XPath

Web Data Management and Distribution

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Outline

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.

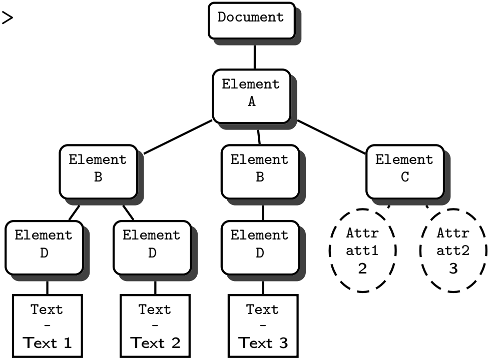
Remark

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

XPath Context

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

a context list $< N_1, N_2, \cdots, N_n >$ 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:

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

- **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: $[/]\text{step}_1/\text{step2}/\ldots/\text{step}_n$

- 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 $\texttt{step}_i$ 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;

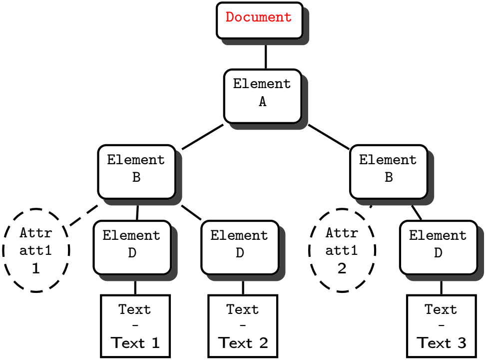
For $i > 1$ if $\mathscr{N} = < N_1, N_2, \cdots, N_n >$ is the result of step $\texttt{step}_{i-1}$, $\texttt{step}_i$ is successively evaluated with respect to the context $[\mathscr{N}, N_j]$, for each $j \in [1, n]$.

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.

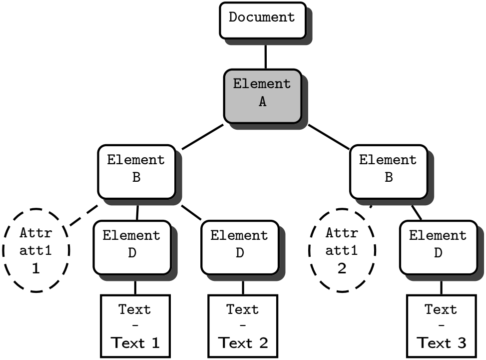
The first step, A, is evaluated with respect to this context.



Evaluation of `/A/B/@att1`

The result is A, the root element.

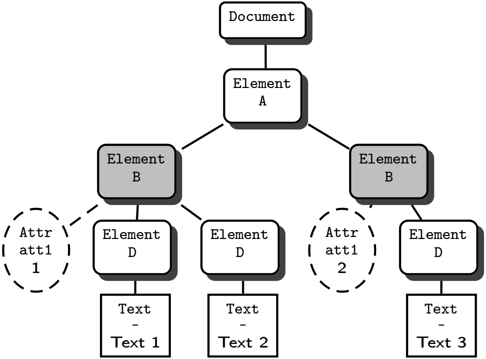
A is the context for the evaluation of the second step, `B`.



Evaluation of /A/B/@att1

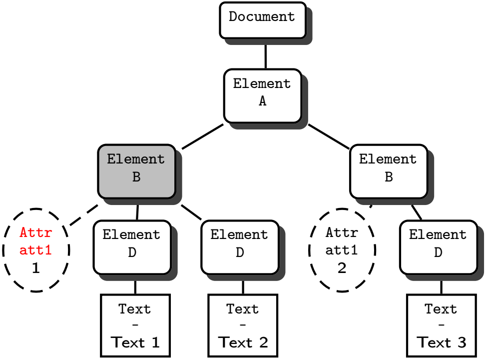
The result is a node list with two nodes B[1], B[2].

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



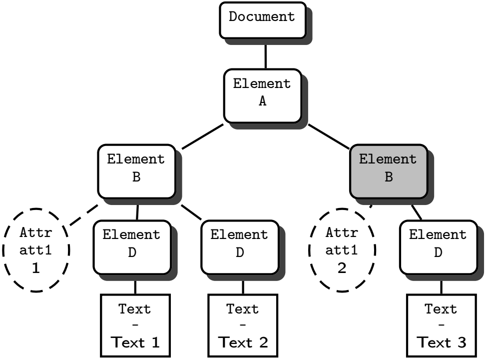
Evaluation of /A/B/@att1

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



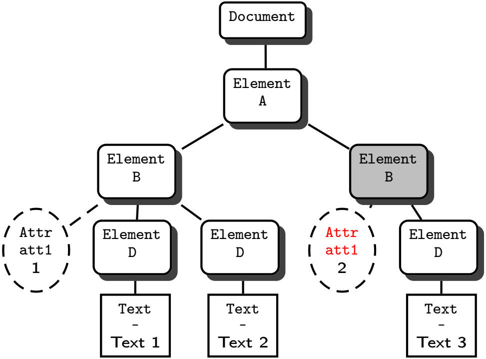
Evaluation of /A/B/@att1

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



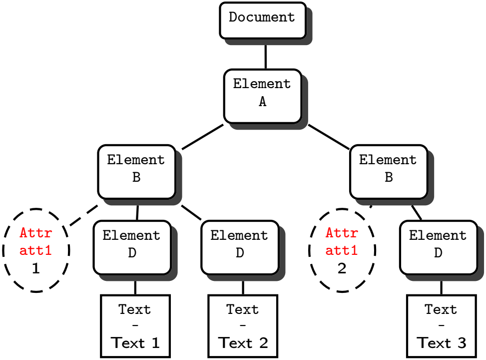
Evaluation of `/A/B/@att1`

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.

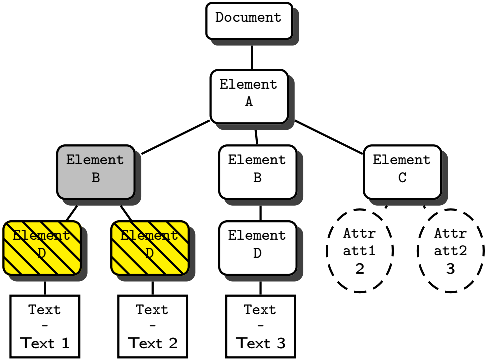
- `child` (default axis).
- `parent` Parent node.
- `attribute` Attribute nodes.
- `descendant` Descendants, excluding the node itself.
- `descendant-or-self` Descendants, including the node itself.
- `ancestor` Ancestors, excluding the node itself.
- `ancestor-or-self` Ancestors, including the node 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`)



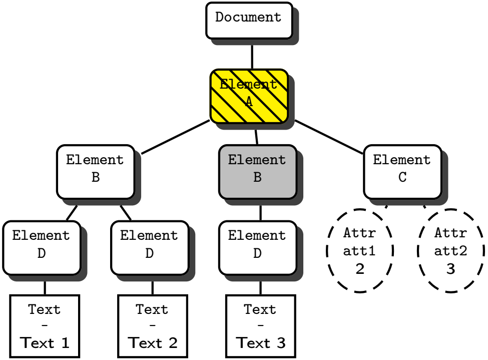
Examples of axis interpretation

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-

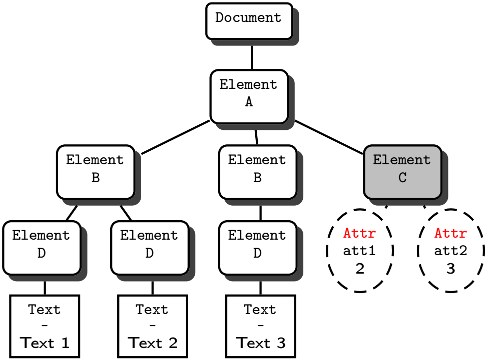
Result of `parent::node()` (may be abbreviated to `..`)



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 `@*`)



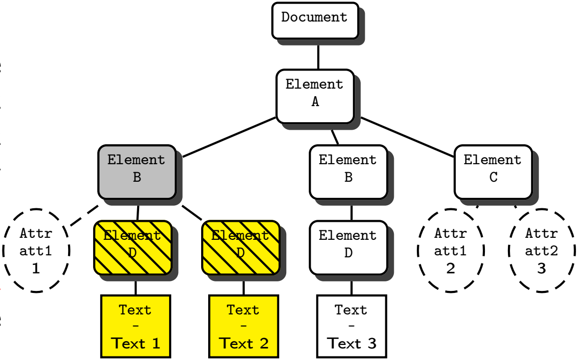
Examples of axis interpretation

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()`



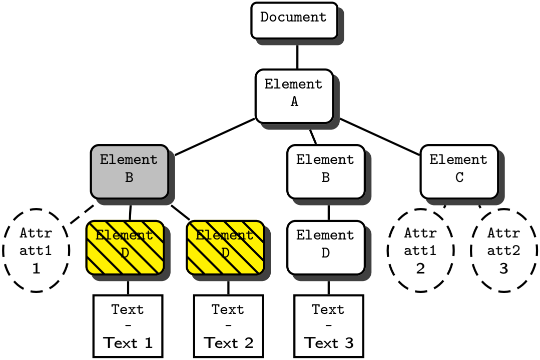
Examples of axis interpretation

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.

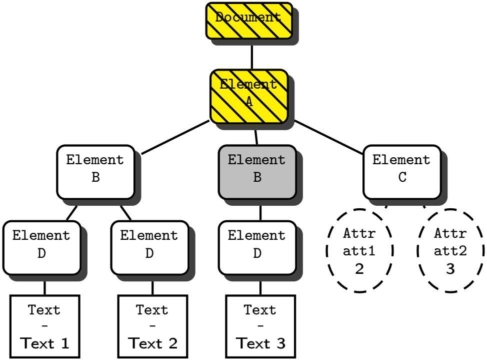
Result of `descendant::*`



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

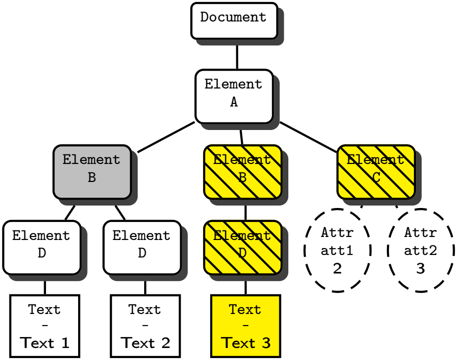
Following axis: all the nodes that follows the context node in the document order.

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()`



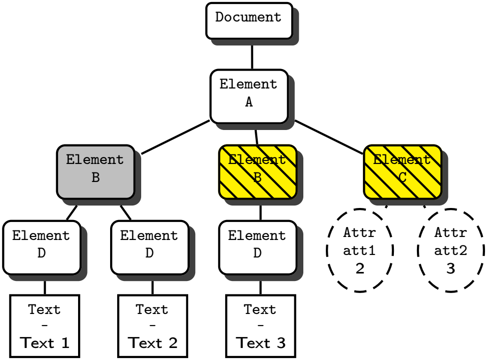
Examples of axis interpretation

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

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



Abbreviations (summary)

Summary of abbrevations:

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

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

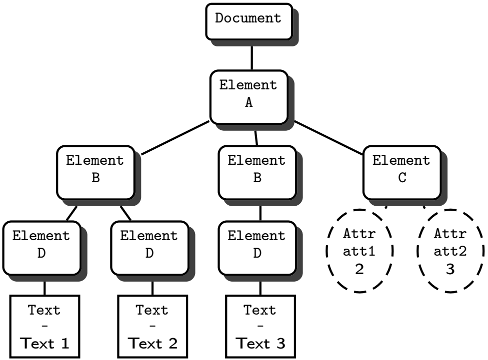
- `//B[@att1=1]`: nodes `B` having an attribute `att1` with value 1;
- `//B[@att1]`: all nodes `B` having an attributes named `att1`!
  $\Rightarrow$ `@att1` is an XPath expression whose result (a node set) is converted to a Boolean.
- `//B/descendant::text()[position()=1]`: the first **Text** node descendant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

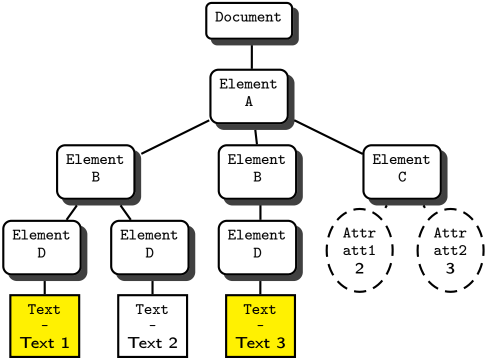
Ex.: `/A/B/descendant::text()[1]`



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	*none*	`true()`, `not($a=3)`
number	Floating-point	`12`, `12.5`	`1 div 33`
string	Ch. strings	`"to"`, `'ti'`	`concat('Hello','!')`
nodeset	Node set	*none*	`/a/b[c=1 or @e]/d`

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>
```

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

Outline

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 $\$s_1, \ldots, \$s_n$

`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

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

XPath 2.0

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

Improved data model tighly 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

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

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