Foundations of XML Data Manipulation

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5. Storage and Manipulation of SSD

Shamelessly “inspired” by

Ioana Manolescu tutorial

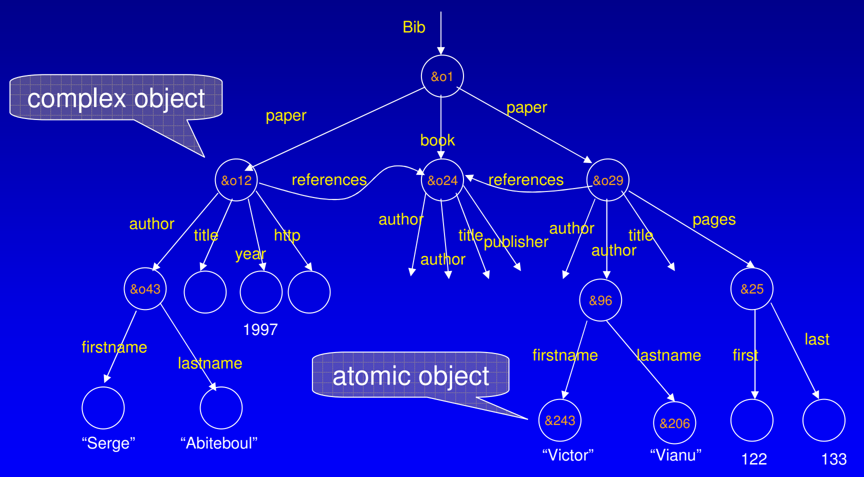
The problem

- Consider the queries
  – $doc // e-mail
  – $doc //.[name = 'ghelli']/e-mail
- We do not want to bring the whole $doc in main memory
- Set manipulation rather than tuple manipulation

Classifying stores

- Essential criteria:
  – Clustering
  – Encoding of parent/child relationship

OEM data model



Storing OEM

- No schema!
- Storing objects in LORE:
  - Store the graph, clustered in depth-first order
  - Operator: Scan(document,path), returns a set of objects

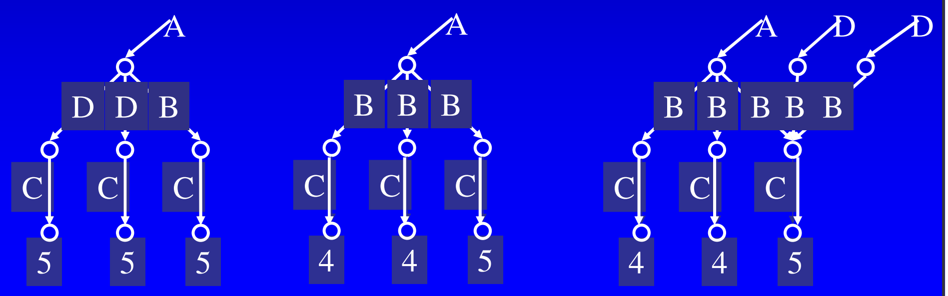
Indexing in LORE

- VIndex(**l**, o, **pred**): all objects o with an incoming l-edge, satisfying the predicate
- LIndex(**o**, **l**, p): all parents of **o** via an **l**-edge
- BIndex(x, **l**, y): all edges labeled **l**

Access plans

- Top down or bottom up navigation?

  select x
  from A.B x
  where x.C = 5

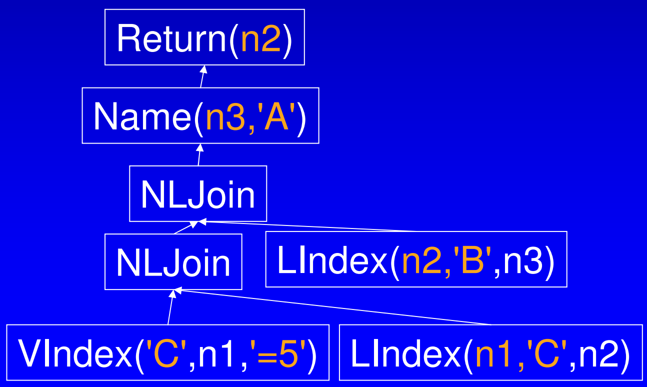


Access plans: bottom up

select x

from A.B x

where x.C = 5

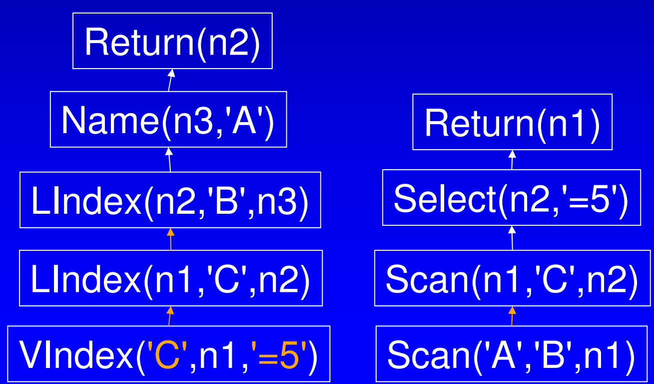


Bottom up and top down

select x

from A.B x

where x.C = 5

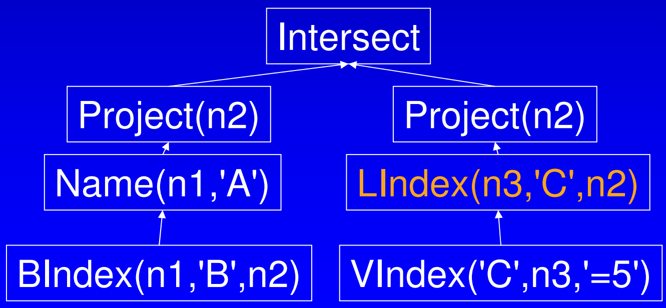


Hybrid access plans

select x

from A.B x

where x.C = 5



Path indexes

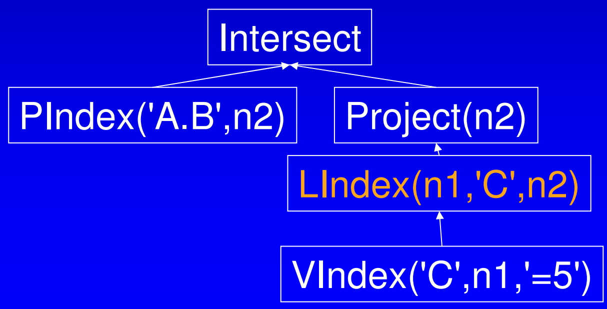
- PIndex(**p**, o): all objects reachable by the path **p**

Using a path index

select x

from A.B x

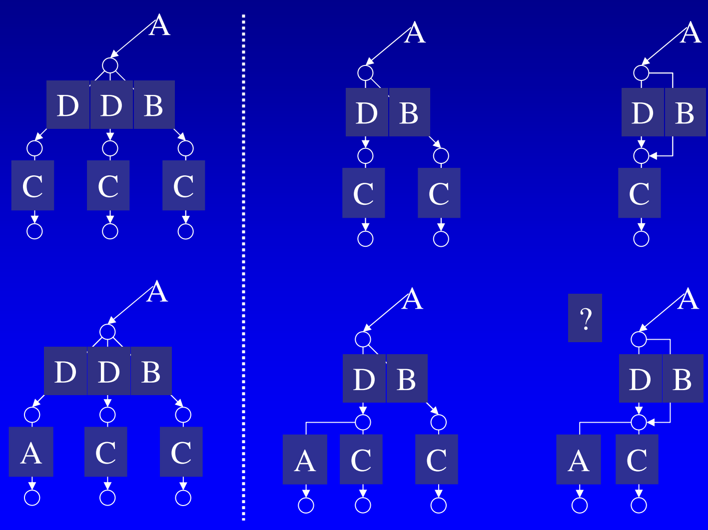
where x.C = 5



DataGuides

- Introduced in Lore: a compact representation of all paths in the graph
- A DG for *s* is an OEM object *d* such that:
  - Every path of *s* reaches exactly one object in *d*
  - Every path in *d* is a path for *s*
- DG: a schema *a posteriori*
- Used to:
  - Inform the user
  - Expand wildcards in paths
  - Inform the optimizer

DataGuides for trees



Building a DataGuide

- Similar to converting a NFA to a DFA
- Linear time for trees
- Exponential in time and space for graphs
- In practice, works well for regular structures

Which dataguide is better?

- Minimal dataguide
- Strong dataguide: if p1 and p2 both reach the same node in *d*, then p1 and p2 have the same target set in *s*
  - Each target-set in the source has its own node and in the guide
  - Easy to build
  - Easy to maintain, by keeping track of the many-to-many node correspondence between *s* and *d*

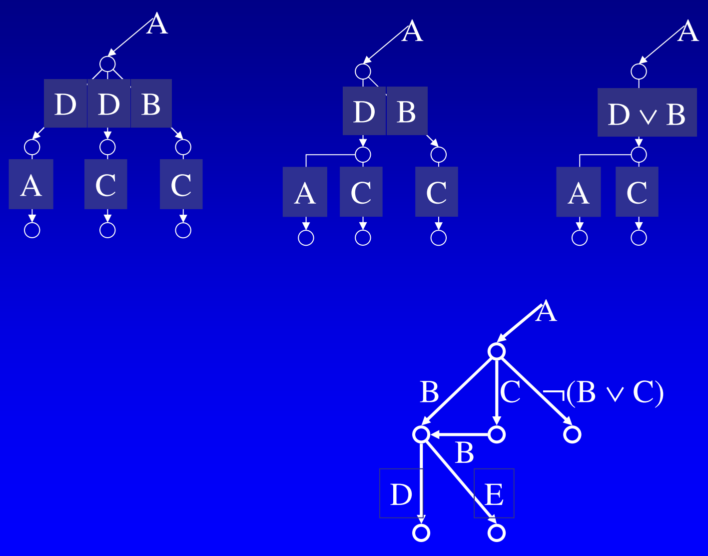
Optimization via dataguide

- Expanding paths: a//z => a/b/z | a/c/d/z
- Deleting paths that are not in the data
- Contracting paths: a/c/e/d/z => //d/z
  - May be more efficient for a bottom-up evaluation
- Keeping statistic information
  - However, statistic are needed for every k-length path, not just for rooted paths

Graph schemas

- Each edge in the scheme is labeled by a label predicate (a set of labels)
- Predicates are deterministic
- Conformance is defined by a simulation between s and d:
  - Root of data in root of schema
  - For every n1 in d1 with n1-l-n2, we have d1-l-d2 with n2 in d2
- No request for surjectivity, or injectivity

Graph Schemas



Graph indexing

- Group nodes in sets, possibly disjoint
- Store the extent of each set
- Grouping criteria:
  - Reachable by exactly the same Forward paths: 1-index
  - Indistinguishable by any F&B path: FB-index
  - Indistinguishable by the paths in a set Q: covering indexes
  - Indistinguishable by any path longer than k: A(k) index

XML Storage in RDBMS

Using RDBMS for XML

- Advantages
  - Transactions
  - Optimization
- Issues
  - Data storage
  - Query translation

Storing data

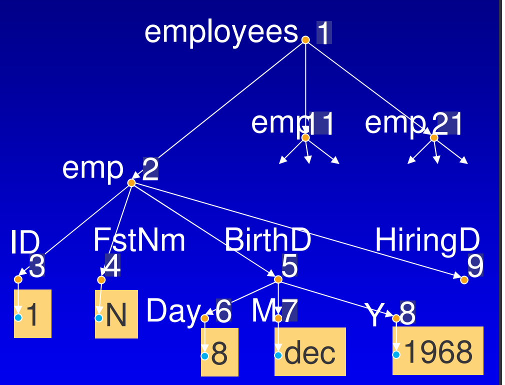
- Data may be schema-less
- Data may have a schema
- Data may change its schema over time

Approaches

- Based on schema:
  - Based only on schema
  - Based on schema + cost informations
- Unknown schema:
  - Derive schema from data
  - Generic approach
- User defined

Unknown schema: the edge table

From	Pos	Tag	To	Data
-	1	employees	1	
1	1	emp	2	
2	1	ID	3	1
2	2	FN	4	Nancy
2	3	BD	5	
5	1	Day	6	8
5	2	Month	7	dec
5	3	Year	8	1968
2	4	HD	9	
9	…	…	…	
1	2	emp	11	
11	…	…	…	
1	3	emp	21	



Navigating the edge table

- //FN/text():

  select e.Data from edge e where e.Tag = 'FN'

- //emp[ID=‘1’]/FN/text()

  select e3.Data

  srom edge e1, edge e2, edge e3

  where e1.Tag = ‘emp’ and e1.to = e2.from
  and e2.Tag = ‘ID’ and e2.Data = 1
  and e1.to = e3.from and e3.Tag = ‘FN’

- Navigation through multi-way join (XPath to FO translation)

Partitioned edge table

From	Pos	Tag	To	Data
-	1	employees	1	
1	1	emp	2	
2	1	ID	3	1
2	2	FN	4	Nancy
2	3	BD	5	
5	1	Day	6	8
5	2	Month	7	dec
5	3	Year	8	1968
2	4	HD	9	
9	…	…	…	
1	2	emp	11	
11	…	…	…	
1	3	emp	21	

employees

From	Pos	To	Data
-	1	1	

emp

From	Pos	To	Data
1	1	2	
1	2	11	
1	3	21	

ID

From	Pos	To	Data
2	1	3	1

Navigation

- //emp[ID='1']/FN/text()

```
select e1.Data
from edge e1, edge e2, edge e3
where e1.Tag = 'emp' and e1.to = e2.from
and e2.Tag = 'ID' and e2.Data = 1
and e1.to = e3.from and e3.Tag = 'FN'
```

⇒

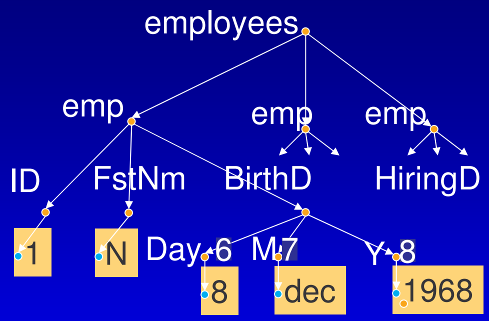
```
select FN.Data
from emp, ID, FN
where emp.to = ID.from and ID.Data = 1
        and emp.to = FN.from
```

- Joining smaller tables

Related storage schemes

- The universal relation:
  - employees ⟗ emp ⟗ ID ⟗ FN ⟗ …
- Materialized views over edges:
  - emp ⟕ ID ⟕ FN ⟕ HD …
- The STORED approach:
  - Materialized views based on pattern frequencies in the database
  - Overflow tables for the rest

Flat storage



ID	First Name	BD-D	BD-M	BD-Y
1	Nancy	8	dec	1968
2	Andrew	19	feb	1952
3	Janet	30	aug	1963
4	Margaret	19	sep	1958

Path partitioning in Monet

- For each root-to-inner-node path:
  - Path(n1,n2,ord):
    - employees.emp{(1,2,1);(1,11,2);(1,21,3)}
    - employees.emp.ID{(2,3,1);…}
- For each root-to-leaf path:
  - Path(n1,val)
    - employees.emp.ID.text{(3,’1’);…}
- Path summary
- No join for linear path expressions

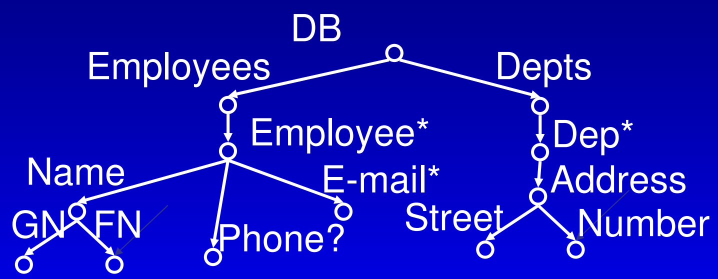
XRel approach: interval coding

- Tables:
  - Path(PathID,PathExpr)
  - Element(DocID, PathID, Start, End, Ordinal)
  - Text(DocID, PathID, Start, End, Value)
  - Attribute(DocID, PathID, Start, End, Value)
- Ancestor relation:
  - N1.start< N2.start and N2.end > N1.end
- Path expression: regexp matching with Path table, join the result with the data tables

XParent

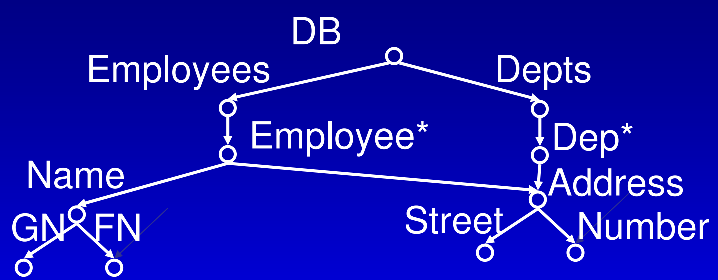
- Tables:
  - LabelPath(ID, lengh, pathExpr)
  - Data(pathID, nID, ord, value)
  - Element(pathID, ord, nID)
  - ParentChild(pID, cID)
- Use ParentChild instead of interval coding: equi-join instead of <-join

Schema-driven storage



DB(Id,Employees,Depts)
Employee(PId,Id,Name,Name.GN,Name.FN,Phone)
E-Mail(PId,Id,E-mail)
Depts(PId,Id,Address,Addr.Street,Addr.Number)

Sharing the address



Employee(PId,Id,Name,Name.GN,Name.FN)
Dep(PId,Id)
Address(PId,Id,Address,Addr.Street,Addr.Number)

Employee(PId,Id,…,Address,Addr.Street,Addr.Number)
Dep(PId,Id,Address,Addr.Street,Addr.Number)

Cost based approach

- Valuate a query load against one possible representation of the DTD
- Schema transformations:
  - type A=[b [Integer], C, d*],
    type C=e [String]
    equivalent to type A=[b [Integer], e [String], d*]
  - a[t1|t2] equivalent to [t1] | a[t2]

User defined mapping

- Express (relational) storage by custom expressions over the XML document
  - Relation = materialized view over the XML document
- Rewrite XQuery to SQL
- R(y,z) :- Auctions.item x, x.@id.text() y, x.price.text() z
- S(u,v) :- Auctions.item t, t.@id.text() u, t.description.text() v
- for $x in //item
  return <res> {$x/price}, {$x/description} </res>
  - select z, v from R, S where R.y=S.u ?
  - Reasoning about: XPath containment, functional dependencies, cardinality constraints

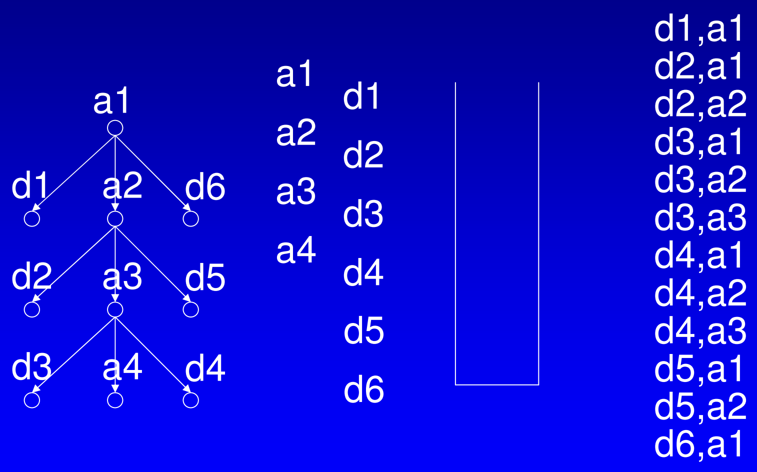
Navigation

- Simple paths:
  - Edge storage and join
  - Path partitioning and union
- Recursive paths:
  - Expansion to simple paths
  - Recursive navigation
  - Structural joins!

Structural Joins

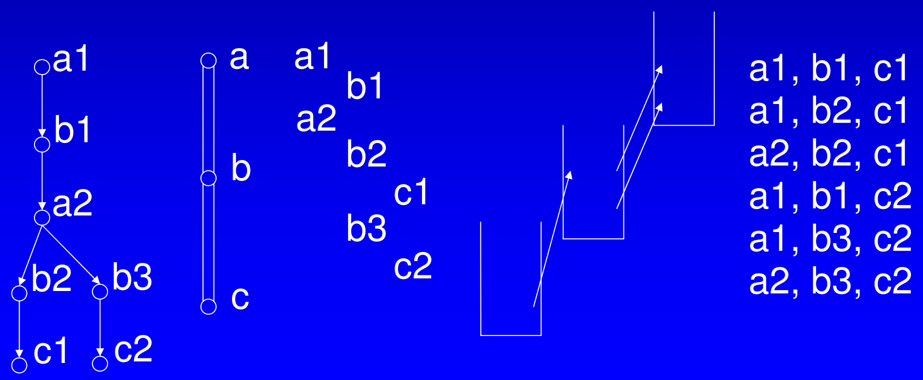
```
a=AList->firstNode; d=DList->firstNode; OutputList=NULL;
while((the input lists are not empty or the stack is not empty){
   if (a.StartPos > stack->top.EndPos
       && d.StartPos > stack->top.EndPos ) {
              stack->pop(); }
   else if (a.StartPos < d.StartPos) {
              stack->push(a)
              a = a->nextNode }
   else  {
              for (a1=stack->bottom; a1 != NULL; a1 = a1->up) {
                     append (a1,d) to OutputList; }
              d = d->nextNode; }
}
```

Stack-tree-desc



Holistic Path Joins

- PathStack: All the joins of a path with one scan
- Compact encoding of solutions



Algorithm PathStack

while ¬end(q) {
    q_{min} = getMinSource(q);
    for q_i in subtreeNodes(q)
        while (¬empty(S[q_i]) and
                topR(S[q_i]) $<$ nextL(T[q_{min}])) pop(S[q_i]); }
push(S[q_{min}], (next(T[q_{min}]), top(S[parent(q_{min})]));
advance(T[q_{min}]);
if (isLeaf(q_{min})) {
    showSolutions(S[q_{min}]);
    pop(S[q_{min}]); }

Holistic Twig Joins

- Consider:
  - for $x in //b, $y in $x//e, $z in $x//d...
- Avoid constructing ($x, $y) pairs for $x which have *e* descendant but no *d* descendant

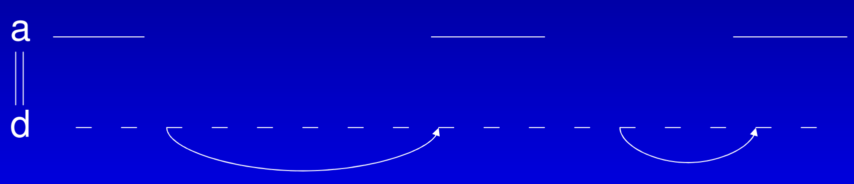
Holistic Twig Joins

```
while ¬end(q) {
    q_act = getNext(q);
    if ¬isRoot(q_act) { cleanStack(parent(q_act), nextL(q_act)); }
    if (isRoot(q_act) or notExpty(S[parent(q_act)]) {
        cleanStack(q_act, nextL(q_act));
        push( S[q_act], ( next(T[q_act]), top(S[parent(q_act)]) );
        advance(T[q_act]);
        if (isLeaf(q_act)) {
            showSolutions(S[q_act]);
            pop(S[q_act]); } }
    else {advance(T[q_act]); }
```

- getNext(q): next stream, skipping elements that do not participate in any solution

Skipping

- Linear time is not optimal:



- Needs the ability to search *d* on the basis of start: *d* is an XBTree

Summary

- Linear complexity join algorithms based on region identifiers
- Sub-linear variants exist, based on *skipping*
- Holistic twig joins reduce intermediary results
- All the factors to keep into account:
  - Data access cost
  - Join cost
  - Sort cost

Some references

- Graph schemas [Fernandez Suciu 98]
- LORE
- The STORED approach [DeutchFernandezSuciu99]
- Schema-driven storage [shanmugasundaram-etal-vldbj99]
- XRel
- XParent
- Path partitioning in Monet [ScKeWiWa WEBDB 00]
- Holistic Path Joins [bks2002-twigjoin]