XML Query Processing

CPS 216
Advanced Database Systems

Announcements (March 31)

- ❖ Course project milestone 2 due today
  - Hardcopy in class or otherwise email please
- ❖ I will be out of town next week
  - No class on Tuesday (April 5); will make up during reading period
  - Badrish Chandramouli will give the lecture on Thursday (April 7)
- ❖ Homework #3 in less than two weeks (April 12)
- ❖ Reading assignment for next week will be assigned through email

Overview

- ❖ Recall that XML queries based on path expressions can be expressed by joins
- ❖ Node/edge-based representation (graphs)
  - Equi-join on *id*'s
  - Chasing pointers ≈ index nested-loop joins
    - ☞"Navigational" approach
- ❖ Interval-based representation (trees)
  - "Containment" joins involving *left* and *right*
  - Sort-merge joins, zig-zag joins with indexes
    - ☞"Structural" approach

Navigational processing in Lore

VLDB 1999

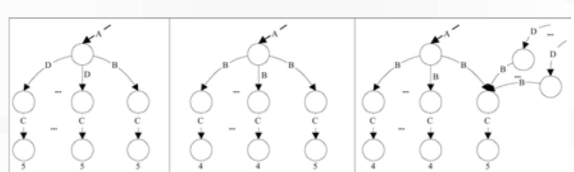
- ❖ Lore data model peculiarity: labels on edges instead of labels on nodes
- ❖ Access paths in Lore
  - Base representation: (parent, label) → child
  - Label index: (child, label) → parent
  - Edge index: label → (parent, child)
  - Value index: (value, label) → node
  - Path index: path expression → node
- ❖ Correspond to the following in a label-on-node model
  - label/value → node
  - (parent, label) → child
  - child → parent

Navigational plans in Lore

`//A/B/C[.=5]`

- ❖ Top down: pointer chasing
  - Start with `//A`, navigate down to `//A/B` and then to `//A/B/C`, and then check values of `C`
- ❖ Bottom up: reverse pointer chasing
  - Start with `//C[.=5]`, navigate up to `//B[/C[.=5]]` and then to `//A[/B/C[.=5]]`
- ❖ Hybrid: top down and bottom up, meet in middle
  - Start with `//A`, navigate down to `//A/B`
  - Start with `//C[.=5]`, navigate up to `//B[/C[.=5]]`
  - Intersect `B` nodes
  - ☞In general, hybrid can combine multiple top-down and bottom-up plans starting from anywhere in the path expression

Comparison of Lore navigational plans

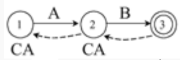


- ❖ Which plan is best depends on the size of the intermediate results it generates
  - Choose the optimal join order!
- ❖ Top down and bottom up are essentially index nested-loop joins ("pure" navigation)
- ❖ Hybrid can use any join strategy to combine subplans

Niagara unnest

VLDB 2003

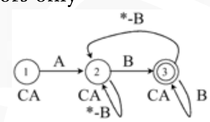
- Unnest: navigation-style processing using finite state machines



- Example: `A/B`
  - Given a list of elements for which `A/B` needs to be evaluated
  - Each state maintains a cursor
  - For each given element, state 1 uses a CA (child-axis) cursor with label `A` to iterate through all `A` children
  - For each `A` child, state 2 uses a CA cursor with label `B` to iterate through all `B` children of the `A` child
- Essentially a sequence of indexed nested-loop joins
  - Top down or bottom up, but not hybrid

Alternative unnest strategies for //

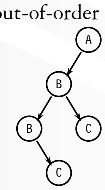
- Example: `A//B`
- Using CA cursors only



- Using DA (descendent-axis) cursor
  - Given node *n* and label `A`, a DA cursor iterates through all *n*`//A` nodes in document order

Surprise with the DA cursor

- Recall that XPath expressions are supposed to return result nodes in document order
- Example: `/A//B/C`
  - DA enumerates descendents in document order
  - But subsequent steps may produce out-of-order results
- Duplicates are also an issue (e.g., query `//A//B//C` on data `/A/B/B/C/C`)



Structural approach

- Binary containment joins (Al-Khalifa et al., *ICDE* 2002)
  - Given *Alist* and *Dlist*, two lists of elements encoded with (*left*, *right*), with each list sorted by *left*
  - Find all pairs of (a, e), where $a \in$ *Alist* and $e \in$ *Dlist*, such that a is a parent (or ancestor) of e
- Example query processing scenario: `//book/author`
  - Using an inverted-list index, retrieve the list of `book` elements sorted by *left*, and the list of `author` elements sorted by *left*
  - Find pairs that actually form parent-child relationships

Tree-based algorithms

<u>Algorithm *Tree-Merge-Anc*</u>

BeginJoinable = 0;

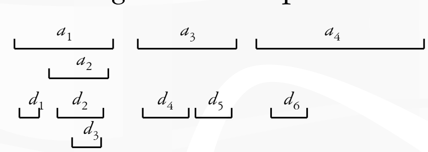
For each a in *Alist*:

Start from *BeginJoinable* and skip *Dlist* until the first element with *left* > a.*left*; update *BeginJoinable*;

Start from *BeginJoinable* and join each d from *Dlist* with a; stop at the first d with *left* > a.*right*;

- An alternative algorithm, *Tree-Merge-Desc*, uses *Dlist* as the outer table instead of *Alist*, and requires minor tweaks to conditions

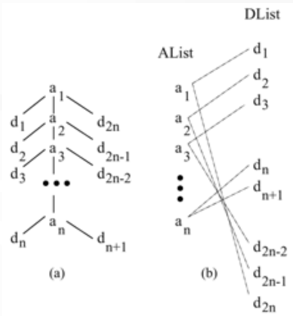
Tree-Merge-Anc example



- a_1: *BeginJoinable* = d_1; stops at d_4
- a_2: *BeginJoinable* = d_2; stops at d_4
- a_3: *BeginJoinable* = d_4; stops at d_6
- a_4: *BeginJoinable* = d_6

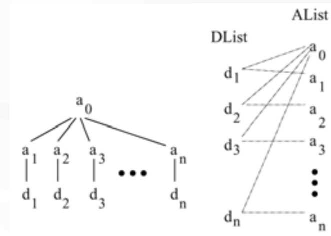
☞ Further optimization is possible to avoid unnecessary rescanning; though in general rescanning cannot be avoided

Worst case of *Tree-Merge-Anc*



- Optimal (up to a constant factor) for //
- Not optimal for /

Worst case of *Tree-Merge-Desc*



- Not even optimal for //
- ☞ Problem: linear access to *Alist* forces unnecessary scanning
- ☞ Idea: create another representation that corresponds more closely to a tree traversal

Stack-based algorithms

<u>Algorithm *Stack-Tree-Desc*</u>

Start with an empty stack *Astack*

While *Astack* or *Alist* or *Dlist* is not empty:

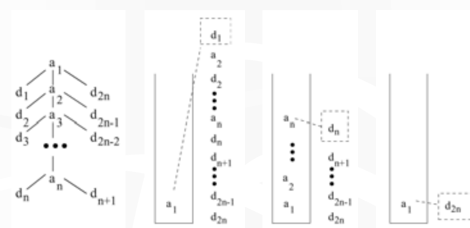
If heads of both *Alist* and *Dlist* come after the top of *Astack*, pop *Astack*;

Else if the head of *Alist* is contained by the top of *Astack*, push it onto *Astack* and advance *Alist*;

Else join the head of *Dlist* with everything on *Astack* and advance *Dlist*;

- ☞ Output is ordered by *Dlist*
- An alternative algorithm, *Stack-Tree-Anc*, orders output by *Alist* but requires more bookkeeping

Stack-Tree-Desc example

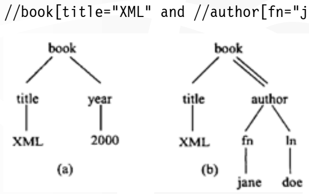


- ☞ Copying from *Alist* to *Astack* avoids the worst cases of *Tree-Merge-Anc* and *Tree-Merge-Desc*

Twigs

- "Twigs" represent longer and possibly branching XPath expressions
  - Problem: find all instances of a given twig in a document
    - More what XPath requires

```
//book[title="XML" and year="2000"]
//book[title="XML" and //author[fn="jane" and ln="doe"]]
```

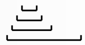


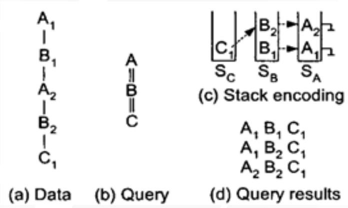
Double edges represent //

Holistic twig join

- Traditional approach: use a sequence of binary containment joins to process a twig
- Problem: intermediate results can get much larger than input and output sizes
  - Example?
- Idea: use a multi-way merge (since all joins are on the same attributes)
  - "Holistic" twig join (Bruno et al., *SIGMOD* 2002)

Compact encoding using stacks

- One stack for each node in the query twig
  - Elements in a stack form a containment chain 
- Each stack element points to one in the parent stack
  - Specifically, the top one that contains it

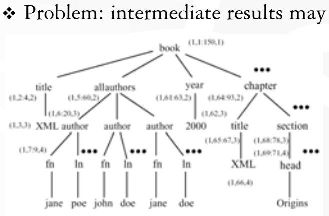


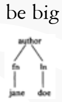
PathStack

- Handles twigs with no branches $q1//q2//\ldots//qn$
- Input lists $T_{q1}, T_{q2}, \ldots, T_{qn}$ and stacks $S_{q1}, S_{q2}, \ldots, S_{qn}$
- While T_{qn} is not empty:
  - Let T_{qmin} be the list whose head has smallest *left*;
  - Clean all stacks: pop while top's *right* < *head*(T_{qmin}).*left*;
  - Push *head*(T_{qmin}) on S_{qmin}, with pointer to *top*($S_{parent(q_{min})}$);
  - If q_{min} is the leaf (*qn*), output results and pop S_{qmin};
- Check properties
  - Elements in a stack form a containment chain
  - Each stack element points to the top one in the parent stack that contains it

Extending *PathStack* to *TwigStack*

- A first cut
  - Decompose a twig into root-to-leaf paths
  - Process each path using *PathStack*
  - Merge solutions for all paths
- Problem: intermediate results may be big





All authors will be returned by *PathStack*, though only the last one should be in the final result

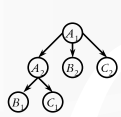
TwigStack

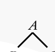
- Generate solutions for each root-to-leaf path
  - Do not use *PathStack*, which generates all solutions
  - Modify *PathStack* to generate only solutions that are parts of the final result (possible if twig contains only //)

    Specifically, when pushing h_q onto stack S_q, ensure that
    - h_q has a descendent $h_{q'}$ in the each input list $T_{q'}$ where *q'* is a child of *q*
    - Each $h_{q'}$ recursively satisfies the above property
- Merge solutions for all paths

TwigStack still suboptimal for /

- Example

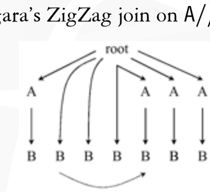




- Desired result: (A_1, B_2, C_2), (A_2, B_1, C_1)
- Initial state: all three stacks empty; ready to push one of A_1, B_1, C_1 onto a stack
- If we want to ensure that non-contributing nodes are never pushed onto the stack, then
  - Cannot decide on A_1 unless we see B_2 and C_2
  - Cannot decide on B_1 or C_1 unless we see A_2

Optimization using an index

- Idea: if there are indexes on input lists ordered by *left*, use these indexes to skip lists more efficiently
- Example: Niagara's ZigZag join on A//B



  - After advancing to the second A, use the index on B list to go directly to the first joining B, instead of scanning B list linearly
  - When processing a B, use the index on A list to skip

Summary of structural approach

- What makes XML containment joins easier than joining lists of arbitrary intervals?
  - Intervals form either disjoint or containment relationships, but they cannot overlap
  - This property is heavily exploited by stack-based algorithms
- Most algorithms in literature assume that bindings must be produced for all nodes in a twig
  - Unnecessary requirement in practice
  - Leads to potentially much larger result sizes
  - Is it possible to have more efficient algorithms that produce bindings for only selected nodes in a twig?

Navigational vs. structural approaches

- In the past some has argued that structural is preferable to navigational
- Niagara argues for a mixed-mode approach, using a cost-based analysis to pick which approach or combination of approaches is better
  - Just like one would implement both index nested-loop join and sort-merge join