Generating Efficient Execution Plans for Vertically Partitioned XML Databases

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The Problem

- Centralized query evaluation techniques for XML well understood
- These techniques do not scale to large collection sizes and heavy workloads
- Goal: use distribution to improve scalability
- Focus on end-to-end cost of query evaluation

Distributed XML Query Evaluation: Two Scenarios

- Integrating multiple data sources
  - Fragmentation is determined by existing data sources
  - Need flexible fragmentation model to express this
- Distribution for performance
  - Choose fragmentation to suit workload
  - Can use more constrained fragmentation model
  - Fragmentation specification allows for distributed query optimization

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Outline

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Fragmenting XML Collections

- Ad-hoc fragmentation
- Structure-based fragmentation

Ad-hoc fragmentation

- Cut arbitrary edges in document tree
- Highly flexible (good for data integration)
- No explicit fragmentation specification
- Limited potential for exploiting fragmentation characteristics for query optimization
- Not a suitable choice for this work

Structure-based Fragmentation

- Fragmentation according to characteristics of data or schema
- Yields a fragmentation specification that can be exploited for query optimization
- Better choice when distributing for performance

Our Fragmentation Model

- Focus on simplicity and precise fragmentation specification
- Focus on partitioning collection (replication is orthogonal)
- Follow semantics of relational fragmentation techniques
  - Horizontal fragmentation (based on predicates/selection)
  - Vertical fragmentation (based on partitioning of schema/projection)
  - Hybrid fragmentation (combination of horizontal and vertical steps)

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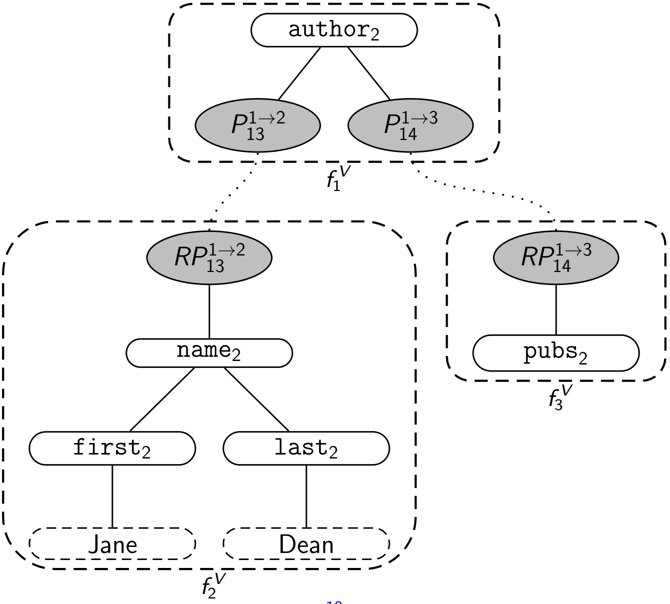
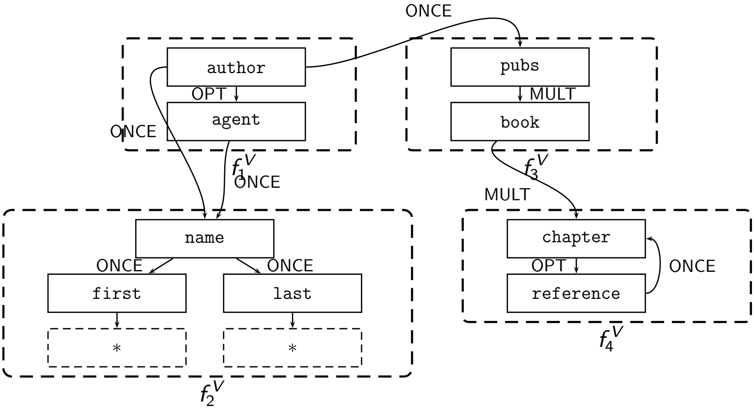
Vertical Fragmentation



Vertical Fragmentation Specification

Vertical fragmentation is specified by a *fragmentation schema*.



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Outline

Query model

XQ, subset of XPath

- Nested paths with child and descendant steps
- Explicit node tests and wild cards
- Value constraints (numeric or textual)
- $Q := \sigma \mid * \mid Q//Q \mid Q/Q \mid Q[q]$

  $q := Q \mid . = / \neq \textit{ str} \mid . = / \neq / \leq / < / \geq / > \textit{ num}$

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Query Example

"Find all references in publications written by authors whose first name is 'William' and whose last name is 'Shakespeare' "

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/author[./name[./first = "William" and
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- Node tests

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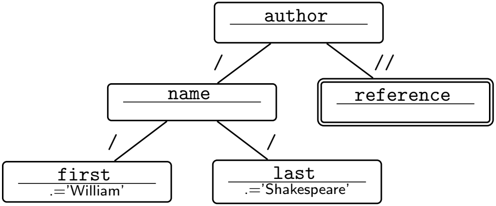
- Node tests
- Value constraints
- Structural constraints

Tree Patterns



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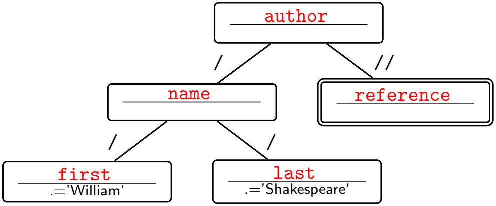

- Pattern nodes with node tests and value constraints

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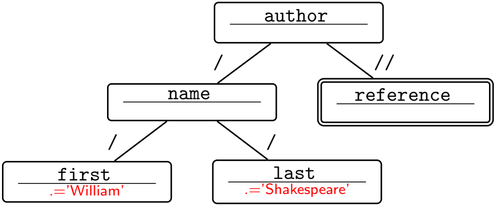

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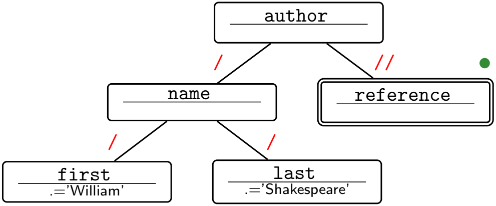

- Pattern nodes with node tests and value constraints
- Edges annotated with XPath axes

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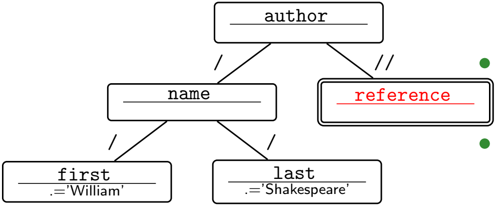
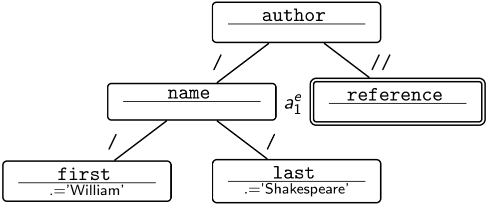
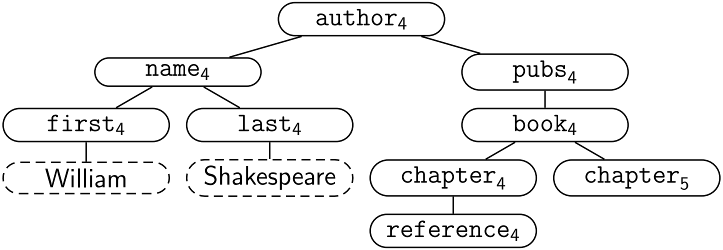


- Pattern nodes with node tests and value constraints
- Edges annotated with XPath axes
- Extraction point nodes

Evaluating Tree Pattern Queries





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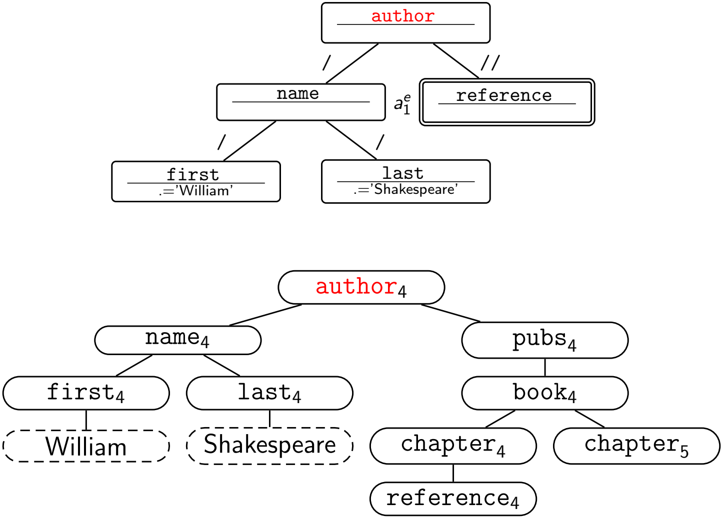

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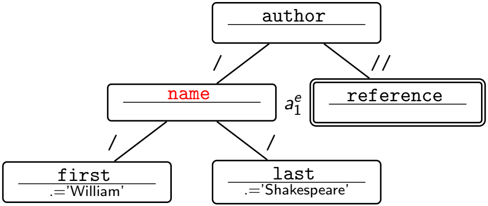

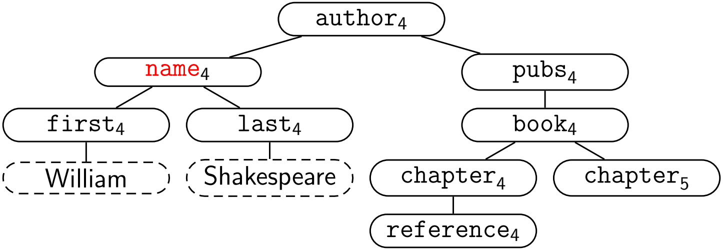

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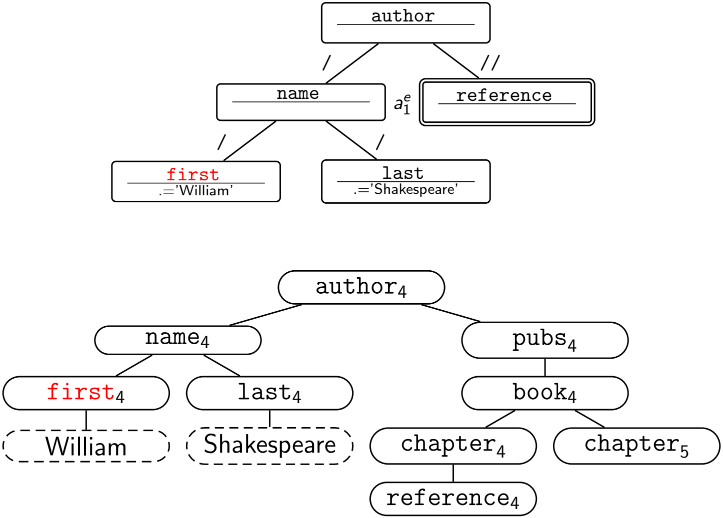

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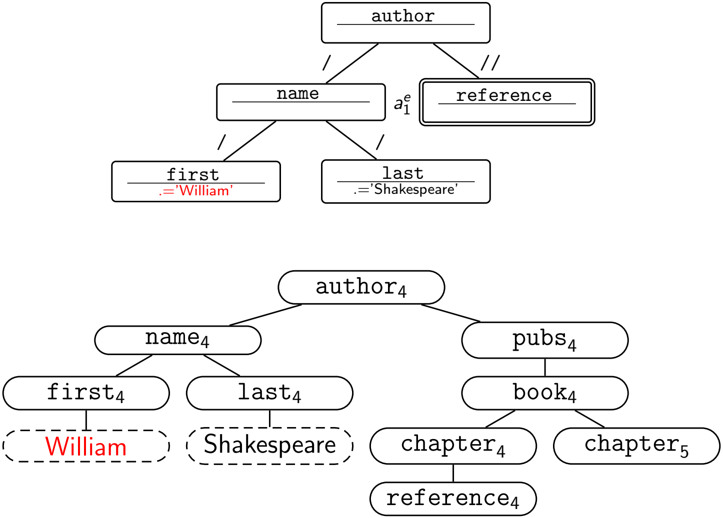

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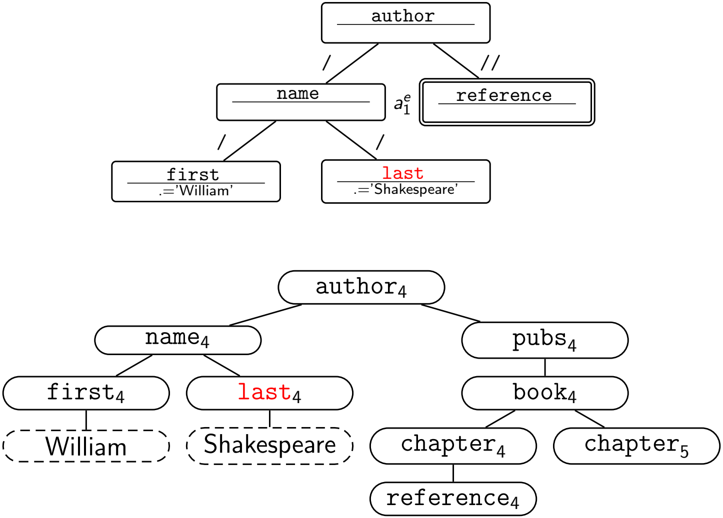

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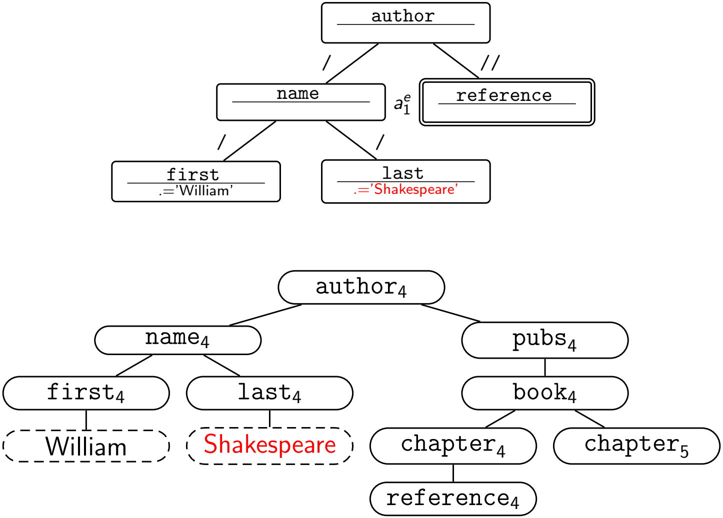

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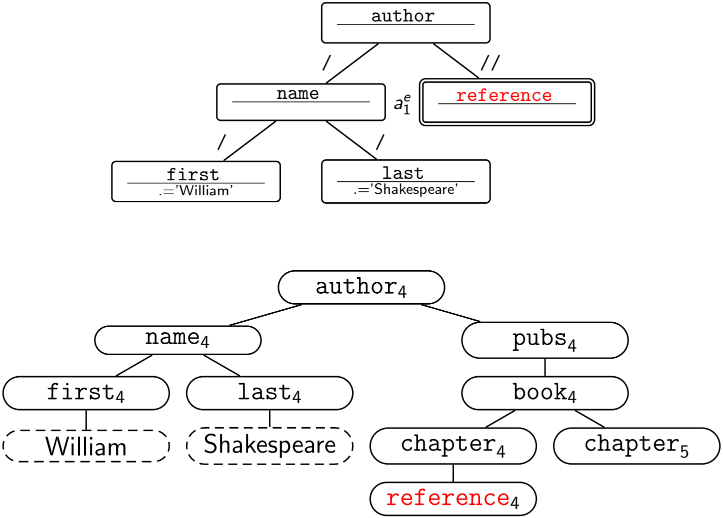

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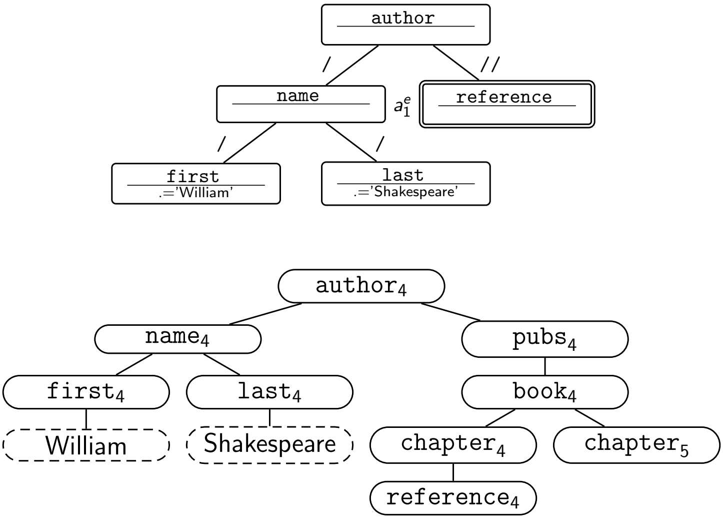

$[a_1^e = \texttt{reference}_4]$

Evaluating Tree Pattern Queries

- Various centralized approaches exist
  - Navigating document trees
  - Structural joins
- We leverage these for distributed query evaluation

Querying Vertically Distributed XML Collections

- Input
  - Fragmentation-unaware tree pattern query
  - Fragmentation schema
- Tasks
  - Annotate tree pattern nodes with corresponding fragments
  - Decompose tree pattern into sub-patterns for individual fragments
  - Convert sub-patterns to local plans using existing techniques (each site is free to choose local strategy)
  - Generate distributed execution plan that specifies how results are combined

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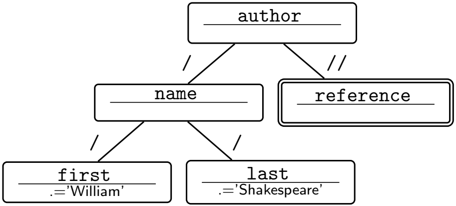

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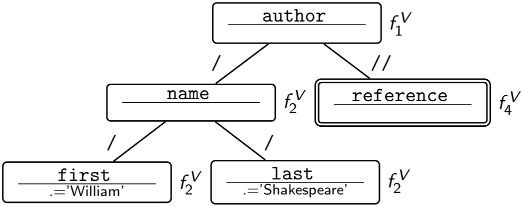

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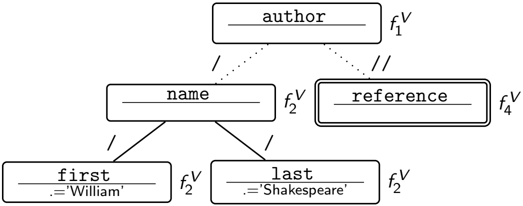

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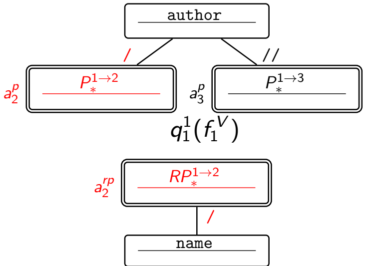

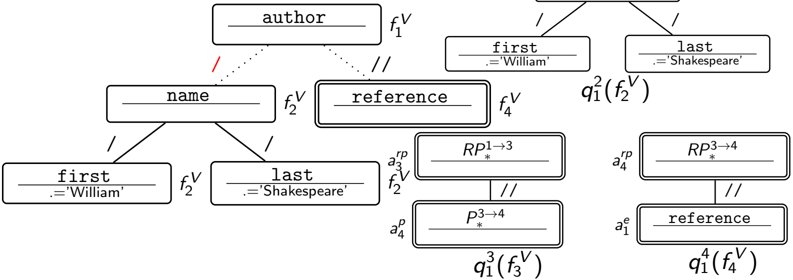

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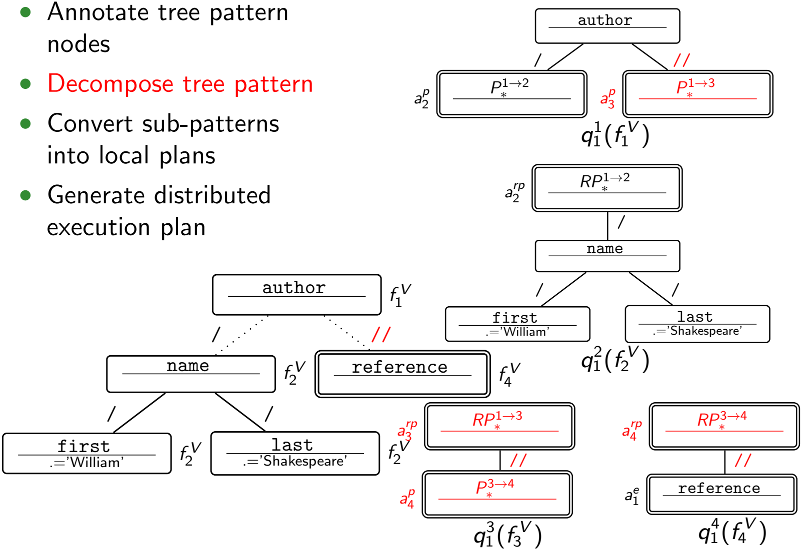

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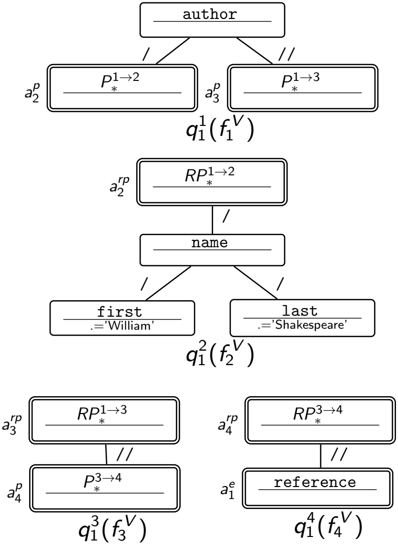

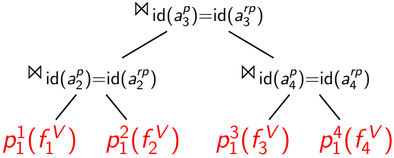

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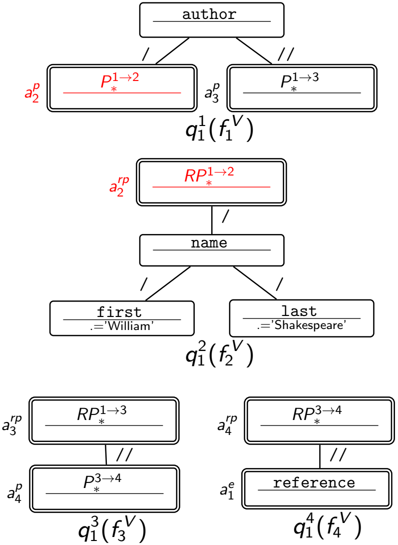

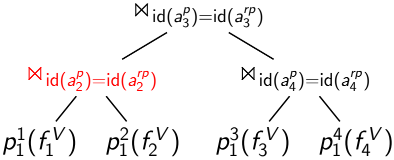

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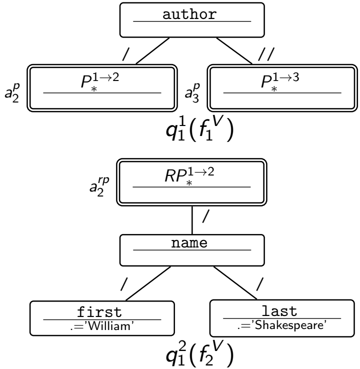

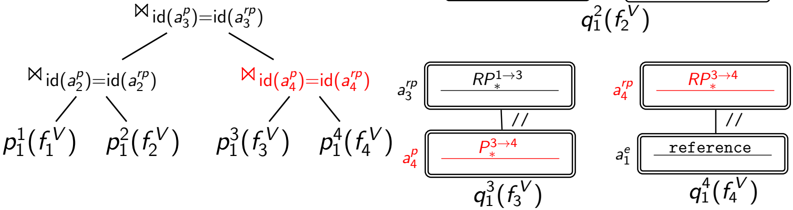

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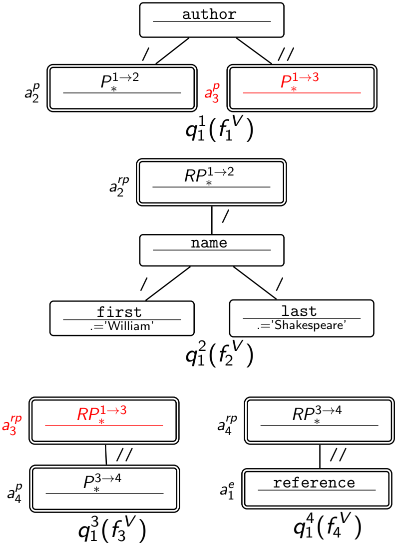

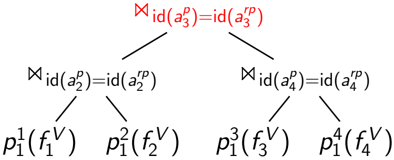

Improving Distributed Execution Plans

- Pruning irrelevant fragments
- Join order
- Push cross-fragment joins into local plans

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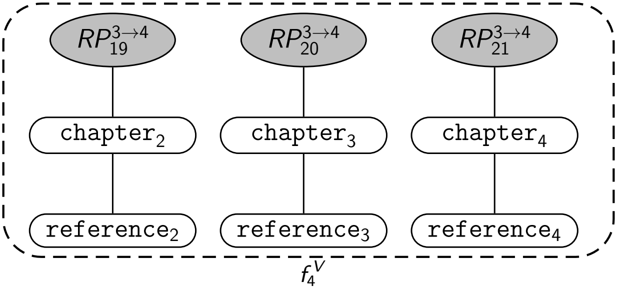
Pushing Cross-Fragment Joins

Large fraction of local results are discarded by cross-fragment join



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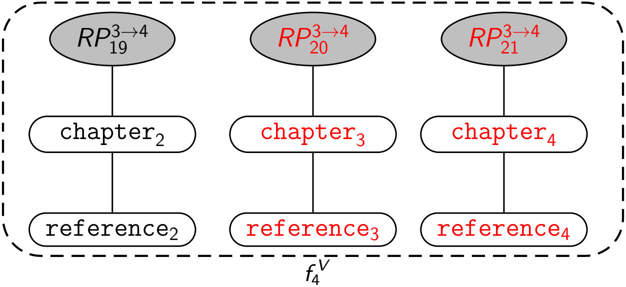

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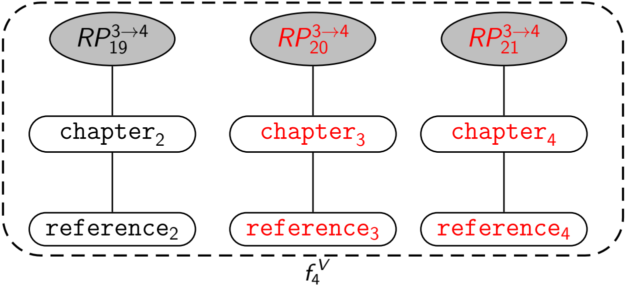
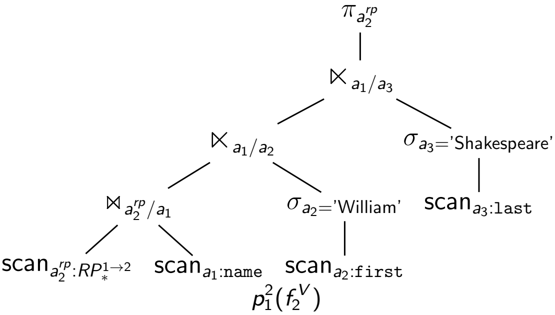


- Idea: only access relevant sub-trees in fragment
- Avoid computing irrelevant local results
- Use pipelining to push cross-fragment join into local plan

A Local Query Plan



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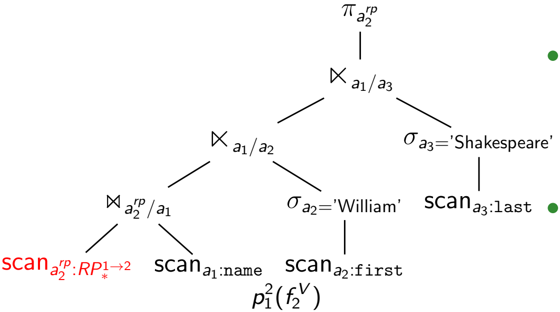

- Plan scans root proxy nodes in fragment
- Idea: filter these root proxy nodes before evaluating remainder of plan
- Works for navigating plans and plans based on structural joins (shown here)

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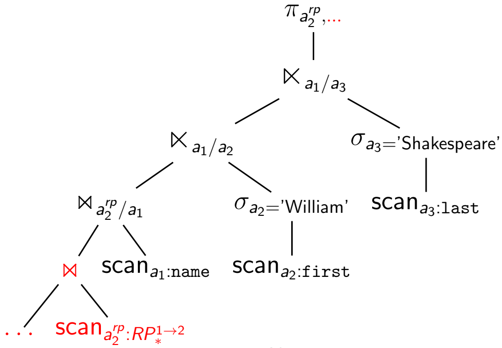

$p_1^2(f_2^V)$

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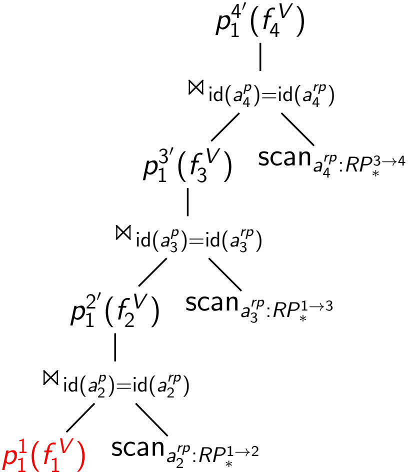

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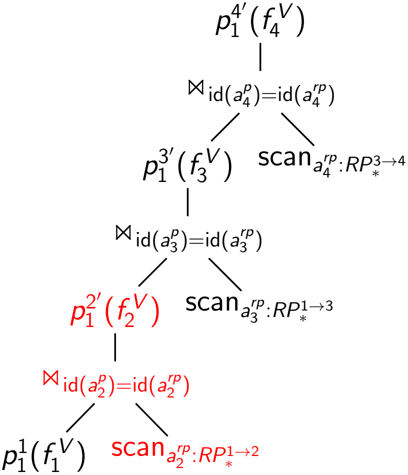

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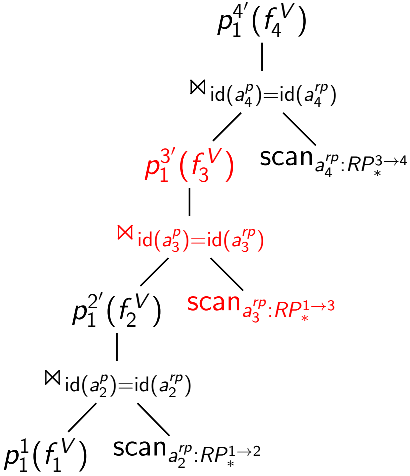

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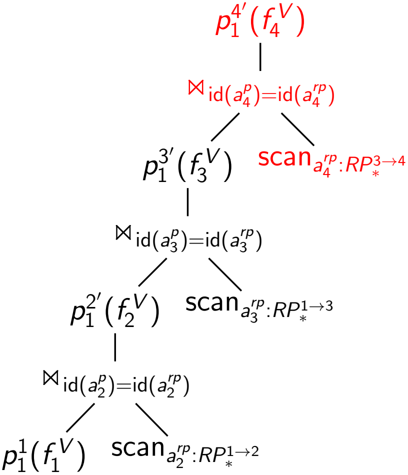


Pushing Cross Fragment Joins: Implementation

- Can use full pipelining if both inputs to join are ordered
- Alternatively, can use index on root proxy nodes
- Full parallelism after first tuple received by local plan

Pushing Cross Fragment Joins

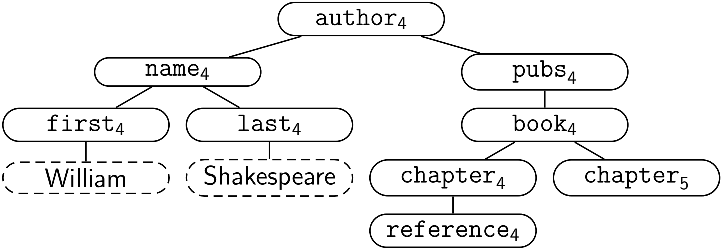
- Avoids accessing large portion of sub-trees within a fragment
- Can only be fully used in left-deep plans
- Decreases flexibility (e.g., where joins are performed)

Label Path Filtering

- Cross-fragment join pushing works well but decreases flexibility
- Goal: find a solution that can obtain partial benefit for scenarios where join pushing cannot be applied
- Idea: use selection instead of join to filter out some root proxy nodes

Label Path Filtering

- Assign to each proxy node the label path from the document root
- Filter for label paths that are compatible with the query



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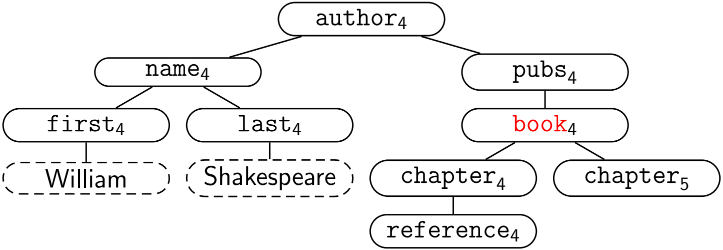
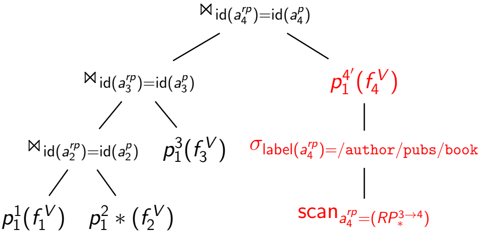


/author/pubs/book

Label Path Filtering



- Assume there are two types of publications: `book` and `article`
- Can use selection to filter chapters based on publication type

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Label Path Filtering

- Can be used in more cases
- Retains higher degree of flexibility
- Benefit is more limited (does not filter all irrelevant root proxy nodes)

Determining the Best Distributed Execution Plan

- Join pushing and label path filtering are not always advantageous
- Determine best execution plan using cost model

Outline

Performance Evaluation

- Implemented techniques within Natix
- 12 GB XMark collection (auction data)
- 1 Amazon EC2 instance for each of each of 10 vertical fragments

Performance Evaluation

- XPathMark queries (with few filtering value constraints)
- Modified, more selective XPathMark queries

A1	/site/closed_auctions/closed_auction/annotation/description/text/keyword
A2	//closed_auction//keyword
A3	/site/closed_auctions/closed_auction//keyword
A4	/site/closed_auctions/closed_auction[annotation/description/text/keyword]/date
A5	/site/closed_auctions/closed_auction[descendant::keyword]/date
A6	/site/people/person[profile/gender and profile/age]/name
B7	//person[profile/@income]/name
A1S	/site/closed_auctions/closed_auction[price > 600]/annotation/description/text/keyword
A2S	//closed_auction[price > 600]//keyword
A3S	/site/closed_auctions/closed_auction[price > 600]//keyword
A4S	/site/closed_auctions/closed_auction[price > 600][annotation/description/text/keyword]/date
A5S	/site/closed_auctions/closed_auction[price > 600][descendant::keyword]/date
A6S	/site/people/person[starts-with(name, 'Ry')][profile/gender and profile/age]/name
B7S	//person[starts-with(name, 'Ry')][profile/@income]/name

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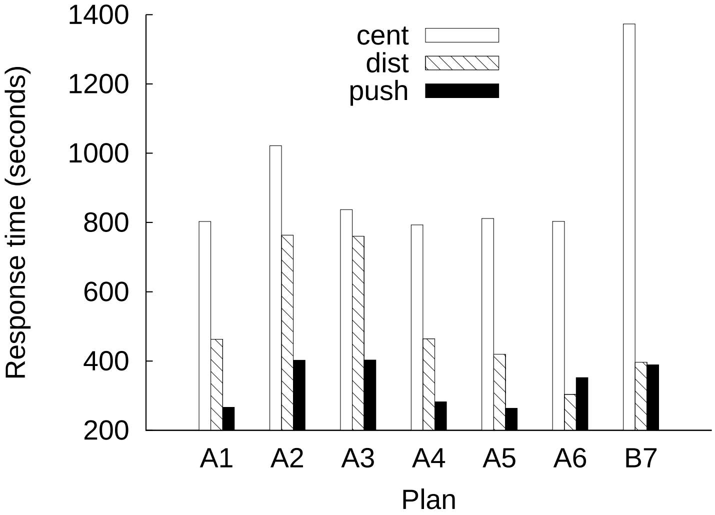
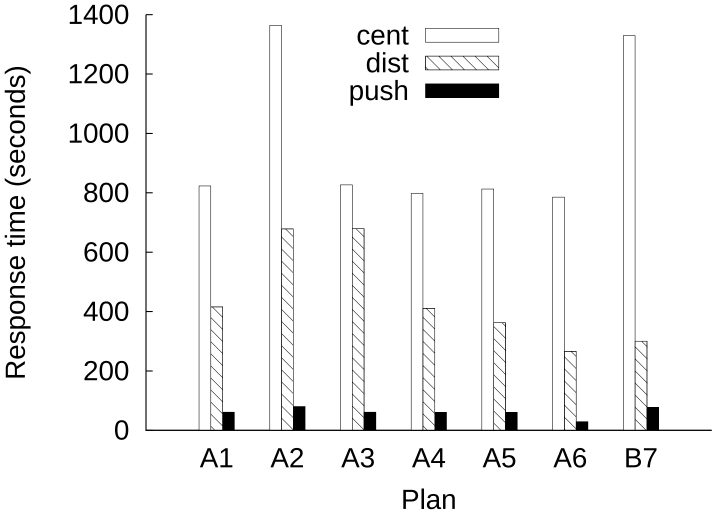
Performance Evaluation: XPathMark



Performance Evaluation: Selective XPathMark



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Conclusions

- Distribution can make XML query evaluation more scalable
- Join pushing can significantly improve query performance
- A cost model is essential for finding the optimal technique for a given query

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References

[1] Patrick Kling, M. Tamer Özsu, Khuzaima Daudjee: Generating Efficient Execution Plans for Vertically Partitioned XML Databases, PVLDB 2010.

[2] Patrick Kling, M. Tamer Özsu, Khuzaima Daudjee: Scaling XML Query Processing: Distribution, Localization and Pruning, DAPD 2011.