ADT 2010

XML/XQuery Data Management

MonetDB/XQuery (1/2)

Beyond Chapter 10 of
Silberschatz, Korth, Sudarshan
“Database System Concepts”

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XML Databases

why

- *Motivation & The Big Picture: XML, DTD, XML Schema, XPath*

what

- *Crash Course XQuery*

WHO ← ←

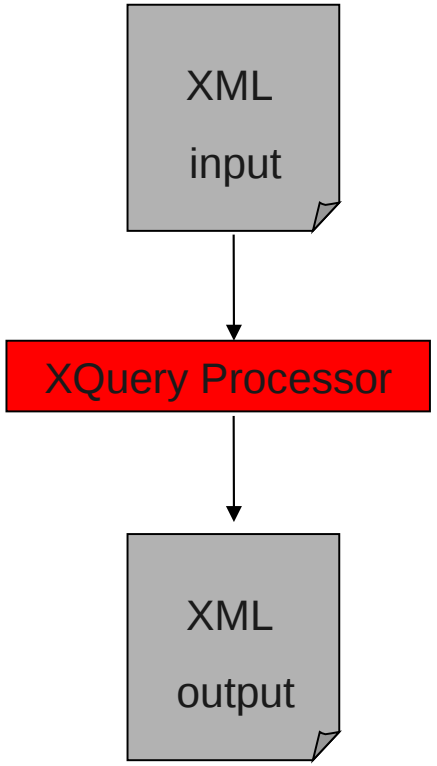
- *XML files ➔ Saxon, Galax, GNU Qexo*
- *XML DBMS ➔ eXist, BerkeleyDB, MonetDB, X-Hive, Tamino, Xyleme, ...*
- *XML RDBMS ➔ Oracle10g, SQLserver 2005, DB2*

how

- *Under The Hood of MonetDB/XQuery*
- *Some Benchmarks*

XML Data Management Systems

- **XML File Processors**
  - *Used as part of a document processing pipeline*
  - *Small documents (messages)*



XML Data Management Systems

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  - *Used as part of a document processing pipeline*
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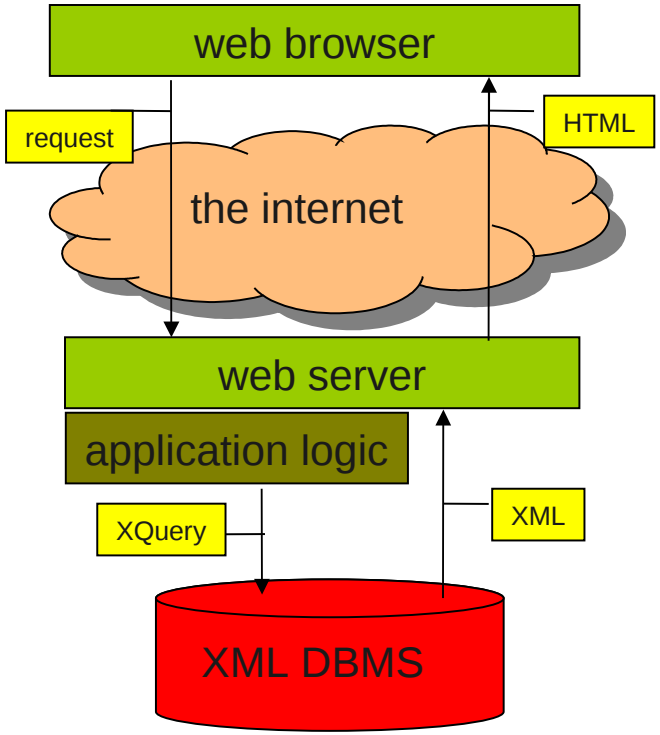
- **XML Databases**
  - *Manage large collections of XML documents*
  - *Text Keyword Search Support (XML contains text..)*
  - *Integration with Web Servers/Platforms*



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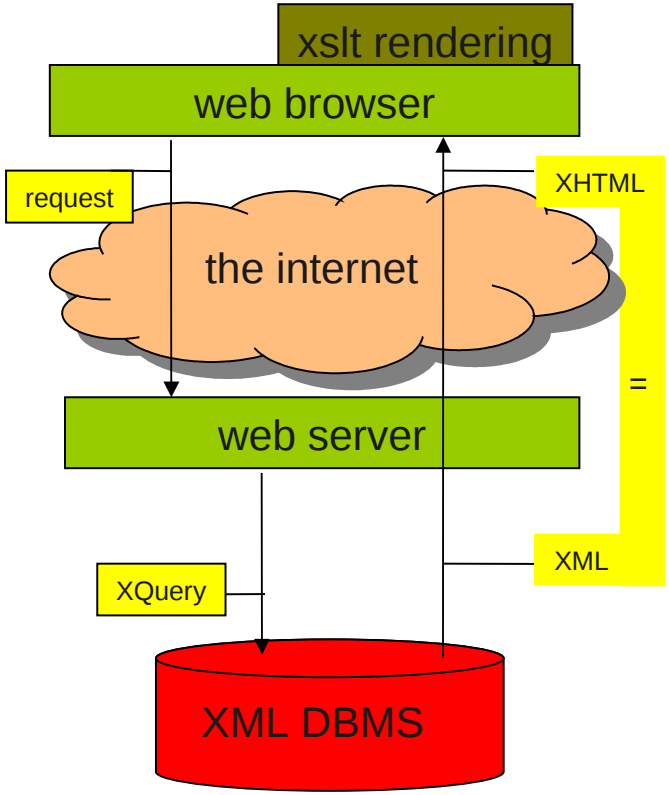

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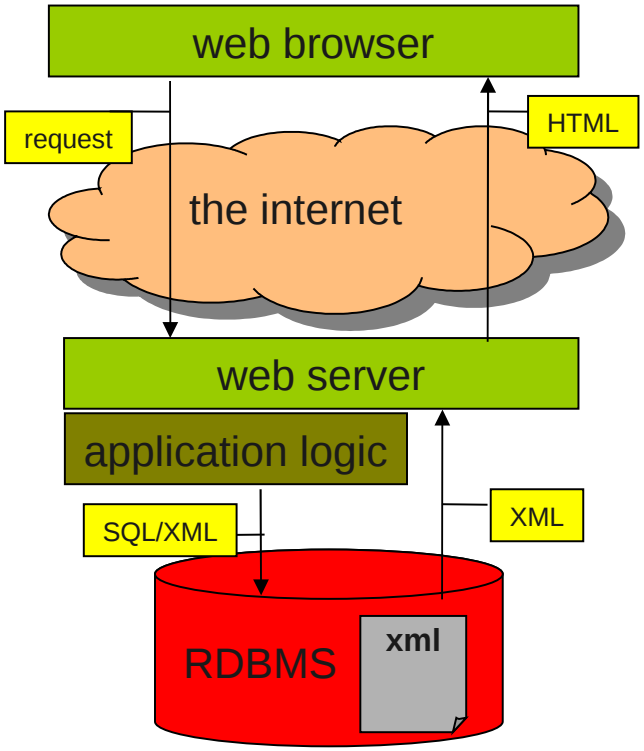
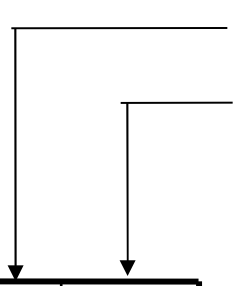


- **RDBMS with XML Functionality**
  - *Easily mix relational and XML, can be very useful for that .ini/properties file*
  - *Query the XML VARCHAR with SQL/XML ➔ ugly but works*

XML Data Management Systems



(Google hits)

(ranking)

Saxon	xquery	**743K**	#1
Qexo	xquery	**41K**	#2
Galax	xquery	**17K**	#3

XML File Processors

eXist	xquery	**1440K**	#1
Mark Logic	xquery	**438K**	#2
Xindice	xquery	**225K**	#2
BerkeleyDB XML	xquery	**142K**	#3
MonetDB	xquery	**87K**	#4
X-Hive	xquery	**65K**	#5
Tamino	xquery	**56K**	#6

XML Databases

Oracle	xquery	**1470K**	#1
SQLServer	xquery	**1220K**	#2

RDBMS with SQL/XML Functionality

XML Databases

- Querying
- How well is XPath/XQuery implemented?
  - All Axes? Collations? XMLSchema? Dynamic Typing? Modules? Recursive UDF?
- Updates
- What update dialect is used? (XUpdate / updateX / WebDAV / other)
  - W3C Update Facility Proposal (since jan 2006!)
- DB properties
- Query performance/throughput (benchmarks published?)
- Update consistency model (fully serializable / snapshot consistency / s.th. less)
- Replication, Failover, Backup facilities
- APIs
- SOAP / WSDL
  - Call a query from outside <=> Calling out from a query
- Web Support
  - Cocoon/apache modules (web sessions, low overhead web queries)
  - XML Beans (J2EE served from XMLDB)
  - WebDAV
- Language bindings
  - XQJ => Java Binding / Xlinq => C# Binding

XML DBMS comparison

	xquery	updates	scalability	replication	fulltext	APIs
eXist	++	+	-	+	+	++
Mark Logic	++	+	+	+	++	+
Apache Xindice	-	+	-	-	-	+
BerkeleyDB XML	++	++	++	+	+	+
MonetDB/XQuery	+	++	+++	-	-	+
X-Hive	++	++	++	++	+	+++
Tamino	+	+	+	++	+	++

XML in a Relational DBMS

- Store XML as a BLOB in relational database
  - index by materializing indexed expressions in separate columns
  - Plus: store XML in parsed and validated form
  - Minus: proprietary solution (blob is a black box)
  - Minus: replicate data for indexing
- Schema-based Shredding
  - Map XML Schema / DTD to SQL DDL
  - Plus: integrates well with relational data
  - Minus: missing tools, complicated
- SQL / XML
  - Extend SQL with XML data type
  - Plus: integrates well with relational data
  - Minus: not clear how it integrates with application, odd „marriage“

History of SQL / XML

- First edition part of SQL:2003
  - Part 14 of the SQL standard
  - Pre-dates XQuery standard!!!
  - Limited functionality - storage and publishing
- Second edition
  - More complete integration of XQuery + XQuery Data Model
  - Advanced Query capabilities
  - Published in 2006

Publishing Rel. Data as XML (1/2)

Phantasy-People

Id	Name
4711	Wutz
911	Potter

```
<Phantasy-People>
<row>
    <Id>4711</Id>
    <Name>Wutz</Name>
</row>
<row>
    <Id>911</Id>
    <Name>Potter</Name>
</row>
</Phantasy-People>
```

Publishing Rel. Data as XML (2/2)

SQL/XML Publishing Example

```
SELECT
   XMLELEMENT(NAME "Department",
                XMLATTRIBUTES (e.department AS "name" ),
                XMLAGG( XMLELEMENT(NAME "emp", e.firstname) )
                        ) AS "department_list"
FROM employee e
WHERE …..
GROUP BY  e.department;
```

firstname	lastname	department
SEAN	LEE	A00
MICHAEL	JOHNSON	B01
VINCENZO	BARELLI	A00
CHRISTINE	SMITH	A00

department_list

```
<Department name="A00">
    <emp>CHRISTINE</emp>
    <emp>VINCENZO </emp>
    <emp>SEAN</emp>
</Department>
```

```
<Department name="B01">
    <emp>MICHAEL</emp>
</Department>
```

Publishing XML as Rel. Table

XMLTable: make table from XML

➔Each item in the sequence returned by the XQuery will result in a row
➔The row data is created with that item as context

```
SELECT X.* from
XMLTABLE  ('$MyDB//customer'
      COLUMNS
      CID       INTEGER       PATH '@id',
      Name      VARCHAR(30)   PATH 'name',
      Type      CHAR(2)       PATH 'name/@type',
      Zip       XML           PATH 'zip'
   ) AS X
```

CID	NAME	TYPE	ZIP
1325	Bobby	US	<zip>33129</zip>
4711	Jane	US	<zip>95023</zip>

XML Type in SQL

- A new type (like varchar, date, numeric)
- SQL:2003 - XML type restricted to
  - XML document or
  - XML element or
  - Sequence of XML elements
- SQL / XML, 2nd edition
  - Full support of XQuery Data Model
  - XML(SEQUENCE), XML(ANY CONTENT), ...

Example (SQL:2003)

```
create table books(
  title   varchar(20),
  authors  XML);
```

No schema validation, no typing!

Title	Authors
XQuery 1.0	<author>D. Chamberlin </author> <author>D. Florescu</author> <author>et al.</author>
MonetDB	„P. Boncz“

- SQL:2006 => explicit validation with `XMLVALIDATE()`

XMLQuery

```
XMLQuery(
  XQuery-expression
  PASSING { BY REF | BY VALUE}
   (value-expression AS identifier [BY REF | BY VALUE])*
  RETURNING { CONTENT|SEQUENCE } { BY REF|BY VALUE}
)
```

- If `PASSING` value has no identifier, then that is context node
- `BY REF` - preserves Id (of an XML type)
- `BY VALUE` - creates a copy of the data

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HOW ➔ ➔

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XQuery Systems: 2 Approaches

Native

Tree is basic data structure

- tree-storage manager
- tree-query processing (algebra)
- tree-query optimization

Re-inventing the wheel?

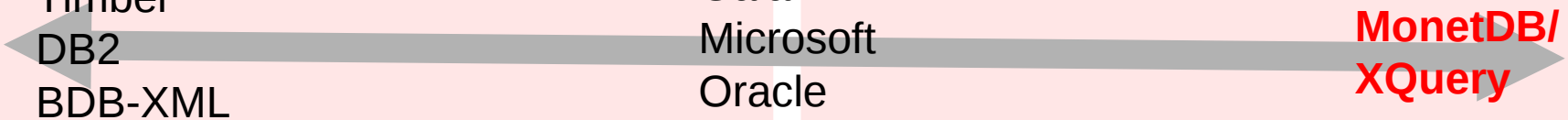
Relational

Leverage RDBMS storage, query processing & optimization

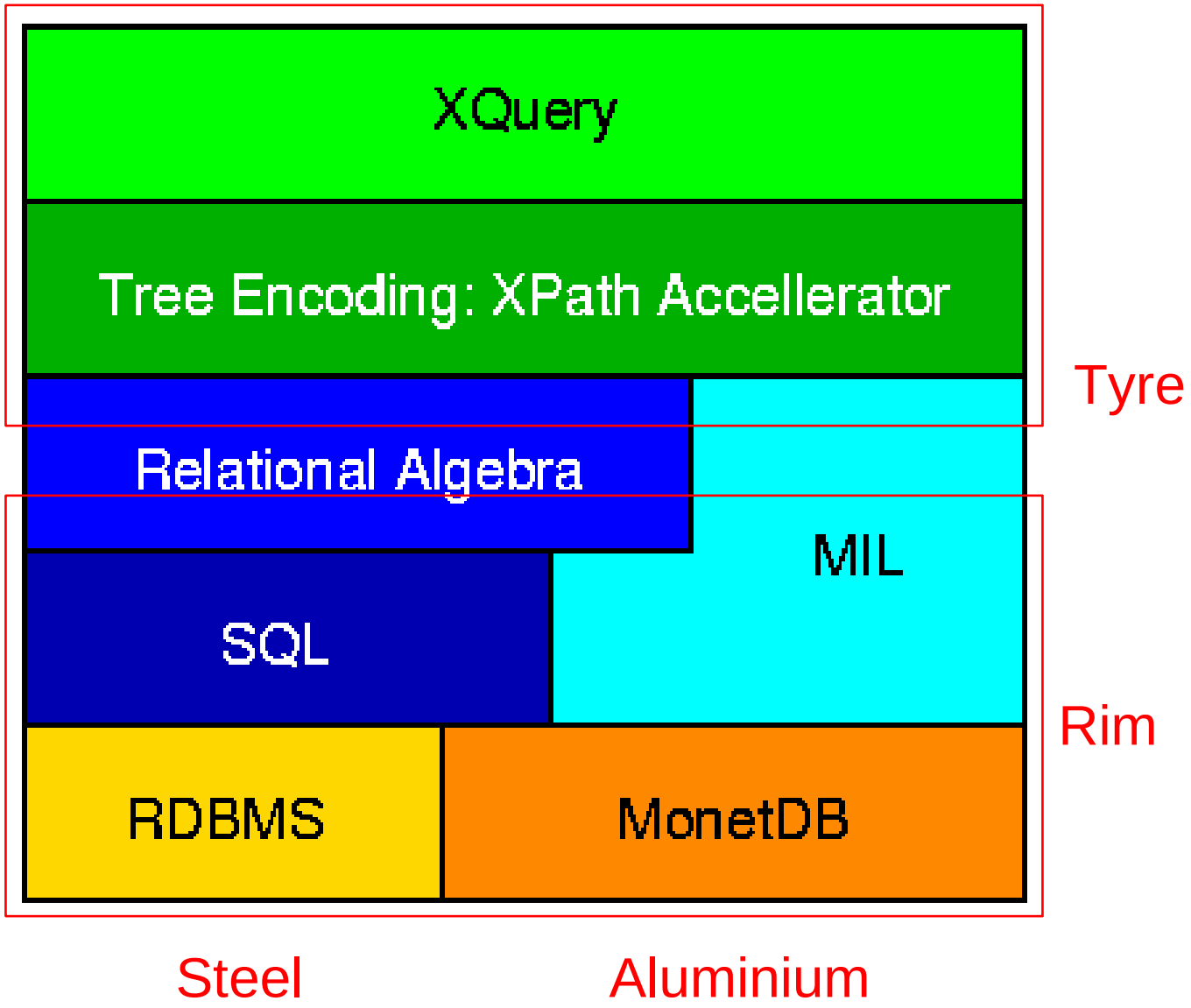
- XML shredded into tables
- XQuery translated into SQL

Let's use the old rim,

but make a new tyre!



The Idea


XQuery
Tree Encoding: XPath Accellerator
Relational Algebra
MIL
SQL
RDBMS
MonetDB
Tyre
Rim
Steel
Aluminium

Storing XML in Relations: Schema-Based Approach

Idea: Use schema information (from a DTD) to find a suitable relational schema.

- Proposed, e. g., by Shanmugasundaram et al., 1999.
- Example:

```
<persons>
  <person>
    <name>John Doe</name>
    <address>
      <street>13 Main Street</street>
      <city>Miami, FL 12345</city>
    </address>
  </person>
  <person>
    <name>Martha Johnson</name>
    <address>
      <street>42 Kin
      <city>New York
    </address>
  </person>
</persons>
```

id	*name*	*street*	*city*
1	John Doe	13 Main Street	Miami, FL 12345
2	Martha Johnson	42 Kings Road	New York, NY 54321

Schema-Based Approach: Benefits & Drawbacks

Some benefits and drawbacks of schema-based storage:

- ⊕ Takes full advantage of specialized data types, indexes,...
- ⊖ Requires DTD/Schema information.
- ⊖ Many issues with XML/XQuery semantics:
  - XML reconstruction,
  - document order,
  - recursive XML documents,...

Schema-based approaches are thus mainly used

- for **data-centric** XML, or
- if **interoperation** with "relational" applications is required.

MonetDB/XQuery

A Fast XQuery Processor Powered by a Relational Engine

Peter Boncz, Stefan Manegold
(CWI Amsterdam)

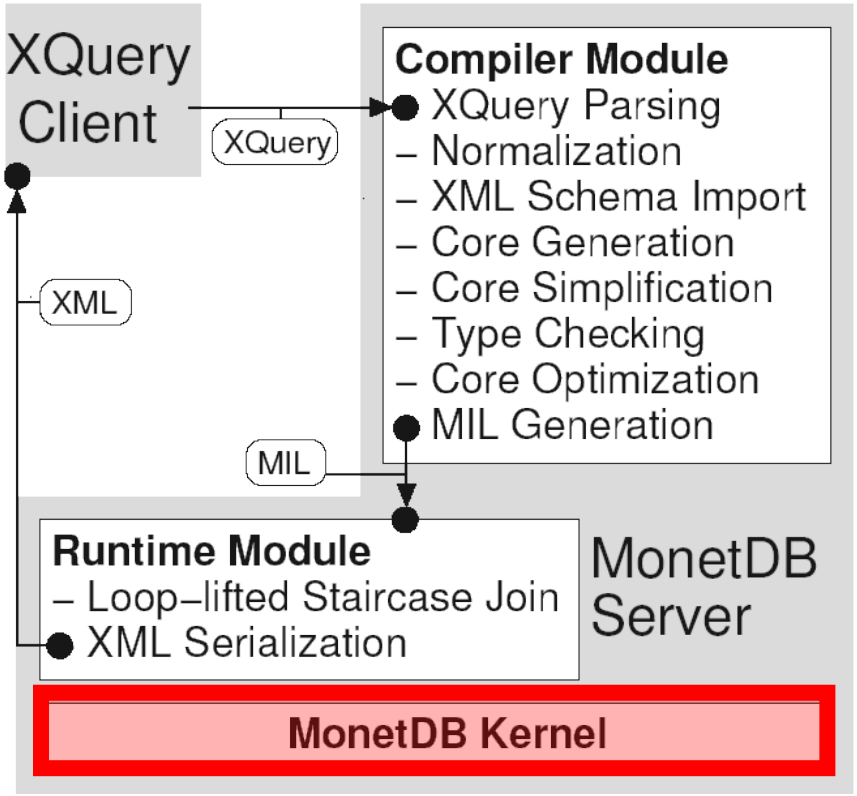
Torsten Grust, Jens Teubner, Jan Rittinger
(Technische Universität München)

Maurice van Keulen
(Technische Universiteit Twente)

[ACM/SIGMOD 2006]

MonetDB

open-source Mozilla license => download at **monetdb-xquery.org**



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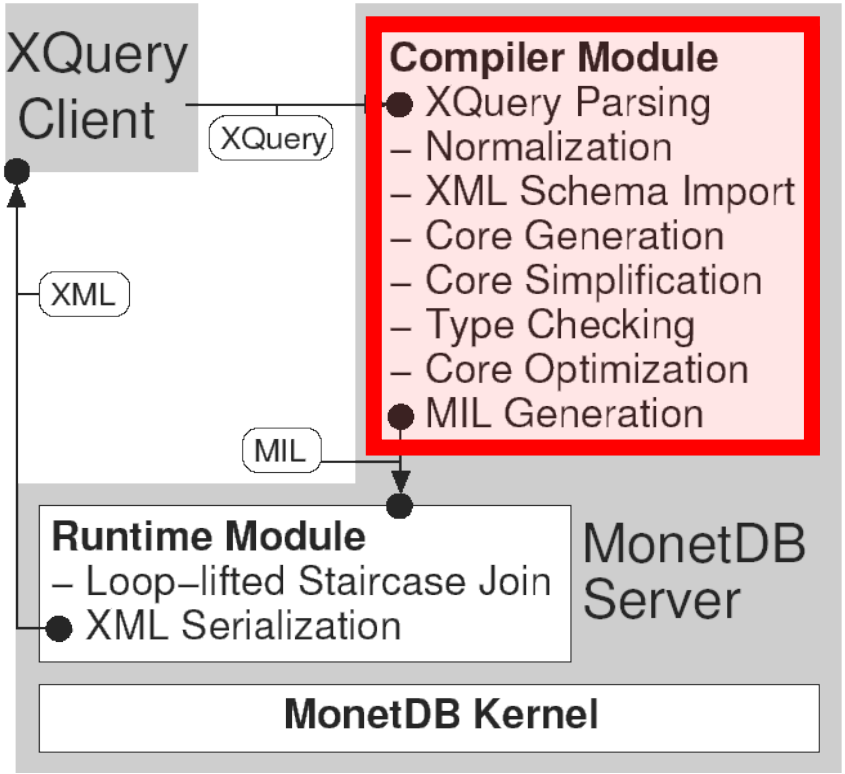

Pathfinder Project

Torsten Grust, Jens Teubner, Jan Rittinger

Maurice van Keulen

Schema-Oblivious Storage: XPath Accelerator

There are schema-independent ways to store XML.

- **XPath accelerator** [Grust 2002]
- Advantages:
  - support for **all XPath axes**, from **any context node**,
  - low space overhead,
  - efficiently implementable.
- Idea:
  - The **sequence of start/end tags** in the serialized XML document implies the full tree information.
  - Encode this sequence in a **numbering scheme**.

XPath Accelerator: *pre/post* plane

Node-based relational encoding of XQuery's data model

```
<a>
   <b>
      <c/>
   </b>
   <d/>
   <e>
      <f>
         <g/>
         <h/>
      </f>
      <i>
         <j/>
      </i>
   </e>
</a>
```

XPath Accelerator: *pre/post* plane

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```
0<a>
   1<b>
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    </b>
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    </e>
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```

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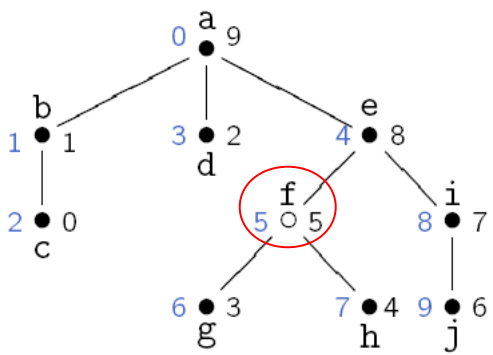

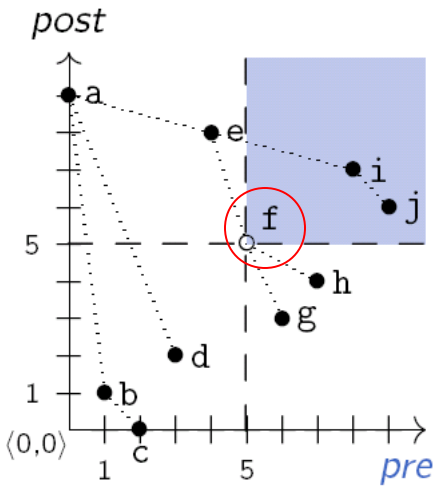

pre	post
0	9
1	1
2	0
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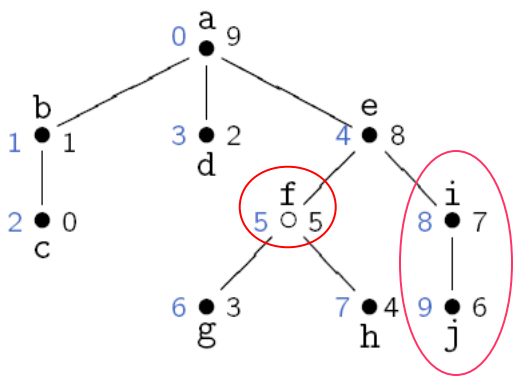

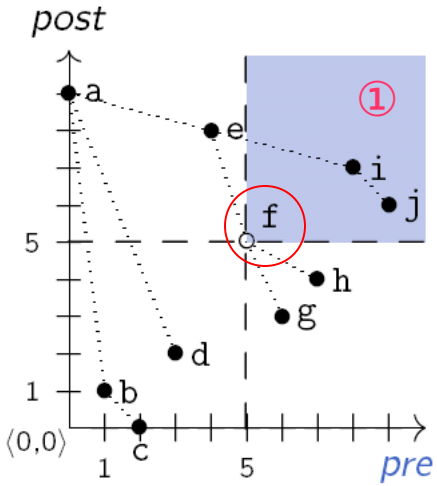

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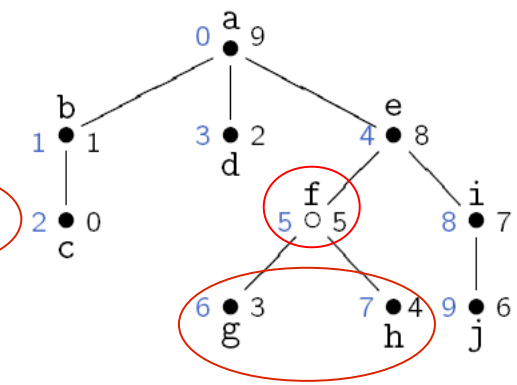

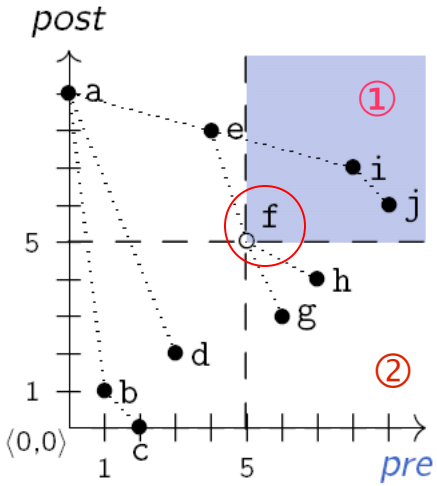

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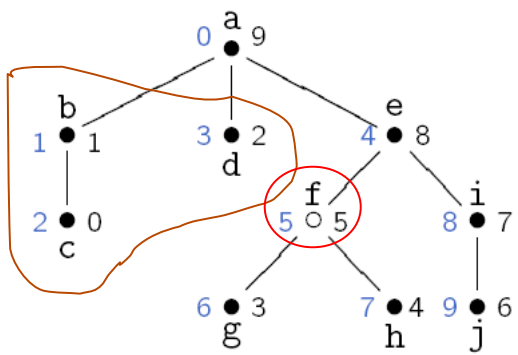

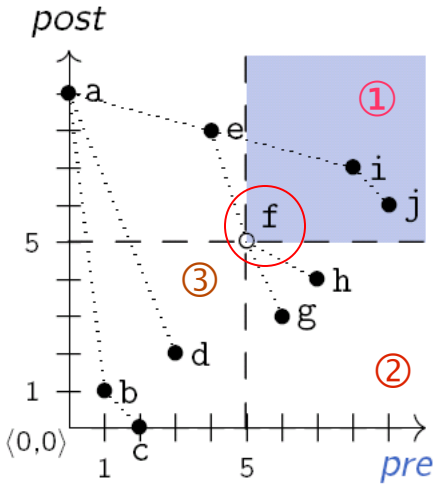

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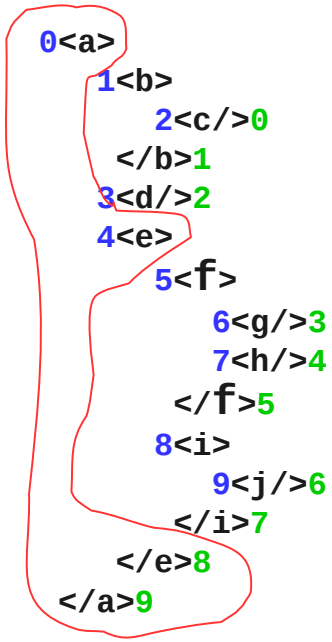

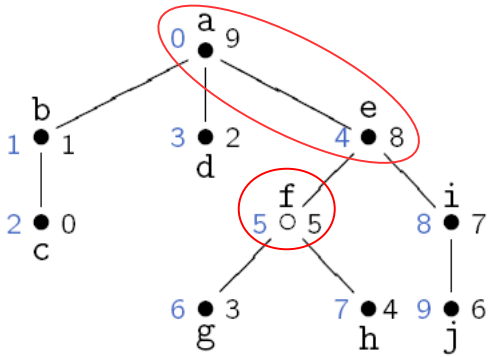

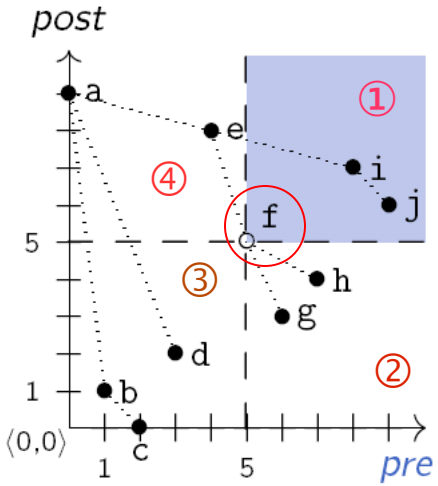

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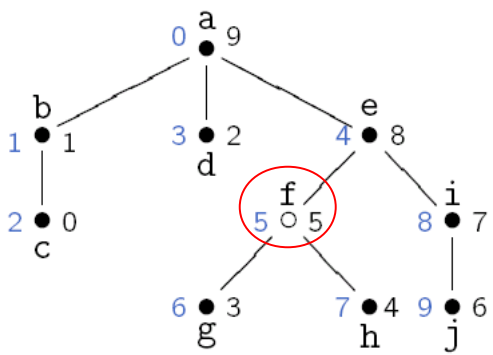

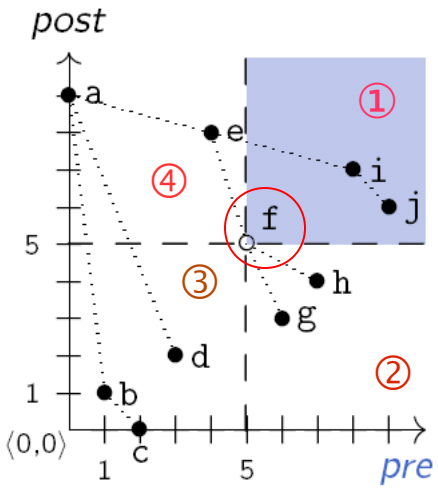

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Similar queries for other XPath axes

pre/post Table & *pre/size/level* Table

```
<a>
   <b>
      <c/>
   </b>
   <d/>
   <e>
      <f>
         <g/>
         <h/>
      </f>
      <i>
         <j/>
      </i>
   </e>
</a>
```

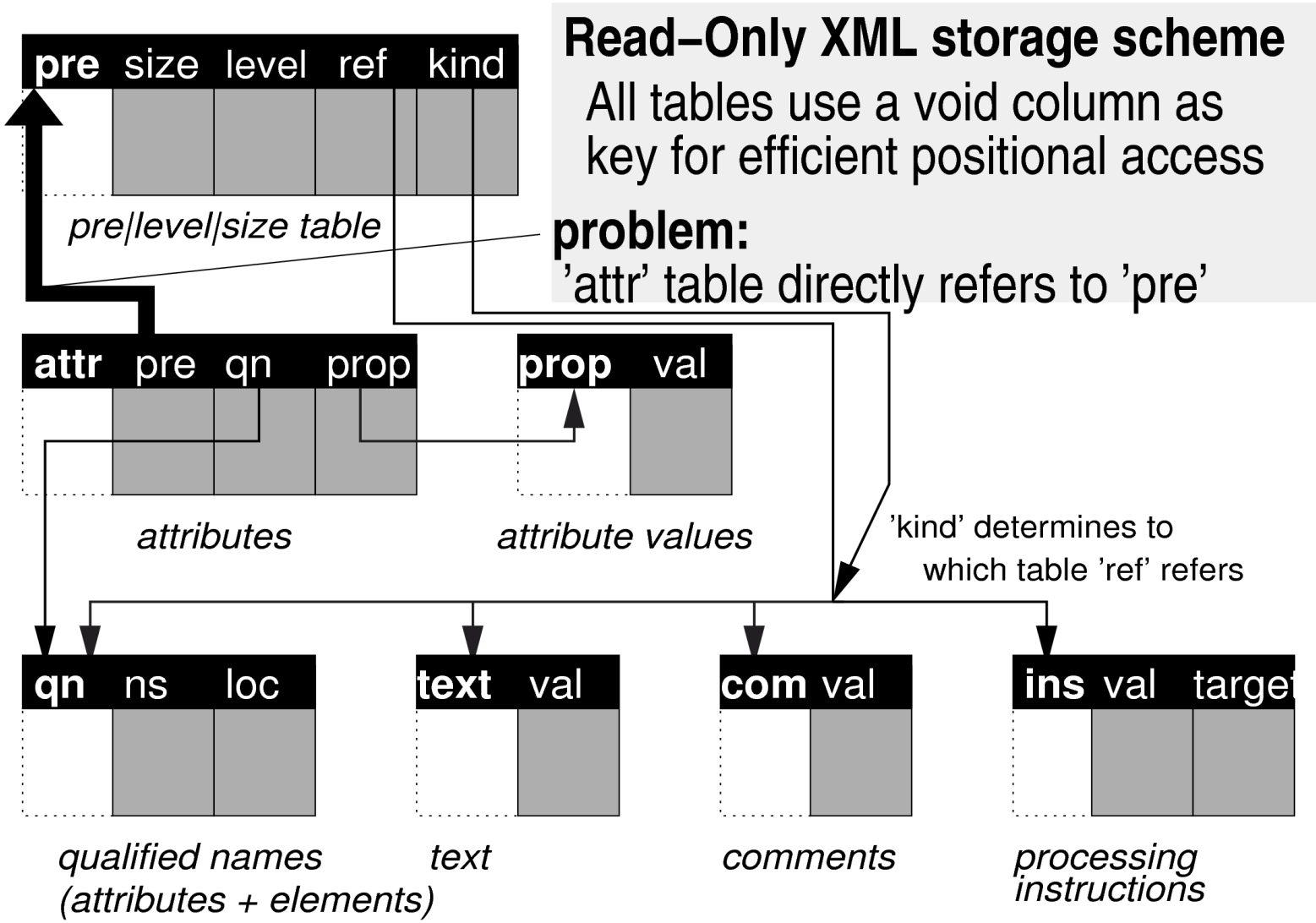
	Pre	Post
a	0	9
b	1	1
c	2	0
d	3	2
e	4	8
f	5	5
g	6	3
h	7	4
i	8	7
j	9	6

→

Pre	Size	Level
0	9	0
1	1	1
2	0	2
3	0	1
4	5	1
5	2	2
6	0	3
7	0	3
8	1	2
9	0	3

Post = pre + size - level

Complete XML Storage Schema



XPath evaluation (SQL)

Example query:
/descendant::open_auction[./bidder]/annotation

```
SELECT DISTINCT a.pre
  FROM doc r, doc oa, doc b, doc a
 WHERE r.pre=0
   AND oa.pre > r.pre AND oa.post < r.post          <- descendant
   AND oa.name = “open_auction” AND oa.kind = “elem”
   AND b.pre > oa.pre AND b.post < oa.post
   AND b.level = oa.level + 1                       } child
   AND b.name = “bidder” AND b.kind < “elem”
   AND a.pre > oa.pre AND a.post < oa.post
   AND a.level = oa.level + 1                       } child
   AND a.name = “annotation” AND a.kind = “elem”
ORDER BY a.pre
```

XQuery Systems: 2 Approaches

Native

Tree is basic data structure

- tree-storage manager
- tree-query processing (algebra)
- tree-query optimization

Re-inventing the wheel?

Relational

Leverage RDBMS storage, query processing & optimization

- XML shredded into tables
- XQuery translated into SQL

Let's use the old rim,

but make a new tyre!

X-Hive
Timber
DB2
BDB-XML

Galax
Microsoft
Oracle

MonetDB/ XQuery

Oracle10g/11g: XQuery Support

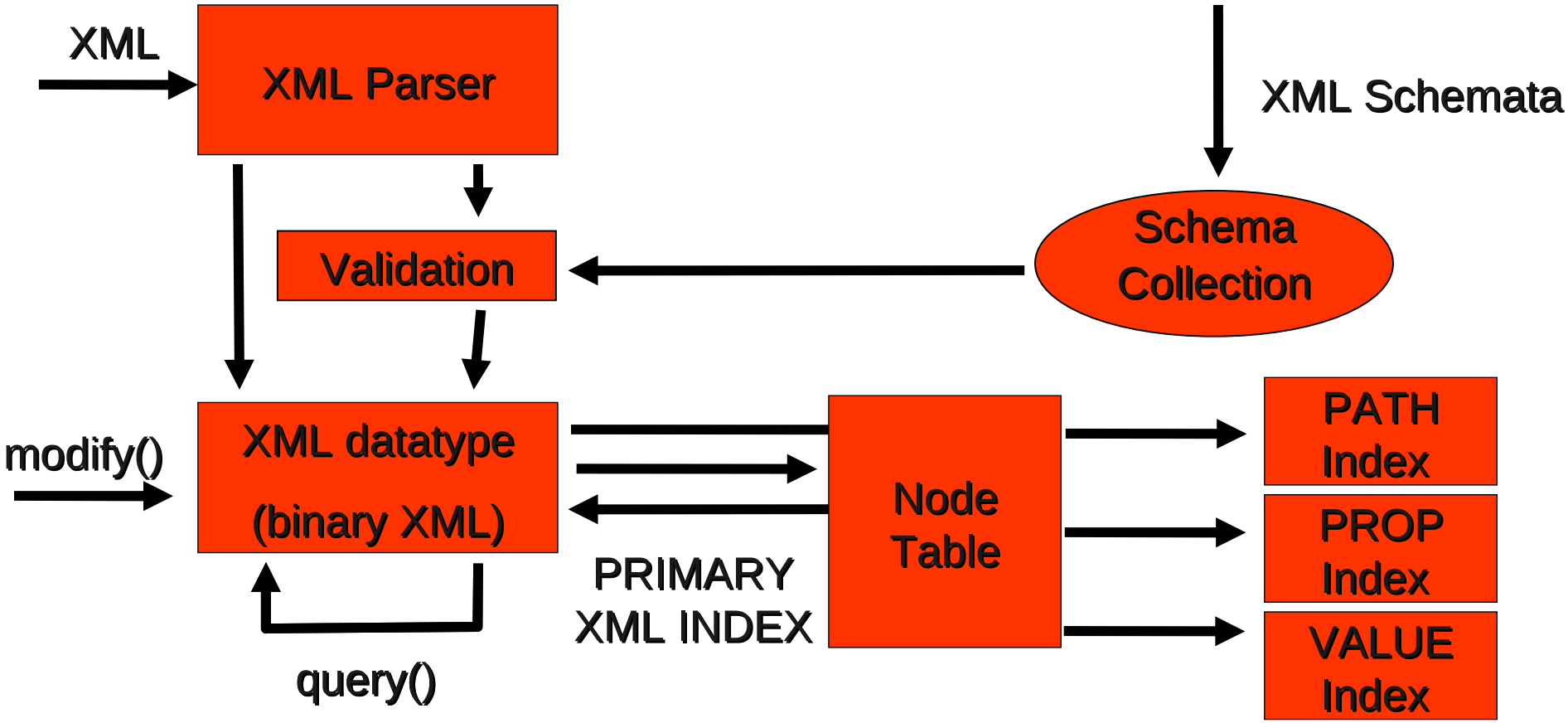
1. XMLDB integrated database engine
   - SQL / XML standard support
   - Optimized queries – rewrite to relational
1. Standalone Java query engine
   - 100% Java
   - Integrated into Oracle App Server -XDS
   - Interoperates with XSLT/XPath

First relational database to ship an XQuery implementation !

Oracle 10g/11g: XQuery database support

- Production in Oracle Database 10gr2
- Supports XMLQuery and XMLTable construct
- Native compilation into SQL /XML structures
- Returns XMLType(Content)
- Can query over relational, O-R, XMLType data
- fn:doc - Maps to XDB Repository on server
- SQLPlus provides *xquery* command to execute XQuery
- XSL-T will also get compiled to XQuery

Microsoft SQL Server 2005: Overview

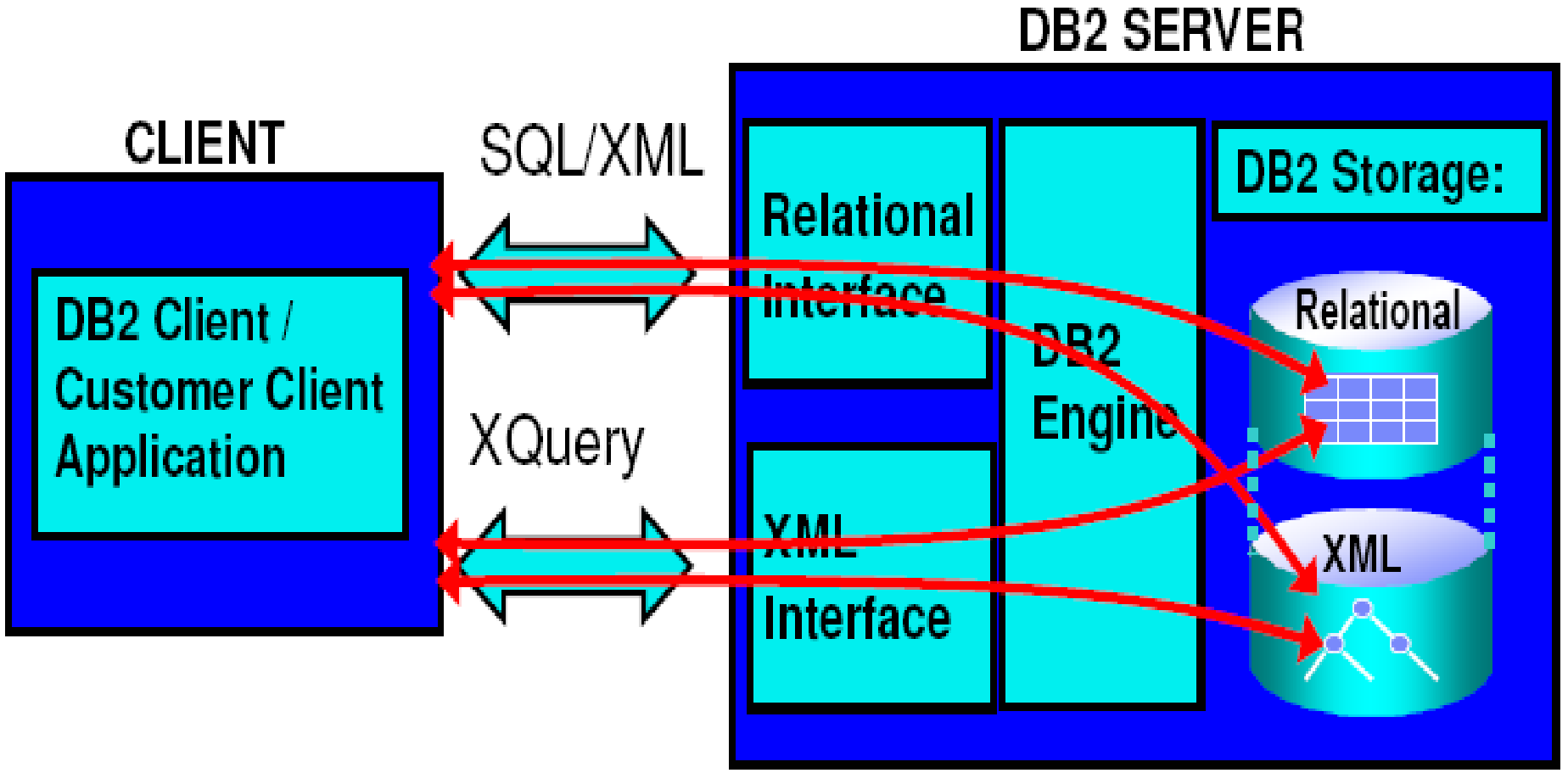


Microsoft SQL Server 2005: Indexing

- Create XML index on XML column

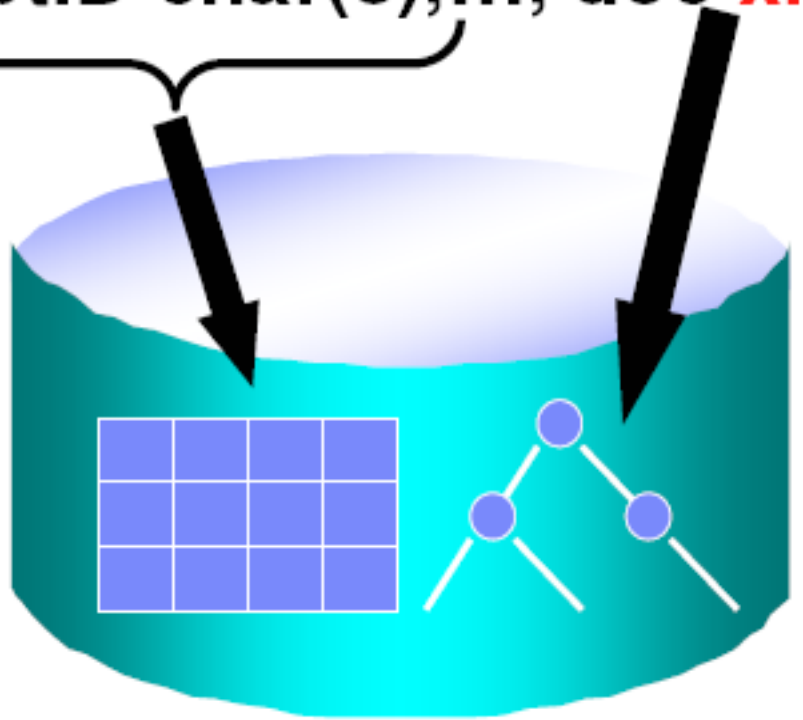
  CREATE PRIMARY XML INDEX idx_1 ON docs (xDoc)
- Creates secondary indexes on tags, values, paths
- Speeds up queries
  - Results can be served directly from index
  - Entire query is optimized
    - Same award winning cost based optimizer
  - Indexes are used as available

IBM DB2 v9: Overview



IBM DB2 v9: Storage

```
create table dept (deptID char(8),..., doc xml);
```



- Relational columns are stored in relational format
- XML columns are stored **natively**
- All XML data is stored in XML-typed columns

IBM DB2 v9: SQL in XQuery

XQuery access to XML column values

Create table dept(docid int, doc xml)

- **Identifying XML data by column**

  Always operates on entire column!

  FOR $d in db2-fn:xmlcolumn("DEPT.DOC")…

- **Identifying XML data via a select statement**

  Leverage predicates/indexes on relational columns

  FOR $d in db2-fn:sqlquery("select doc from dept")…

  FOR $d in db2-fn:sqlquery("select doc from dept where deptID LIKE 'PR%' ")…

  FOR $d in db2-fn:sqlquery("select dept.doc from dept, unit
  where dept.deptID=unit.ID and unit.headcount > 200")…

IBM DB2 v9: XQuery in SQL

XMLQUERY: embed XQuery in SQL

```
create table dept(deptID char(8) primary key,  doc xml);
create table  unit(unitID char(8), headcount integer, bldg integer);
```

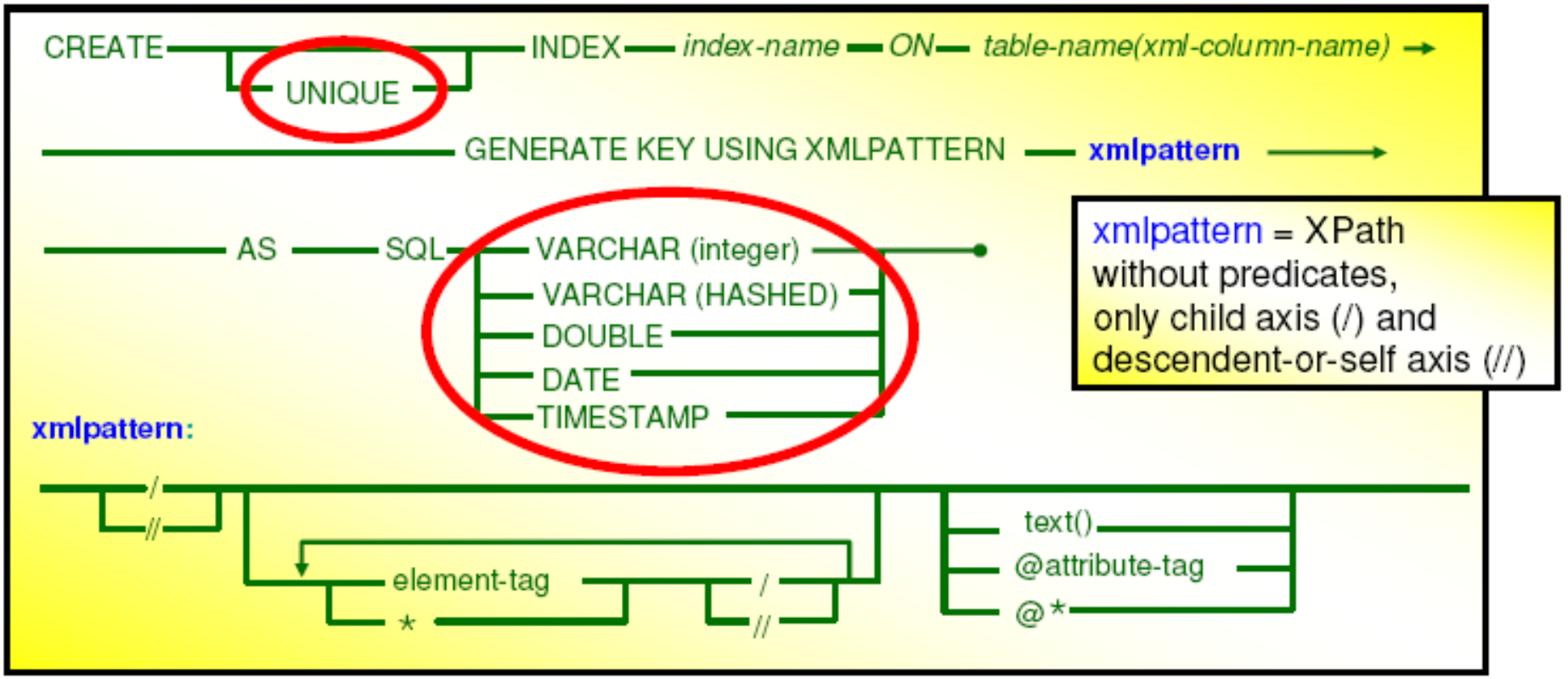
```
select deptID,xmlquery('for $d in $deptdoc/dept
                        where $d/@bldg = 101
                        return $d/name' passing doc as "deptdoc")
from dept
where deptID <> "PR27";
```

```
select d.deptID , u.headcount,
       xmlquery('$deptdoc/dept/name' passing d.doc as "deptdoc")
from dept d, unit u
where d.deptID=u.unitID
and  u.headcount > 200
and xmlexists('$deptdoc/dept/employee/name' passing d.doc as "deptdoc")
```

IBM DB2 v9: Indexing

XML Index DDL

- **create index idx1 on T(xmlcol)**
  generate key using xmlpattern '/a/b/@c'
  as sql date



- Declaration & use of namespace prefix supported (not shown above)