New Standards from W3C: XPath, XQuery, and XSLT

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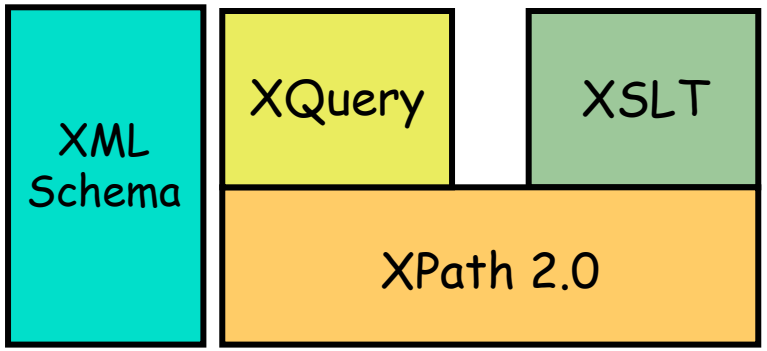
New from W3C

- Jan. 23, 2007: three new W3C "Recommendations"
  - XQuery 1.0: a new XML query language
  - XSLT 2.0: a major enhancement to an existing standard for stylesheets and transforms
  - XPath 2.0: the common subset of XQuery and XSLT
- XQuery and XSLT share:
  - data model
  - function library
  - type system
  - navigation syntax



- These new standards are motivated by convergence of two types of information: documents and data

Evolution of document markup

- "Blue-pencil" instructions to typesetter
- Appearance-related commands in word processors
- Separation of content from appearance
  - Content marked up with generic tags (SGML)
  - Appearance controlled by "style sheets" (DSSSL)
- The explosion of hypertext and the Web (early '90's)
  - HTML: a specific vocabulary of tags for hypertext
  - XML: simpler than SGML, more flexible than HTML
  - W3C standards (HTML 1995, XML 1998, XSL 2001)

Evolution of databases

- Early databases relied on explicit "navigation"
- Since about 1980, most business data has been relational
  - Data in tables, uniform rows and columns
  - Data has no intrinsic order
  - Automatic optimization of access paths
- A standard language: SQL

```
SELECT price * qty
FROM parts
WHERE name = "Bolt"
```

PARTS

NAME	PRICE	QTY
Bolt	0.75	300
Nut	0.12	300

Convergence of data and documents

- The Web led to new requirements for business data
  - purchase orders, medical records, insurance records, etc.
- Much of this data looks like "documents"
  - Intrinsic order
  - Heterogeneous (every instance is different)
  - Sparse
  - Hierarchic
- Databases need a self-describing data format
  - XML is the obvious choice
  - Metadata mixed with data as "tags"
  - All major database vendors are investing in XML

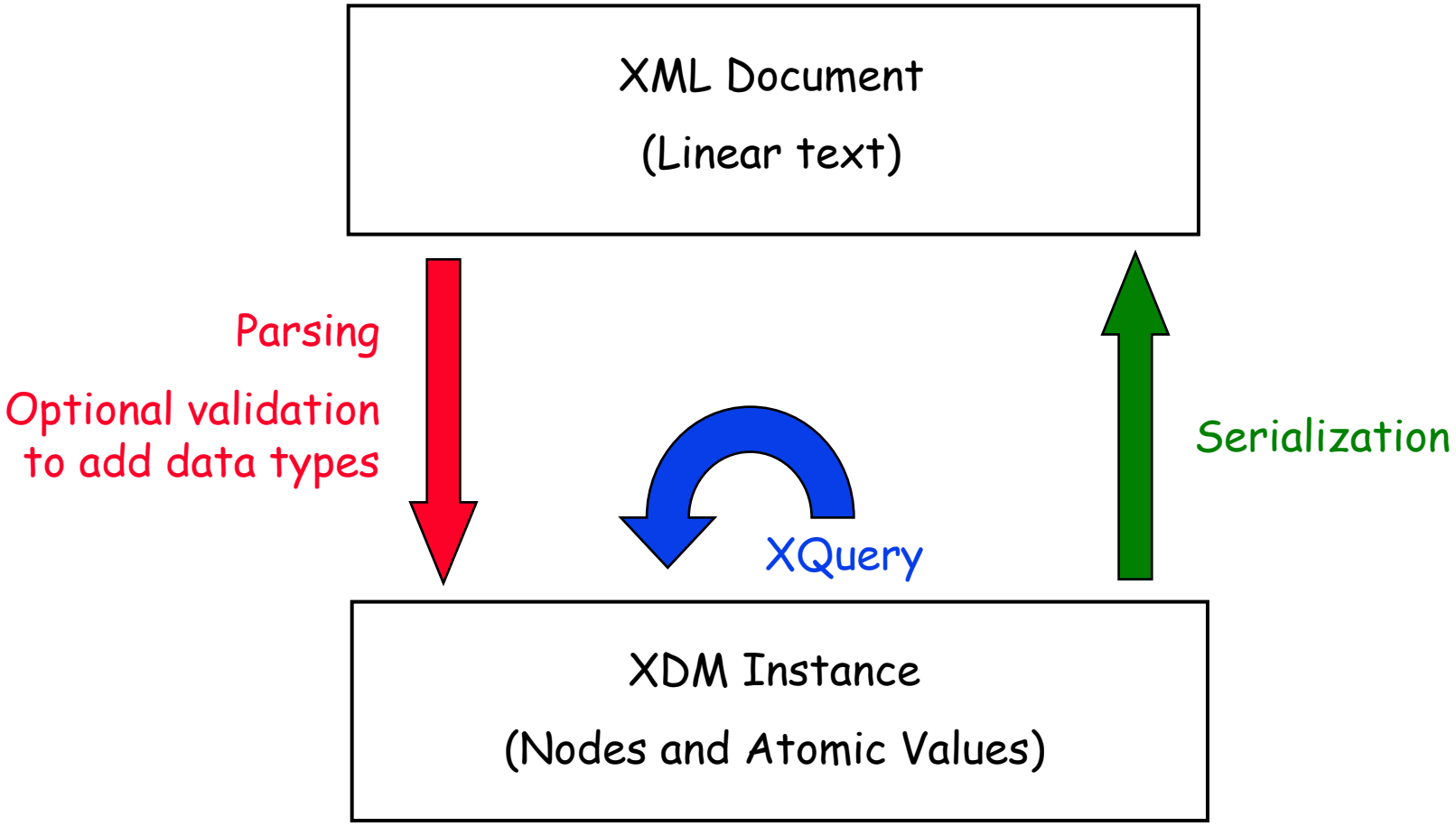
Beginnings of XML Query

- QL '98 Conference, Boston (W3C)
  - Resulted in ~50 proposals for an XML query language
- The XML Query Working Group
  - Chartered by W3C in October 1999
  - Representatives from about 30 companies
  - Studied QL '98 proposals and generated some new ones
  - Also looked at possible extensions to SQL
  - Decided to develop a new language: "XQuery"

Principles of XQuery Design

- Closure
  - Define a data model and a set of operators that are closed under the data model
- Compositionality
  - XQuery consists of several kinds of expressions
  - Every expression can be evaluated without side effects
  - Expressions can be composed with full generality
- Compatibility with existing XML Standards
  - Type system of XML Schema
  - Naming conventions of XML Namespaces
  - Navigation syntax of XPath (shared with XSLT)

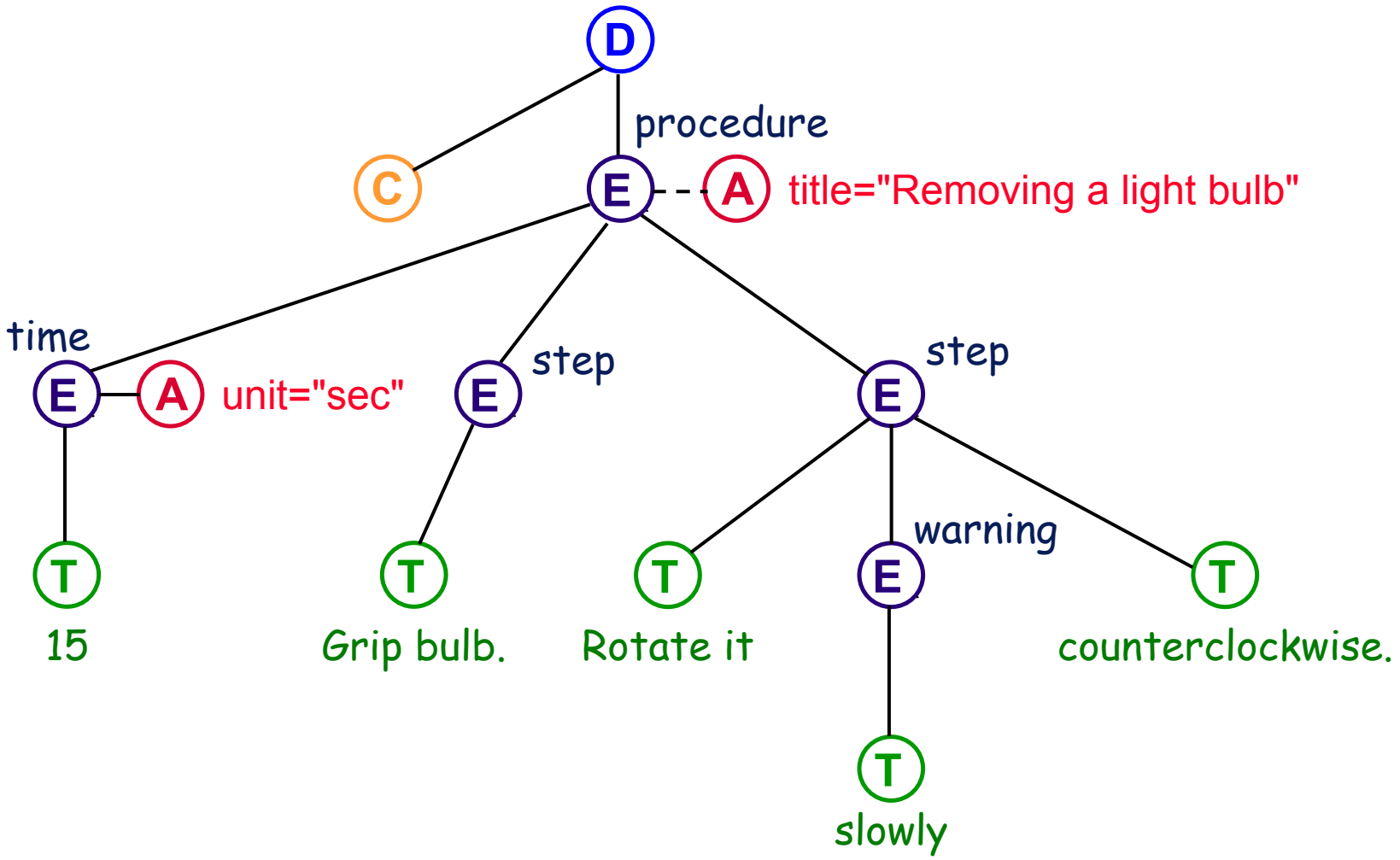
The XQuery Data Model (XDM)



An XML Document ...

```
<?xml version = "1.0"?>
<!-- Requires one trained person -->
<procedure title = "Removing a light bulb">
   <time unit = "sec">15</time>
   <step>Grip bulb.</step>
   <step>
      Rotate it
      <warning>slowly</warning>
      counterclockwise.
   </step>
</procedure>
```

... and its XDM Representation



Learning from existing standards

- XSLT (XML Stylesheet Language: Transforms)
- Used for transforming XML documents
  - Often into HTML for display or printing
  - Sometimes into another type of XML document
  - Sometimes into something else (PDF etc.)
- XSLT:
  - uses an XML syntax
  - is based on matching "patterns"
    (each pattern can generate some output)
  - uses XPath for navigation (finding patterns)

XPath

- XPath is used for finding nodes that match a pattern
- XPath can find things but cannot create new things
- The simplest form of XPath looks like a downward path with optional predicates
- Each step returns a list of nodes in document order
- These nodes in turn provide context for the next step
- Example:

```
/company[@location = "Denver"]
    /employee[secretary]/language[1]
```

XPath has 3 kinds of predicates

- Boolean expressions:

```
book[author = "Mark Twain"]
```

- Numeric expressions:

```
chapter[2]
```

- Existence tests:

```
book[appendix]
person[married]
```

(Tests existence, not value!)

- It's not always possible to distinguish these statically
  - Makes optimization difficult

XPath design philosophy

- Few types
  - Boolean, String, Number, Node Set
- Few errors (do something reasonable and keep moving)
  - Cast to the needed type (very permissive)
  - Use the first element in a list if you need only one
- Implicit operations
  - Extract the value of a node when you need it
  - Comparisons based on existential quantifiers

`bonus > salary` means:

```
some b in bonus, s in salary
   satisfies number(b) > number(s)
```

Decision to use XPath in XQuery

- Adopt XPath as a navigation syntax
- Update XPath to the type system of XML Schema
- Use XPath semantics for arithmetic, comparisons, etc.
- Invent other composable expressions for additional functionality (constructors, etc.)
- A path is a "leaf" of the XQuery expression tree

Some implications of using XPath

- Case-sensitive language
- No reserved words

  `return` is a name
- Can't use / for division

  `a/b` vs. `a div b`
- a-b is a name

  `a-b` vs. `a - b`

Some XQuery expressions

- Iteration: `for $x in expr1 return expr2`
- Conditional: `if (test) then expr1 else expr2`
- Existential: `some $x in expr1 satisfies test2`
- Universal: `every $x in expr1 satisfies test2`
- Set operations: `union, intersect, except`
- Constructors:

```
<greeting>Hello</greeting>
<revenue>{$price * $quantity}</revenue>
```

Meanwhile, back at XSLT

- Updating XPath to the type system of XML Schema
- Extending XPath with new kinds of expressions (if-then-else, set operations, existential and universal quantifiers, iterating functions over sequences, etc.)
- Agreement (2001)
  - 2 working groups get "joint custody" of XPath-2
  - Common functionality to be pushed into XPath-2
  - Path expression is no longer a "leaf" (full compositionality)
  - Working groups agree to meet jointly with each other and with Schema

Fun with XPath 1.0

- `a[b = 5]`
  returns a-elements that have ***any*** b-child with value 5

- `a[b+0 = 5]`
  returns a-elements whose ***first*** b-child has value 5

- `a[b-0 = 5]`
  returns a-elements that have any child named "b-0" with value 5

Fun with XPath 1.0, continued

- `//person[8]`
  returns the eighth person in document order
- `//person[shoesize]`
  returns all persons who have at least one shoesize
- `//person[shoesize + 0]`
  returns persons whose position in the list of persons is equal to their (first) shoesize

Fun with XPath 1.0, continued

- Comparisons:
  - "4" = "4.0" returns False (compared as strings)
  - "4" >= "4.0" returns True (compared as numbers)
  - "4" <= "4.0" returns True (compared as numbers)
- These elements are "equal" according to the "=" operator:

```
<book>
   <author> Mark Twain </author>
   <title> Huckleberry Finn </title>
</book>

<book>
   <title> Mark Twain </title>
   <author> Huckleberry Finn </author>
</book>
```

What did we do about this?

- XQuery wanted strong and consistent typing
  - Adding a number to a list is an error
  - Comparing a number to a string is an error
  - Strings are always compared as strings, not numbers
  - Deep-equal function defined for comparing elements
- XSLT wanted backward compatibility
- Both languages wanted to be supersets of XPath-2
- The compromise:
  - XPath-2 has a "compatibility mode"
  - XQuery always turns it off (not compatible with XPath-1)
  - XSLT gives the user a choice

Issue: transitive comparisons

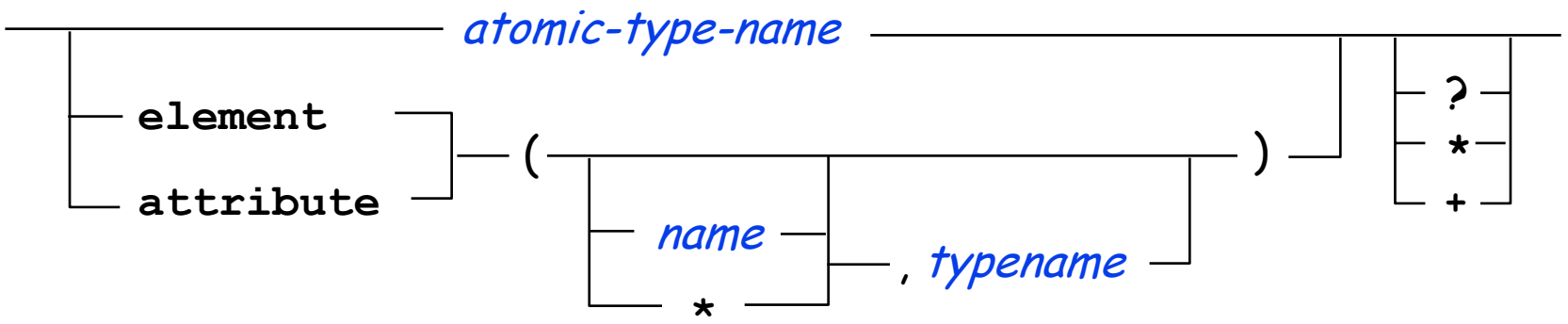
- XPath comparison ops: `=` `!=` `<` `<=` `>` `>=`
- Existential semantics
  - `author = "Gray"` is true if any author is Gray
  - Not good for exact comparisons
- Not transitive
  - (1, 2) = (2, 3) and (2, 3) = (3, 4) but (1, 2) ! = (3, 4)
  - (1, 4) > (2, 3) and (1, 4) < (2, 3) are both true
  - Not good for ordering, grouping
- We added "value comparisons": `eq ne lt le gt ge`
  - Transitive
  - Raise an error if either operand has multiple values

Issue: errors and indeterminacy

- An expression may evaluate its operands in any order
- Some expressions may either return a result or raise an error
  - `bonus > 5 and salary div 0 > 6`
  - `some $c in $cars satisfies $c/price div $c/mileage < 1000`
  - `product[price > 100]` (allowed to use an index)
- General principle: No need to search for data that could only raise errors

Issue: types

- Where do types come from?
  - Named typing vs. structural typing
  - What is this? `<a>12</a>`
  - Each operator has its own rules for untyped data
- What is the syntax of a type?
  - Used in function signatures, node tests, cast expressions
  - Simplified:



What did we do right?

- We took existing standards seriously (XPath, Schema, Namespaces)
- XQuery operates on XML in its own data model
  - No need to transform XML into something else
  - Much less code than conventional XML apps
  - Rapid prototyping, apps are easy to build and change
- Declarative, functional language (optimizable)
- Gracefully integrates navigation with construction
- Usable in many environments
  - Typed and untyped data
  - Stand-alone or with a host language
  - With file systems, databases, streams and feeds

What did we do wrong?

- We took existing standards seriously
  - Inherited all the complexity and foibles of XPath + Schema + Namespaces
  - `$x[$y]` might be a positional predicate, or might not
  - Schema has 44 built-in types, two kinds of inheritance, "substitution groups", "nillable" elements, etc.
- Our syntax is fragile and sometimes ugly
  - No reserved words: `return` is a query
  - What is this? `delete union + 2`
  - Double-token approach: `do delete`
- We left out some important things
  - Updates, grouping, error handling, text search
- We took ***way*** too long

Why did it take so long?

- We took existing standards seriously
  - We had to reconcile XPath with XML Schema
  - We spent a lot of time on the type system
- We published several working drafts per year and responded to public comments
  - ~2000 public comments during "last call" period
- We developed a shared function library (128 functions)
- We built a comprehensive test suite
  - More than 15,000 test cases
  - 14 implementations have submitted test results
  - 11 have demonstrated at least 98% conformance

Where are we now?

- XPath-2 adapts XPath to the Schema type system and adds many new operators:

  `for` `if-then-else` `some` `every` `intersect` `eq` etc.

- XQuery includes all of XPath-2 plus:
  constructors, FLWOR, user-defined functions, etc.

- XSLT-2 includes all of XPath-2 plus:
  grouping, user-defined functions, validation, etc.

- Both languages share a new function library

Comparison of XQuery and XSLT

- XQuery and XSLT are (roughly) equivalent in power
  - Both are Turing-complete languages
  - Open-source translator available from XQuery into XSLT
- Some things are easier to do in one than the other
  - XSLT is more oriented toward documents, formatting, whole-document transformations
  - XQuery more oriented toward data, extraction of small query results, SQL users

XQuery and XSLT

- XSLT is older and more established
  - XSLT: 20M Google hits, 25 books on Amazon
  - XQuery: 5M Google hits, 8 books on Amazon
- XQuery is gaining traction
  - W3C lists 48 XQuery implementations (some partial)
  - Some are databases, XML or hybrid
  - Some are data integrators (merge and transform XML data)
  - Several are free and open-source
  - FLWOR Foundation: www.flworfound.org

Ongoing work at W3C

- The Query working group has been rechartered
- Working drafts nearing last call:
  - XQuery Update Facility (insert, delete, replace, rename)
  - Full-text search (ranking, stemming, synonyms, etc.)
- Now in the requirements stage:
  - XQuery 1.1 (grouping, try/catch, etc.)
  - Scripting extensions (sequential execution, assignments, while-loops, local variables, etc.)