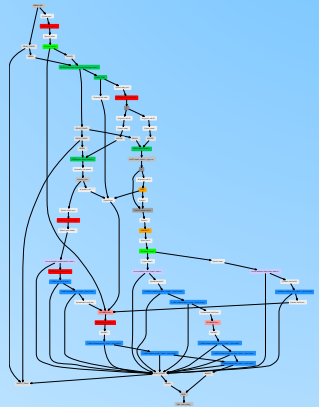


Pathfinder: XQuery Compilation Techniques for Relational Database Targets

Jens Teubner · Technische Universität München

Joint work with:

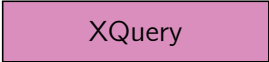
Torsten Grust, Peter Boncz, Martin Kersten, Maurice van Keulen,
Stefan Manegold, Sjoerd Mullender, Jan Rittinger, Marc H. Scholl, ...



Challenge: Construction of a Scalable XQuery Processor

XQuery:

- tree-structured XML data
- ordered sequences of items: (x_1, \dots, x_n)
- explicit iteration: `for $v in e1 return e2`
- side effects: `element t { e }`



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Re-use existing RDBMS technology?

- flat, unordered data model: tables of tuples
- bulk-oriented processing
- no side effects

RDBMS

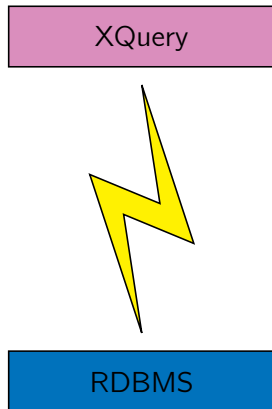
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This talk bridges the apparent gap.

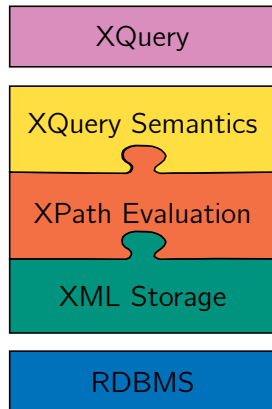
trees, sequences, iteration, side effects

compositional compilation: **loop-lifting**

relational step evaluation: **staircase join**

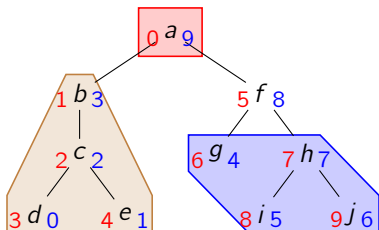
tree encoding: **XPath accelerator**

tables of tuples, relational algebra, SQL

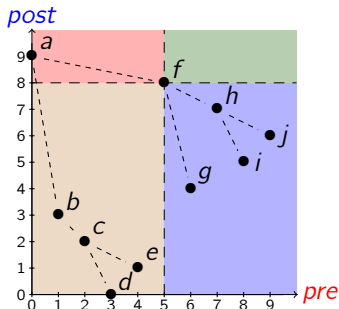


Pathfinder is a full open-source implementation of these techniques.

Pathfinder's XML Storage is based on XPath Accelerator (Grust '02)

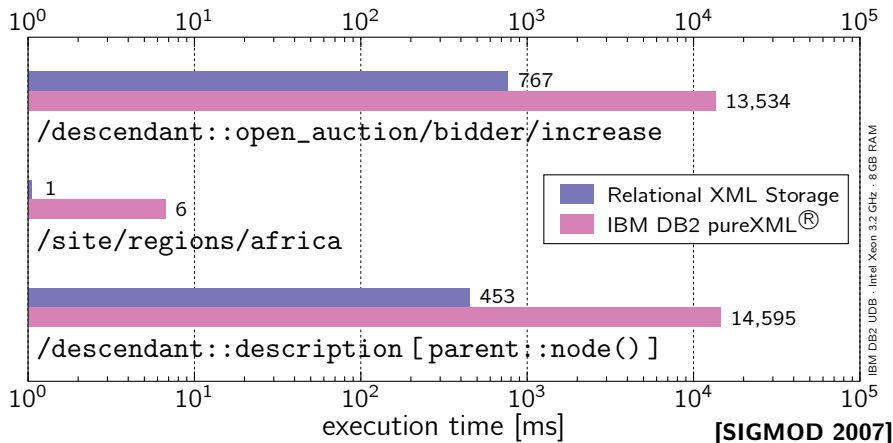


<i>n</i>	<i>pre</i>	<i>post</i>
<i>a</i>	0	9
<i>b</i>	1	3
<i>c</i>	2	2
<i>d</i>	3	0
<i>e</i>	4	1
<i>f</i>	5	8
<i>g</i>	6	4
⋮	⋮	⋮



- **Any** encoding providing **node identity**/**document order** suffices.
- We actually use a variant of this encoding: *pre/size/level*.

Relational XML storage can beat native XPath processors.



- Use B-trees with **low-selectivity** prefixes (e.g., *level*, tag names)!

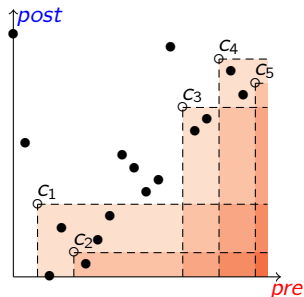
XPath is the backbone of every XQuery processor.

XPath:

- Context is a **set** of nodes
- Document order, duplicate-free result

Problems:

- Repeated scans over the same area
- Expensive sorting and duplicate elimination



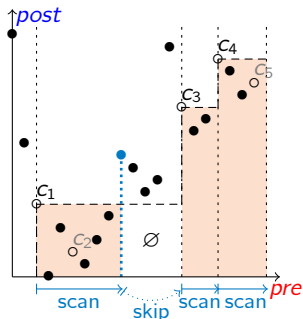
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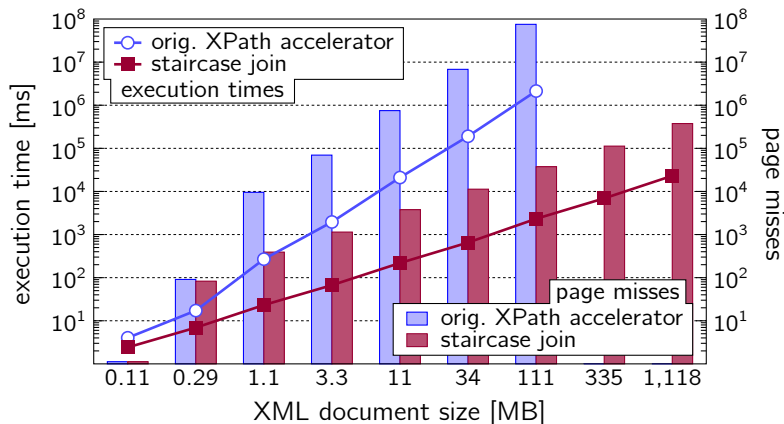
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Staircase join: [VLDB 2003]

- Encapsulates **tree awareness** in a single join operator
- **Cache-friendly** and **XPath-compliant**

We injected staircase join into PostgreSQL 7.3.



■ Query: `/descendant::age/ancestor::person`

[VLDB 2004 Demo]

XPath is only part the story.

- Variables and iteration: `for $v in e1 return e2`
- Sequence construction: `(e1, e2)`
- Element construction: `element { e1 } { e2 }`
- Dynamic typing: `e1 instance of e2`
- etc.

XQuery is a functional language, though.

- Process independent FLWOR iterations in **parallel**
- Use **bulk-oriented** processing capabilities of modern RDBMSs

Loop-lifting: Encode independent iterations using a single relation.

```
for $x in (1, 2, 3) return $x to 3
```

- Column *iter* labels independent iterations.
- Sequence order is maintained in column *pos*.
- This is the **loop-lifted** encoding of an XQuery item sequence.
- The compilation procedure operates on loop-lifted sequence representations only.

<i>iter</i>	<i>pos</i>	<i>item</i>
1	1	1
1	2	2
1	3	3
2	1	2
2	2	3
3	1	3

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1	1	1	\mathcal{T}_{int}
1	2	2	\mathcal{T}_{int}
1	3	3	\mathcal{T}_{int}
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2	2	3	\mathcal{T}_{int}
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This representation is highly versatile.

- Item types to support **dynamic type** semantics

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<i>iter</i>	<i>pos</i>	<i>item</i>	<i>type</i>	<i>score</i>
1	1	1	\mathcal{T}_{int}	1
1	2	2	\mathcal{T}_{int}	1
1	3	3	\mathcal{T}_{int}	1
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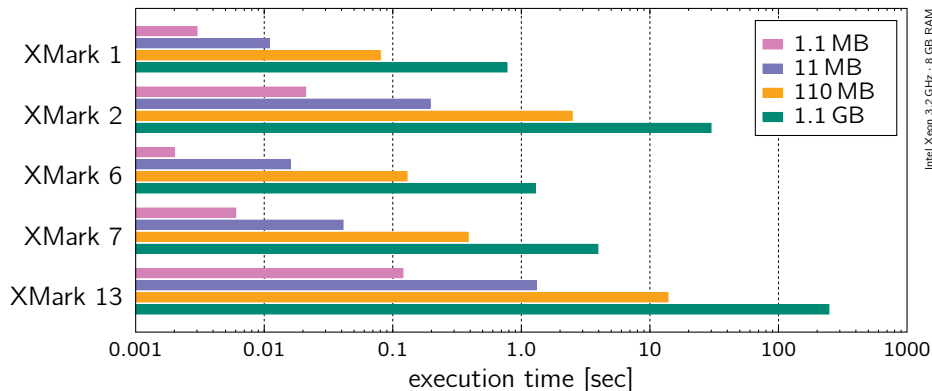
This representation is highly versatile.

- Item types to support **dynamic type** semantics
- Additional information to support, e.g., XQuery **full-text** search



Commodity RDBMSs readily provide all the functionality we need.

E.g., SQL on IBM DB2 Universal Database V 8.2.



Intel Xeon 3.2 GHz · 8 GB RAM

[VLDB 2004]



Pathfinder is a full implementation of a loop-lifting compiler.

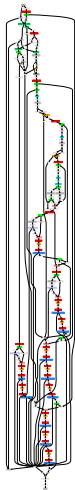
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The resulting plans can be of significant size, though.



XMark Q8 - 34 MB - Intel Xeon 3.2 GHz - 8 GB RAM

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112 sec



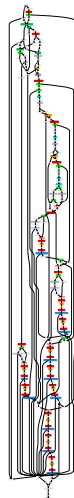
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103 sec 112 sec



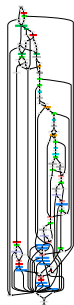
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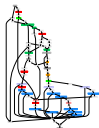
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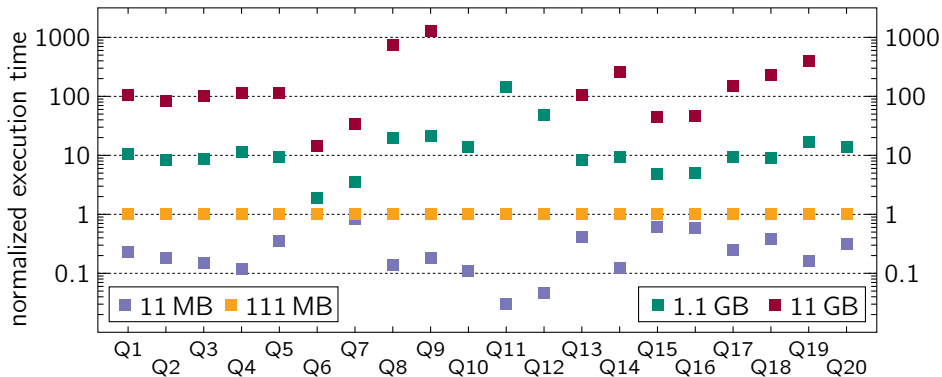
- 1 **constant propagation**,
- 2 **projection pushdown**,
- 3 **functional dependency** and **data flow analyses**, and
- 4 algebraic **join detection**.

(You saw these optimizations in yesterday's demo session.)



Pathfinder targets the main-memory RDMBS MonetDB.

- Queries over multi-gigabyte XML instances answered in **interactive time** (XMark: 18 of 20 queries in \ll 1 min on 1.1 GB)
- Unprecedented **scalability**



[SIGMOD 2006, VLDB 2005 Demo]

A complete and purely relational XQuery processing stack:



A relational tree encoding, derived from **XPath accelerator**, maps XML document trees into relational tables.

- Re-use of mature storage and indexing techniques

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XQuery Semantics

The **loop-lifting** compilation procedure maps arbitrary XQuery expressions to primitives of relational algebra.

- Implementation of iterative XQuery semantics in terms of efficient, bulk-oriented processing

Pathfinder is an ongoing, joint research project with CWI Amsterdam, U Twente, and U Konstanz.

- Algebraic **optimization**, **cost** and **result size estimation**
- New functionality: **recursion**, **dynamic typing**, and **validation**
- Alternative back-ends: **Idefix** (UKN), **SQL:1999** [SIGMOD 2007]

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- X-RPC: XQuery processing in **peer-to-peer** networks
- XIRAF: **multi-hierarchical** XML documents
- Tijah: **full-text retrieval** for the MonetDB/XQuery system
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pathfinder ('pɑːθ,fɑndə) *n.* a person who makes or finds a way, esp. through unexplored areas or fields of knowledge.