

XPath

Web Data Management and Distribution

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Outline

- 1 Introduction
- 2 Path Expressions
- 3 Operators and Functions
- 4 XPath examples
- 5 XPath 2.0
- 6 Reference Information
- 7 Exercise

XPath

- An **expression language** to be used in another host language (e.g., XSLT, XQuery).
- Allows the description of **paths** in an XML tree, and the retrieval of nodes that match these paths.
- Can also be used for performing some (limited) operations on XML data.

Example

`2*3` is an XPath **literal expression**.

`//*[@msg="Hello world"]` is an XPath **path expression**, retrieving all elements with a `msg` attribute set to "Hello world".

Content of this presentation

Mostly XPath 1.0: a W3C recommendation published in 1999, widely used. Also a *basic* introduction to XPath 2.0, published in 2007.

XPath Data Model

XPath expressions operate over **XML trees**, which consist of the following **node types**:

- **Document**: the **root node** of the XML document;
- **Element**: element nodes;
- **Attribute**: attribute nodes, represented as children of an **Element** node;
- **Text**: text nodes, i.e., leaves of the XML tree.

Remark

Remark 1 The XPath data model features also **ProcessingInstruction** and **Comment** node types.

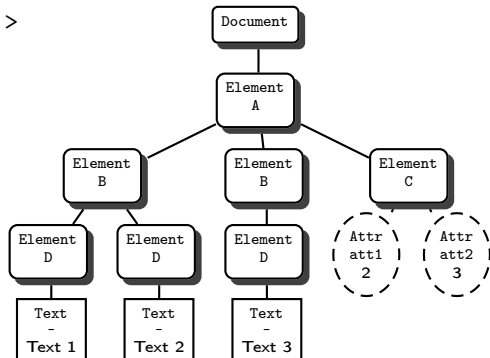
Remark 2 Syntactic features specific to serialized representation (e.g., entities, literal section) are ignored by XPath.

From serialized representation to XML trees

```

<?xml version="1.0"
      encoding="UTF-8"?>
<A>
  <B>
    <D>Text 1</D>
    <D>Text 2</D>
  </B>
  <B>
    <D>Text 3</D>
  </B>
  <C att1="2"
     att2="3"/>
</A>

```



XPath Data Model (cont.)

- The **root node** of an XML tree is the (unique) **Document** node;
- The **root element** is the (unique) **Element** child of the root node;
- A node has a **name**, or a **value**, or both
 - ▶ an **Element** node has a name, but no value;
 - ▶ a **Text** node has a value (a character string), but no name;
 - ▶ an **Attribute** node has both a name and a value.
- *Attributes are special!* Attributes are not considered as first-class nodes in an XML tree. They must be addressed specifically, when needed.

Remark

The expression “*textual value of an **Element** N* ” denotes the concatenation of all the **Text** node values which are descendant of N , taken in the **document order**.

Outline

- 1 Introduction
- 2 Path Expressions**
 - Steps and expressions
 - Axes and node tests
 - Predicates
- 3 Operators and Functions
- 4 XPath examples
- 5 XPath 2.0
- 6 Reference Information

XPath Context

A step is evaluated in a specific **context** $[< N_1, N_2, \dots, N_n >, N_c]$ which consists of:

a **context list** $< N_1, N_2, \dots, N_n >$ of nodes from the XML tree;

a **context node** N_c belonging to the context list.

Information on the context

- The **context length** n is a positive integer indicating the **size** of a contextual list of nodes; it can be known by using the function **last()**;
- The **context node position** $c \in [1, n]$ is a positive integer indicating the **position** of the context node in the context list of nodes; it can be known by using the function **position()**.

XPath steps

The basic component of XPath expression are **steps**, of the form:

$$\text{axis}::\text{node-test}[P_1][P_2]\dots[P_n]$$

axis is an **axis name** indicating what the direction of the step in the XML tree is (**child** is the default).

node-test is a **node test**, indicating the kind of nodes to select.

P_i is a **predicate**, that is, any XPath expression, evaluated as a boolean, indicating an additional condition. There may be no predicates at all.

Interpretation of a step

A step is evaluated with respect to a **context**, and returns a **node list**.

Example

`descendant::C[@att1='1']` is a step which denotes all the **Element** nodes named C having an **Attribute** node att1 with value 1.

Path Expressions

A path expression is of the form: `[/]step1/step2/.../stepn`

A path that begins with `/` is an **absolute** path expression;

A path that does not begin with `/` is a **relative** path expression.

Example

`/A/B` is an **absolute** path expression denoting the **Element** nodes with name B, children of the root named A;

`./B/descendant::text()` is a **relative** path expression which denotes all the **Text** nodes descendant of an **Element** B, itself child of the context node;

`/A/B/@att1[. > 2]` denotes all the **Attribute** nodes @att1 whose value is greater than 2.

`.` is a special step, which refers to the context node. Thus, `./toto` means the same thing as `toto`.

Evaluation of Path Expressions

Each step step_i is interpreted with respect to a **context**; its result is a **node list**.

A step step_i is evaluated with respect to the context of step_{i-1} . More precisely:

For $i = 1$ (**first step**) if the path is **absolute**, the context is a singleton, the root of the XML tree; else (**relative paths**) the context is defined by the environment;

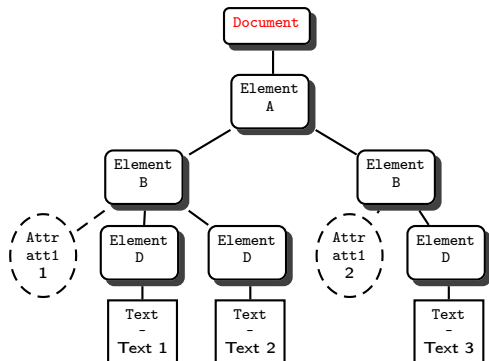
For $i > 1$ if $\mathcal{N} = \langle N_1, N_2, \dots, N_n \rangle$ is the result of step step_{i-1} , step_i is successively evaluated with respect to the context $[\mathcal{N}, N_j]$, for each $j \in [1, n]$.

The result of the path expression is the node set obtained after evaluating the last step.

Evaluation of /A/B/@att1

The path expression is absolute: the context consists of the root node of the tree.

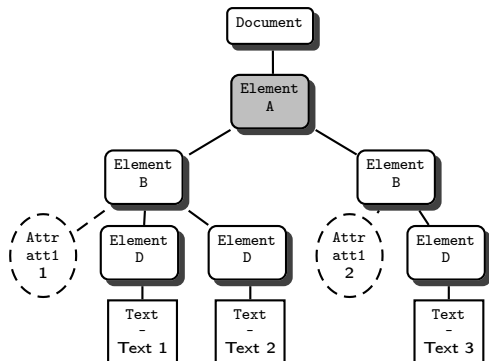
The first step, A, is evaluated with respect to this context.



Evaluation of /A/B/@att1

The result is **A**, the root element.

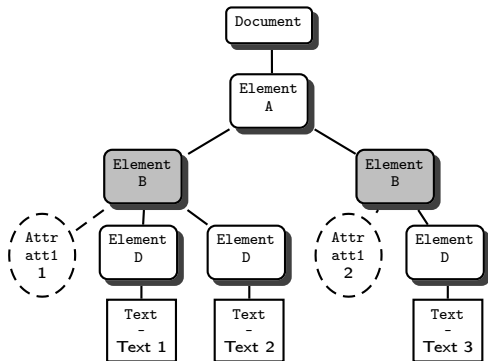
A is the context for the evaluation of the second step, B.



Evaluation of /A/B/@att1

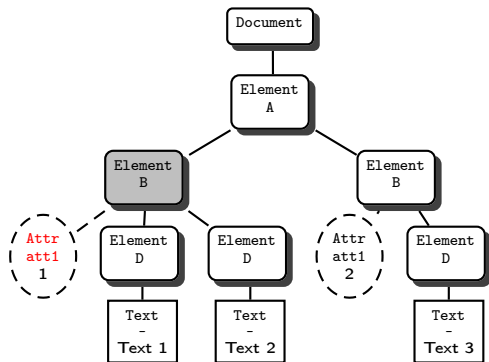
The result is a node list with two nodes **B[1]**, **B[2]**.

@att1 is first evaluated
with the context node
B[1].



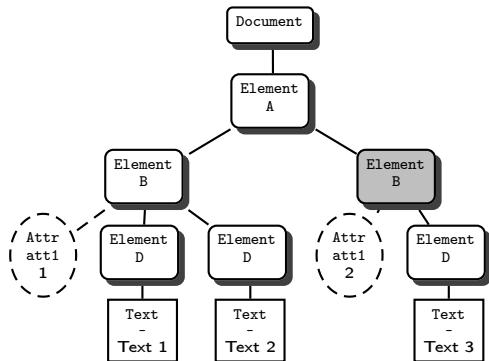
Evaluation of /A/B/@att1

The result is the attribute node of **B[1]**.



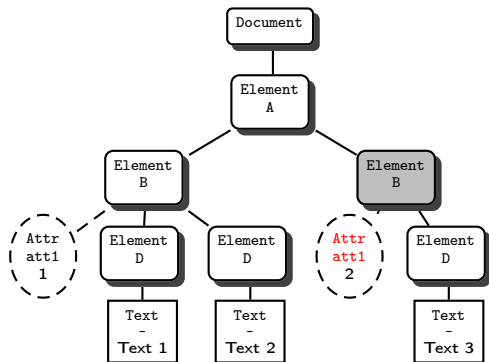
Evaluation of /A/B/@att1

@att1 is also evaluated
with the context node
B[2].



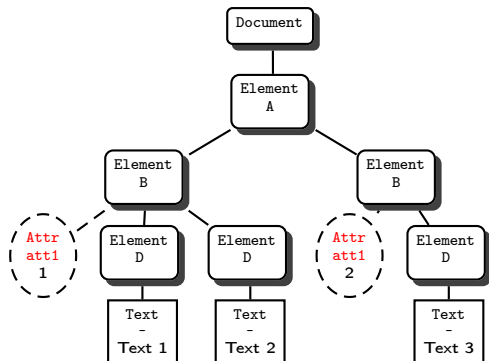
Evaluation of /A/B/@att1

The result is the attribute node of **B[2]**.



Evaluation of /A/B/@att1

Final result: the node set union of all the results of the last step, @att1.



Axes

An axis = a set of nodes determined from the context node, **and** an ordering of the sequence.

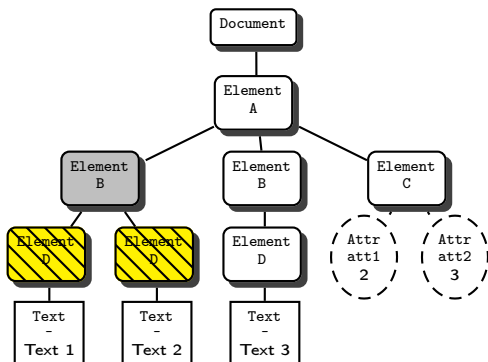
- **child** (default axis).
- **parent** Parent node.
- **attribute** Attribute nodes.
- **descendant** Descendants, excluding the node itself.
- **descendant-or-self** Descendants, including the node itself.
- **ancestor** Ancestors, excluding the node itself.
- **ancestor-or-self** Ancestors, including the node itself.
- **following** Following nodes in **document order**.
- **following-sibling** Following siblings in **document order**.
- **preceding** Preceding nodes in **document order**.
- **preceding-sibling** Preceding siblings in **document order**.
- **self** The context node itself.

Examples of axis interpretation

Child axis: denotes the **Element** or **Text** children of the context node.

Important: An **Attribute** node has a parent (the element on which it is located), but an attribute node is *not* one of the children of its parent.

Result of `child::D` (equivalent to `D`)



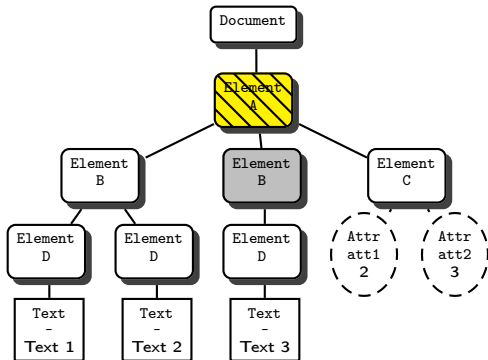
Examples of axis interpretation

Parent axis: denotes the parent of the context node. The node test is either an element name, or `*` which matches all names, `node()` which matches all node types.

Always a **Element** or **Document** node, or an empty node-set (if the parent does not match the node test or does not satisfy a predicate).

`..` is an abbreviation for `parent::node()`: the parent of the context node, whatever its type, if it ex-

Result of `parent::node()` (may be abbreviated to `..`)

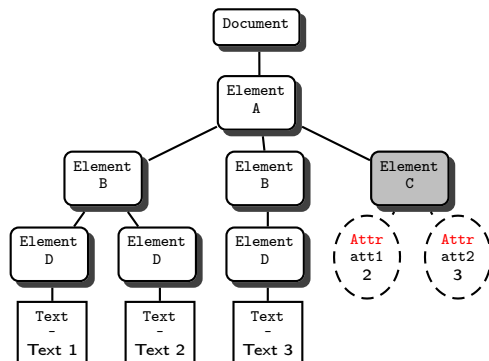


Examples of axis interpretation

Attribute axis: denotes the attributes of the context node.

The node test is either the attribute name, or `*` which matches all the names.

Result of `attribute::*` (equiv. to `@*`)



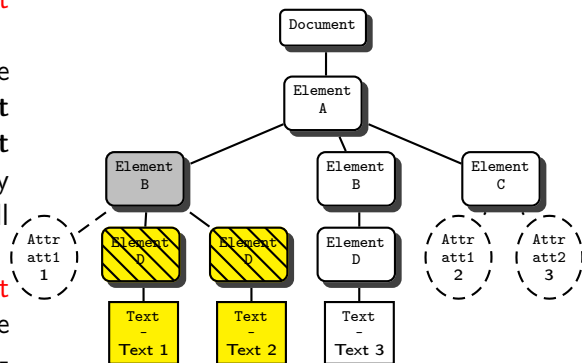
Examples of axis interpretation

Descendant axis: all the descendant nodes, **except** the **Attribute** nodes.

The node test is either the node name (for **Element** nodes), or ***** (any **Element** node) or **text()** (any **Text** node) or **node()** (all nodes).

The context node does **not** belong to the result: use **descendant-or-self** instead.

Result of `descendant::node()`



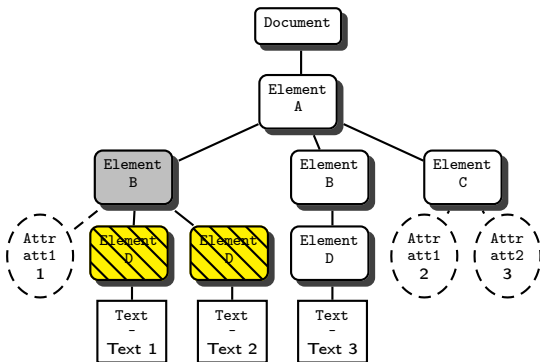
Examples of axis interpretation

Descendant axis: all the descendant nodes, **except** the **Attribute** nodes.

The node test is either the node name (for **Element** nodes), or ***** (any **Element** node) or **text()** (any **Text** node) or **node()** (all nodes).

The context node does **not** belong to the result: use **descendant-or-self** instead.

Result of **descendant::***



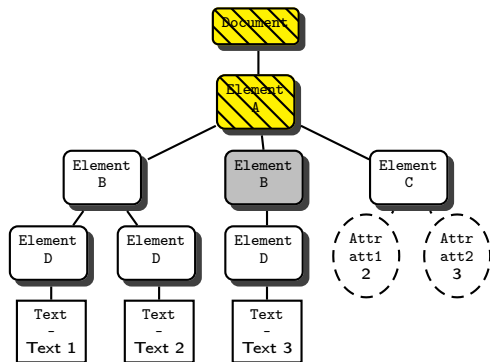
Examples of axis interpretation

Ancestor axis: all the ancestor nodes.

The node test is either the node name (for **Element** nodes), or `node()` (any **Element** node, and the **Document** root node).

The context node does **not** belong to the result: use `ancestor-or-self` instead.

Result of `ancestor::node()`



Examples of axis interpretation

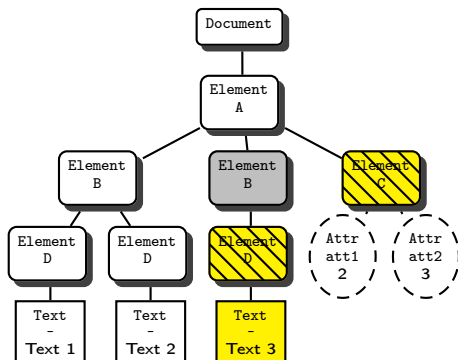
Following axis: all the nodes that follows the context node in the document order.

Attribute nodes are *not* selected.

The node test is either the node name, `* text()` or `node()`.

The axis `preceding` denotes all the nodes the precede the context node.

Result of `following::node()`



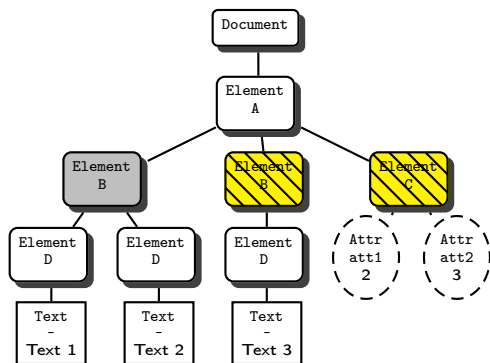
Examples of axis interpretation

Following sibling axis:
all the nodes that follows the context node, and share the same parent node.

Same node tests as **descendant** or **following**.

The **preceding-sibling** axis denotes all the nodes the precede the context node.

Result of `following-sibling::node()`



Abbreviations (summary)

Summary of abbreviations:

<code>somename</code>	<code>child::somename</code>
<code>.</code>	<code>self::node()</code>
<code>..</code>	<code>parent::node()</code>
<code>@someattr</code>	<code>attribute::someattr</code>
<code>a//b</code>	<code>a/descendant-or-self::node()/b</code>
<code>//a</code>	<code>/descendant-or-self::node()/a</code>

Examples

`@b` selects the `b` attribute of the context node.

`../*` selects all siblings of the context node, itself included (unless it is an attribute node).

`//@someattr` selects all `someattr` attributes wherever their position in the document.

Node Tests (summary)

A node test has one of the following forms:

`node()` any node.

`text()` any text node.

* any element (or any attribute for the `attribute` axis).

`ns:*` any element or attribute in the namespace bound to the prefix `ns`.

`ns:toto` any element or attribute whose name is `ns:toto`

Examples

`a/node()` selects all nodes which are children of a `a` node, itself child of the context node.

`xsl:*` selects all elements whose namespace is `ns` and that are children of the context node.

`/*` selects the top-level element node.

XPath Predicates

- Boolean expression, built with **tests** and the Boolean connectors **and** and **or** (negation is expressed with the `not()` function);
- a **test** is
 - ▶ either an XPath expression, whose result is converted to a Boolean;
 - ▶ a comparison or a call to a Boolean function.

Important: predicate evaluation requires several rules for converting nodes and node sets to the appropriate type.

Example

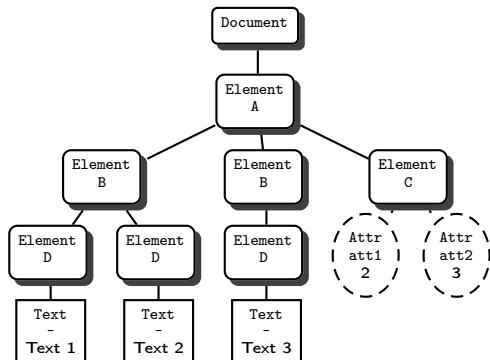
- `//B[@att1=1]`: nodes **B** having an attribute `att1` with value 1;
- `//B[@att1]`: all nodes **B** having an attributes named `att1`!
⇒ `@att1` is an XPath expression whose result (a node set) is converted to a Boolean.
- `//B/descendant::text()[position()=1]`: the first **Text** node descendant of each node **B**.
Can be abbreviated to `//B/descendant::text()[1]`.

Predicate evaluation

A step is of the form
`axis::node-test[P]`.

- First
`axis::node-test` is evaluated: one obtains an intermediate result I
- Second, for each node in I , P is evaluated: the step result consists of those nodes in I for which P is true.

Ex.: `/A/B/descendant::text()[1]`

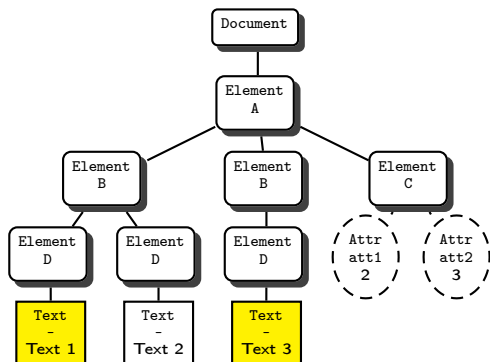


Predicate evaluation

Beware: an XPath step is **always** evaluated with respect to the context of the previous step.

Here the result consists of those **Text** nodes, first descendant (in the document order) of a node **B**.

Result of `/A/B//text()[1]`



XPath 1.0 Type System

Four primitive types:

Type	Description	Literals	Examples
boolean	Boolean values	<i>none</i>	<code>true()</code> , <code>not(\$a=3)</code>
number	Floating-point	12, 12.5	<code>1 div 33</code>
string	Ch. strings	"to", 'ti'	<code>concat('Hello', '!')</code>
nodeset	Node set	<i>none</i>	<code>/a/b[c=1 or @e]/d</code>

The `boolean()`, `number()`, `string()` functions **convert** types into each other (no conversion to nodesets is defined), but this conversion is done in an **implicit** way most of the time.

Rules for **converting to a boolean**:

- A number is true if it is neither 0 nor *NaN*.
- A string is true if its length is not 0.
- A nodeset is true if it is not empty.

Rules for **converting a nodeset to a string**:

- The string value of a nodeset is the string value of its first item in document order.
- The string value of an element or document node is the concatenation of the character data in all text nodes below.
- The string value of a text node is its character data.
- The string value of an attribute node is the attribute value.

Examples (Whitespace-only text nodes removed)

```
<a toto="3">  
  <b titi='tutu'><c /></b>  
  <d>tata</d>  
</a>
```

<code>string(/)</code>	<code>"tata"</code>
<code>string(/a/@toto)</code>	<code>"3"</code>
<code>boolean(/a/b)</code>	<code>true()</code>
<code>boolean(/a/e)</code>	<code>false()</code>

Outline

- 1 Introduction
- 2 Path Expressions
- 3 Operators and Functions**
- 4 XPath examples
- 5 XPath 2.0
- 6 Reference Information
- 7 Exercise

Operators

The following operators can be used in XPath.

`+`, `-`, `*`, `div`, `mod` standard arithmetic operators (Example: `1+2*-3`).

Warning! `div` is used instead of the usual `/`.

`or`, `and` boolean operators (Example: `@a and c=3`)

`=`, `!=` equality operators. Can be used for strings, booleans or numbers. **Warning!** `//a!=3` means: there is an `a` element in the document whose string value is different from 3.

`<`, `<=`, `>=`, `>` relational operators (Example: `($a<2) and ($a>0)`).

Warning! Can only be used to compare numbers, not strings. If an XPath expression is embedded in an XML document, `<` must be escaped as `<`;

`|` union of nodesets (Example: `node()|@*`)

Remark

`$a` is a **reference** to the variable `a`. Variables can not be defined in XPath, they can only be referred to.

Node Functions

- `count($s)` returns the **number of items** in the nodeset `$s`
- `local-name($s)` returns the **name** of the first item of the nodeset `$s` in document order, **without** the namespace prefix; if `$s` is omitted, it is taken to be the context item
- `namespace-uri($s)` returns the **namespace URI** bound to the prefix of the name of the first item of the nodeset `$s` in document order; if `$s` is omitted, it is taken to be the context item
- `name($s)` returns the **name** of the first item of the nodeset `$s` in document order, **including** its namespace prefix; if `$s` is omitted, it is taken to be the context item

String Functions

- `concat($s1, ..., $sn)` concatenates the strings s_1, \dots, s_n
- `starts-with($a, $b)` returns `true()` if the string `$a` starts with `$b`
- `contains($a, $b)` returns `true()` if the string `$a` contains `$b`
- `substring-before($a, $b)` returns the substring of `$a` before the first occurrence of `$b`
- `substring-after($a, $b)` returns the substring of `$a` after the first occurrence of `$b`
- `substring($a, $n, $l)` returns the substring of `$a` of length `$l` starting at index `$n` (indexes start from 1). `$l` may be omitted.
- `string-length($a)` returns the length of the string `$a`
- `normalize-space($a)` removes all leading and trailing whitespace from `$a`, and collapse all whitespace to a single character
- `translate($a, $b, $c)` returns the string `$a`, where all occurrences of a character from `$b` has been replaced by the character at the same place in `$c`.

Boolean and Number Functions

`not($b)` returns the **logical negation** of the boolean `$b`

`sum($s)` returns the **sum** of the values of the nodes in the nodeset `$s`

`floor($n)` rounds the number `$n` to the **next lowest** integer

`ceiling($n)` rounds the number `$n` to the **next greatest** integer

`round($n)` rounds the number `$n` to the **closest** integer

Examples

`count(//*)` returns the number of elements in the document

`normalize-space(' titi toto ')` returns the string "titi toto"

`translate('baba','abcdef','ABCDEF')` returns the string "BABA"

`round(3.457)` returns the number 3

Outline

- 1 Introduction
- 2 Path Expressions
- 3 Operators and Functions
- 4 XPath examples**
- 5 XPath 2.0
- 6 Reference Information
- 7 Exercise

Examples (1)

`child::A/descendant::B` : `B` elements, descendant of an `A` element, itself child of the context node;
Can be abbreviated to `A//B`.

`child::* / child::B` : all the `B` grand-children of the context node:

`descendant-or-self::B` : elements `B` descendants of the context node, plus the context node itself if its name is `B`.

`child::B[position()=last()]` : the last child named `B` of the context node.

Abbreviated to `B[last()]`.

`following-sibling::B[1]` : the first sibling of type `B` (in the document order) of the context node,

Examples (2)

`/descendant::B[10]` the tenth element of type **B** in the document.

Not: the tenth element of the document, if its type is **B**!

`child::B[child::C]` : child elements **B** that have a child element **C**.

Abbreviated to `B[C]`.

`/descendant::B[@att1 or @att2]` : elements **B** that have an attribute `att1` or an attribute `att2`;

Abbreviated to `//B[@att1 or @att2]`

`*[self::B or self::C]` : children elements named **B** or **C**

Outline

- 1 Introduction
- 2 Path Expressions
- 3 Operators and Functions
- 4 XPath examples
- 5 XPath 2.0**
- 6 Reference Information
- 7 Exercise

XPath 2.0

An extension of XPath 1.0, backward compatible with XPath 1.0. Main differences:

Improved data model tightly associated with XML Schema.

⇒ a new **sequence** type, representing ordered set of nodes and/or values, with duplicates allowed.

⇒ XSD types can be used for node tests.

More powerful new operators (loops) and better control of the output (limited tree restructuring capabilities)

Extensible Many new built-in functions; possibility to add user-defined functions.

XPath 2.0 is **also** a subset of XQuery 1.0.

Path expressions in XPath 2.0

New node tests in XPath 2.0:

`item()` any node or atomic value

`element()` any element (eq. to `child::*` in XPath 1.0)

`element(author)` any element named `author`

`element(*, xs:person)` any element of type `xs:person`

`attribute()` any attribute

Nested paths expressions:

Any expression that returns a sequence of nodes can be used as a step.

```
/book/(author | editor)/name
```

Outline

- 1 Introduction
- 2 Path Expressions
- 3 Operators and Functions
- 4 XPath examples
- 5 XPath 2.0
- 6 Reference Information**
- 7 Exercise

XPath 1.0 Implementations

Large number of implementations.

`libxml2` Free **C** library for parsing XML documents, supporting XPath.

`java.xml.xpath` **Java** package, included with JDK versions starting from 1.5.

`System.Xml.XPath` **.NET** classes for XPath.

`XML::XPath` Free **Perl** module, includes a command-line tool.

`DOMXPath` **PHP** class for XPath, included in PHP5.

`PyXML` Free **Python** library for parsing XML documents, supporting XPath.

References

- <http://www.w3.org/TR/xpath>
- *XML in a nutshell*, Eliotte Rusty Harold & W. Scott Means, O'Reilly

Outline

- 1 Introduction
- 2 Path Expressions
- 3 Operators and Functions
- 4 XPath examples
- 5 XPath 2.0
- 6 Reference Information
- 7 Exercise**

Exercise

```
<a>
  <b><c /></b>
  <b id="3" di="7">bli <c /><c><e>bla</e></c></b>
  <d>bou</d>
</a>
```

We suppose that all text nodes containing only whitespace are removed from the tree.

- Give the result of the following XPath expressions:
 - ▶ `//e/preceding::text()`
 - ▶ `count(//c|//b/node())`
- Give an XPath expression for the following problems, and the corresponding result:
 - ▶ Sum of all attribute values
 - ▶ Text content of the document, where every "b" is replaced by a "c"
 - ▶ Name of the child of the last "c" element in the tree