

Course: The XPath Language

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Why XPath?

Search, selection and extraction of information from XML documents are essential for any kind of XML processing.

- XPath is the W3C standard language for expressing traversal and navigation in XML trees.

XPath Introduction

- A common syntax and semantics for many web languages
- A W3C recommendation (www.w3.org/TR/xpath)
- Compact syntax, not in XML, for use within XML attributes
- A language for expressing paths
- XPath operates on the logical (tree) structure of XML documents, not on their syntax

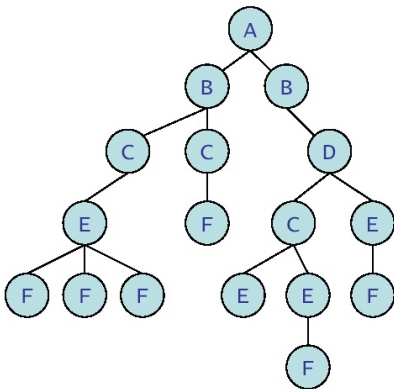
XPath Expressions

- XPath provides a powerful mechanism for navigating in XML trees: the *location path*
- A *location path* is a sequence of *location steps* separated by '/':

$$\underbrace{\text{child} :: \text{chapter}}_{\text{location step}} / \underbrace{\overbrace{\text{descendant}}^{\text{axis}} :: \overbrace{\text{section}}^{\text{nodetest}}}_{\text{location step}} / \underbrace{\text{child} :: \text{para}}_{\text{location step}}$$

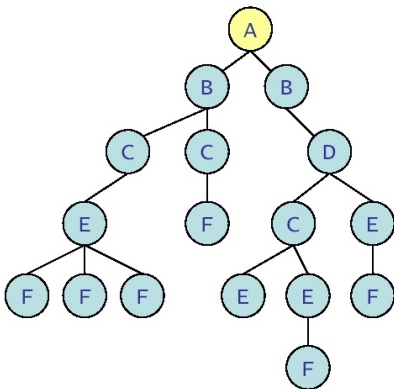
Evaluating a *location path*

- Starting from a context node, a *location path* returns a *node-set*
- Each node of this *node-set* becomes in turn the context node for evaluating the next *step*



Evaluating a *location path*

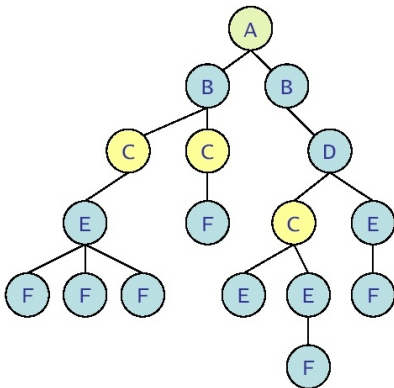
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Context node

Evaluating a *location path*

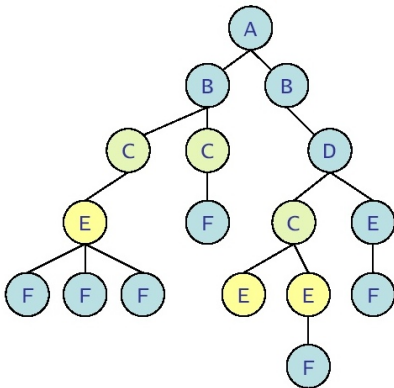
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descendant::C

Evaluating a *location path*

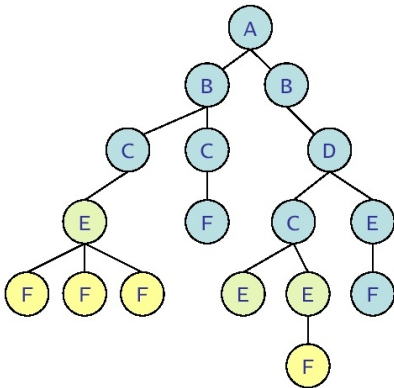
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descendant::C/child::E

Evaluating a *location path*

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descendant::C/child::E/child::F

Evaluation Context

- Every XPath expression is evaluated with respect to a *context* that includes:
 - the *context node*
 - 2 integers > 0 obtained from the evaluation of the last *step*:
 - *context size*: the number of nodes in the *node-set*
 - *context position*: the index of the context node in the *node-set*
 - a set of variable bindings (expressed in the host language)
- Navigation “propagates” the *context*: evaluation of a *step* yields a new *context state*
- Remark: a *location path* starting with '/' indicates that the initial *context* is set to the root of the document, such a *location path* is called “*absolute*”

Zoom on *location steps*

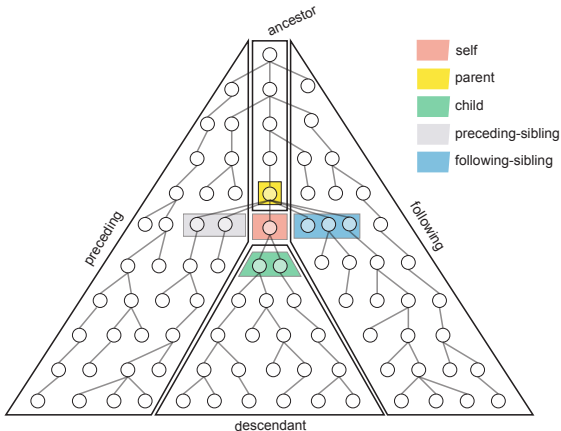
- A each navigation step, nodes can be filtered using *qualifiers*
- General syntax of a *location step*:

axis::nodetest[qualifier][qualifier]

- A *location step* is composed of 3 parts:
 1. an *axis*: specify the relation between the context node and returned nodes
 2. a *nodetest*: type and name of returned nodes
 3. optional *qualifiers* that further filter nodes
- Qualifiers are applied one after the other, once the selection is performed by the *axis* and *nodetest*
- A qualifier returns a *node-set* that is filtered by the next qualifier
- Example: `child::section[child::para][child::b]`

Axes

- Indicates where in the tree (with respect to the context node) selected nodes must be searched
- XPath defines 13 *axes* allowing navigation, including:



- 5 *axes* define a partition of tree nodes

Axes

- Each *axis* has a direction: forward or backward (w.r.t *document ordering*)
- Other axes:
 - ancestor-or-self, descendant-or-self
 - attribute: selects attributes of the context node (element)
 - namespace: selects namespace nodes of the context node

Nodetest

- The *nodetest* of a *location step* indicates which nodes must be chosen on the considered *axis*
- A *nodetest* filters nodes, e.g.:

Test	Semantics
<code>node()</code>	let any node pass
<code>text()</code>	preserve only text nodes
<code>comment()</code>	preserve only comment nodes
<i>name</i>	preserve only elements/attributes with tag " <i>name</i> "
*	preserve arbitrary elements/attributes

- Remarks:

1. $path/child::* \subseteq path/child::node()$
2. $path/attribute::node() \not\subseteq path/child::node()$

Qualifier

- A *qualifier* filters a *node-set* depending on the *axis* and returns a *newnode-set*
- A *qualifier* is a boolean expression evaluated depending on the *context*:
 - context node
 - *context size*: number of nodes in the *node-set*
 - *context position*: index of the context node in the *node-set*, in the order of the document (or in reverse document order for *backward axes*)
- Each node of a *node-set* is kept only if the evaluation of the *qualifier* for this node returns *true*
- Examples:
 - `following-sibling::para[position()=last()]`
 - `child::para[position() mod 2 = 1]`

Value Comparisons

- *Qualifiers* may include comparisons:

$path[path_1 \text{ eq } path_2]$ $\text{eq} \in \{=, \neq, <, >, \leq, \geq\}$

- **Existential** semantics:

$node\text{-}set_1 \text{ eq } node\text{-}set_2$
iff

$\exists n_1 \in node\text{-}set_1, \exists n_2 \in node\text{-}set_2 \mid \text{string}\text{-}value(n_1) \text{ eq } \text{string}\text{-}value(n_2)$

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- $\text{string}\text{-}value(n)$: concatenation of all descendant text nodes in *document order*
 - Example: descendant::chapter[child::section="Conclusion"]
- all “chapter” nodes whose **at least one** “section” child has *string-value* “Conclusion”.

Value Comparisons

- *Qualifiers* may include comparisons:

$path[path_1 \text{ eq } path_2]$ $eq \in \{=, !=, <, >, <=, >=\}$

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- $\text{string-value}(n)$: concatenation of all descendant text nodes in *document order*
 - Example: descendant::chapter[child::section="Conclusion"]
- all “chapter” nodes whose **at least one** “section” child has *string-value* “Conclusion”.
- Comparisons may involve (implicit) type casting (ex: a[b>7])

General XPath Expressions

- A general XPath *expression* is a *location path*, or a union of *location paths* separated by '|'
- *Qualifiers* may include boolean expressions:
`path[(path eq path) or (qualifier and not(qualifier))]`
- An XPath expression may include *variables* (notation: \$x)
 - variables are bound by the host language (i.e. they are constants ☺)
 - they are part of the evaluation context

Observation on Data Value Comparisons

- Assume variable $\$x$ is bound to a *node-set*
- What do you think of the following XPath expressions e_1 and e_2 ?

$\$x="foo"$
⏟
 e_1

$\text{not}(\$x!="foo")$
⏟
 e_2

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- e_1 is different from e_2 :
 - e_1 is true iff there exists a node in $\$x$ which has *string-value* foo;
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¹have an empty *string-value*

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- Owing to **negation** and comparison defined by **existential quantification**, we can formulate **universal quantification**...
 - “chapter” nodes whose **all** children “section” are empty¹?
 - `descendant::chapter[not(child::section!="")]`

¹have an empty *string-value*

Basic Functions

- *Node-sets* are not the only types of XPath expressions: there are *boolean*, *numerical* and *string* expressions too
- Every XPath implementation must provide at least a list of basic functions called *Core Function Library* (c.f. appendix)
- Examples:
 - `last()`: a number, the *context size*
 - `position()`: a number, the *context position*
 - `count(node-set)`: number of nodes in the *node-set*
 - `concat(string, string, string*)`: concatenate several strings
 - `contains(str1, str2)`: boolean, true if *str1* contains *str2*
 - ...
- Any XPath expression can be used within a *qualifier*, for instance:

```
descendant::recipe[count(descendant::ingredients)<5 and  
contains(child::title, "cake")]
```

Abbreviated Syntax

- `child::` is the default axis, it can be omitted
- `@` is a shorthand for `attribute::`
- `//` is a shorthand for `/descendant-or-self::node()/`
- `.` is a shorthand for `self::node()`
- `..` is a shorthand for `parent::node()`
- `[4]` is a shorthand for `[position()=4]`

Example	Expanded Form
<code>book/section</code>	<code>child::book/child::section</code>
<code>p[@id="bla"]</code>	<code>child::p[attribute::id="bla"]</code>
<code>./p</code>	<code>self::node()/descendant-or-self::node()/child::p</code>
<code>../title</code>	<code>parent::node()/child::title</code>
<code>p[3]</code>	<code>child::p[position()=3]</code>

Question...

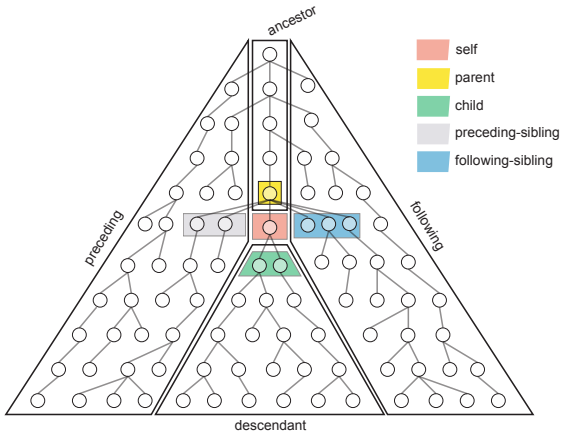
What do you think of the following XPath expressions e_1 and e_2 ?

$\underbrace{\text{self::title}}_{e_1}$

$\underbrace{\text{parent::node()/child::title}}_{e_2}$

Question...

Can we rewrite the XPath expression `following::p` without the axis `following`?



XPath: A Core Component for XML Technologies

- XPath is used in:
 - **XSLT**: selection of document parts to be transformed
 - **XQuery**: XPath is the (main) subset of the query language
 - **XPointer**: identification of XML fragments
 - **XLink**: definition of hypertext links
 - **XML Schema**: expressing the tree region in which unicity is guaranteed
 - **XForms**: expressing dependencies (data bindings)
 - ...
- Often, it is even the **essential** component

Intermediate demo (xmllint)

XPath and Static Analysis (1/2)

- Many different ways to express navigation to the same nodes
- Two XPath expressions might share the same semantics² even if they differ syntactically (and operationally!)

`child::a[child::b]/following-sibling::c`

`child::c[preceding-sibling::a[child::b]]`

- Determining query equivalence is crucial (e.g. optimization)

²The semantics of an XPath expression is to be understood as the final set of nodes resulting from the evaluation of the expression.

XPath and Static Analysis (2/2)

- What about the following expressions?

`descendant::d[parent::b]/following-sibling::a`

`ancestor-or-self::* / descendant-or-self::b/a[preceding-sibling::d]`

- Question for next time(s): how would you write a program that checks whether two XPath expressions are equivalent (i.e. return the same set of nodes when applied from the same context in any tree)?

XPath *Core Function Library*

Functions over *node-sets*

- `last()`: a number, the *context size*
- `position()`: a number, the *context position*
- `count(node-set)`: number of nodes in the *node-set*
- `id(object)`: selects elements by their unique ID
- `local-name(node-set)`: returns the local part of the expanded-name of the node in the argument *node-set* that is first in document order.
- `namespace-uri(node-set)`: returns the namespace URI of the expanded-name of the node in the argument *node-set* that is first in document order
- `name(node-set)`: returns a string containing the whole name of the node in the argument *node-set* that is first in document order

String Functions

- `string(object)`: convert *object* to a string
- `concat(string, string, string*)`: concatenate several strings
- `start-with(string1, string2)` : boolean, true if *string1* starts with *string2*
- `contains(str1, str2)` : boolean, true if *str1* contains *str2*
- `substring-before(string1, string2)`: the substring of *string1* before the first occurrence of *string2*
- `substring-after(string1, string2)`: the substring of *string1* after the first occurrence of *string2*
- `substring(string, number1, number2)`: the substring of *string* that starts at position *number1* and whose length is *number2*
- `string-length(string)`: number of characters in *string*
- `normalize-space(string)`: remove beginning, ending and double spaces
- `translate(s1, s2, s3)`: replace in *s1* each char of *s2* by the char of same position in *s3*
example : `translate("bar", "abc", "ABC")` returns BAR

Boolean Functions

- `boolean(object)`: convert *object* into boolean, returns true if non zero number, non empty *node-set*, string with non zero length
- `not(boolean)`: negation of *boolean*
- `true()`
- `false()`
- `lang(string)`: the language (attribute `xml:lang`) of context node is the same or a sublanguage of *string*

Arithmetic Functions

- `number(object)`: convert *object* into a number
- `sum(node-set)`: sum of the (type casted) number representation of each node in the *node-set*
- `floor(number)`: greatest integer less or equal to *number*
- `ceiling(number)`: smallest integer greater than or equal to *number*
- `round(number)`: the closest integer of *number*

Operator Precedence

1. `<=`, `<`, `>=`, `>`
2. `=`, `!=`
3. `and`
4. `or`

References

For those who want to learn more...

About XPath

Semantics: [1], Analysis: [2,3], Transformation: [4]

- [1] XPath Formal Semantics and Beyond: a Coq based approach. Pierre Genevès and Jean-Yves Vion-Dury. Emerging Trends Proceedings of the 17th International Conference on Theorem Proving in Higher Order Logic: TPHOLs 2004, pages 181-198.
- [2] Eliminating dead-code from XQuery programs. Pierre Genevès and Nabil Layaïda. Proceedings of the 32nd ACM/IEEE International Conference on Software Engineering (ICSE) - Volume 2, pages 305-306, 2010.
- [3] Impact of XML schema evolution. Pierre Genevès, Nabil Layaïda and Vincent Quint. ACM Transactions on Internet Technology (TOIT), volume 11, number 1.
- [4] Compiling XPath for streaming access policy. Pierre Genevès and Kristoffer Rose. Proceedings of the 2005 ACM Symposium on Document Engineering, pages 52-54, 2005.