An Introduction to XML and Web Technologies

The XPath Language

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Objectives

- Location steps and paths
- Typical locations paths
- Abbreviations
- General expressions

XPath Expressions

- Flexible notation for **navigating** around trees
- A basic technology that is **widely used**
  - *uniqueness* and *scope* in XML Schema
  - *pattern matching* an *selection* in XSLT
  - *relations* in XLink and XPointer
  - *computations* on values in XSLT and XQuery

Location Paths

- A *location path* evaluates to a **sequence** of nodes
- The sequence is **sorted** in document order
- The sequence will **never** contain **duplicates**

Locations Steps

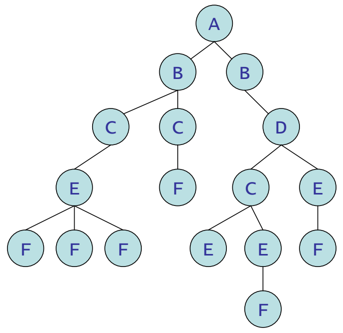
- The location path is a sequence of *steps*
- A *location step* consists of
  - an *axis*
  - a *nodetest*
  - some *predicates*

axis :: *nodetest* [*Exp*$_1$] [*Exp*$_2$] …

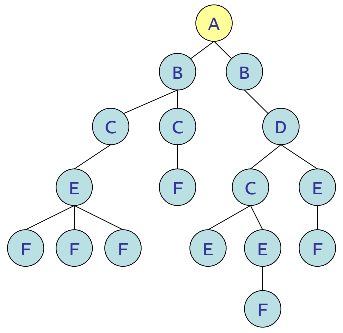
Evaluating a Location Path

- A step maps a *context node* into a sequence
- This also maps sequences to sequences
  - each node is used as context node
  - and is replaced with the result of applying the step
- The path then applies each step in turn

An Example

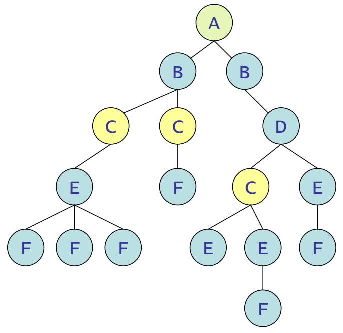


An Example



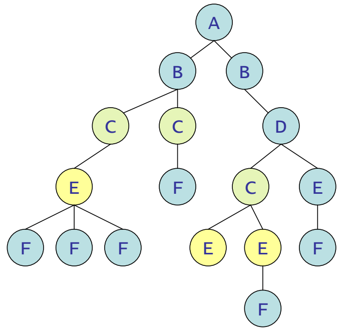
Context node

An Example



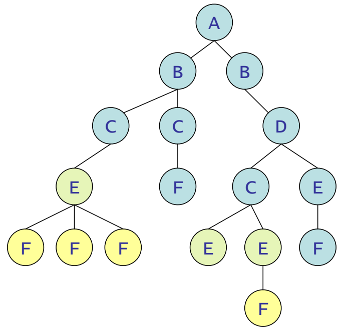
```
descendant::C
```

An Example



```
descendant::C/child::E
```

An Example



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

Contexts

- The *context* of an XPath evaluation consists of
  - a context *node* (a node in an XML tree)
  - a context *position* and *size* (two nonnegative integers)
  - a set of *variable bindings*
  - a *function library*
  - a set of *namespace declarations*
- The application determines the initial context
- If the path starts with '/' then
  - the initial context node is the root
  - the initial position and size are 1

Axes

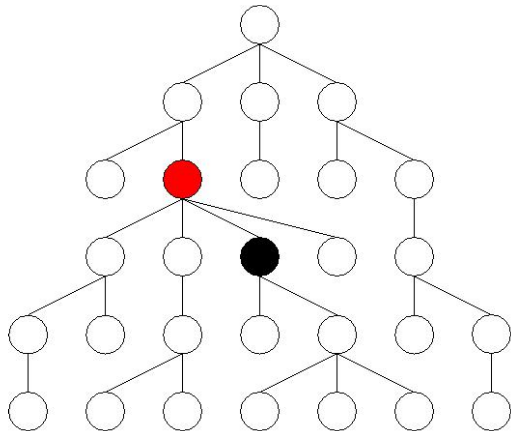
- An axis is a sequence of nodes
- The axis is evaluated relative to the context node
- XPath supports 12 different axes

•`child`	•`attribute`
•`descendant`	•`following`
•`parent`	•`preceding`
•`ancestor`	•`self`
•`following-sibling`	•`descendant-or-self`
•`preceding-sibling`	•`ancestor-or-self`

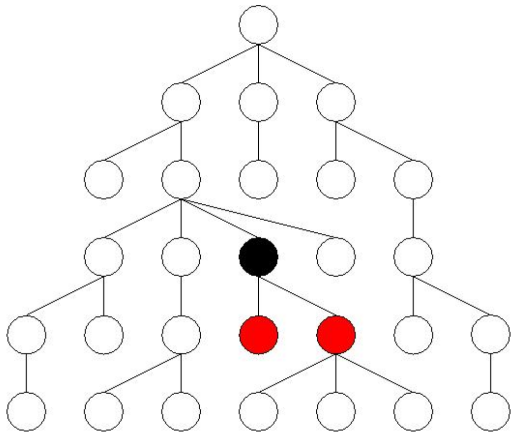
Axis Directions

- Each axis has a *direction*
- *Forwards* means document order:
  - `child, descendant, following-sibling, following, self, descendant-or-self`
- *Backwards* means reverse document order:
  - `parent, ancestor, preceding-sibling, preceding`
- Stable but depends on the implementation:
  - `attribute`

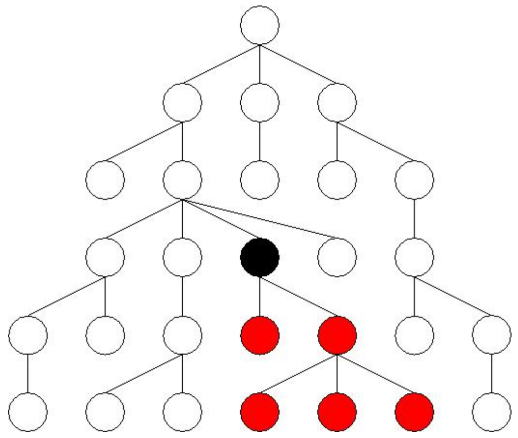
The `parent` Axis



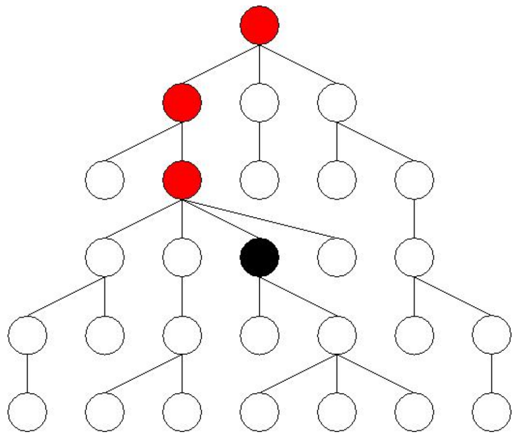
The `child` Axis



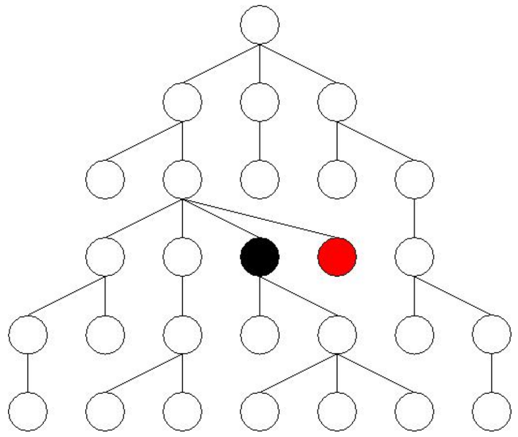
The descendant Axis



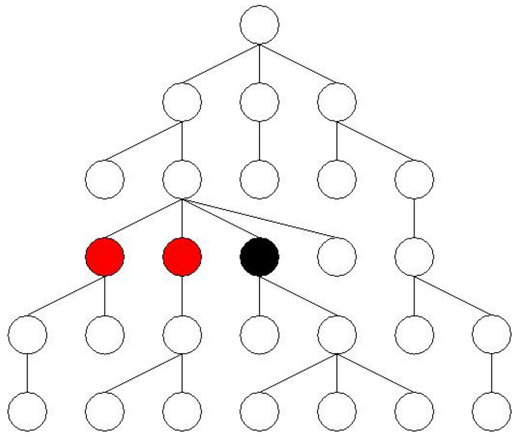
The ancestor Axis



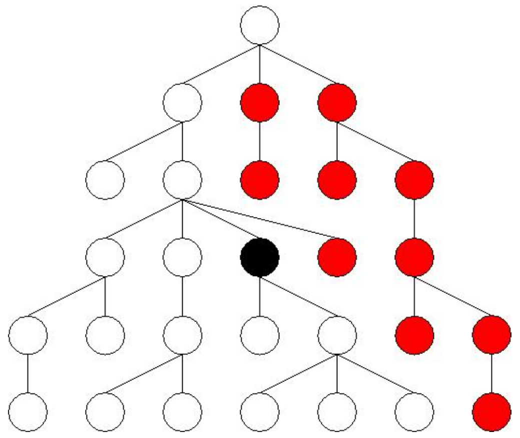
The following-sibling Axis



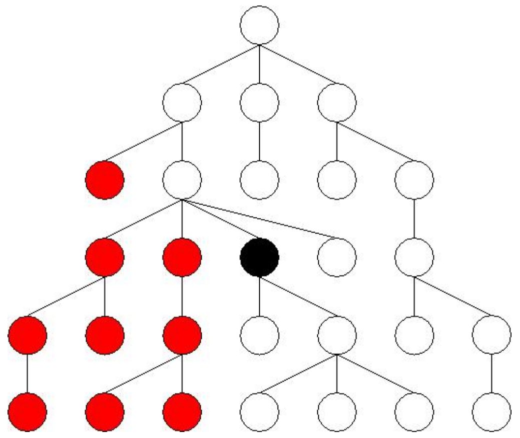
The preceding-sibling Axis



The `following` Axis



The `preceding` Axis



Node Tests

- `text()`
- `comment()`
- `processing-instruction()`
- `node()`
- `*`
- *QName*
- `*:`*NCName*
- *NCName*`:*`

Predicates

- General XPath expressions
- Evaluated with the current node as context
- Result is coerced into a boolean
  - a number yields true if it equals the context position
  - a string yields true if it is not empty
  - a sequence yields true if it is not empty

Abbreviations

```
/child::rcp:collection/child::rcp:recipe
     /child::rcp:ingredient
```

↓

```
/rcp:collection/rcp:recipe/rcp:ingredient
```

```
/child::rcp:collection/child::rcp:recipe
     /child::rcp:ingredient/attribute::amount
```

↓

```
/rcp:collection/rcp:recipe/rcp:ingredient/@amount
```

`/descendant-or-self::node()/` → `//`

`self::node()` → `.`   `parent::node()` → `..`

General Expressions

- Every expression evaluates to a *sequence* of
  - *atomic values*
  - *nodes*
- Atomic values may be
  - *numbers*
  - *booleans*
  - Unicode *strings*
  - *datatypes* defined in XML Schema
- Nodes have *identity*

Atomization

- A sequence may be *atomized*
- This results in a sequence of *atomic values*
- For element nodes this is the *concatenation* of all descendant *text nodes*
- For other nodes this is the *obvious string*

Literal Expressions

```
42
3.1415
6.022E23
'XPath is a lot of fun'
"XPath is a lot of fun"
'The cat said "Meow!"'
"The cat said ""Meow!"""
"XPath is just
     so much fun"
```

Arithmetic Expressions

- `+, -, *, div, idiv, mod`
- Operators are generalized to sequences
  - if any argument is empty, the result is empty
  - if all argument are singleton sequences of numbers, the operation is performed
  - otherwise, a runtime error occurs

Variable References

```
$foo
$bar:foo
```

- `$foo-17` refers to the variable ”`foo-17`”
- Possible fixes:
  `($foo)-17`, `$foo -17`, `$foo+-17`

Sequence Expressions

- The ’`,`’ operator concatenates sequences
- Integer ranges are constructed with ’`to`’
- Operators: `union`, `intersect`, `except`
- Sequences are always *flattened*
- These expression give the same result:

```
(1,(2,3,4),((5)),(),(((6,7),8,9))
1 to 9
1,2,3,4,5,6,7,8,9
```

Path Expressions

- Locations paths are expressions
- The may start from arbitrary sequences
  - evaluate the path for each node
  - use the given node as context node
  - context position and size are taken from the sequence
  - the results are combined in document order

Filter Expressions

- Predicates generalized to *arbitrary* sequences
- The expression '`.`' is the *context item*
- The expression:

```
(10 to 40)[. mod 5 = 0 and position()>20]
```

has the result:

```
30, 35, 40
```

Value Comparison

- Operators: `eq`, `ne`, `lt`, `le`, `gt`, `ge`
- Used on atomic values
- When applied to arbitrary values:
  - atomize
  - if either argument is empty, the result is empty
  - if either has length >1, the result is false
  - if incomparable, a runtime error
  - otherwise, compare the two atomic values

```
8 eq 4+4
(//rcp:ingredient)[1]/@name eq "beef cube steak"
```

General Comparison

- Operators: =, `!=`, <, <=, >, >=
- Used on general values:
  - atomize
  - if there exists two values, one from each argument, whose comparison holds, the result is true
  - otherwise, the result is false

```
8 = 4+4
(1,2) = (2,4)
//rcp:ingredient/@name = "salt"
```

Node Comparison

- Operators: `is`, <<, >>
- Used to compare nodes on identity and order
- When applied to arbitrary values:
  - if either argument is empty, the result is empty
  - if both are singleton nodes, the nodes are compared
  - otherwise, a runtime error

```
(//rcp:recipe)[2] is
     //rcp:recipe[rcp:title eq "Ricotta Pie"]
/rcp:collection << (//rcp:recipe)[4]
(//rcp:recipe)[4] >> (//rcp:recipe)[3]
```

Be Careful About Comparisons

```
((//rcp:ingredient)[40]/@name,(//rcp:ingredient)[40]/@amount) eq
((//rcp:ingredient)[53]/@name, (//rcp:ingredient)[53]/@amount)
```

Yields false, since the arguments are not singletons

```
((//rcp:ingredient)[40]/@name, (//rcp:ingredient)[40]/@amount) =
((//rcp:ingredient)[53]/@name, (//rcp:ingredient)[53]/@amount
```

Yields true, since the two names are found to be equal

```
((//rcp:ingredient)[40]/@name, (//rcp:ingredient)[40]/@amount) is
((//rcp:ingredient)[53]/@name, (//rcp:ingredient)[53]/@amount)
```

Yields a runtime error, since the arguments are not singletons

Algebraic Axioms for Comparisons

•Reflexivity: $x = x$

•Symmetry: $x = y \Rightarrow y = x$

•Transitivity: $x = y \wedge y = z \Rightarrow x = z$
$x < y \wedge y < z \Rightarrow x < z$

•Anti-symmetry: $x \leq y \wedge y \leq x \Rightarrow x = y$

•Negation: $x \neq y \Leftrightarrow \neg x = y$

XPath Violates Most Axioms

- Reflexivity?
  `()=()` yields false
- Transitivity?
  `(1,2)=(2,3)`, `(2,3)=(3,4)`, not `(1,2)=(3,4)`
- Anti-symmetry?
  `(1,4)<=(2,3)`, `(2,3)<=(1,4)`, not `(1,2)=(3,4)`
- Negation?
  `(1)!=()` yields false, `(1)=()` yields false

Boolean Expressions

- Operators: `and`, `or`
- Arguments are coerced, false if the value is:
  - the boolean false
  - the empty sequence
  - the empty string
  - the number zero
- Constants use functions `true()` and `false()`
- Negation uses `not(…)`

Functions

- XPath has an extensive *function library*
- Default *namespace* for functions:

```
http://www.w3.org/2006/xpath-functions
```

- 106 functions are required
- More functions with the *namespace*:

```
http://www.w3.org/2001/XMLSchema
```

Function Invocation

- Calling a function with 4 arguments:

```
fn:avg(1,2,3,4)
```

- Calling a function with 1 argument:

```
fn:avg((1,2,3,4))
```

Arithmetic Functions

```
fn:abs(-23.4) = 23.4
fn:ceiling(23.4) = 24
fn:floor(23.4) = 23
fn:round(23.4) = 23
fn:round(23.5) = 24
```

Boolean Functions

```
fn:not(0) = fn:true()
fn:not(fn:true()) = fn:false()
fn:not("") = fn:true()
fn:not((1)) = fn:false()
```

String Functions

```
fn:concat("X","ML") = "XML"
fn:concat("X","ML"," ","book") = "XML book"
fn:string-join(("XML","book")," ") = "XML book"
fn:string-join(("1","2","3"),"+") = "1+2+3"
fn:substring("XML book",5) = "book"
fn:substring("XML book",2,4) = "ML b"
fn:string-length("XML book") = 8
fn:upper-case("XML book") = "XML BOOK"
fn:lower-case("XML book") = "xml book"
```

Regexp Functions

```
fn:contains("XML book","XML") = fn:true()
fn:matches("XML book","XM..[a-z]*") = fn:true()
fn:matches("XML book",".*Z.*") = fn:false()
fn:replace("XML book","XML","Web") = "Web book"
fn:replace("XML book","[a-z]","8") = "XML 8888"
```

Cardinality Functions

```
fn:exists(()) = fn:false()
fn:exists((1,2,3,4)) = fn:true()
fn:empty(()) = fn:true()
fn:empty((1,2,3,4)) = fn:false()
fn:count((1,2,3,4)) = 4
fn:count(//rcp:recipe) = 5
```

Sequence Functions

```
fn:distinct-values((1, 2, 3, 4, 3, 2)) = (1, 2, 3, 4)
fn:insert-before((2, 4, 6, 8), 2, (3, 5))
      = (2, 3, 5, 4, 6, 8)
fn:remove((2, 4, 6, 8), 3) = (2, 4, 8)
fn:reverse((2, 4, 6, 8)) = (8, 6, 4, 2)
fn:subsequence((2, 4, 6, 8, 10), 2) = (4, 6, 8, 10)
fn:subsequence((2, 4, 6, 8, 10), 2, 3) = (4, 6, 8)
```

Aggregate Functions

```
fn:avg((2, 3, 4, 5, 6, 7)) = 4.5
fn:max((2, 3, 4, 5, 6, 7)) = 7
fn:min((2, 3, 4, 5, 6, 7)) = 2
fn:sum((2, 3, 4, 5, 6, 7)) = 27
```

Node Functions

```
fn:doc("http://www.brics.dk/ixwt/recipes/recipes.xml")
fn:position()
fn:last()
```

Coercion Functions

```
xs:integer("5") = 5
xs:integer(7.0) = 7
xs:decimal(5) = 5.0
xs:decimal("4.3") = 4.3
xs:decimal("4") = 4.0
xs:double(2) = 2.0E0
xs:double(14.3) = 1.43E1
xs:boolean(0) = fn:false()
xs:boolean("true") = fn:true()
xs:string(17) = "17"
xs:string(1.43E1) = "14.3"
xs:string(fn:true()) = "true"
```

For Expressions

- The expression

```
for $r in //rcp:recipe
  return fn:count($r//rcp:ingredient[fn:not(rcp:ingredient)])
```

returns the value

```
11, 12, 15, 8, 30
```

- The expression

```
 for $i in (1 to 5)
   for $j in (1 to $i)
     return $j
```

returns the value

```
 1, 1, 2, 1, 2, 3, 1, 2, 3, 4, 1, 2, 3, 4, 5
```

Conditional Expressions

```
fn:avg(
  for $r in //rcp:ingredient return
    if ( $r/@unit = "cup" )
      then xs:double($r/@amount) * 237
    else if ( $r/@unit = "teaspoon" )
      then xs:double($r/@amount) * 5
    else if ( $r/@unit = "tablespoon" )
      then xs:double($r/@amount) * 15
    else ()
)
```

Quantified Expressions

```
some $r in //rcp:ingredient
  satisfies $r/@name eq "sugar"
```

```
fn:exists(
  for $r in //rcp:ingredient return
    if ($r/@name eq "sugar") then fn:true() else ()
)
```

XPath 1.0 Restrictions

- Many implementations only support XPath 1.0
- Smaller function library
- Implicit casts of values
- Some expressions change semantics:

  ```
  "4" < "4.0"
  ```

  is false in XPath 1.0 but true in XPath 2.0

XPointer

- A fragment identifier mechanism based on XPath
- Different ways of pointer to the fourth recipe:

```
...#xpointer(//recipe[4])
...#xpointer(//rcp:recipe[./rcp:title ='Zuppa Inglese'])
...#element(/1/5)
...#r102
```

XLink

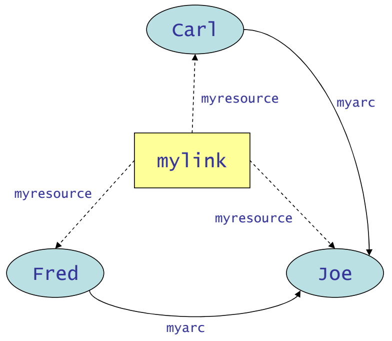
- *Generalizing* hyperlinks from HTML to XML
- Allow *many-to-many* relations
- Allow *third party links*
- Allow *arbitrary* element names

- Not widely used…

An XLink Link

```
<mylink xmlns:xlink="http://www.w3.org/1999/xlink"
        xlink:type="extended">
  <myresource xlink:type="locator"
              xlink:href="students.xml#Carl" xlink:label="student"/>
  <myresource xlink:type="locator"
              xlink:href="students.xml#Fred" xlink:label="student"/>
  <myresource xlink:type="locator"
              xlink:href="teachers.xml#Joe" xlink:label="teacher"/>
  <myarc xlink:type="arc"
         xlink:from="student" xlink:to="teacher"/>
</mylink>
```

A Picture of the XLink



Simple Links

```
<mylink xlink:type="simple" xlink:href="..." xlink:show="..." .../>
```

```
<mylink xlink:type="extended">
  <myresource xlink:type="resource"
              xlink:label="local"/>
  <myresource xlink:type="locator"
              xlink:label="remote" xlink:href="..."/>
  <myarc xlink:type="arc"
         xlink:from="local" xlink:to="remote" xlink:show="..."
   .../>
</mylink>
```

HTML Links in XLink

```
<a xlink:type="simple"
   xlink:href="..."
   xlink:show="replace"
   xlink:actuate="onRequest"/>
```

The HLink Alternative

```
<hlink namespace="http://www.w3.org/1999/xhtml"
       element="a"
       locator="@href"
       effect="replace"
       actuate="onRequest"
       replacement="@target"/>
```

Essential Online Resources

- http://www.w3.org/TR/xpath/
- http://www.w3.org/TR/xpath20/
- http://www.w3.org/TR/xlink/
- http://www.w3.org/TR/xptr-framework/