Et tu, XML?

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Acknowledgements

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The W3C XML Query Working Group

Disclaimer: This talk. is a personal view.
Other members of XML Query may disagree.

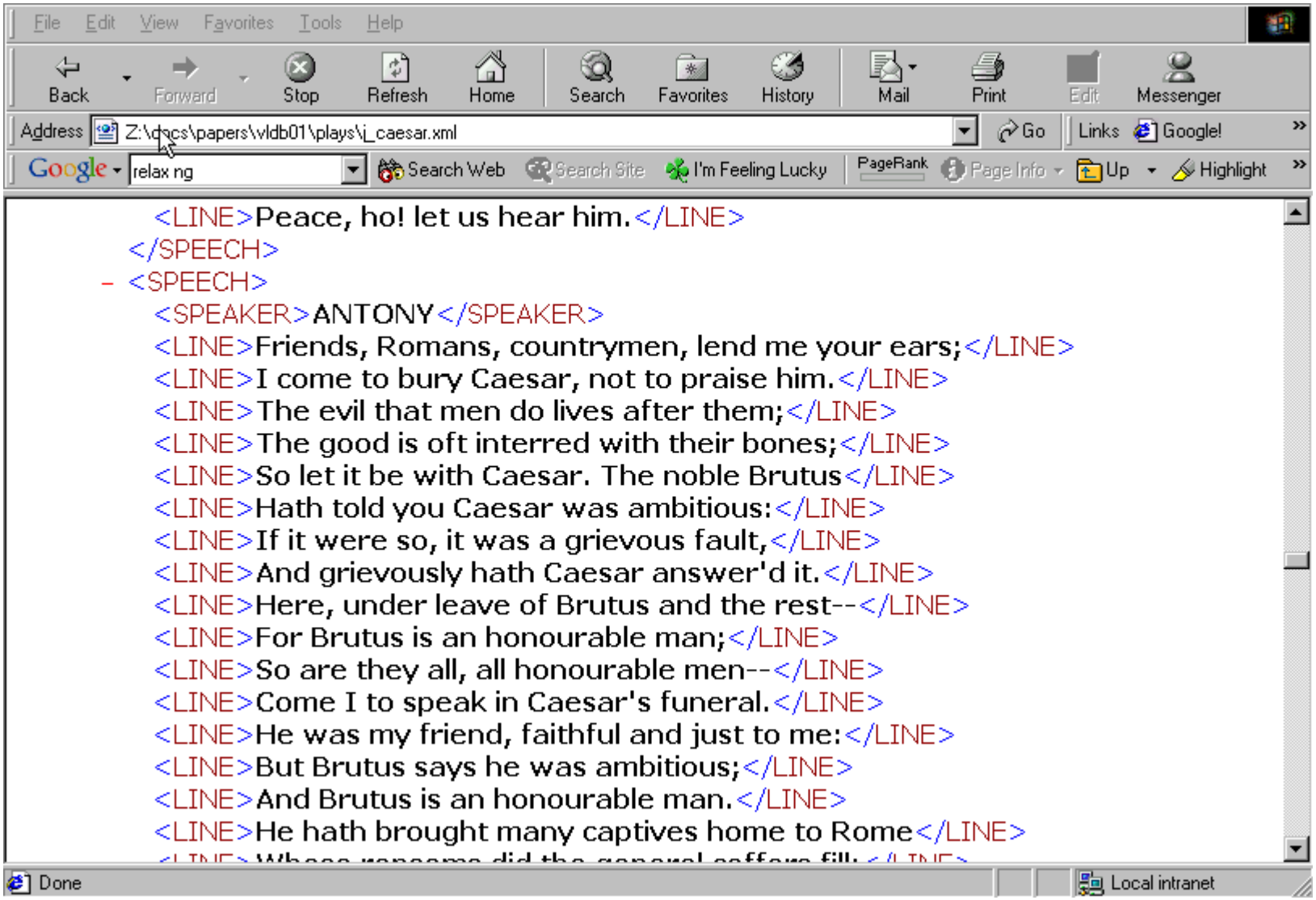
Prologue

Friends, romans, computer scientists, lend me your ears!
I come to bury the relational database, not to praise it.
The evil that standards committees do lives after them ;
the good is oft interred with their core dumps ;
so let it be with relations. The noble XML
hath told you that relations were ambitious.
Here under leave of XML and the W3C —
for XML is an honourable standard ;
so are they all, all honourable standards —
come I to speak at relations funeral.
Relations were my friend, faithful and just to me.
But XML says relations were ambitious,
and XML is an honourable standard.
Relations hath brought many captives home to Rome
whose ransom did the coffers of Oracle, IBM, and Microsoft fill.
Did this in relations seem ambitious?
Yet XML says relations were ambitious,
and XML is an honourable standard.

Shakespeare in XML

```
<SPEECH>
  <SPEAKER>ANTONY</SPEAKER>
  <LINE>Friends, Romans, countrymen, lend me your ears;</LINE>
  <LINE>I come to bury Caesar, not to praise him.</LINE>
  <LINE>The evil that men do lives after them;</LINE>
  <LINE>The good is oft interred with their bones;</LINE>
  <LINE>So let it be with Caesar. The noble Brutus</LINE>
  <LINE>Hath told you Caesar was ambitious:</LINE>
  <LINE>Here, under leave of Brutus and the rest--</LINE>
  <LINE>For Brutus is an honourable man;</LINE>
  <LINE>So are they all, all honourable men--</LINE>
  <LINE>Come I to speak in Caesar's funeral.</LINE>
  <LINE>He was my friend, faithful and just to me:</LINE>
  <LINE>But Brutus says he was ambitious;</LINE>
  <LINE>And Brutus is an honourable man.</LINE>
  ...
</SPEECH>
```

Shakespeare in XML on the web



Shakespeare in Lisp

```
(SPEECH
  (SPEAKER "ANTONY")
  (LINE "Friends, Romans, countrymen, lend me your ears;")
  (LINE "I come to bury Caesar, not to praise him.")
  (LINE "The evil that men do lives after them;")
  (LINE "The good is oft interred with their bones;")
  (LINE "So let it be with Caesar. The noble Brutus")
  (LINE "Hath told you Caesar was ambitious:")
  (LINE "Here, under leave of Brutus and the rest--")
  (LINE "For Brutus is an honourable man;")
  (LINE "So are they all, all honourable men--")
  (LINE "Come I to speak in Caesar's funeral.")
  (LINE "He was my friend, faithful and just to me:")
  (LINE "But Brutus says he was ambitious;")
  (LINE "And Brutus is an honourable man.")
  ...
)
```

Part I

Some XML applications

The Four Webs

- Computers
- Voice
- Wireless
- Television

The Four Webs

- Computers — xHTML
- Voice — Voice XML
- Wireless — WAP/WML
- Television — bHTML

Voice XML


Voice eXtensible Markup Language → (VoiceXML)
VoiceXML
FORUM
FORUM GOALS
GET THE SPEC
MEMBERS ONLY
VOICEXML REVIEW E-ZINE
MEET OUR MEMBERS
JOIN THE FORUM
NEWS & EVENTS
FAQ's
CONTACT US
TUTORIALS
September 3, 2001
The Business of VoiceXML
speechTECHNOLOGY MAGAZINE
The July/August issue of Speech Technology magazine offers an insightful look at VoiceXML as told through interviews conducted with various VoiceXML Forum members. The article, entitled "The Business Side of VoiceXML: Faster Time to Market is Only Part of the Story", covers topics including:
NEWS
1 August 2001
VoiceXML Forum membership grows to 537 member companies--including 4 Sponsor Members, 59 Promoter Members

ebXML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Logo
Presentations
Resources
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White Papers
TECHNICAL WORK
Overview
Business Process
Core Components
Collaboration Protocol
Messaging
Registry / Repository
Implementation
ebXML enables enterprises of any size, in any location to meet and conduct business through the exchange of XML-based messages.
ebXML NEWS
[01 August 2001] OpenTravel Alliance Endorses ebXML
[30 July 2001] UN/CEFACT Forms e-Business Transition Ad hoc Working Group
[21 June 2001] OASIS Forms ebXML Technical Committees
[22 May 2001] UN/CEFACT and OASIS
INDUSTRY SUPPORT
Open Applications Group to incorporate ebXML into 182 mature Business Object Documents
Korea Institute for Electronic Commerce (KIEC) Opens Prototype ebXML Registry & Repository
Covisint Supports ebXML Technology Findings
More ebXML Adoption News
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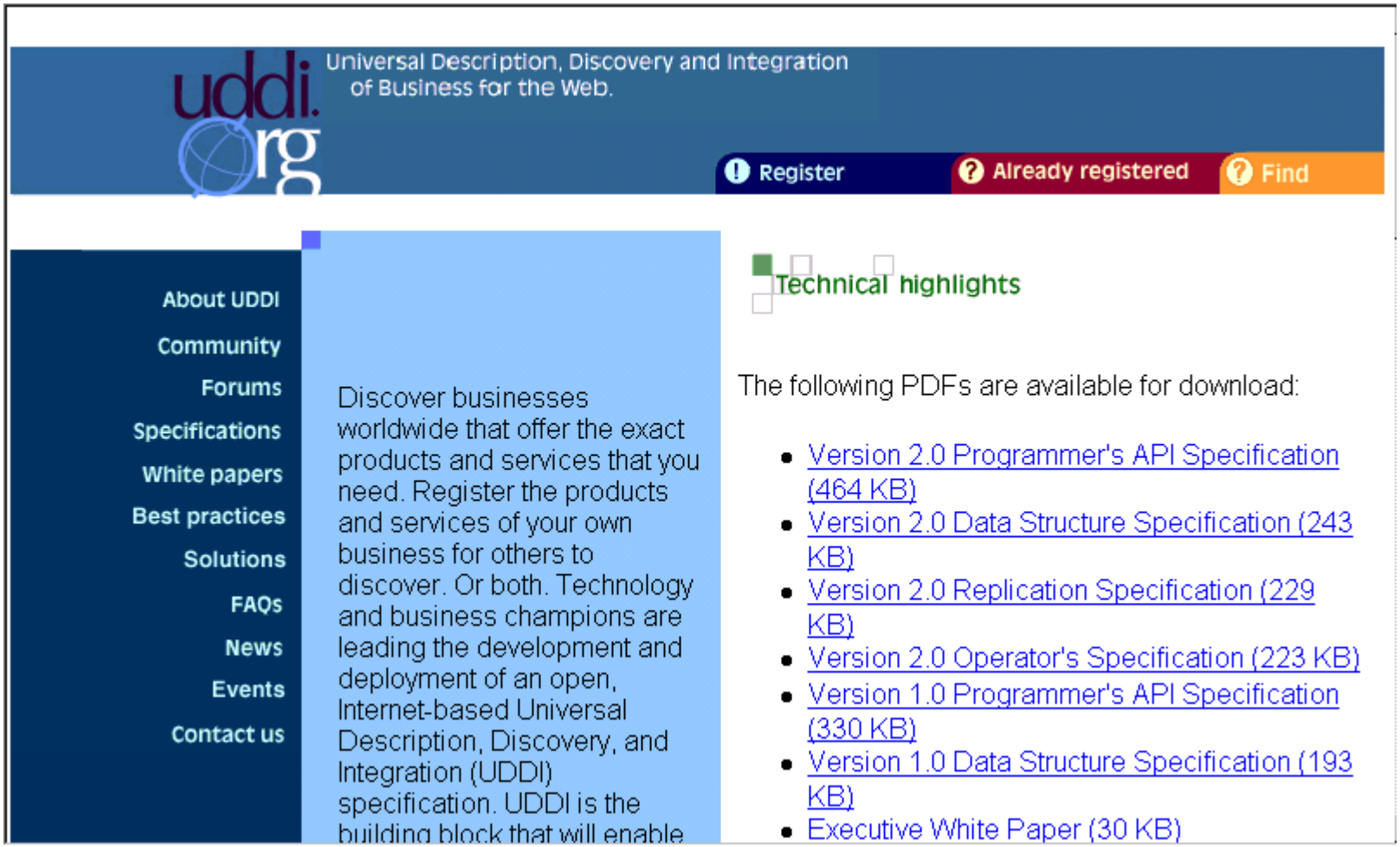
Book excerpt: ebXML: The

UDDI


uddi.org
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White papers
Best practices
Solutions
FAQs
News
Events
Contact us
Discover businesses worldwide that offer the exact products and services that you need. Register the products and services of your own business for others to discover. Or both. Technology and business champions are leading the development and deployment of an open, Internet-based Universal Description, Discovery, and Integration (UDDI) specification. UDDI is the building block that will enable
Technical highlights
The following PDFs are available for download:
Version 2.0 Programmer's API Specification (464 KB)
Version 2.0 Data Structure Specification (243 KB)
Version 2.0 Replication Specification (229 KB)
Version 2.0 Operator's Specification (223 KB)
Version 1.0 Programmer's API Specification (330 KB)
Version 1.0 Data Structure Specification (193 KB)
Executive White Paper (30 KB)

XML Schema Recommendation

XML Schema Part 1: Structures

W3C Recommendation 2 May 2001

This version:

http://www.w3.org/TR/2001/REC-xmlschema-1-20010502/

(in XML (with its own DTD, XSL stylesheet) and HTML), with separate provision of the schema and DTD for schemas described herein.

Latest version:

http://www.w3.org/TR/xmlschema-1/

Previous version:

http://www.w3.org/TR/2001/PR-xmlschema-1-20010330/

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XQuery Working Draft

XQuery 1.0: An XML Query Language

W3C Working Draft 07 June 2001

This version:
http://www.w3.org/TR/2001/WD-xquery-20010607
Latest version:
http://www.w3.org/TR/xquery
Previous version:
http://www.w3.org/TR/2001/WD-xquery-20010215/
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XQuery Formalism Working Draft

XQuery 1.0 Formal Semantics

W3C Working Draft 07 June 2001

This version:

http://www.w3.org/TR/2001/WD-query-semantics-20010607

Latest version:

http://www.w3.org/TR/query-semantics/

Previous versions:

http://www.w3.org/TR/2001/WD-query-algebra-20010215/

http://www.w3.org/TR/2000/WD-query-algebra-20001204/

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Part II

An introduction to XQuery

Influences

Languages that influence XQuery include:

SQL

OQL, O_2

Nested Relational Algebra, Kleisli

Xduce

XML-QL, Yatl, Lorel

XPath, XQL, XSLT

XML Schema, TRex, Relax

Quilt

Part III

Data model

Some XML data

```
<BOOKS>
  <BOOK YEAR="1999 2003">
    <AUTHOR>Abiteboul</AUTHOR>
    <AUTHOR>Buneman</AUTHOR>
    <AUTHOR>Suciu</AUTHOR>
    <TITLE>Data on the Web</TITLE>
    <REVIEW>A truly <EM>fine</EM> book.</REVIEW>
  </BOOK>
  <BOOK YEAR="2002">
    <AUTHOR>Buneman</AUTHOR>
    <TITLE>XML in Scotland</TITLE>
    <REVIEW><EM>Truly the <EM>best</EM> ever!</EM></REVIEW>
  </BOOK>
</BOOKS>
```

Data model

XML

```
<BOOK YEAR="1999 2003">
  <AUTHOR>Abiteboul</AUTHOR>
  <AUTHOR>Buneman</AUTHOR>
  <AUTHOR>Suciu</AUTHOR>
  <TITLE>Data on the Web</TITLE>
  <REVIEW>A truly <EM>fine</EM> book.</REVIEW>
</BOOK>
```

XQuery

```
element BOOK {
  attribute YEAR { 1999, 2003 },
  element AUTHOR { "Abiteboul" },
  element AUTHOR { "Buneman" },
  element AUTHOR { "Suciu" },
  element TITLE { "Data on the Web" },
  element REVIEW { "A truly", element EM { "fine" }, "book." }
}
```

Part IV

Types

DTD (Document Type Definition)

```
<!ELEMENT BOOKS (BOOK*)>
<!ELEMENT BOOK (AUTHOR+, TITLE, REVIEW?)>
<!ATTLIST BOOK YEAR CDATA #OPTIONAL>
<!ELEMENT AUTHOR (#PCDATA)>
<!ELEMENT TITLE (#PCDATA)>
<!ENTITY % INLINE "( #PCDATA | EM )*">
<!ELEMENT REVIEW %INLINE;>
<!ELEMENT EM %INLINE;>
```

Schema

```
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema">
  <xsd:element name="BOOKS">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element ref="BOOK"
          minOccurs="0" maxOccurs="unbounded"/>
      </xsd:sequence>
    </xsd:complexType>
  </xsd:element>
```

Schema, continued

```
<xsd:element name="BOOK">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="AUTHOR" type="xsd:string"
         minOccurs="1" maxOccurs="unbounded"/>
      <xsd:element name="TITLE" type="xsd:string"/>
      <xsd:element name="REVIEW" type="INLINE"
         minOccurs="0" maxOccurs="1"/>
    <xsd:sequence>
    <xsd:attribute name="YEAR" type="NONEMPTY-INTEGER-LIST"
      use="optional"/>
  </xsd:complexType>
</xsd:element>
```

Schema, continued[2]

```
  <xsd:complexType name="INLINE" mixed="true">
    <xsd:choice minOccurs="0" maxOccurs="unbounded">
      <xsd:element name="EM" type="INLINE"/>
    </xsd:choice>
  </xsd:complexType>
  <xsd:simpleType name="INTEGER-LIST">
    <xsd:list itemType="xsd:integer"/>
  </xsd:simpleType>
  <xsd:simpleType name="NONEMPTY-INTEGER-LIST">
    <xsd:restriction base="INTEGER-LIST">
      <xsd:minLength value="1"/>
    </xsd:restriction>
  </xsd:simpleType>
</xsd:schema>
```

XQuery types

```
define element BOOKS { BOOK* }
define element BOOK { YEAR?, AUTHOR+, TITLE, REVIEW }
define attribute YEAR { integer+ }
define element AUTHOR { string }
define element TITLE { string }
define group INLINE { ( string | EM )* }
define element REVIEW { INLINE }
define element EM { INLINE }
```

XQuery types

There is vigorous debate over whether XQuery should use any type notation other than Schema!

Every XQuery type is a group

```
  define attribute YEAR { integer+ }
  define element AUTHOR { string }
=
  define group YEAR {
    attribute YEAR { integer+ }
  }
  define group AUTHOR {
    element AUTHOR { string }
  }
```

Nesting XQuery types

```
define element BOOKS { BOOK* }
define element BOOK {
  attribute YEAR { integer+ } ?,
  element AUTHOR { string } +,
  element TITLE { string },
  element REVIEW { INLINE } ?
}
define group INLINE {
  ( string | element EM { INLINE } )*
}
```

Data integration — DTD

```
<!ELEMENT AMAZON-CATALOGUE (AMAZON-BOOK*)>
<!ELEMENT AMAZON-BOOK (TITLE,AUTHOR+,PRICE,ISBN)>
<!ELEMENT FATBRAIN-CATALOGUE (FATBRAIN-BOOK*)>
<!ELEMENT FATBRAIN-BOOK (AUTHOR+,TITLE,ISBN,PRICE)>
```

Data integration — Schema

```
<xsd:element name="AMAZON-CATALOGUE">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="BOOK"
        minOccurs="0" maxOccurs="unbounded">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element ref="TITLE"/>
            <xsd:element ref="AUTHOR"
              minOccurs="1" maxOccurs="unbounded"/>
            <xsd:element ref="PRICE"/>
            <xsd:element ref="ISBN"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
```

Data integration — Schema, continued

```
<xsd:element name="FATBRAIN-CATALOGUE">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="BOOK"
        minOccurs="0" maxOccurs="unbounded">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element ref="AUTHOR"
              minOccurs="1" maxOccurs="unbounded"/>
            <xsd:element ref="TITLE"/>
            <xsd:element ref="ISBN"/>
            <xsd:element ref="PRICE"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
```

Data integration — XQuery

```
define group AMAZON-BOOK {
  element BOOK { TITLE,AUTHOR+,PRICE,ISBN }
}
define group FATBRAIN-BOOK {
  element BOOK { AUTHOR+,TITLE,ISBN,PRICE }
}
define element CATALOGUE { AMAZON-BOOK*,FATBRAIN-BOOK* }
```

Like "DTD with Specialization".

Violates Schema "consistent element restriction".

Tree grammars and tree automata

	deterministic	non-deterministic
top-down		
bottom-up		

Tree grammars and tree automata

	deterministic	non-deterministic
top-down	Class 1	Class 2
bottom-up	Class 2	Class 2

Tree grammars and tree automata

	deterministic	non-deterministic
top-down	Class 1	Class 2
bottom-up	Class 2	Class 2

Tree grammar Class 0: DTD

Tree automata Class 1: Schema

Tree automata Class 2: XQuery, XDuce, Relax

$$\text{Class } 0 < \text{Class } 1 < \text{Class } 2$$

Class 0 and Class 2 have good closure properties.

Class 1 does not.

Wildcard types

Wildcard types model unstructured data

```
define group AnySimpleType {
  string | integer | ...
}
define group AnyAttribute {
  attribute * { AnySimpleType* }
}
define group AnyElement {
  element * { AnyItem* }
}
define group AnyItem {
  AnySimpleType | AnyAttribute | AnyElement
}
define group AnyType {
  AnyItem*
}
```

Part V

XQuery expressions

Projection and construction

Return title and authors of all books

```
for $book in /BOOKS/BOOK return
  <BOOK>{ $book/TITLE, $book/AUTHOR }</BOOK>
```

$\Rightarrow$

```
<BOOK>
  <TITLE>Data on the Web</TITLE>
  <AUTHOR>Abiteboul</AUTHOR>
  <AUTHOR>Buneman</AUTHOR>
  <AUTHOR>Suciu</AUTHOR>
</BOOK>
<BOOK>
  <TITLE>XML in Scotland</TITLE>
  <AUTHOR>Buneman</AUTHOR>
</BOOK>
```

Projection and construction

Return title and authors of all books

```
for $book in /BOOKS/BOOK return
  <BOOK>{ $book/TITLE, $book/AUTHOR }</BOOK>
```

$\in$

```
element BOOK {
  element TITLE { string },
  element AUTHOR { string }+
}*
```

Selection and existential

Return year and title of all books published before 2000

```
for $book in /BOOKS/BOOK
where $book/@YEAR < 2000
return
  <BOOK>{ $book/@YEAR, $book/TITLE }</BOOK>
```

$\Rightarrow$

```
<BOOK YEAR="1999 2003">
  <TITLE>Data on the Web</TITLE>
</BOOK>
```

$\in$

```
element BOOK {
  attribute YEAR { integer+ },
  element TITLE { string }
}*
```

An equivalent formulation

Return year and title of all books published before 2000

```
for $book in /BOOKS/BOOK
where $book/@YEAR < 2000
return
  <BOOK>{ $book/@YEAR, $book/TITLE }</BOOK>
```

=

```
for $book in /BOOKS/BOOK return
  if $book/@YEAR < 2000 then
    element BOOK { $book/@YEAR, $book/TITLE }
  else
    ()
```

```
$book/@YEAR < 2000
```

=

```
some $year in $book/@YEAR satisfying $year < 2000
```

Selection and projection with XPath

Return title of all books written before 2000

```
/BOOKS/BOOK[@YEAR < 2000]/TITLE
```

$\Rightarrow$

```
<TITLE>Data on the Web</TITLE>
```

$\in$

```
element TITLE { string } *
```

An equivalent formulation

Return title of all books written before 2000

```
  /BOOKS/BOOK[@YEAR < 2000]/TITLE
=
  for $root in / return
    for $books in $root/BOOKS return
      for $book in $books/BOOK return
        where $book/@YEAR < 2000 return
          $book/TITLE
```

Getting the number wrong

Return book with title ”Data on the Web”

```
/BOOK/BOOK[TITLE = "Data on the Web"]
```

$\in$

```
BOOK*
```

How do we exploit keys and relative keys?

Getting the number right

Return book with title ”Data on the Web”

```
  treat as BOOK? (
    /BOOK/BOOK[TITLE = "Data on the Web"]
  )
∈
  BOOK?
```

Nesting

Return titles for each author

```
let $books := /BOOKS/BOOK
for $author IN distinct($books/AUTHOR) return
  <AUTHOR NAME={ $author }>{
    $books/BOOK[AUTHOR = $author]/TITLE
  }</AUTHOR>
```

$\Rightarrow$

```
<AUTHOR NAME="Abiteboul">
  <TITLE>Data on the Web</TITLE>
</AUTHOR>
<AUTHOR NAME="Buneman">
  <TITLE>Data on the Web</TITLE>
  <TITLE>XML in Scotland</TITLE>
</AUTHOR>
<AUTHOR NAME="Suciu">
  <TITLE>Data on the Web</TITLE>
</AUTHOR>
```

Nesting

Return titles for each author

```
let $books := /BOOKS/BOOK
for $author IN distinct($books/AUTHOR) return
  <AUTHOR NAME={ $author }>{
    $books/BOOK[AUTHOR = $author]/TITLE
  }</AUTHOR>
```

$\in$

```
element AUTHOR {
  attribute NAME { string },
  element TITLE { string }*
}
```

Nesting, getting the number right

Return titles for each author

```
define element TITLE { string }
let $books := /BOOKS/BOOK
for $author IN distinct($books/AUTHOR) return
  <AUTHOR NAME={ $author }>{
    treat at TITLE+ (
      $books/BOOK[AUTHOR = $author]/TITLE
    )
  }</AUTHOR>
```

$\in$

```
element AUTHOR {
  attribute NAME { string },
  element TITLE { string }+
}
```

Join

Titles of all books that cost more at Amazon than at Fatbrain

```
let $amazon := document("http://www.amazon.com/books.xml"),
    $fatbrain := document("http://www.fatbrain.com/books.xml")
for $amazon_book IN $amazon/BOOKS/BOOK,
    $fatbrain_book IN $fatbrain/BOOKS/BOOK
where $amazon_book/ISBN = $fatbrain_book/ISBN
  and $amazon_book/PRICE > $fatbrain_book/PRICE
return $amazon_book/TITLE
```

Unordered

Titles of all books that cost more at Amazon than at Fatbrain, in any convenient order

```
unordered(
  let $amazon := document("http://www.amazon.com/books.xml"),
      $fatbrain := document("http://www.fatbrain.com/books.xml")
  for $amazon_book IN $amazon/BOOKS/BOOK,
      $fatbrain_book IN $fatbrain/BOOKS/BOOK
  where $amazon_book/ISBN = $fatbrain_book/ISBN
    and $amazon_book/PRICE > $fatbrain_book/PRICE
  return $amazon_book/TITLE
)
```

An error

Return title and ISBN of each book

```
  for $book in /BOOKS/BOOK return
    <ANSWER>{ $book/TITLE, $book/ISBN }</ANSWER>
```

$\in$

```
  element ANSWER { TITLE }*
```

Finding an error by assertion

Return title and ISBN of each book

```
define element ANSWER {
  element TITLE { string },
  element ISBN { string }
}
for $book in /BOOKS/BOOK return
  assert as ANSWER (
    <ANSWER>{ $book/TITLE, $book/ISBN }</ANSWER>
  )
```

Assertions might be added automatically when there is a global element declaration and no conflicting local declarations.

Finding an error by omission

Return title and ISBN of each book

```
define element BOOKS { BOOK* }
define element BOOK { AUTHOR+, TITLE }
define element AUTHOR { string }
define element TITLE { string }
for $book in /BOOKS/BOOK return
  <ANSWER>{ $book/TITLE, $book/ISBN }</ANSWER>
```

Note `$book/ISBN` $\in$ `()`.

Idea: Report an error when $e \in$ `()` and $e \neq$ `()`.

Wildcards, computed names

Turn all attributes into elements, and vice versa

```
define function swizzle (AnyElement $x) returns AnyElement {
  element {name($x)} {
    for $a in $x/@* return element {name($a)} {$a/data()},
    for $e in $x/* return attribute {name($e)} {$e/data()}
  }
}
swizzle(<TEST A="a" B="b">
          <C>c</C>
          <D>d</D>
        </TEST>)
```

⇒

```
<TEST C="c" D="D">
  <A>a</A>
  <B>b</B>
</TEST>
```

Typing can lose information

Return all Amazon and Fatbrain books by Buneman

```
  define element CATALOGUE { AMAZON-BOOK*,FATBRAIN-BOOK* }
  for $book in /CATALOGUE/BOOK
  where $book/AUTHOR = "Buneman" return
    $book
```

$\in$

```
  ( AMAZON-BOOK | FATBRAIN-BOOK )*
```

Part VI

Syntax

Templates

Convert book listings to HTML format

```
<HTML><H1>My favorite books</H1>
  <UL>{
    for $book in /BOOKS/BOOK return
      <LI>
        <EM>{ $book/TITLE/data() }</EM>,
        { $book/@YEAR/data()[position()=last()] }.
      </LI>
  }</UL>
</HTML>
```

⇒

```
<HTML><H1>My favorite books</H1>
  <UL>
    <LI><EM>Data on the Web</EM>, 2003.</LI>
    <LI><EM>XML in Scotland</EM>, 2002.</LI>
  </UL>
</HTML>
```

XQueryX

A query in XQuery:

```
FOR $b in document("bib.xml")//book
WHERE $b/publisher = "Morgan Kaufmann" AND $b/year = "1998"
RETURN
  $b/title
```

The equivalent in XQueryX:

```
<q:query xmlns:q="http://www.w3.org/2001/06/xqueryx">
 <q:flwr>
   <q:forAssignment variable="$b">
     <q:step axis="SLASHSLASH">
       <q:function name="document">
         <q:constant datatype="CHARSTRING">bib.xml</q:constant>
       </q:function>
       <q:identifier>book</q:identifier>
     </q:step>
   </q:forAssignment>
```

XQueryX, continued

```
<q:where>
  <q:function name="AND">
    <q:function name="EQUALS">
      <q:step axis="CHILD">
        <q:variable>$b</q:variable>
        <q:identifier>publisher</q:identifier>
      </q:step>
      <q:constant datatype="CHARSTRING">Morgan Kaufmann</q:consta
    </q:function>
    <q:function name="EQUALS">
      <q:step axis="CHILD">
        <q:variable>$b</q:variable>
        <q:identifier>year</q:identifier>
      </q:step>
      <q:constant datatype="CHARSTRING">1998</q:constant>
    </q:function>
  </q:function>
</q:where>
```

XQueryX, continued[2]

```
    <q:return>
      <q:step axis="CHILD">
        <q:variable>$b</q:variable>
        <q:identifier>title</q:identifier>
      </q:step>
    </q:return>
  </q:flwr>
</q:query>
```

Part VII

Typing rules

Types

unit type	u	::=	`string`	string
		|	`integer`	integer
		|	`attribute` a `{` t `}`	attribute
		|	`attribute *` `{` t `}`	any attribute
		|	`element` a `{` t `}`	element
		|	`element *` `{` t `}`	any element
type	t	::=	u	unit type
		|	`()`	empty sequence
		|	t `,` t	sequence
		|	t `|` t	choice
		|	t`?`	optional
		|	t`+`	one or more
		|	t`*`	zero or more
		|	x	type reference

Documents

string	s	::=	`""` , `"a"`, `"b"`, ..., `"aa"`, ...	
integer	i	::=	..., `-1`, `0`, `1`, ...	
document	d	::=	s	string
		|	i	integer
		|	`attribute` a `{` d `}`	attribute
		|	`element` a `{` d `}`	element
		|	`()`	empty sequence
		|	d `,` d	sequence

Type of a document — $d \in t$

$$\frac{}{s \in \texttt{string}} \quad \text{(string)}$$

$$\frac{}{i \in \texttt{integer}} \quad \text{(integer)}$$

$$\frac{d \in t}{\texttt{element } a \texttt{ \{ } d \texttt{ \} } \in \texttt{element } a \texttt{ \{ } t \texttt{ \} }} \quad \text{(element)}$$

$$\frac{d \in t}{\texttt{element } a \texttt{ \{ } d \texttt{ \} } \in \texttt{element * \{ } t \texttt{ \} }} \quad \text{(any element)}$$

$$\frac{d \in t}{\texttt{attribute } a \texttt{ \{ } d \texttt{ \} } \in \texttt{element } a \texttt{ \{ } t \texttt{ \} }} \quad \text{(attribute)}$$

$$\frac{d \in t}{\texttt{attribute } a \texttt{ \{ } d \texttt{ \} } \in \texttt{element * \{ } t \texttt{ \} }} \quad \text{(any attribute)}$$

$$\frac{d \in t \qquad \texttt{define group } x \texttt{ \{ } t \texttt{ \} }}{d \in x} \quad \text{(group)}$$

Type of a document, continued

$$\frac{}{() \in ()} \quad \text{(empty)}$$

$$\frac{d_1 \in t_1 \qquad d_2 \in t_2}{d_1 \text{ , } d_2 \in t_1 \text{ , } t_2} \quad \text{(sequence)}$$

$$\frac{d_1 \in t_1}{d_1 \in t_1 \text{ | } t_2} \quad \text{(choice 1)}$$

$$\frac{d_2 \in t_2}{d_2 \in t_1 \text{ | } t_2} \quad \text{(choice 2)}$$

$$\frac{d \in t\text{+?}}{d \in t\text{*}} \quad \text{(star)}$$

$$\frac{d \in t \text{ , } t\text{*}}{d \in t\text{+}} \quad \text{(plus)}$$

$$\frac{d \in () \text{ | } t}{d \in t\text{?}} \quad \text{(option)}$$

Subtyping and type equivalence

Definition. Write $t_1 \subseteq t_2$ iff for all d, if $d \in t_1$ then $d \in t_2$.

Definition. Write $t_1 = t_2$ iff $t_1 \subseteq t_2$ and $t_2 \subseteq t_1$.

Examples

$$t \subseteq t\texttt{?} \subseteq t\texttt{*}$$
$$t \subseteq t\texttt{+} \subseteq t\texttt{*}$$
$$t_1 \subseteq t_1 \texttt{ | } t_2$$
$$t \texttt{ , () } = t = \texttt{ () , } t$$
$$t_1 \texttt{ , (} t_2 \texttt{ | } t_3\texttt{) } = \texttt{(} t_1 \texttt{ , } t_2\texttt{) | (} t_1 \texttt{ , } t_3\texttt{)}$$
$$\texttt{element } a \texttt{ \{ } t_1 \texttt{ | } t_2 \texttt{ \} } = \texttt{element } a \texttt{ \{ } t_1 \texttt{ \} | element } a \texttt{ \{ } t_2 \texttt{ \}}$$

Can decide whether $t_1 \subseteq t_2$ using tree automata.

Type of an expression — $E \vdash e \in t$

environment E ::= $\$v_1 \in t_1, \ldots, \$v_n \in t_n$

$$\frac{E \quad \text{contains} \quad \$v \in t}{E \vdash \$v \in t} \qquad \text{(variable)}$$

$$\frac{E \vdash e_1 \in t_1 \qquad E, \$v \in t_1 \vdash e_2 \in t_2}{E \vdash \texttt{let } \$v \texttt{ := } e_1 \texttt{ return } e_2 \in t_2} \qquad \text{(let)}$$

$$\frac{}{E \vdash () \in ()} \qquad \text{(empty)}$$

$$\frac{E \vdash e_1 \in t_1 \qquad E \vdash e_2 \in t_2}{E \vdash e_1 \texttt{ , } e_2 \in t_1 \texttt{ , } t_2} \qquad \text{(sequence)}$$

$$\frac{E \vdash e \in t_1 \qquad t_1 \cap t_2 \neq \emptyset}{E \vdash \texttt{treat as } t_2 \texttt{ (} e \texttt{)} \in t_2} \qquad \text{(treat as)}$$

$$\frac{E \vdash e \in t_1 \qquad t_1 \subseteq t_2}{E \vdash \texttt{assert as } t_2 \texttt{ (} e \texttt{)} \in t_2} \qquad \text{(assert as)}$$

Quantifiers

quantifier q ::=

`()`	exactly zero	$t \cdot () = ()$
`-`	exactly one	$t \cdot - = t$
`?`	zero or one	$t \cdot ? = t?$
`+`	one or more	$t \cdot + = t+$
`*`	zero or more	$t \cdot * = t*$

,	()	-	?	+	*
()	()	-	?	+	*
-	-	+	+	+	+
?	?	+	*	+	*
+	+	+	+	+	+
*	*	+	*	+	*

|	()	-	?	+	*
()	()	?	?	*	*
-	?	-	?	+	*
?	?	?	?	*	*
+	*	+	*	+	*
*	*	*	*	*	*

·	()	-	?	+	*
()	()	()	()	()	()
-	()	-	?	+	*
?	()	?	?	*	*
+	()	+	*	+	*
*	()	*	*	*	*

$\leq$	()	-	?	+	*
()	$\leq$		$\leq$		$\leq$
-		$\leq$	$\leq$	$\leq$	$\leq$
?			$\leq$		$\leq$
+				$\leq$	$\leq$
*					$\leq$

Typing for loops

Return all Amazon and Fatbrain books by Buneman

```
define element CATALOGUE { AMAZON-BOOK*,FATBRAIN-BOOK* }
for $book in /CATALOGUE/BOOK
where $book/AUTHOR = "Buneman" return
  $book
```

$\in$

```
( AMAZON-BOOK | FATBRAIN-BOOK )*
```

$$\frac{E \vdash e_1 \in t_1 \qquad E, \$x \in \mathsf{P}(t_1) \vdash e_2 \in t_2}{E \vdash \texttt{for } \$x \texttt{ in } e_1 \texttt{ return } e_2 \in t_2 \cdot \mathsf{Q}(t_1)} \quad \text{(for)}$$

$$\mathsf{P}(\texttt{AMAZON-BOOK*,FATBRAIN-BOOK*}) = \texttt{AMAZON-BOOK | FATBRAIN-BOOK}$$
$$\mathsf{Q}(\texttt{AMAZON-BOOK*,FATBRAIN-BOOK*}) = \texttt{*}$$

Prime types

unit type	u	::=	`string`	string
		|	`integer`	integer
		|	`attribute` a `{` t `}`	attribute
		|	`attribute *` `{` t `}`	any attribute
		|	`element` a `{` t `}`	element
		|	`element *` `{` t `}`	any element
prime type	p	::=	u	unit type
		|	p `|` p	choice

Factoring

$$
\begin{array}{lcl}
\mathsf{P}'(u) & = & \{u\} \\
\mathsf{P}'(()) & = & \{\} \\
\mathsf{P}'(t_1\,,\,t_2) & = & \mathsf{P}'(t_1) \cup \mathsf{P}'(t_2) \\
\mathsf{P}'(t_1 \mid t_2) & = & \mathsf{P}'(t_1) \cup \mathsf{P}'(t_2) \\
\mathsf{P}'(t?) & = & \mathsf{P}'(t) \\
\mathsf{P}'(t+) & = & \mathsf{P}'(t) \\
\mathsf{P}'(t*) & = & \mathsf{P}'(t)
\end{array}
\qquad
\begin{array}{lcl}
\mathsf{Q}(u) & = & - \\
\mathsf{Q}(()) & = & () \\
\mathsf{Q}(t_1\,,\,t_2) & = & \mathsf{Q}(t_1)\,,\,\mathsf{Q}(t_2) \\
\mathsf{Q}(t_1 \mid t_2) & = & \mathsf{Q}(t_1) \mid \mathsf{Q}(t_2) \\
\mathsf{Q}(t?) & = & \mathsf{Q}(t) \cdot ? \\
\mathsf{Q}(t+) & = & \mathsf{Q}(t) \cdot + \\
\mathsf{Q}(t*) & = & \mathsf{Q}(t) \cdot *
\end{array}
$$

$$
\begin{array}{lcll}
\mathsf{P}(t) & = & () & \text{if } \mathsf{P}'(t) = \{\} \\
 & = & u_1 \mid \cdots \mid u_n & \text{if } \mathsf{P}'(t) = \{u_1, \ldots, u_n\}
\end{array}
$$

Factoring theorem. For every type t, prime type p, and quantifier q, we have $t \subseteq p \cdot q$ iff $\mathsf{P}(t) \subseteq p?$ and $\mathsf{Q}(t) \leq q$.

Corollary. For every type t, we have $t \subseteq \mathsf{P}(t) \cdot \mathsf{Q}(t)$.

Uses of factoring

$$\frac{E \vdash e_1 \in t_1 \qquad E, \$x \in \mathsf{P}(t_1) \vdash e_2 \in t_2}{E \vdash \texttt{for}\ \$x\ \texttt{in}\ e_1\ \texttt{return}\ e_2 \in t_2 \cdot \mathsf{Q}(t_1)} \quad \text{(for)}$$

$$\frac{E \vdash e \in t}{E \vdash \texttt{unordered}(e) \in \mathsf{P}(t) \cdot \mathsf{Q}(t)} \quad \text{(unordered)}$$

$$\frac{E \vdash e \in t}{E \vdash \texttt{distinct}(e) \in \mathsf{P}(t) \cdot \mathsf{Q}(t)} \quad \text{(distinct)}$$

$$\frac{E \vdash e_1 \in \texttt{integer} \cdot q_1 \qquad q_1 \leq ? \qquad E \vdash e_2 \in \texttt{integer} \cdot q_2 \qquad q_2 \leq ?}{E \vdash e_1 \texttt{+} e_2 \in \texttt{integer} \cdot q_1 \cdot q_2} \quad \text{(arithmetic)}$$

Part VIII

Conclusions

XML Schema formalism

XML Schema: Formal Description

W3C Working Draft, 20 March 2001

This version:
http://www.w3.org/TR/2001/WD-xmlschema-formal-20010320/
Latest version:
http://www.w3.org/TR/xmlschema-formal/
Editors:
Allen Brown (Microsoft) allenbr@microsoft.com
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Philip Wadler (Avaya) wadler@avaya.com

XML Schema formalism

6 Validation

6.1 Content validation

We write $d \ in \ g$ if forest d matches group g.

EMPTY:

$$\frac{}{\varepsilon \ in \ e}$$

SEQUENCE:

$$\frac{d_1 \ in \ g_1 \quad d_2 \ in \ g_2}{d_1 , d_2 \ in \ g_1 , g_2}$$

CHOICE 1:

$$\frac{d \ in \ g_1}{d \ in \ g_1 \mid g_2}$$

CHOICE 2:

$$\frac{d \ in \ g_2}{d \ in \ g_1 \mid g_2}$$

Relax

RELAX NG Specification

Committee Specification 11 August 2001

This version:

Committee Specification: 11 August 2001

Editors:

James Clark <jjc@jclark.com>, MURATA Makoto <mura034@attglobal.net>

Relax

6.2. Patterns

The axioms and inference rules for patterns use the following notation:

p

ranges over patterns (elements matching the pattern production)

$cx \mid\!\!- a; m =\!\!\sim p$

asserts that with respect to context cx, the attributes a and the sequence of elements and strings m matches the pattern p

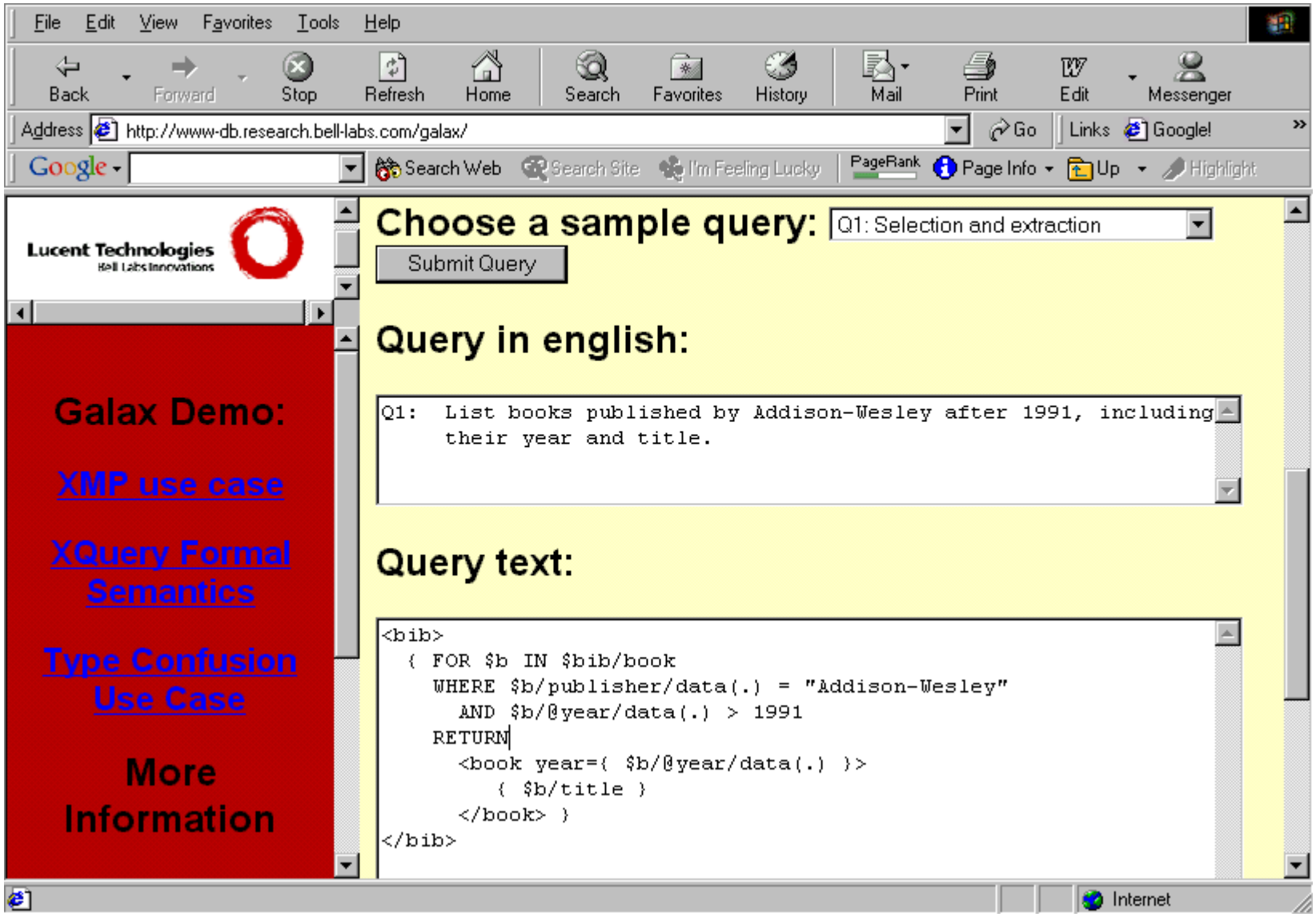
6.2.1. choice pattern

The semantics of the `choice` pattern are as follows:

$$\text{(choice 1)}\quad \frac{cx \mid\!\!- a; m =\!\!\sim p_1}{cx \mid\!\!- a; m =\!\!\sim \texttt{<choice>}\, p_1\, p_2\, \texttt{</choice>}}$$

$$\text{(choice 2)}\quad \frac{cx \mid\!\!- a; m =\!\!\sim p_2}{cx \mid\!\!- a; m =\!\!\sim \texttt{<choice>}\, p_1\, p_2\, \texttt{</choice>}}$$

Galax


File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites History Mail Print Edit Messenger
Address http://www-db.research.bell-labs.com/galax/
Go Links Google!
Search Web Search Site I'm Feeling Lucky PageRank Page Info Up Highlight
Lucent Technologies
Bell Labs Innovations
Galax Demo:
XMP use case
XQuery Formal Semantics
Type Confusion Use Case
More Information
Choose a sample query:
Q1: Selection and extraction
Submit Query
Query in english:
Q1: List books published by Addison-Wesley after 1991, including their year and title.
Query text:
<bib>
{ FOR $b IN $bib/book
WHERE $b/publisher/data(.) = "Addison-Wesley"
AND $b/@year/data(.) > 1991
RETURN
<book year={ $b/@year/data(.) }>
{ $b/title }
</book> }
</bib>
Internet

Some research topics

How to trade-off accuracy for simplicity in types?

How to exploit keys and relative keys?

How to integrate keys and relative keys into types?

How to handle graphs?

How to handle fixpoints as in Datalog?

How to integrate with OO view of data?

Links

My XML page

http://www.research.avayalabs.com/~wadler/xml/

W3C XML Query page

http://www.w3.org/XML/Query.html

XML Query demonstrations

Galax - AT&T, Lucent, and Avaya

http://www-db.research.bell-labs.com/galax/

Quip - Software AG

http://www.softwareag.com/developer/quip/

XQuery demo - Microsoft

http://131.107.228.20/xquerydemo/

Conclusions

There is nothing to XML
There is everything to XML

Industry resists formal methods
Industry welcomes formal methods

The best thing you can do is work on standards
The worst thing you can do is work on standards

You need XML
XML needs you

Epilogue

Beware the ides of March!