"/>
      <element name="author" type="uct:authorType"/>
      <element name="version" type="uct:versionType"/>
   </sequence>
</complexType>

<element name="uct" type="uct:uctType"/>

</schema>
```

Binding XML Instances to Schemata

- In order to specify the XML Schema for a particular XML document, use the `schemaLocation` attribute in the root tag (and elsewhere if necessary).
- `schemaLocation` contains a space-separated list of pairs of namespaces and the associated URLs of XML Schema definitions.
  - `schemaLocation="namespace schemaURL"`
- `schemaLocation` is defined in the W3C's XMLSchema-instance namespace so this must be defined as well.
  - `xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"`
    `xsi:schemaLocation="namespace schemaURL"`

Qualified Valid XML

```
<uct xmlns="http://www.uct.ac.za"
     xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
     xsi:schemaLocation="http://www.uct.ac.za
       uct.xsd"
>

   <title>test XML document</title>
   <author email="pat@cs.uct.ac.za"
           office="410"
           type="lecturer">Pat Pukram</author>
   <version>
      <number>1.0</number>
   </version>

</uct>
```

cool trick: use one of Xerces's sample programs, like dom.Counter with a "-v" parameter, to do Schema validation!

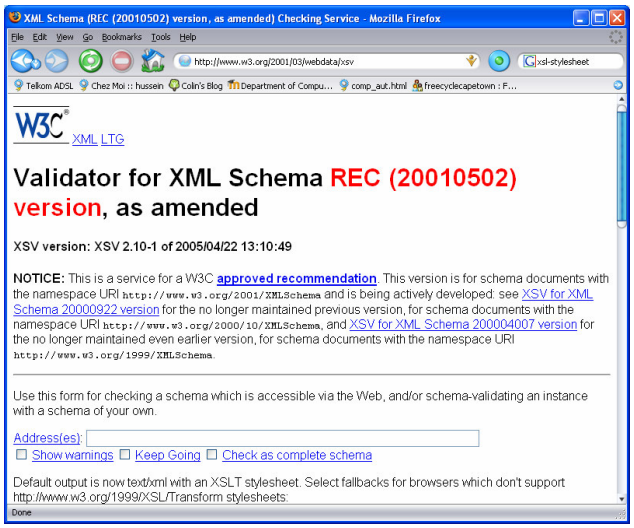
Validating XML (using Schema)

- Using an online service
  - http://www.w3.org/2001/03/webdata/xsv
- Running validator from command-line

```
#!/bin/sh
export CLASSPATH=/usr/local/share/xerces-
  2_4_0/xmlParserAPIs.jar:/usr/local/share/xerces
  -2_4_0/xercesImpl.jar:/usr/local/share/xerces-
  2_4_0/xercesSamples.jar
/usr/local/jdk1.4.2/bin/java -
  DproxyHost=cache.uct.ac.za -DproxyPort=8080
  dom.Counter -s -v -f -p dom.wrappers.Xerces $1
```

- Embedding validator in program
  - Parse the document with a validation switch turned on – validation is a core part of the parser (e.g., Xerces).

W3C Schema Validator



Exercise 5a: XML Schema Validation

- Open a Command Prompt window (usually from Accessories on WinXP).
- Change directory to the exercise folder.
- Type the command (on one line):
  - `java -classpath xercesImpl.jar;xercesSamples.jar dom.Counter -v -s -f uct1.xml`
  - Output should be:
    - `[Error] uct1.xml:1:6: cvc-elt.1: Cannot find the declaration of element 'uct'.`
      `uct1.xml: 731;40;0 ms (5 elems, 3 attrs, 0 spaces, 56 chars)`
  - This is because the validator cannot find a schema.
- Note that the second line prints statistics on the XML since that is the function of dom.Counter – this is not part of the validation.

Exercise 5b: XML Schema Validation

- Type the command:
  - `java -classpath xercesImpl.jar;xercesSamples.jar dom.Counter -v -s -f uct2.xml`
  - Output should be:
    - `[Error] uct2.xml:1:35: cvc-elt.1: Cannot find the declaration of element 'uct'.`
      `uct2.xml: 731;30;0 ms (5 elems, 4 attrs, 0 spaces, 56 chars)`
  - Now, even though there is a namespace, there is still no schema declared.

Exercise 5c: XML Schema Validation

- Type the command:
  - `java -classpath xercesImpl.jar;xercesSamples.jar dom.Counter -v -s -f uct3.xml`
  - Output should be:
    - `uct3.xml: 821;30;0 ms (5 elems, 6 attrs, 0 spaces, 56 chars)`
  - This time no errors are reported because the XML is well-formed, valid and connected to its Schema using the right namespace and Schema URL.

Exercise 5d: XML Schema Validation

- Type the command:
  - `java -classpath xercesImpl.jar;xercesSamples.jar dom.Counter -v -s -f uct_error1.xml`
  - Output should be:
    - `[Error] uct_error1.xml:1:6: cvc-elt.1: Cannot find the declaration of element 'uct'.`
      `[Fatal Error] uct_error1.xml:7:6: The element type "number" must be terminated by the matching end-tag "</number>".`
  - The first error occurs because there is no namespace and schemaLocation.
  - The second error is fatal because the XML is not well-formed!

Exercise 5e: XML Schema Validation

- Type the command:
  - `java -classpath xercesImpl.jar;xercesSamples.jar dom.Counter -v -s -f uct_error2.xml`
  - Output should be:
    - `[Error] uct_error2.xml:11:14: cvc-complex-type.2.4.d: Invalid content was found starting with element 'abstract'. No child element is expected at this point.`
      `uct_error2.xml: 911;40;0 ms (6 elems, 6 attrs, 0 spaces, 63 chars)`
  - The XML is invalid because "abstract" is not defined in the schema.

Exercise 5f: XML Schema Validation

- Type the command:
  - `java -classpath xercesImpl.jar;xercesSamples.jar dom.Counter -v -s -f uct_error3.xml`
  - Output should be:
    - `[Error] uct_error3.xml:6:66: cvc-complex-type.2.4.a: Invalid content was found starting with element 'author'. One of '{"http://www.uct.ac.za":title}' is expected. uct_error3.xml: 891;40;0 ms (4 elems, 6 attrs, 0 spaces, 35 chars)`
  - The XML is invalid because the title element is required but is missing.

Exercise 5g: XML Schema Validation

- Type the command:
  - `java -classpath xercesImpl.jar;xercesSamples.jar dom.Counter -v -s -f uct_error4.xml`
  - Output should be:
    - `[Error] uct_error4.xml:7:11: cvc-complex-type.2.4.a: Invalid content was found starting with element 'title'. One of '{"http://www.uct.ac.za":author}' is expected. uct_error4.xml: 901;30;0 ms (6 elems, 6 attrs, 0 spaces, 73 chars)`
  - The XML is invalid because there is a second title and only one is defined in the schema.

XPath

XPath

- XML Path Language (XPath) is a language to address particular nodes or sets of nodes of an XML document.
- Using XPath expressions we can write precise expressions to select nodes without procedural DOM statements.
- Examples:
  - uct/title
  - uct/version/number
  - uct/author/@office

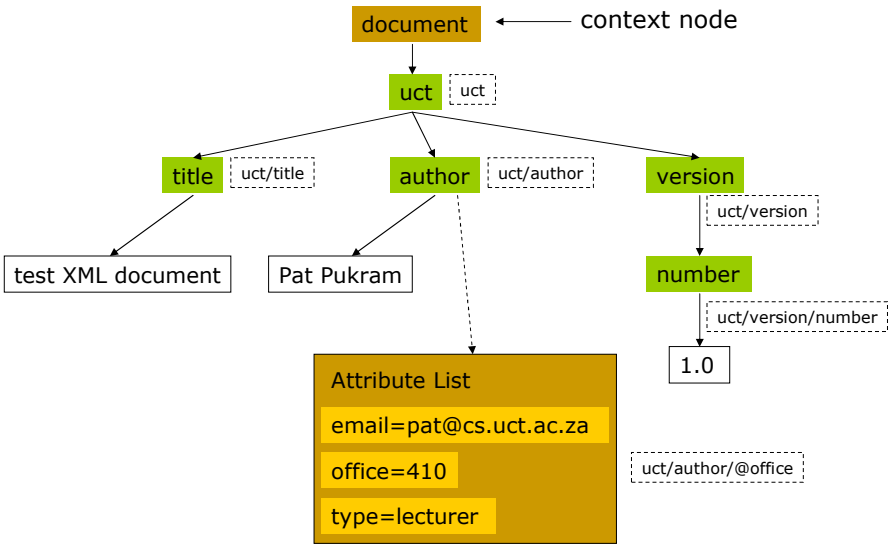
XPath Syntax

- Expressions are separated by "/".
- In general, each subexpression matches one or more nodes in the DOM tree.
- Each sub-expression has the form:
  - axis::node[condition1][condition2]…
  - where axis can be used to select children, parents, descendents, siblings, etc.
- Shorthand notation uses symbols for the possible axes.

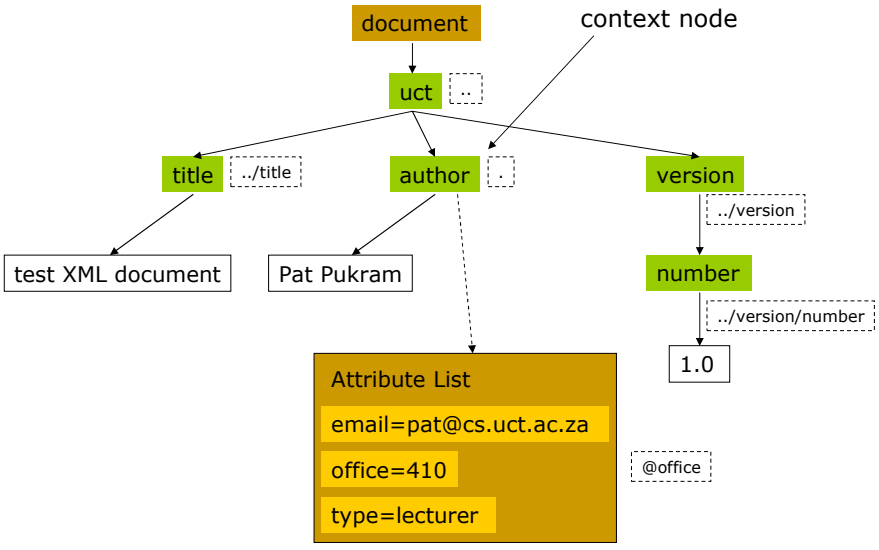
XPath Shorthand

Expression	What it selects in current context
title	"title" children
*	All children
@office	"office" attribute
author[1]	First author node
/uct/title[last()]	Last title within uct node at top level of document
//author	All author nodes that are descendent from top level
.	Context node
..	Parent node
version[number]	Version nodes that have "number" children
version[number='1.0']	Version nodes for which "number" has content of "1.0"

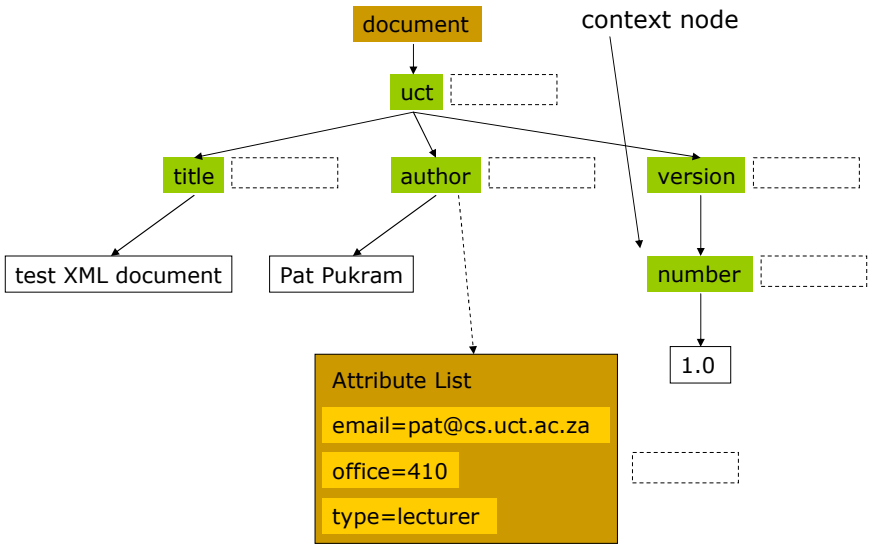
XPath Example 1



XPath Example 2



XPath Exercise



XSL - XSLT

XSL

- XML Stylesheet Language (XSL) is used to convert structured data in XML to a "human-friendly" representation.
- 2-step process:
  - Transform XML data (XSLT)
  - Process formatting instructions and generate output (XSL-FO)

Philosophically, besides programmers, nobody should ever have to read/write XML!

- In systems that are WWW-based, the first step is more useful – XSL Transformations (XSLT) – as XHTML is directly "processed" by browsers.

XSLT

- XSLT is a declarative language, written in XML, to specify transformation rules for XML fragments.
- XSLT can be used to convert any arbitrary XML document into XHTML or other XML formats (e.g., different metadata formats).
- Example:

```
<template match="uct:author">
    <dc:creator>
        <value-of select="."/>
    </dc:creator>
</template>
```

XSLT Basic Idea

source XML

```
<uct xmlns="http://www.uct.ac.za">
   <title>test XML document</title>
</uct>
```

XSLT

```
<xsl:stylesheet version='1.0'
 xmlns:xsl='http://www.w3.org/1999/XSL/Transform'
 xmlns:uct='http://www.uct.ac.za'
 xmlns:uwc='http://www.uwc.ac.za'
>
   <xsl:template match="uct:uct">
      <uwc:uwc>
         <uwc:title>test XML document</uwc:title>
      </uwc:uwc>
   </xsl:template>
</xsl:stylesheet>
```

transformed XML

```
<?xml version="1.0"?>
<uwc:uwc
     xmlns:uwc='http://www.uwc.ac.za'
     xmlns:uct='http://www.uct.ac.za'
>
  <uwc:title>test XML document</uwc:title>
</uwc:uwc>
```

Applying XSLT Transformations

- Running processor from command-line
  - xsltproc uct.xsl uct.xml
- Running processor from within browser (static page)

```
<?xml version="1.0"?>
<?xml-stylesheet type="text/xsl" href="uct.xsl"?>
```

- Embedding processor in program

```
var processor = new XSLTProcessor ();
var dataXML =
  document.implementation.createDocument("", "", null);
dataXML.async = false;
dataXML.load("uct.xml");
var dataXSL =
  document.implementation.createDocument("", "", null);
dataXSL.async = false;
dataXSL.load('uct.xsl');
processor.reset();
processor.importStylesheet(dataXSL);
```

XSLT Templates

- Templates of replacement XML are specified along with criteria for matching in terms of XPath expressions.
- XSLT processors attempt to match the root XML tag with a template. If this fails they descend one level and try to match each of the root's children, etc.
- In the previous example, all occurrences of the "uct:uct" tag will be replaced by the contents of the template.

XSLT Special Tags

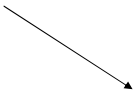
- Special tags in the XSL namespace are used to control transformation.

- value-of, text, element
  - Create nodes in result document.
- apply-templates, call-template
  - Apply template rules explicitly.
- variable, param, with-param
  - Local variables and parameter passing.
- if, choose, for-each
  - Procedural language constructs.

Creating Element nodes

- *element* is replaced by an XML element with the indicated tag.
  - Example:
    - `<element name="dc:publisher">UCT</element>`

```
<xsl:template match="uct:uct">
   <uwc:uwc>
      <xsl:element name="uwc:title">
      </xsl:element>
   </uwc:uwc>
</xsl:template>
```

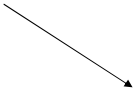


```
<uwc:uwc
     xmlns:uwc='http://www.uwc.ac.za'
     xmlns:uct='http://www.uct.ac.za'
>
   <uwc:title/>
</uwc:uwc>
```

Creating Text nodes

- *text* is replaced by the textual content.
  - Example:
    - `<text>1.0</text>`

```
<xsl:template match="uct:uct">
   <uwc:uwc>
      <xsl:element name="uwc:title">
         <xsl:text>test XML document</xsl:text>
      </xsl:element>
   </uwc:uwc>
</xsl:template>
```

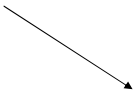


```
<uwc:uwc
     xmlns:uwc='http://www.uwc.ac.za'
     xmlns:uct='http://www.uct.ac.za'
>
   <uwc:title>test XML document</uwc:title>
</uwc:uwc>
```

Element and Text Shorthand

- Elements and text nodes can usually be included directly in templates.
  - Example
    - Instead of `<element name="xxx"/>`
    - Use `<xxx/>`

```
<xsl:template match="uct:uct">
   <uwc:uwc>
      <uwc:title>
         test XML document
      </uwc:title>
   </uwc:uwc>
</xsl:template>
```

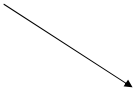


```
<uwc:uwc
     xmlns:uwc='http://www.uwc.ac.za'
     xmlns:uct='http://www.uct.ac.za'
>
   <uwc:title>test XML document</uwc:title>
</uwc:uwc>
```

Copying values across

- *value-of* is replaced with the textual content of the nodes identified by the XPath expression.
  - Example:
    - `<value-of select="uct:title"/>`

```
<xsl:template match="uct:uct">
   <uwc:uwc>
      <uwc:title>
         <xsl:value-of select="uct:title"/>
      </uwc:title>
   </uwc:uwc>
</xsl:template>
```



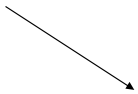
```
<uwc:uwc
     xmlns:uwc='http://www.uwc.ac.za'
     xmlns:uct='http://www.uct.ac.za'
>
   <uwc:title>test XML document</uwc:title>
</uwc:uwc>
```

Applying Templates Explicitly

- *apply-templates* explicitly and recursively applies templates to the specified nodes.
  - Example:
    - `<apply-templates select="uct:version"/>`

```
<xsl:template match="uct:uct">
   <uwc:uwc>
      <uwc:title>
         <xsl:value-of select="uct:title"/>
      </uwc:title>
      <xsl:apply-templates select="uct:author"/>
   </uwc:uwc>
</xsl:template>

<xsl:template match="uct:author">
   <uwc:author>
      <xsl:value-of select="."/>
   </uwc:author>
</xsl:template>
```



```
<uwc:uwc
      xmlns:uwc='http://www.uwc.ac.za'
      xmlns:uct='http://www.uct.ac.za'
>
   <uwc:title>test XML document</uwc:title>
   <uwc:author>Pat Pukram</uwc:author>
</uwc:uwc>
```

Calling Templates

- *call-template* calls a template like a function. This template may have parameters and must have a *name* attribute instead of a *match*.
- Example:

```
<call-template name="doheader">
   <with-param name="lines">5</with-param>
</call-template>

<template name="doheader">
   <param name="lines">2</param>
   …
</template>
```

Variables

- *variable* sets a local variable in a template or globally. In XPath expressions, a $ prefix indicates a variable or parameter instead of a node.
  - Example:
    - `<variable name="institution">UCT</variable>`
      `<value-of select="$institution"/>`
- Expressions also can be inserted into attributes in generated nodes. Surround the expression with { and } to tell XSLT it is not a literal string.
  - Example:
    - `<place institution="{$institution}"/>`

Procedural Constructs

- Generate a tree of nodes if a condition holds.
  - `<if test="position()=last()">…</if>`
- Generate a different tree of nodes, depending on which of a number of a conditions holds.
  - ```
    <choose>
       <when test="$val=1">…</when>
       <otherwise>…</otherwise>
    </choose>
    ```
- Iterate over a set of nodes matching an expression and generate a tree for each. This has the same effect as *apply-templates*.
  - `<for-each select="uct:number">…</for-each>`
    ```

Full XSLT 1/2

```
<xsl:stylesheet version='1.0'
 xmlns:xsl='http://www.w3.org/1999/XSL/Transform'
 xmlns:xsi='http://www.w3.org/2001/XMLSchema-instance'
 xmlns:uct='http://www.uct.ac.za'
 xmlns='http://www.w3.org/1999/xhtml'
 exclude-result-prefixes='xsi uct'
>

<!--
   UCT to HTML transformation
   Hussein Suleman
   v1.0 : 10 May 2007
-->

   <xsl:output method="xml" omit-xml-declaration="yes"
      omit-namespace="html"/>

   <xsl:variable name="institution">
      <xsl:text>UCT</xsl:text>
   </xsl:variable>
```

Full XSLT 2/2

```
    <xsl:template match="uct:uct">
      <html>
         <head>
            <title>UCT Information Page</title>
         </head>
         <body>
            <h1><xsl:value-of select="uct:title"/></h1>
            <hr/>
            <xsl:apply-templates select="uct:author"/>
            <h2>Publisher</h2><p><xsl:value-of select="$institution"/></p>
            <xsl:apply-templates select="uct:version"/>
         </body>
      </html>
   </xsl:template>

   <xsl:template match="uct:author">
      <h2>Author</h2>
      <p><xsl:value-of select="."/></p>
   </xsl:template>

   <xsl:template match="uct:version">
      <h2>Version</h2>
      <p><xsl:value-of select="uct:number"/></p>
   </xsl:template>

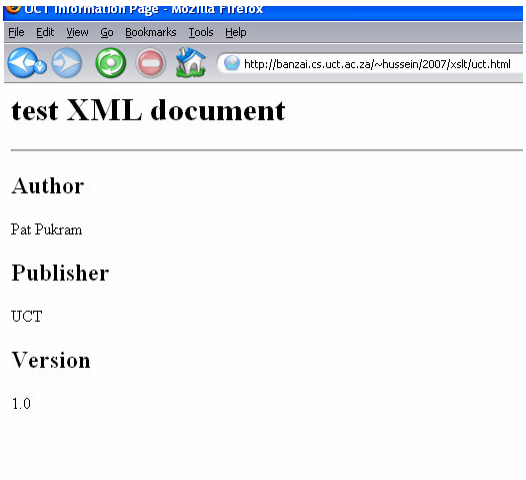
</xsl:stylesheet>
```

note: this is not the simplest XSLT for this problem

Transformed XML (XHTML Source)

```
<html xmlns="http://www.w3.org/1999/xhtml">
   <head>
    <title>UCT Information Page</title>
  </head>
  <body>
     <h1>test XML document</h1>
     <hr/>
     <h2>Author</h2>
     <p>Pat Pukram</p>
     <h2>Publisher</h2>
     <p>UCT</p>
     <h2>Version</h2>1.0</body>
</html>
```

XHTML Rendered



Exercise 6: XSLT

- View the uct.xsl stylesheet in your browser.
- In the workshop folder, copy uct3.xml to uct4.xml.
- Edit uct4.xml and add the following line just below the XML declaration (or as the top line if there is no declaration).
  - `<?xml-stylesheet type="text/xsl" href="uct.xsl"?>`
- View the uct4.xml file in your browser.
  - It should appear in its transformed state (as HTML).
  - View source to see the original file.
  - Note that this is XML→XHTML (because the end result is to view in a browser) but you do not always do this…

XSL - FO

XSL Formatting Objects

- XSL-FO is a language to specify the layout of elements on pages.
- Page masters (templates) are first defined and then content is flowed onto the pages.
  - Formatting attributes are similar to CSS!
- XSLT is typically used to convert XML into XSL-FO, then an FO processor (such as Apache FOP) converts the FO into a document format (such as PDF).

Example XSL-FO

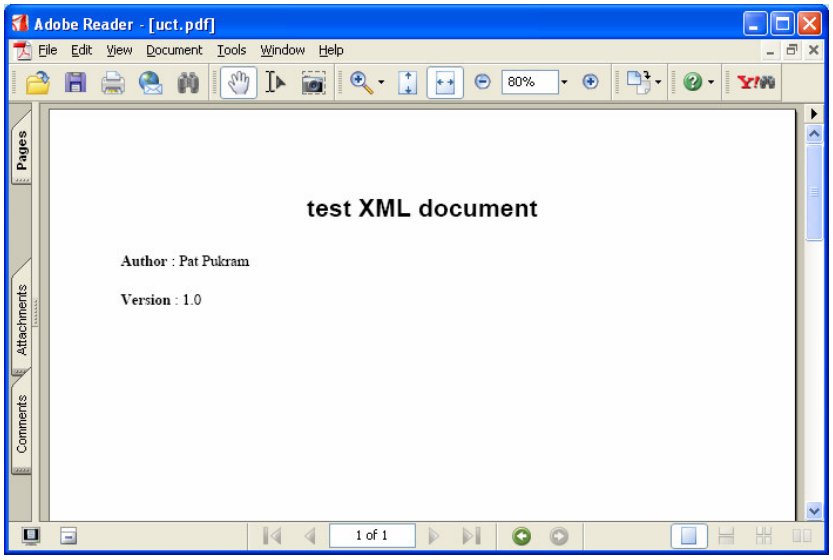
```
<fo:root xmlns:fo="http://www.w3.org/1999/XSL/Format">

<fo:layout-master-set>
   <fo:simple-page-master margin-right="1cm" margin-left="1cm" margin-top="1cm" margin-bottom="1cm" page-
width="210mm" page-height="297mm" master-name="first">
      <fo:region-after extent="1cm"/>
      <fo:region-body margin-top="1cm" margin-bottom="2cm" margin-left="1cm" margin-right="1cm"/>
   </fo:simple-page-master>
</fo:layout-master-set>

<fo:page-sequence master-reference="first">
   <fo:flow flow-name="xsl-region-body">
      <fo:block margin="0" padding="12px 0 12px 0" font-weight="bold" text-align="center" font-
size="20pt" font-family="sans-serif">test XML document</fo:block>
      <fo:block margin="0" padding="12px 0 6px 0" font-size="12pt" font-family="serif"><fo:inline font-
weight="bold">Author</fo:inline> : Pat Pukram</fo:block>
      <fo:block margin="0" padding="12px 0 6px 0" font-size="12pt" font-family="serif"><fo:inline font-
weight="bold">Version</fo:inline> :
      1.0</fo:block>
   </fo:flow>
</fo:page-sequence>

</fo:root>
```

XSL-FO→PDF Output



Example XSLT (XSL-FO) 1/3

```
<!--
   XSL FOP stylesheet to convert the UCT metadata record
   into
   FO suitable for FOP to convert into a PDF

   Hussein Suleman
   1 August 2005
-->

<xsl:stylesheet
 version='1.0'
 xmlns:xsl='http://www.w3.org/1999/XSL/Transform'
 xmlns:source='http://www.uct.ac.za'
 xmlns:fo='http://www.w3.org/1999/XSL/Format'
 xmlns:html='http://www.w3.org/1999/xhtml'
>

<xsl:output method="xml" omit-xml-declaration="yes"/>
```

Example XSLT (XSL-FO) 2/3

```
<xsl:template match="source:uct">
   <fo:root>
      <fo:layout-master-set>
         <fo:simple-page-master margin-right="1cm"
                                margin-left="1cm"
                                margin-top="1cm"
                                margin-bottom="1cm"
                                page-width="210mm"
                                page-height="297mm"
                                master-name="first">
            <fo:region-after extent="1cm"/>
            <fo:region-body margin-top="1cm" margin-bottom="2cm"
                            margin-left="1cm" margin-right="1cm"/>
         </fo:simple-page-master>
      </fo:layout-master-set>
      <fo:page-sequence master-reference="first">
         <fo:flow flow-name="xsl-region-body">
            <xsl:apply-templates select="*"/>
         </fo:flow>
      </fo:page-sequence>
   </fo:root>
</xsl:template>
```

Example XSLT (XSL-FO) 3/3

```
<xsl:template match="source:title">
   <fo:block margin="0" padding="12px 0 12px 0" font-weight="bold"
             text-align="center" font-size="20pt" font-family="sans-serif">
      <xsl:value-of select="."/>
   </fo:block>
</xsl:template>

<xsl:template match="source:author">
   <fo:block margin="0" padding="12px 0 6px 0"
             font-size="12pt" font-family="serif">
      <fo:inline font-weight="bold">Author</fo:inline> :
      <xsl:value-of select="."/>
   </fo:block>
</xsl:template>

<xsl:template match="source:version">
   <fo:block margin="0" padding="12px 0 6px 0"
             font-size="12pt" font-family="serif">
      <fo:inline font-weight="bold">Version</fo:inline> :
      <xsl:value-of select="source:number"/>
   </fo:block>
</xsl:template>

</xsl:stylesheet>
```

XQuery

XQuery

- XQuery specifies advanced functional queries over XML documents and collections.
- XQuery is a superset of XPath 1.0, and parallel specification for XPath 2.0 and XSLT 2.0.

XQuery Expressions 1/2

- Primary expressions
  - `12.1, "Hello world"` (literals)
  - `$firstauthor` (variable)
  - `xq:string-concat ()` (function call)
- Path expressions
  - `document("test.xml")//author`
  - `para[5][@type="warning"]`
  - `child::chapter[child::title='Intro']`

XQuery Expressions 2/2

- Arithmetic/Comparison/Logic expressions
  - `$unit-price - $unit-discount`
  - `//product[weight gt 100]`
  - `1 eq 1 and 2 eq 2`
- Sequence expressions
  - `(1, 2, (3))`
  - `(10, 1 to 4)`
  - `(1 to 100)[. mod 5 eq 0]`
  - `$seq1 union $seq2`

FLWOR Expressions

- For-Let-Where-OrderBy-Return
- Iterates over a sequence of nodes, with intermediate binding of variables.
- Most useful for database-like "join" operations.

FLWOR Example

```
for $d in fn:doc("depts.xml")//deptno
let $e := fn:doc("emps.xml")//emp[deptno = $d]
where fn:count($e) >= 10
order by fn:avg($e/salary) descending
return
   <big-dept>
      {
      $d,
      <headcount>{fn:count($e)}</headcount>,
      <avgsal>{fn:avg($e/salary)}</avgsal>
      }
   </big-dept>
```

(from specification)

FLWOR For, Let

- `for` and `let` create a sequence of tuples with bound variables.
- Can have multiple `for`s and multiple `let`s.
- Multiple `for`s result in a Cartesian product of the sequences.
  - ```
    for $car in ("Ford", "Chevy"),
        $pet in ("Cat", "Dog")
    ```
- Multiple `let`s result in multiple intermediate variable bindings per tuple of nodes.

FLWOR Where, OrderBy, Return

- `where` filters the list of tuples, by removing those that do not satisfy the expression.
- `return` specifies result for each tuple.
- `order by` specifies the expression to use to order the tuples – the expression can use nodes not included in the result.
  - ```
    for $e in $employees
    order by $e/salary descending
    return $e/name
    ```

FLWOR for DB Joins

```
<ucthons>
   {
      for $stud in fn:doc("students.xml")//student
      for $proj in
        fn:doc("projects.xml")//project[id = $stud/id]
      order by $stud/name
      return
         <honsproj>
           <studentname>{$stud/name}</studentname>
           <projectname>{$proj/name}</projectname>
         </honsproj>
   }
</ucthons>
```

XML Databases

XML Databases

- Databases must be Unicode-compliant! (usually UTF-8)
- Options:
  - Blob: Store XML documents or fragments in tables.
  - Tree: Store XML as sequence of nodes with child relationships explicitly indicated.
  - Relation: Store XML in specialised tables/relations as defined by XML structure.
  - Flat files: Store each XML document in a file.

Blob/Clob/etc.

Id	XMLBlob
TestXML	<uct> <title>test XML document</title> <author email="pat@cs.uct.ac.za" office="410" type="lecturer">Pat Pukram</author> <version> <number>1.0</number> </version> </uct>

Tree Representation

Nodes

Id	Type	Label	Value
1	Element		uct
2	Element		title
3	Text		test XML document
4	Element		author
5	Attribute	email	pat@cs.uct.ac.za
6	Attribute	office	410
7	Attribute	type	lecturer
8	Text		Pat Pukram
9	Element		version
10	Element		number
11	Text		1.0

Links

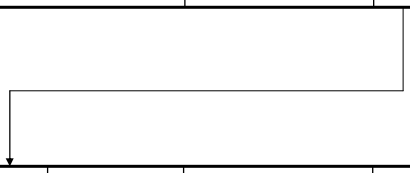
Parent id	Child id
1	2
2	3
1	4
4	5
4	6
4	7
4	8
1	9
9	10
10	11

Note: Whitespace nodes have been ignored!

Relation Representation

main table

Institute	Title	VersionNumber	id
uct	test XML document	1.0	1



id	Author	Email	Office	Type
1	Pat Pukram	pat@cs.uct.ac.za	410	lecturer

author table

Evaluation

- Blob: fast insert/select for XML documents, but slow querying.
- Tree: fast location of single nodes and sequences of nodes, but slow to enforce structure of XML.
- Relation: fast data query and extraction, but could be many tables and thus slow to insert/select XML documents.
- Flat file: fast load/store, but slow queries.

Are we only interested in relational queries? Google-like queries?

that's all folks!

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