XPath

MPRI 2.26.2: Web Data Management

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[a] Based on slides from the Webdam book by Serge Abiteboul, Ioana Manolescu, Philippe Rigaux, Marie-Christine Rousset, Pierre Senellart
`https://webdam.inria.fr/Jorge/files/slxpath.pdf`

Introduction

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.
  - → `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`".

XPath versions

- XPath 1.0: a W3C recommendation published in 1999
- XPath 2.0, published in 2007: based on the same data model as XQuery
- XPath 3.0, published in 2014: support for first-class functions
- XPath 3.1, published in 2017: moving towards support for JSON

→ Focus on XPath 1.0 because it is the most widely used

XPath Data Model

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

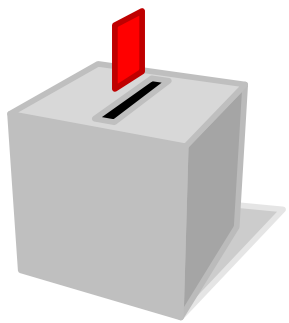
- **Document**: the root node of the XML document;
- **Element**: element nodes;
- **Attribute**: attribute nodes, represented as children of an **Element** node;
- **Text**: text nodes, i.e., leaves of the XML tree.
- Also **ProcessingInstruction** and **Comment**.

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

POLL: XML trees

How many nodes in the XML tree for `<a b="c">d</a>`

- **A**: 2
- **B**: 3
- **C**: 4
- **D**: 5



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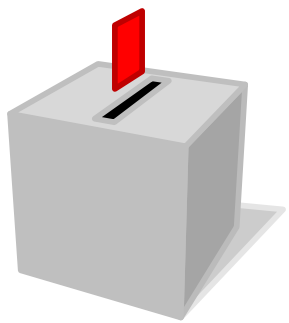
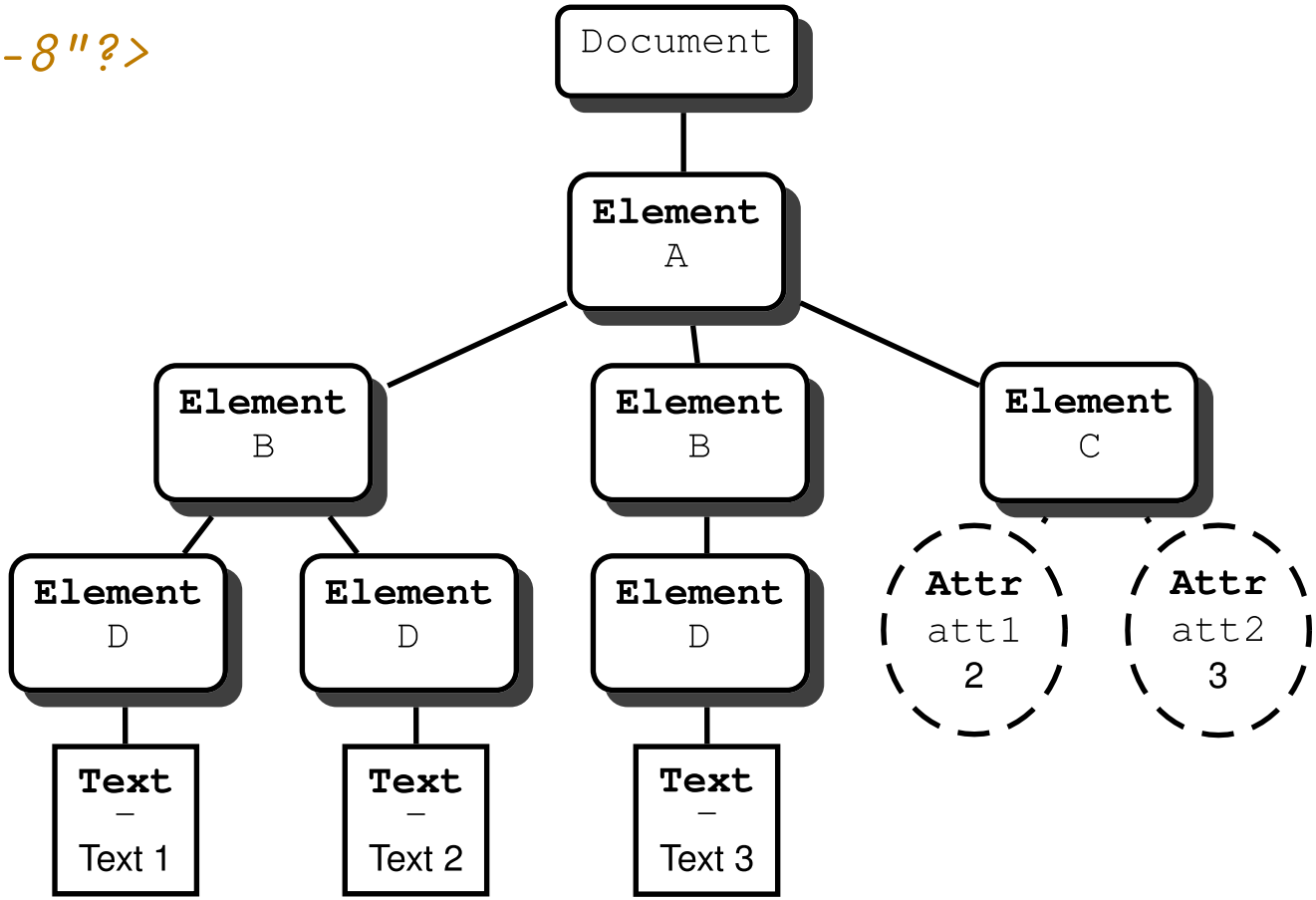


From serialized representation to XML trees

```
<?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 att2="a"
     att3="b"/>
</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 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.

Path Expressions

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()`.

The context list never contains duplicates and is always sorted in document order

XPath steps

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

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

axis is an **axis name** giving the direction of the step

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

The P_i are **predicates**: XPath expressions, evaluated as Booleans, indicating additional conditions

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`, descendant of the context node, having an **Attribute** node `att1` with value `1`

Path Expressions

A path expression is of the form: [/]$\text{step}_1/\text{step}_2/\ldots/\text{step}_n$

- 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` (of a `B` node child of the `A` root element) whose value is > 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;

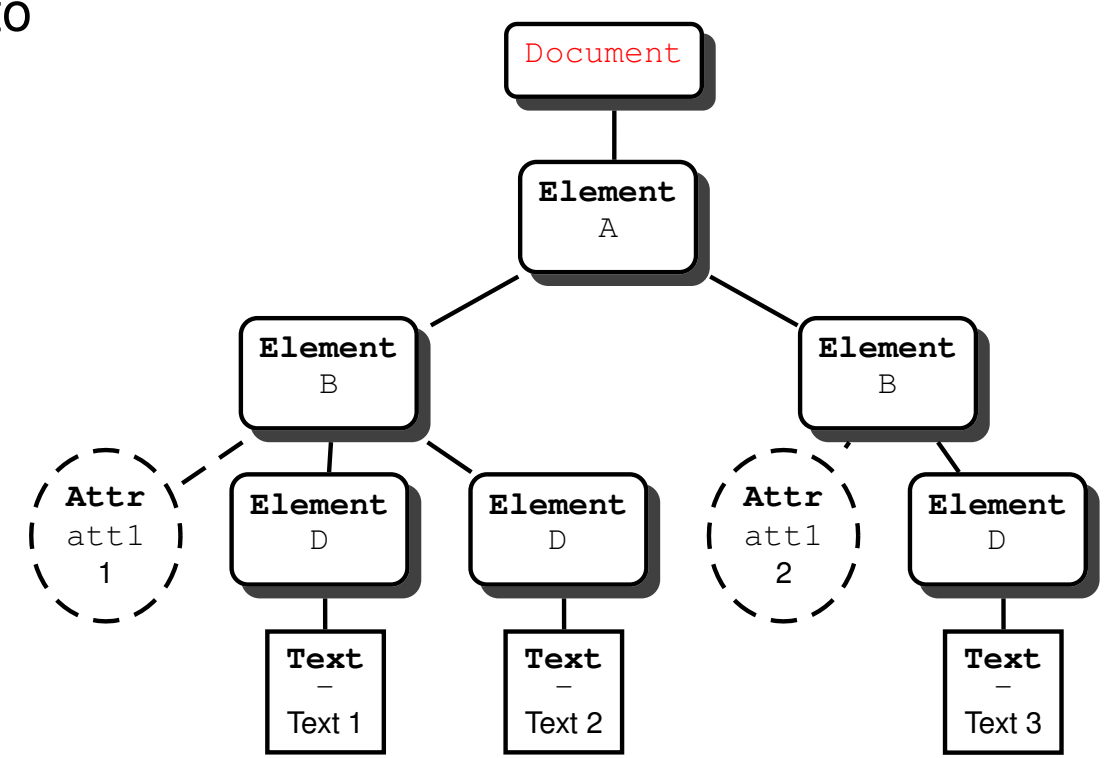
For $i > 1$ if $\mathcal{N} =< N_1, N_2, \cdots, N_n >$ is the result of step $\texttt{step}_{i-1}$, $\texttt{step}_i$ is successively evaluated with respect to the context $[\mathcal{N}, N_j]$, for each $j \in [1, n]$, and the union of all returned nodes (in document order) gives the result of the step.

The result of the path expression is the node set which is the result of the last step.

Evaluation of `/A/B/@att1`

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

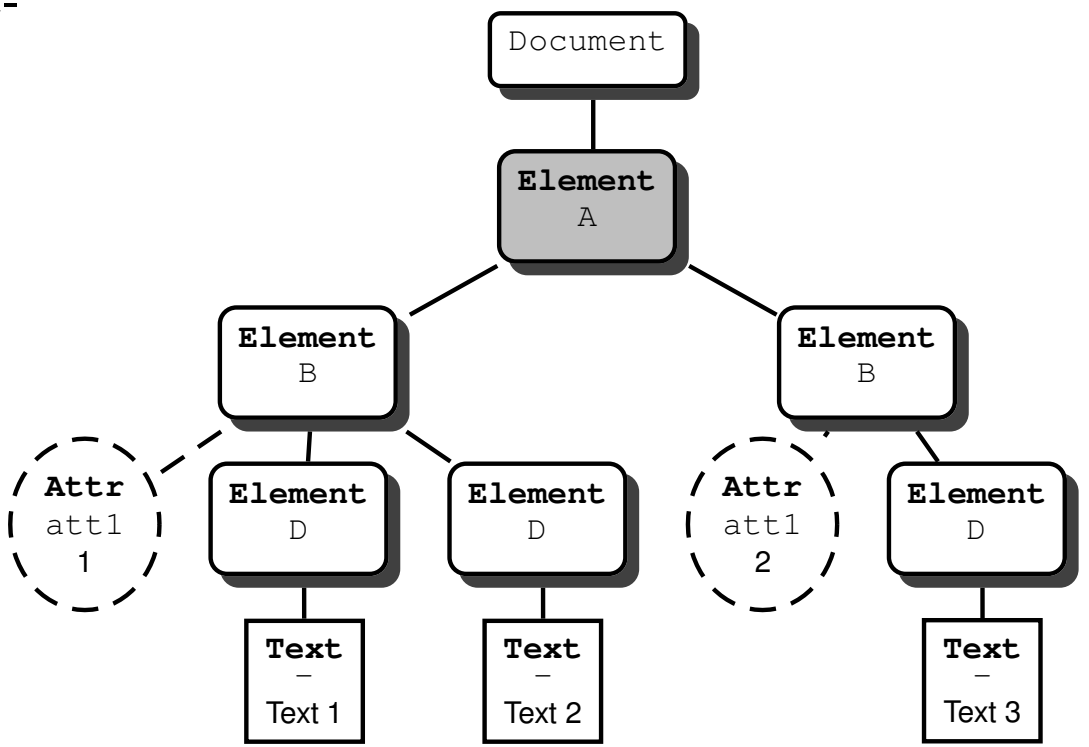
The first step, `A`, is evaluated with respect to this context.



Evaluation of `/A/B/@att1`

The result is A, the root element.

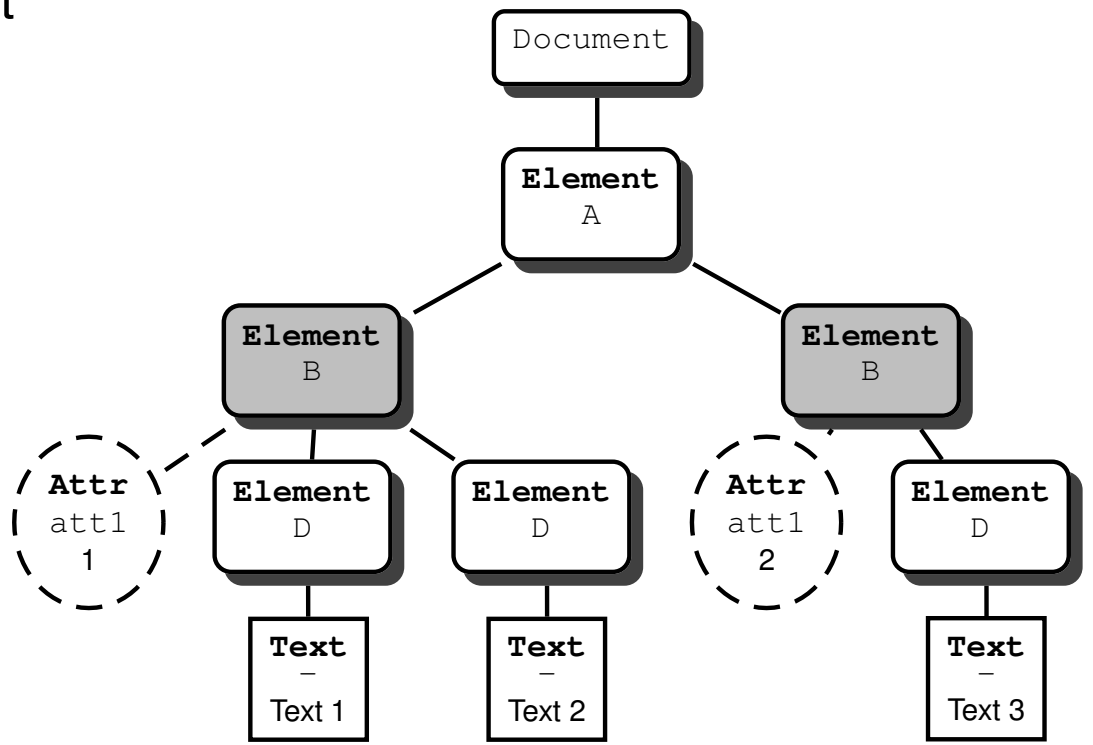
A is the context for the evaluation of the second step, `B`.



Evaluation of `/A/B/@att1`

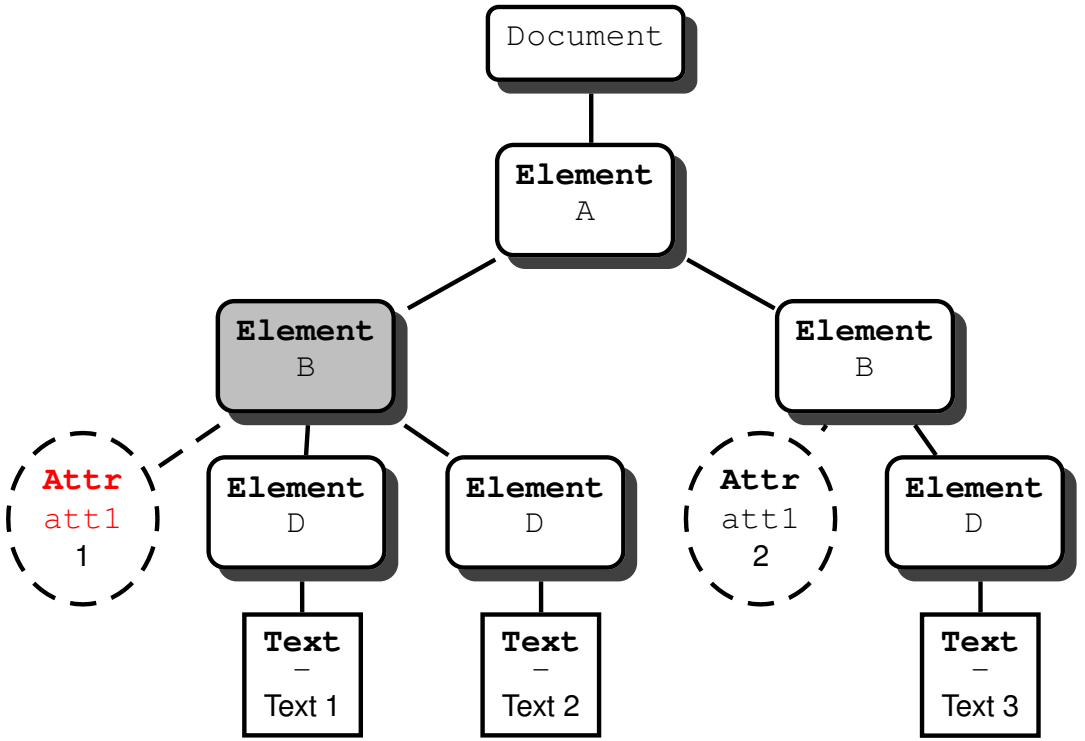
The result is a node list with two nodes B[1], B[2].

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



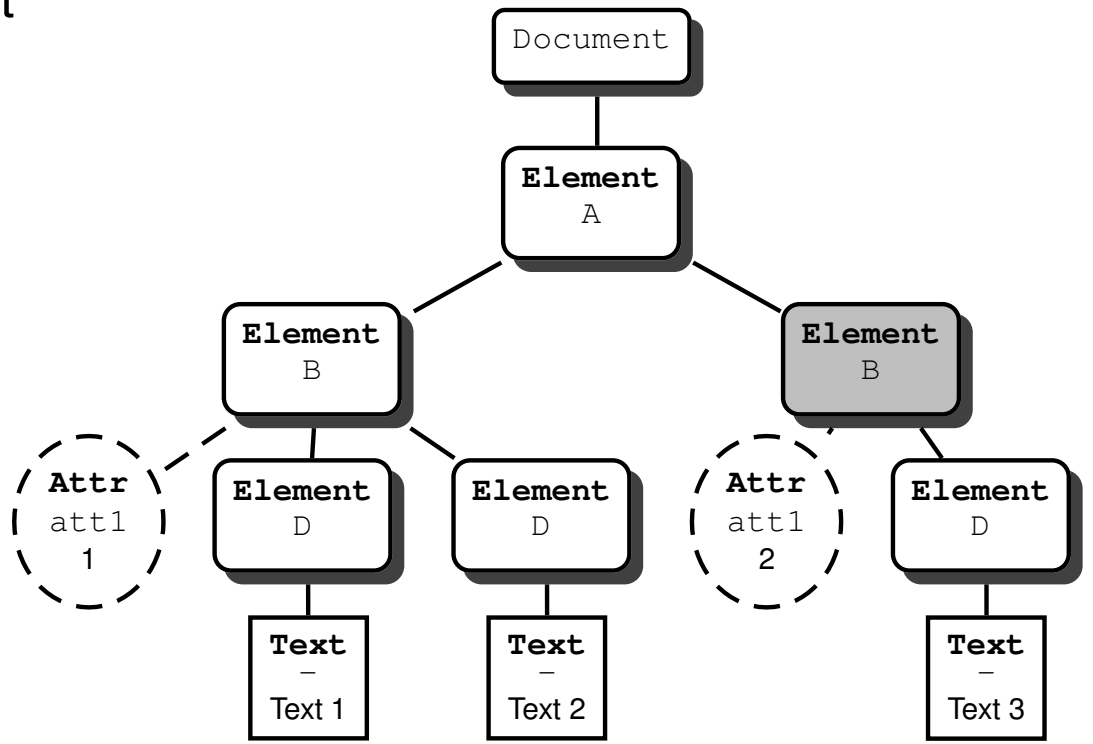
Evaluation of `/A/B/@att1`

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



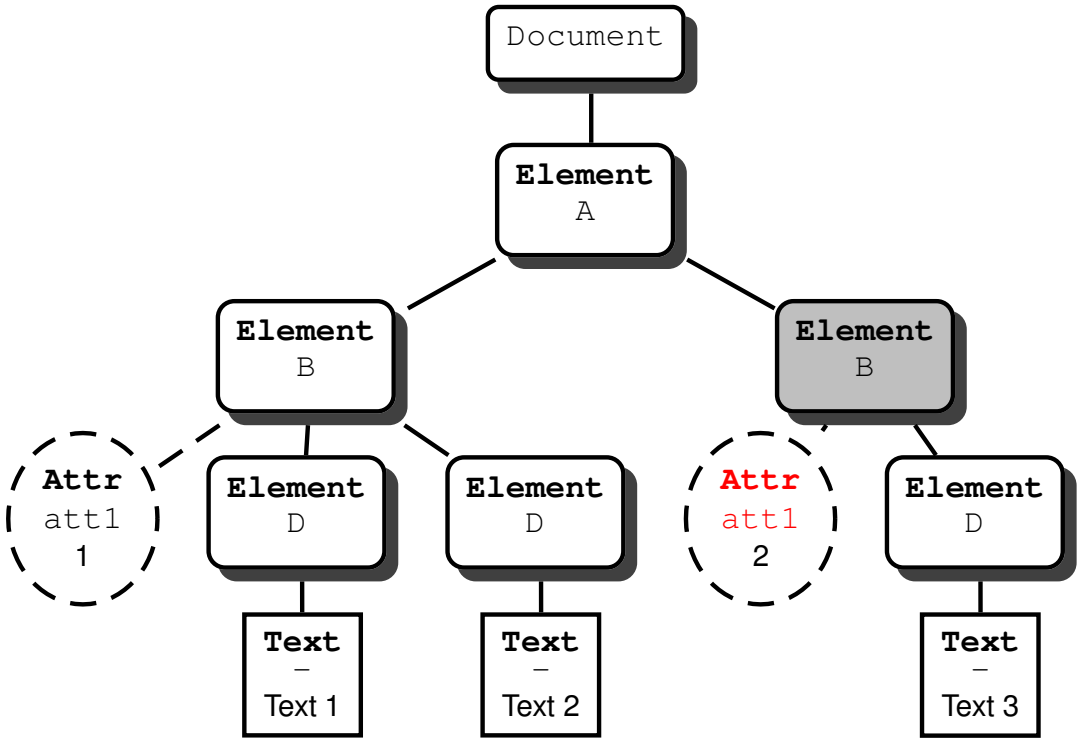
Evaluation of `/A/B/@att1`

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



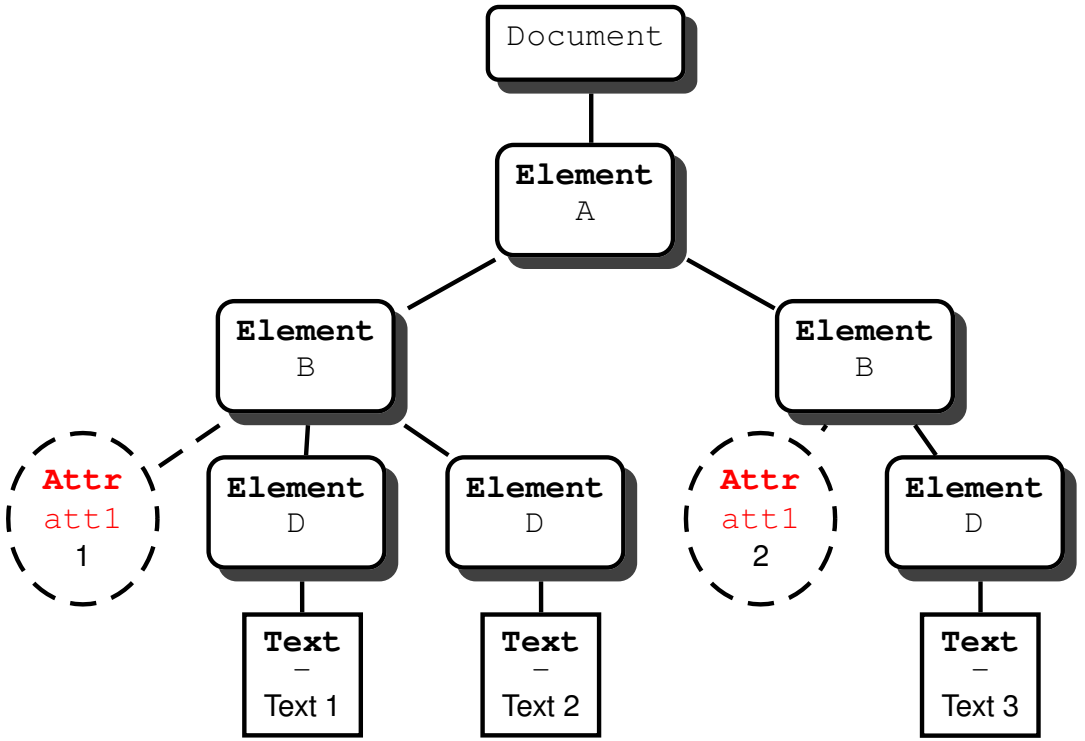
Evaluation of `/A/B/@att1`

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.

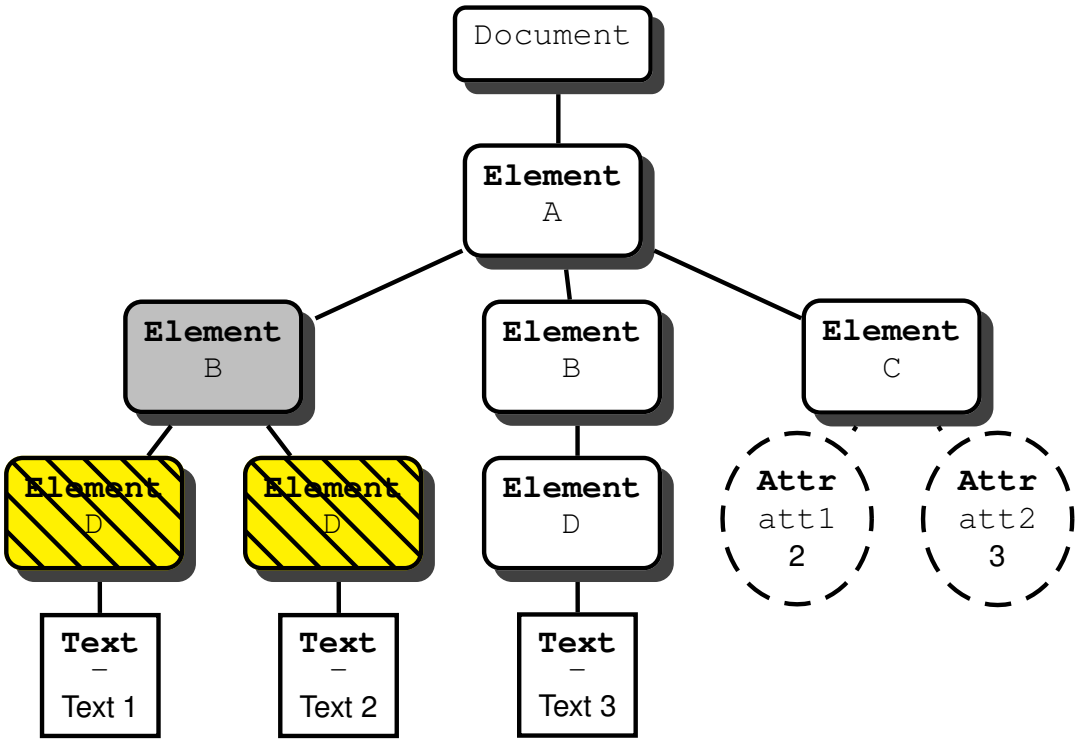
- `child`: (**default axis**).
- `parent`: Parent node.
- `attribute`: Attribute nodes.
- `descendant`: Descendants, excluding the node itself.
- `descendant-or-self`: Descendants, including the node itself.
- `ancestor`: Ancestors, excluding the node itself.
- `ancestor-or-self`: Ancestors, including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

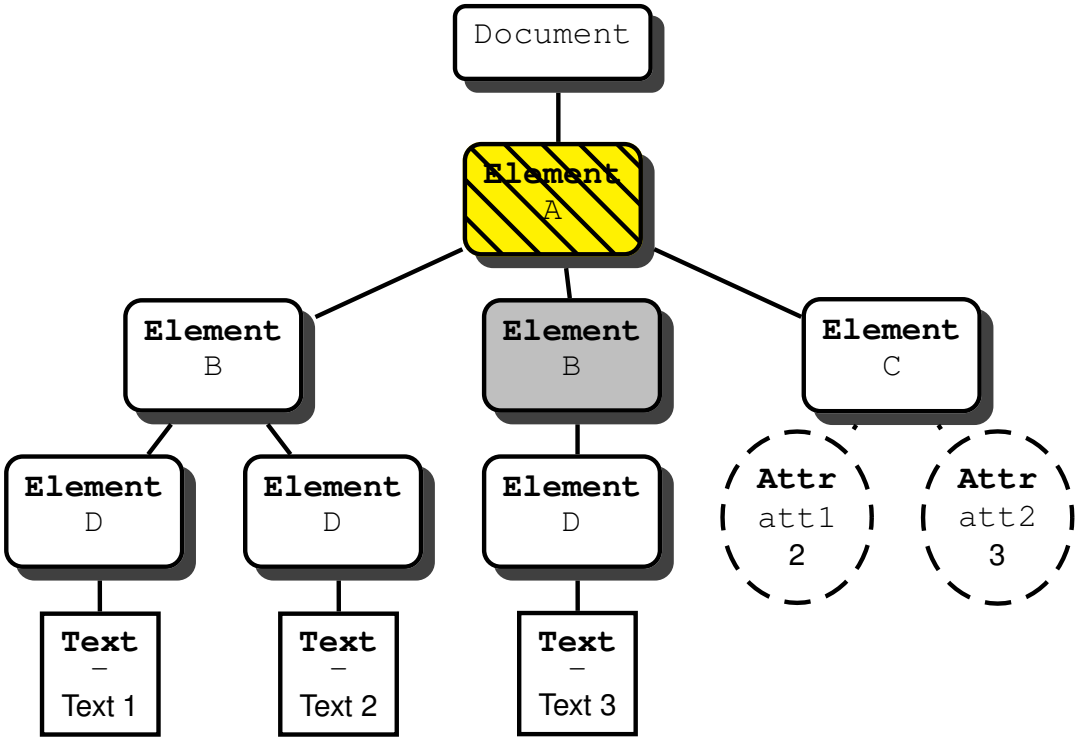
Result of `child::D` (equivalent to `D`)



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.

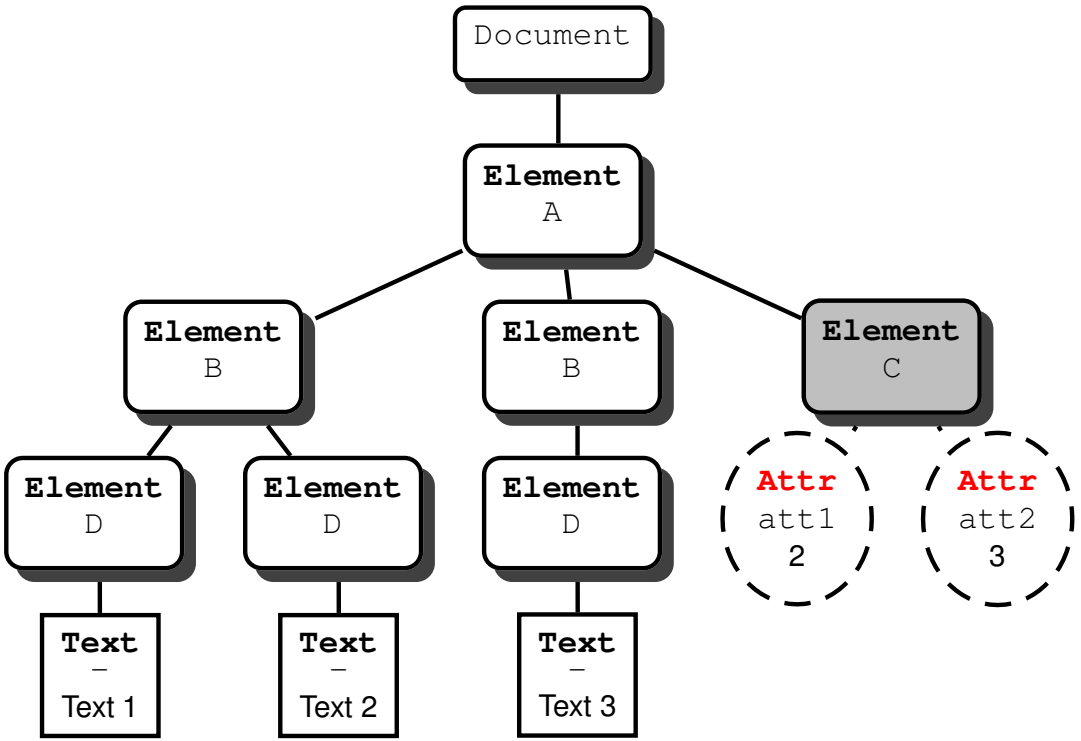
Result of `parent::node()` (may be abbreviated to `..`)



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.

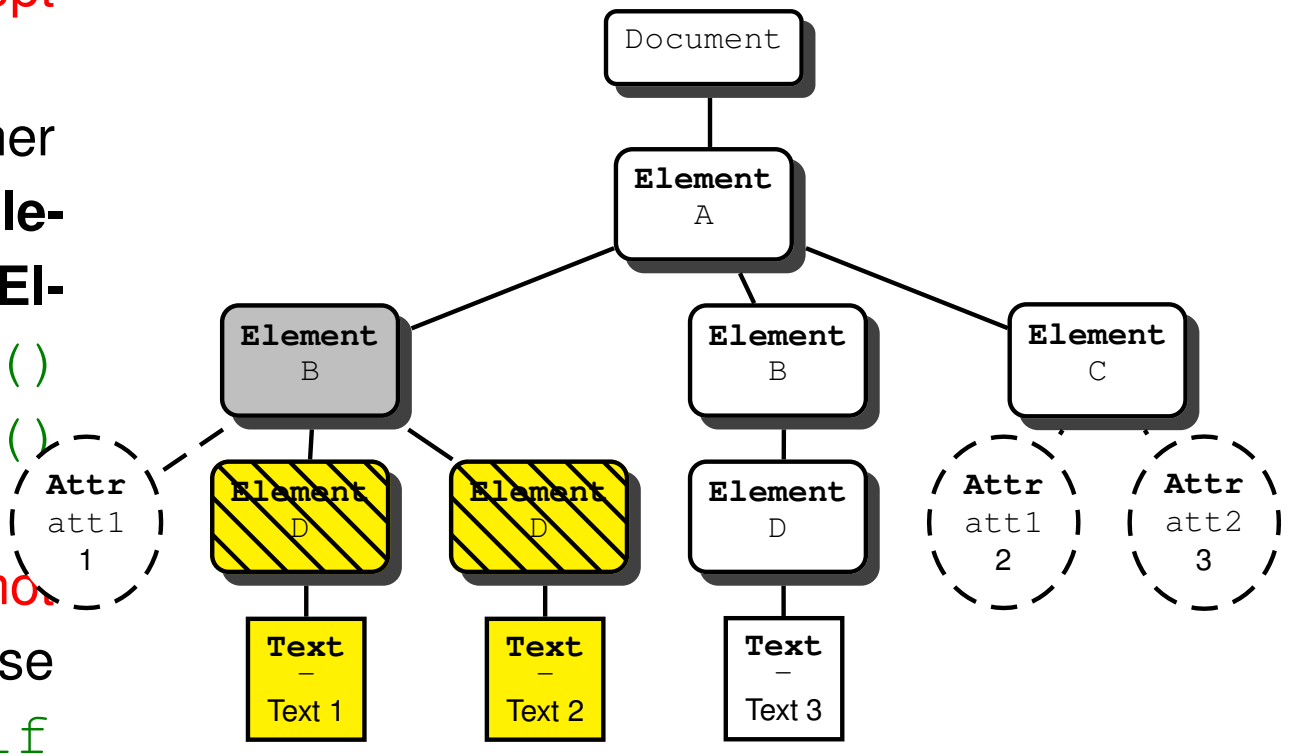
Result of `attribute::*` (equiv. to `@*`)



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()`



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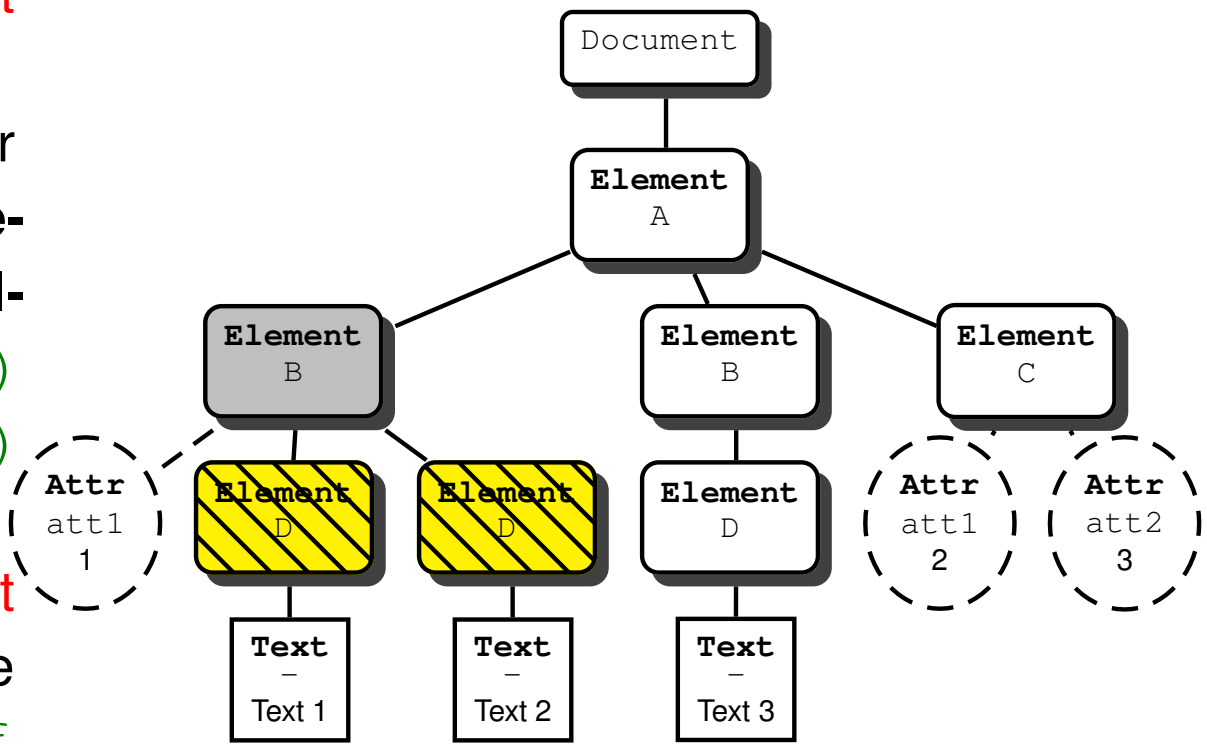
The context node does not belong to the result: use `descendant-or-self` instead.

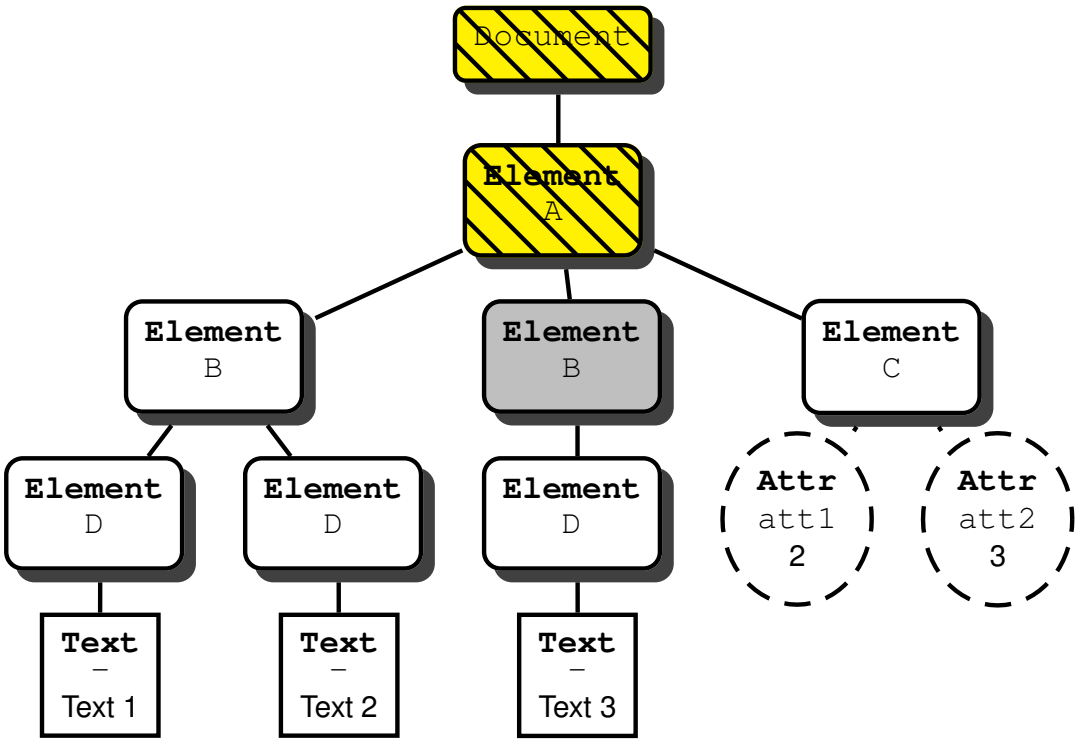
Result of `descendant::*`



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.

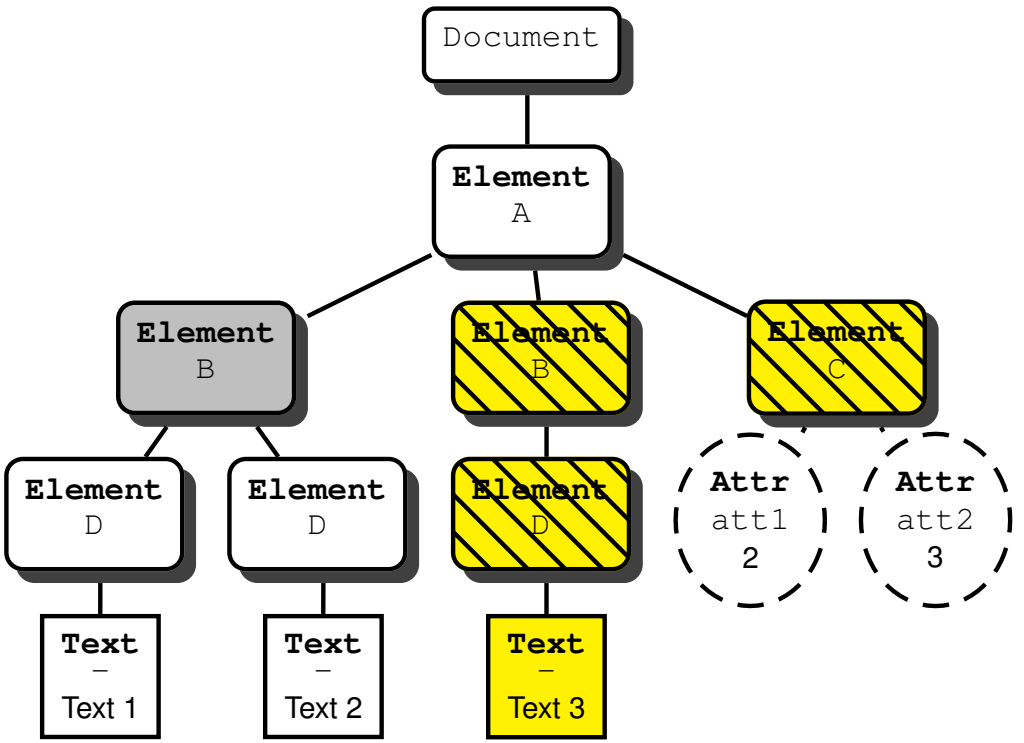
Result of `ancestor::node()`



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()`



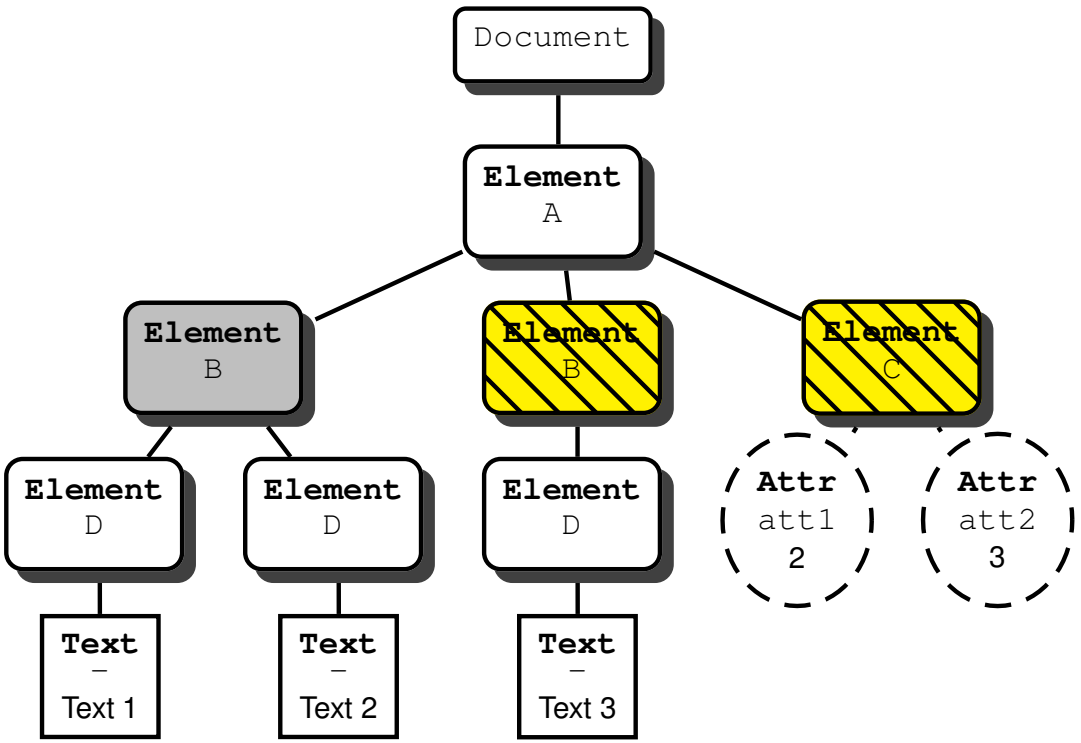
Examples of axis interpretation

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)

`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 element siblings of the context node, itself included (if it is an element node)

`//@someattr` selects all `someattr` attributes

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 in the namespace bound to the prefix `ns`
`toto`	any element whose name is `toto`

Examples

`a/node()`	selects all nodes which are children of an `a` node, itself child of the context node
`xsl:*`	selects all elements whose namespace is bound to the prefix `xsl` 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

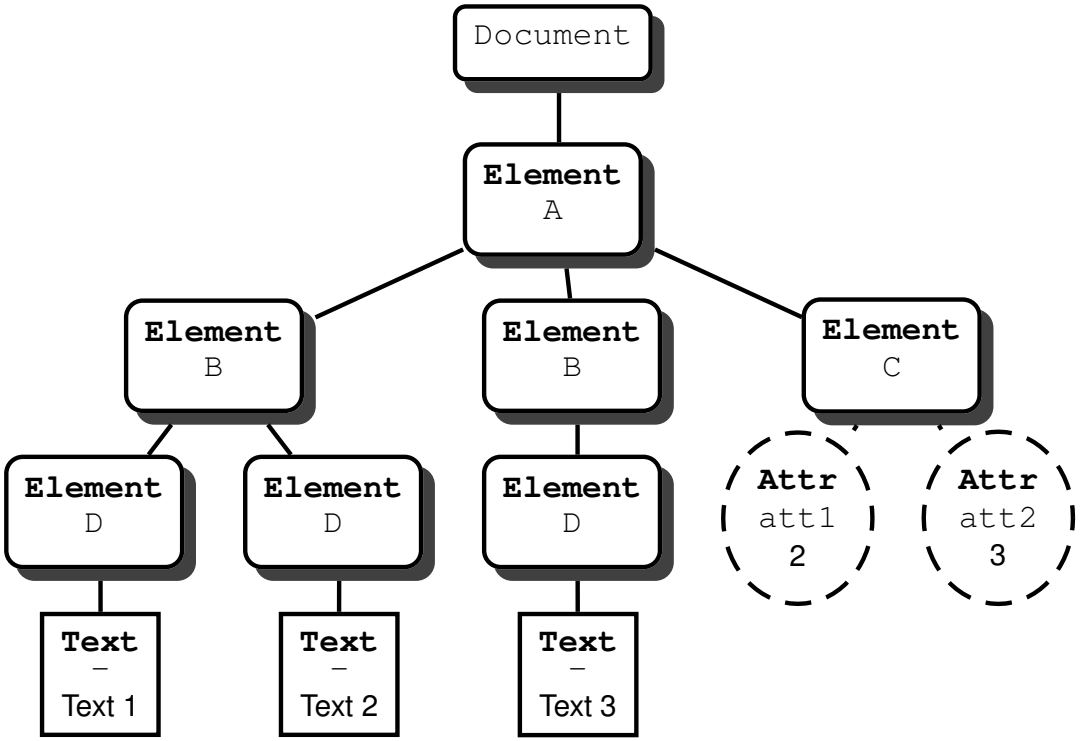
- `//B[@att1=1]`: nodes `B` having an attribute `att1` with value 1;
- `//B[@att1]`: all nodes `B` having an attribute named `att1`
- `//B/descendant::text()[position()=1]`: the first **Text** descendant of each `B`. Also: `//B/descendant::text()[1]`.

Predicate evaluation

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

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

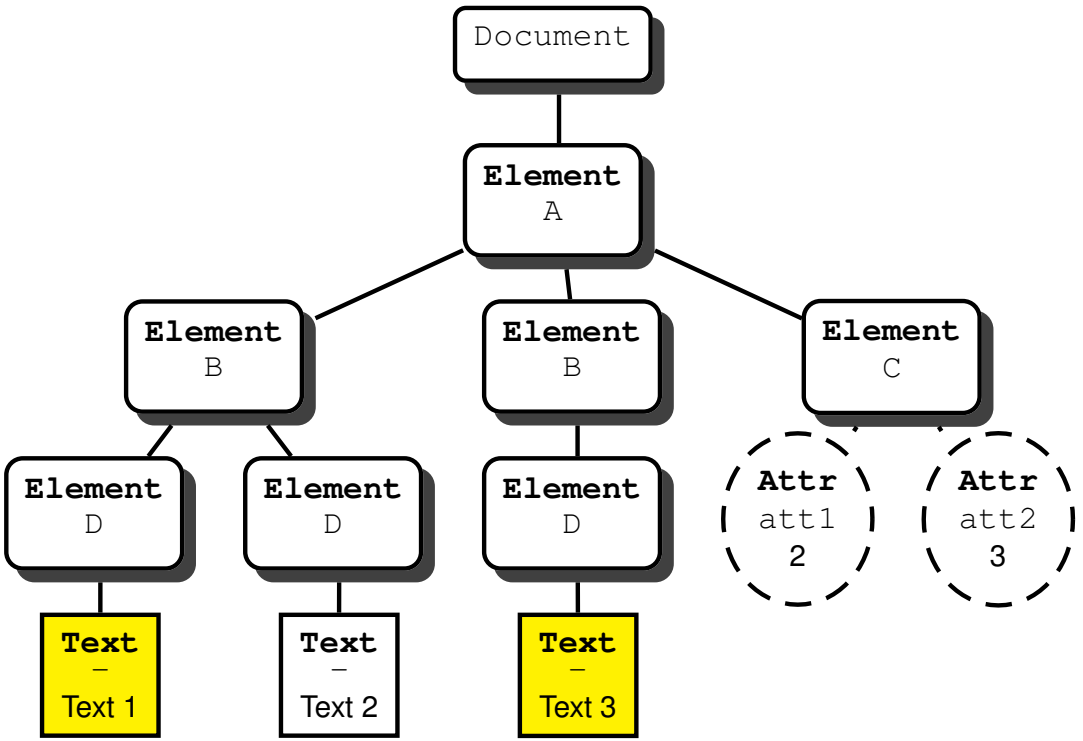
- First `axis::node-test` is evaluated: one obtains an intermediate result *I*
- Second, for each node in *I*, *P* is evaluated: the step result consists of those nodes in *I* for which *P* is true.



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/descendant::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	Strings	`"to"`, `'ti'`	`concat('Hello',',!')`
nodeset	Node set	*none*	`/a/b[c=1 or @e]/d`

- Conversion is implicit most of the time
  - → 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.
- No way to convert to a nodeset
- `boolean()`, `number()`, `string()` for explicit conversions

Operators and Functions

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.

`<, <=, >=, >` relational operators (Example: `($a<2) and ($a>0)`). If an XPath expression is embedded in an XML document, `<` must be escaped as `<`.

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

String Functions

`concat($s1,...,$sn)` concatenates the strings $s_1, \ldots, s_n$

`starts-with($a,$b)` returns `true()` if `$a` starts with `$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).

`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

`translate($a,$b,$c)` returns `$a` where all occurrences of a char of `$b` has been replaced by the corresponding one 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 "`titi toto`"

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

`round(3.457)` returns the number 3

XPath examples

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.

`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`

XPath 2.0

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
```

Reference Information

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.

Actual tools

```
xmllint --shell file.xml
> cat /my/expression/

xmlstarlet -t -m /my/expression -c . file.xml
```

References

- `https://www.w3.org/TR/xpath`
- *XML in a nutshell*, Eliotte Rusty Harold & W. Scott Means, O'Reilly
- *XPath 2.0 Programmer's Reference*, Michael Kay, Wrox