XML and Databases

Lecture 3
XML into RDBMS

Sebastian Maneth
NICTA and UNSW

CSE@UNSW -- Semester 1, 2010

Lecture 3

XML Into RDBMS

Memory Representations

Facts

→ DOM is easy to use, but memory heavy.
in-memory size usually 5-10 times larger than size of original file.

→ SAX is very flexible.
Using arrays or binary trees wo backward pointers,
in-memory size is approx. same as size of original file.

→ Can be further improved using DAGs/sharing-Graphs
& coding/compression for data values.

Memory Representations

Facts

→ DOM is easy to use, but memory heavy.
in-memory size usually 5-10 times larger than size of original file.

→ SAX is very flexible.
Using arrays or binary trees wo backward pointers,
in-memory size is approx. same as size of original file.

→ Can be further improved using DAGs/sharing-Graphs
& coding/compression for data values.

TODAY

→ How can we map XML into a relational DB?

Memory Representations

Facts

→ DOM is easy to use, but memory heavy.
in-memory size usually 5-10 times larger than size of original file.

→ SAX is very flexible.
Using arrays or binary trees wo backward pointers,
in-memory size is approx. same as size of original file.

→ Can be further improved using DAGs/sharing-Graphs
& coding/compression for data values.

TODAY

→ How can we map XML into a relational DB?

… but first: Memory efficient *tree traversals* using e.g. DOM?

Traversals and Pre/Post-Encoding

1. Pre-Order Traversal (recursively)
2. Post-Order
3. Pre-Order (iteratively)
4. Into RDBMS with Pre/Post-encoding

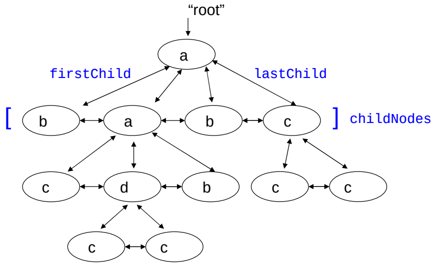
TODAY

→ How can we map XML into a relational DB?

… but first: Memory efficient *tree traversals* using e.g. DOM?

Tree Traversals

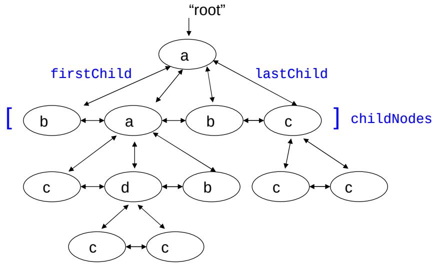
Start at root node; want to visit every node.



Tree Traversals

Start at root node; want to visit every node.

(1) *recursively*

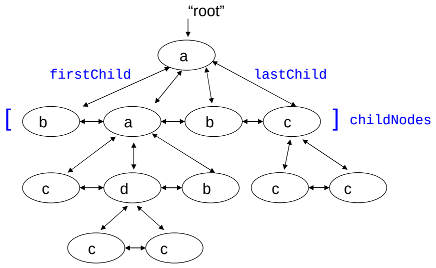


Tree Traversals

Start at root node; want to visit every node.

(1) *recursively*

```
Traverse(n:Node){
  print(n);
  For m in childNodes(n) Traverse(m)
}
```



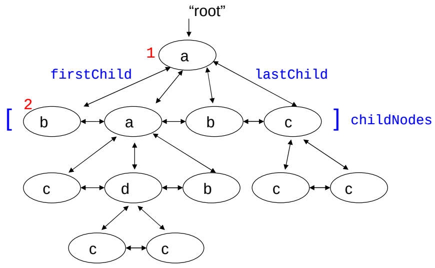
Tree Traversals

```
Tr(1)
  pr(1)
  Tr(2)
    pr(2)
```

Start at root node; want to visit every node.

(1) *recursively*

```
Traverse(n:Node){
  print(n);
  For m in childNodes(n) Traverse(m)
}
```



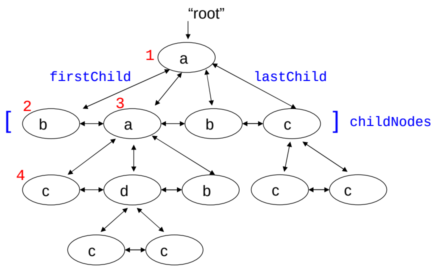
Tree Traversals

```
Tr(1)
  pr(1)
  Tr(2)
    pr(2)
  Tr(3)
    pr(3)
    Tr(4)
      pr(4)
```

Start at root node; want to visit every node.

(1) *recursively*

```
Traverse(n:Node){
  print(n);
  For m in childNodes(n) Traverse(m)
}
```



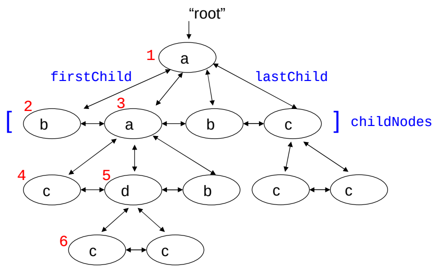
Tree Traversals

```
Tr(1)
  pr(1)
  Tr(2)
    pr(2)
  Tr(3)
    pr(3)
    Tr(4)
      pr(4)
    Tr(5)
      pr(5)
      Tr(6)
        pr(6)
```

Start at root node; want to visit every node.

(1) *recursively*

```
Traverse(n:Node){
  print(n);
  For m in childNodes(n) Traverse(m)
}
```



13

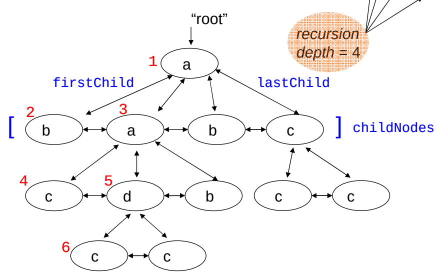
Tree Traversals

Start at root node; want to visit every node.

(1) *recursively*

```
Traverse(n:Node){
  print(n);
  For m in childNodes(n) Traverse(m)
}
```

```
Tr(1)
  pr(1)
  Tr(2)
    pr(2)
  Tr(3)
    pr(3)
    Tr(4)
      pr(4)
    Tr(5)
      pr(5)
      Tr(6)
        pr(6)
```



14

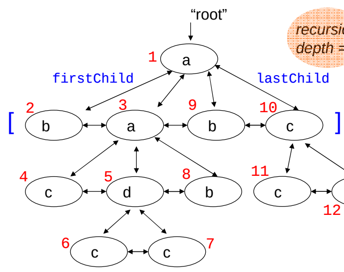
Tree Traversals

Start at root node; want to visit every node.

(1) *recursively*

```
Traverse(n:Node){
  print(n);
  For m in childNodes(n) Traverse(m)
}
```

```
Tr(1)
  pr(1)
  Tr(2)
    pr(2)
  Tr(3)
    pr(3)
    Tr(4)
      pr(4)
    Tr(5)
      pr(5)
      Tr(6)
        pr(6)
      Tr(7)
        pr(7)
    Tr(8)
      pr(8)
  Tr(9)
    pr(9)
  Tr(10)
    pr(10)
    Tr(11)
      pr(11)
    Tr(12)
      pr(12)
END
```



15

Tree Traversals

Start at root node; want to visit every node.

(1) *recursively*

```
Traverse(n:Node){
  print(n);
  For m in childNodes(n) Traverse(m)
}
```

Memory need proportional to the *height* of the XML doc tree.

→ Should be fine.
Usually *height* (XML doc) is small. (≤ 15)

16

Tree Traversals

Start at root node; want to visit every node.

(1) *recursively*

```
Traverse(n:Node){
  print(n);
  For m in childNodes(n) Traverse(m)
}
```

Memory need proportional to the *height* of the XML doc tree.

→ Should be fine.
Usually *height* (XML doc) is small. (≤ 15)

Problematic

2nd recursion on children

```
TR(n:Node){
  print(n);
  if(m=firstChild(n))!=NIL then Tr(m);
  if(m=nextSibling(n))!=NIL then Tr(m)
}
```

17

Tree Traversals

Start at root node; want to visit every node.

(1) *recursively*

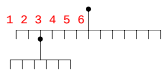
```
Traverse(n:Node){
  print(n);
  For m in childNodes(n) Traverse(m)
}
```

Memory need proportional to the *height* of the XML doc tree.

→ Should be fine.
Usually *height* (XML doc) is small. (≤ 15)

Problematic

2nd recursion on children




```
TR(n:Node){
  print(n);
  if(m=firstChild(n))!=NIL then Tr(m);
  if(m=nextSibling(n))!=NIL then Tr(m)
}
```

18

Tree Traversals

Start at root node; want to visit every node.

(1) *recursively*

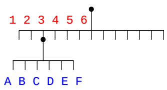
```
Traverse(n:Node){
  print(n);
  For m in childNodes(n) Traverse(m)
}
```

Memory need proportional to the *height* of the XML doc tree.

→ Should be fine.
Usually *height* (XML doc) is small. (≤ 15)

Problematic

2nd recursion on children




```
TR(n:Node){
  print(n);
  if(m=firstChild(n))!=NIL then TR(m);
  if(m=nextSibling(n))!=NIL then TR(m)
}
```

```
TR(1);pr(1)
  TR(2);pr(2)
    TR(3);pr(3)
      TR(A);pr(A)
        TR(B);pr(B)
```

Tree Traversals

Start at root node; want to visit every node.

(1) *recursively*

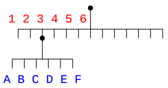
```
Traverse(n:Node){
   print(n);
   For m in childNodes(n) Traverse(m)
}
```

Memory need proportional to the *height* of the XML doc tree.

→ Should be fine.
Usually *height* (XML doc) is small. (≲ 15)

Problematic

2nd recursion on children




```
TR(n:Node){
  print(n);
  if(m=firstChild(n))!=NIL then Tr(m);
  if(m=nextSibling(n))!=NIL then Tr(m)
}
```

```
TR(1);pr(1)
  TR(2);pr(2)
    TR(3);pr(3)
      TR(A);pr(A)
        TR(B);pr(B)
```

Memory need proportional to max. length of (firstChild | nextSibling)*-path

Tree Traversals

Start at root node; want to visit every node.

(1) *recursively*

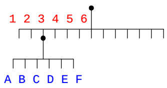
```
Traverse(n:Node){
   print(n);
   For m in childNodes(n) Traverse(m)
}
```

Memory need proportional to the *height* of the XML doc tree.

→ Should be fine.
Usually *height* (XML doc) is small. (≲ 15)

Problematic

2nd recursion on children

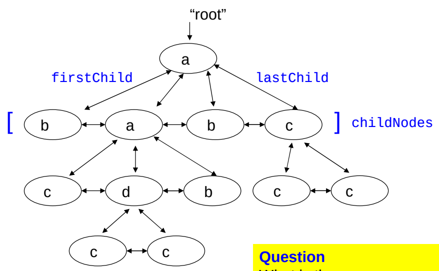



```
Tr(n:Node){
  print(n);
  if(m=firstChild(n))!=NIL then Tr(m);
  if(m=nextSibling(n))!=NIL then Tr(m)
}
```

```
TR(1);pr(1)
  TR(2);pr(2)
    TR(3);pr(3)
      TR(A);pr(A)
        TR(B);pr(B)
```

Can be HUGE!!! =size(tree)

Memory need proportional to max. length of (firstChild | nextSibling)*-path



Question
What is the max recursion depth on this tree?

```
Tr(n:Node){
  print(n);
  if(m=firstChild(n))!=NIL then Tr(m);
  if(m=nextSibling(n))!=NIL then Tr(m)
}
```

Can be HUGE!!! =size(tree)

Memory need proportional to max. length of (firstChild | nextSibling)*-path

Tree Traversals

Start at root node; want to visit every node.

(1) *recursively*

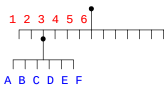
```
Traverse(n:Node){
   print(n);
   For m in childNodes(n) Traverse(m)
}
```

Memory need proportional to the *height* of the XML tree.

→ Should be fine.
Usually *height* (XML doc) is small. (≲ 15)

Problematic

2nd recursion on children



Recall binary tree (firstChild/nextSibling) encoding.

Question
In the binary tree, what corresponds to this number?

```
TR(1);pr(1)
  TR(2);pr(2)
    TR(3);pr(3)
      TR(A);pr(A)
        TR(B);pr(B)
```

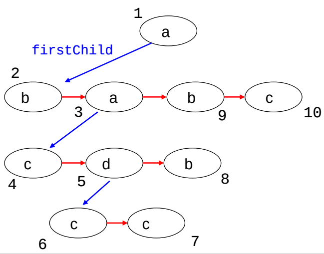
max. length of (firstChild | nextSibling)*-path

Binary Tree Encoding

Recall "firstChild/nextSibling" encoding.

The "firstChild" becomes the `left` pointer
The "nextSibling" becomes the `right` pointer

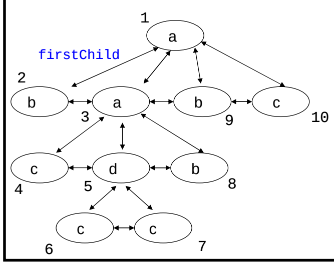
per Node
2 pointers/IDs
+ label info




```
ID  fc:ns:lab
-------------
1   (2:-:a)
2   (-:3:b)
3   (4:9:a)
4   (-:5:c)
5   (6:8:d)
6   (-:7:c)
7   (-:-:c)
8   (-:-:b)
9   (-:10:b)
10  (-,-:c)
```


Tree Traversals

→ both, `Traverse` and `TR` can be executed on the **fc**/**ns**-*binary tree encoding*.

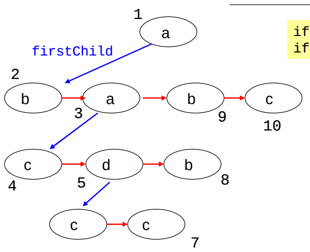


Tree Traversals

→ both, `Traverse` and `Tr` can be executed on the **fc**/**ns**-*binary tree encoding*.

```
For m in childNodes(n) Traverse(n)
```

```
if(m=n->left)!=NIL
{ while(m=n->right)!=NIL Traverse(m)
}
```




```
if(m=firstChild(n))!=NIL then TR(m);
if(m=nextSibling(n))!=NIL then TR(m)
```

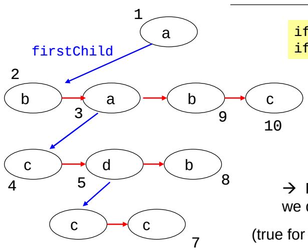
```
if(m=n->left)!=NIL then TR(m)
if(m=n->right)!=NIL then TR(m)
```

Tree Traversals

→ both, `Traverse` and `Tr` can be executed on the **fc**/**ns**-*binary tree encoding*.

```
For m in childNodes(n) Traverse(n)
```

```
if(m=n->left)!=NIL
{ while(m=n->right)!=NIL Traverse(m)
}
```




```
if(m=firstChild(n))!=NIL then Tr(m);
if(m=nextSibling(n))!=NIL then Tr(m)
```

```
if(m=n->left)!=NIL then TR(m)
if(m=n->right)!=NIL then TR(m)
```

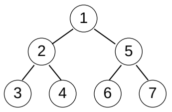
→ Recursion takes care of the fact that we do not have parent pointers. ☺

(true for both, unranked & binary tree)

Other Traversals

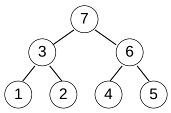
We discussed the Pre-order of the tree.
(or, in XML-jargon: *document-order*).

Realized by `Traverse & TR`



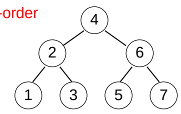
Post-order of a tree =

```
1. Traverse left subtree in post-order
2. Traverse right subtree in post-order
3. Visit the root
```



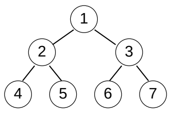
→ Reverse Polish Notation

In-order



→ Binary Search Tree (increasing)

Breadth-First
(left-to-right)
"level-order"

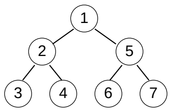


```
q.enq(root);
while(NOT q.empty){ Visit(q.deq);
  If(q->Left!=NIL) q.enq(q->Left)
  If(q->Right!=NIL) q.enq(q->Right)}
```

Other Traversals

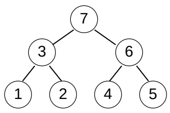
We discussed the Pre-order of the tree.
(or, in XML-jargon: *document-order*).

Realized by `Traverse & TR`



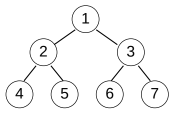
Post-order of a tree =

```
1. Traverse left subtree in post-order
2. Traverse right subtree in post-order
3. Visit the root
```



→ Reverse Polish Notation

Breadth-First
(left-to-right)
"level-order"



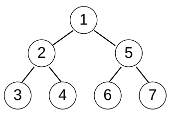
Memory need
proportional
to
max. #nodes on one level

```
q.enq(root);
while(NOT q.empty){ Visit(q.deq);
  If(q->Left!=NIL) q.enq(q->Left)
  If(q->Right!=NIL) q.enq(q->Right)}
```

Other Traversals

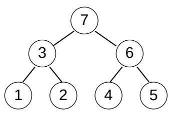
We discussed the Pre-order of the tree.
(or, in XML-jargon: *document-order*).

Realized by `Traverse & TR`



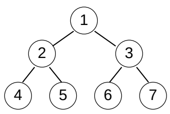
Post-order of a tree =

```
1. Traverse left subtree in post-order
2. Traverse right subtree in post-order
3. Visit the root
```



→ Reverse Polish Notation

Breadth-First
(left-to-right)
"level-order"



Can be HUGE!!!

Memory need
proportional
to
max. #nodes on one level

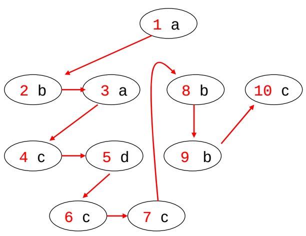
```
q.enq(root);
while(NOT q.empty){ Visit(q.deq);
  If(q->Left!=NIL) q.enq(q->Left)
  If(q->Right!=NIL) q.enq(q->Right);}
```

Pre-Order

We saw how to compute
Pre-order (and Post and In)

(1) recursively

memory need: O(*max_height*)



31

Pre-Order

We saw how to compute
Pre-order (and Post and In)

(1) recursively

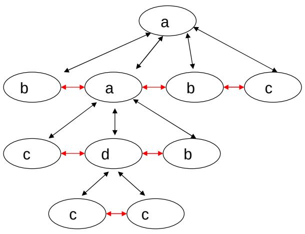
memory need: O(*max_height*)

How to compute Pre-order

(2) *iteratively*

→ Memory need?

```
i=1;
n=root;
pre(i)=n;
while(firstChild(n)!=NIL)
  {  n=firstChild(n);
     pre(++i)=n;
  }
```



32

Pre-Order

We saw how to compute
Pre-order (and Post and In)

(1) recursively

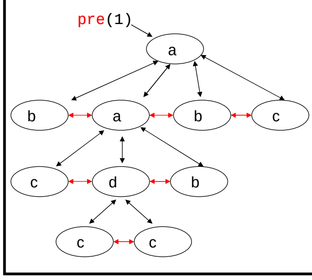
memory need: O(*max_height*)

How to compute Pre-order

(2) *iteratively*

→ Memory need?

```
i=1;
n=root;
pre(i)=n;
while(firstChild(n)!=NIL)
  {  n=firstChild(n);
     pre(++i)=n;
  }
```



33

Pre-Order

We saw how to compute
Pre-order (and Post and In)

(1) recursively

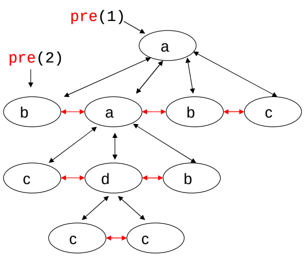
memory need: O(*max_height*)

How to compute Pre-order

(2) *iteratively*

→ Memory need?

```
i=1;
n=root;
pre(i)=n;
while(firstChild(n)!=NIL)
  {  n=firstChild(n);
     pre(++i)=n;
  }
```



34

Pre-Order

We saw how to compute
Pre-order (and Post and In)

(1) recursively

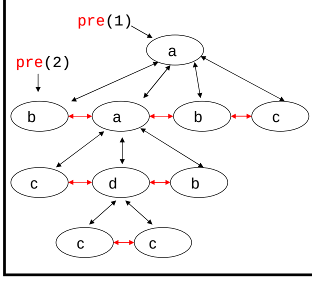
memory need: O(*max_height*)

How to compute Pre-order

(2) *iteratively*

→ Memory need?

```
i=1;
n=root;
pre(i)=n;
repeat {
  while(firstChild(n)!=NIL)
    {  n=firstChild(n);
       pre(++i)=n;
    }
  while(nextSibling(n)=NIL)
    {  n=parent(n);}
  n=nextSibling(n);
  pre(++i)=n;
}
```



35

Pre-Order

We saw how to compute
Pre-order (and Post and In)

(1) recursively

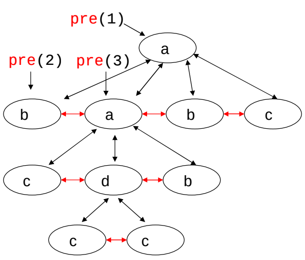
memory need: O(*max_height*)

How to compute Pre-order

(2) *iteratively*

→ Memory need?

```
i=1;
n=root;
pre(i)=n;
repeat {
  while(firstChild(n)!=NIL)
    {  n=firstChild(n);
       pre(++i)=n;
    }
  while(nextSibling(n)=NIL)
    {  n=parent(n);}
  n=nextSibling(n);
  pre(++i)=n;
}
```



36

Pre-Order

We saw how to compute
Pre-order (and Post and In)

(1) recursively

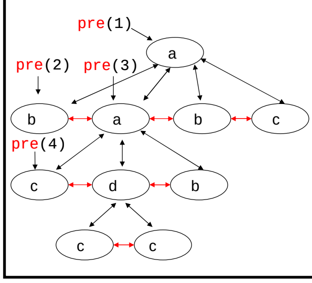
memory need: O(*max_height*)

How to compute Pre-order

(2) *iteratively*

→ Memory need?

```
i=1;
n=root;
pre(i)=n;
repeat {
  while(firstChild(n)!=NIL)
    {  n=firstChild(n);
       pre(++i)=n;
    }
  while(nextSibling(n)=NIL)
    {  n=parent(n);}
  n=nextSibling(n);
  pre(++i)=n;
}
```



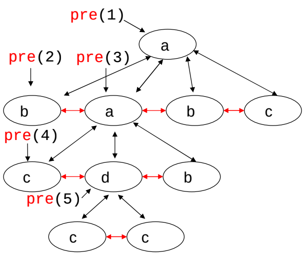
Pre-Order

37

We saw how to compute
Pre-order (and Post and In)

(1) recursively

memory need: O(*max_height*)



How to compute Pre-order

(2) *iteratively*

→ Memory need?

```
i=1;
n=root;
pre(i)=n;
repeat {
  while(firstChild(n)!=NIL)
    {  n=firstChild(n);
       pre(++i)=n;
    }
  while(nextSibling(n)=NIL)
    {  n=parent(n);}
  n=nextSibling(n);
  pre(++i)=n;
}
```

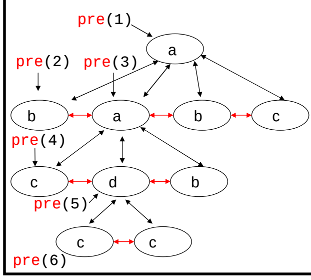
Pre-Order

38

We saw how to compute
Pre-order (and Post and In)

(1) recursively

memory need: O(*max_height*)



How to compute Pre-order

(2) *iteratively*

→ Memory need?

```
i=1;
n=root;
pre(i)=n;
repeat {
  while(firstChild(n)!=NIL)
    {  n=firstChild(n);
       pre(++i)=n;
    }
  while(nextSibling(n)=NIL)
    {  n=parent(n);}
  n=nextSibling(n);
  pre(++i)=n;
}
```

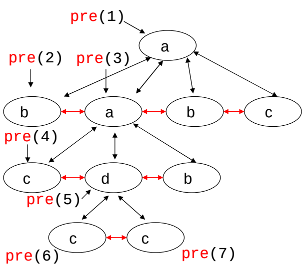
Pre-Order

39

We saw how to compute
Pre-order (and Post and In)

(1) recursively

memory need: O(*max_height*)



How to compute Pre-order

(2) *iteratively*

→ Memory need?

```
i=1;
n=root;
pre(i)=n;
repeat {
  while(firstChild(n)!=NIL)
    {  n=firstChild(n);
       pre(++i)=n;
    }
  while(nextSibling(n)=NIL)
    {  n=parent(n);}
  n=nextSibling(n);
  pre(++i)=n;
}
```

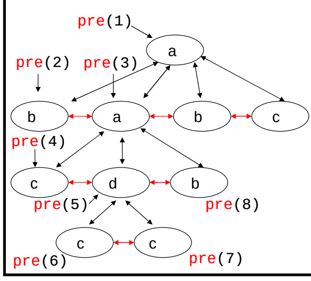
Pre-Order

40

We saw how to compute
Pre-order (and Post and In)

(1) recursively

memory need: O(*max_height*)



How to compute Pre-order

(2) *iteratively*

→ Memory need?

```
i=1;
n=root;
pre(i)=n;
repeat {
  while(firstChild(n)!=NIL)
    {  n=firstChild(n);
       pre(++i)=n;
    }
  while(nextSibling(n)=NIL)
    {  n=parent(n);}
  n=nextSibling(n);
  pre(++i)=n;
}
```

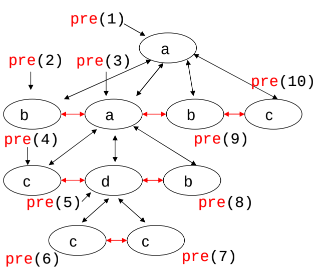
Pre-Order

41

We saw how to compute
Pre-order (and Post and In)

(1) recursively

memory need: O(*max_height*)



How to compute Pre-order

(2) *iteratively*

→ Memory need?

```
i=1;
n=root;
pre(i)=n;
repeat {
  while(firstChild(n)!=NIL)
    {  n=firstChild(n);
       pre(++i)=n;
    }
  while(nextSibling(n)=NIL)
    {  n=parent(n);}
  n=nextSibling(n);
  pre(++i)=n;
}
```

if(n=NIL)then break; ☺

Pre-Order

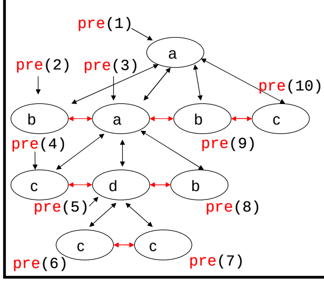
42

How to compute Pre-order

(2) *iteratively*

→ Memory need?

No recursion!
Needs *constant memory!*
(only one pointer)




```
i=1;
n=root;
pre(i)=n;
repeat {
  while(firstChild(n)!=NIL)
    {  n=firstChild(n);
       pre(++i)=n;
    }
  while(nextSibling(n)=NIL)
    {  n=parent(n);}
  n=nextSibling(n);
  pre(++i)=n;
}
```

if(n=NIL)then break; ☺

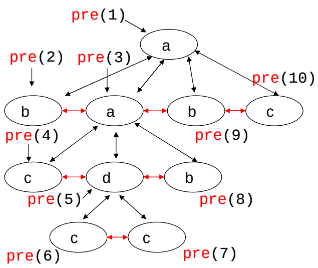
43

Pre-Order

Question

Given a *binary tree*, (top-down, no parent) how much memory do you need to compute pre?

No recursion!
Needs *constant memory!*
(only one pointer)




```
i=1;
n=root;
pre(i)=n;
repeat {
  while(firstChild(n)!=NIL)
    {  n=firstChild(n);
       pre(++i)=n;
    }
  while(nextSibling(n)=NIL)
    {  n=parent(n);}
  n=nextSibling(n);
  pre(++i)=n;
}
```

if(n=NIL)then break; ☺

44

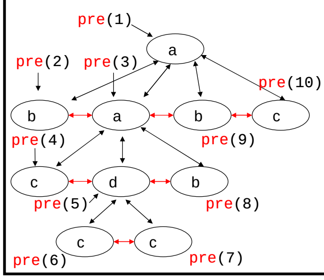
Pre-Order

Question

Given a *binary tree*, (top-down, no parent) how much memory do you need to compute pre?

→ Can you do it w. *constant memory*?

No recursion!
Needs *constant memory!*
(only one pointer)




```
i=1;
n=root;
pre(i)=n;
repeat {
  while(firstChild(n)!=NIL)
    {  n=firstChild(n);
       pre(++i)=n;
    }
  while(nextSibling(n)=NIL)
    {  n=parent(n);}
  n=nextSibling(n);
  pre(++i)=n;
}
```

if(n=NIL)then break; ☺

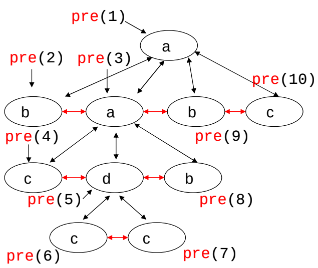
45

Pre-Order

Question

Fun (MS ji)
How much memory you need to check for cycles, in a single-linked (pointer) list?

No recursion!
Needs *constant memory!*
(only one pointer)




```
i=1;
n=root;
pre(i)=n;
repeat {
  while(firstChild(n)!=NIL)
    {  n=firstChild(n);
       pre(++i)=n;
    }
  while(nextSibling(n)=NIL)
    {  n=parent(n);}
  n=nextSibling(n);
  pre(++i)=n;
}
```

if(n=NIL)then break; ☺

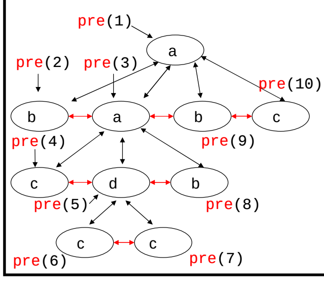
46

Pre-Order

Question

Do you see how to do Post- and In-oder iteratively?

No recursion!
Needs *constant memory!*
(only one pointer)




```
i=1;
n=root;
pre(i)=n;
repeat {
  while(firstChild(n)!=NIL)
    {  n=firstChild(n);
       pre(++i)=n;
    }
  while(nextSibling(n)=NIL)
    {  n=parent(n);}
  n=nextSibling(n);
  pre(++i)=n;
}
```

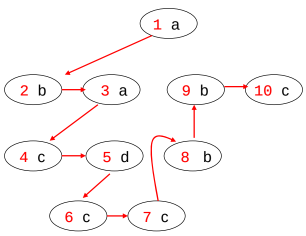
if(n=NIL)then break; ☺

47

Pre-Order

From pre( )

we can compute → PreFollowing(n) = { nodes m with pre(m) > n }
→ PrePreceding(n) = { nodes m with pre(m) < n }




```
pre
-------------
1
2
3
4
5
6
7
8
9
10
```

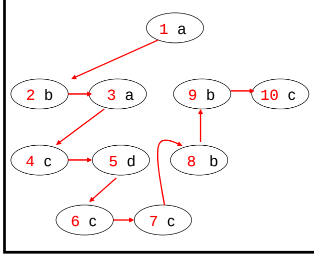
48

Pre-Order

What is this?

From pre( )

we can compute → PreFollowing(n) = { nodes m with pre(m) > n }
→ PrePreceding(n) = { nodes m with pre(m) < n }

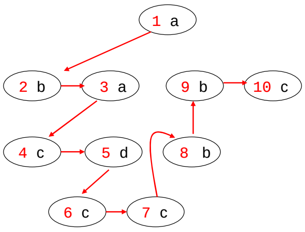



```
pre
-------------
1
2
3
4
5
6
7
8
9
10
```

Pre-Order

From `pre( )` What is this?

we can compute
→ `PreFollowing`(n) = { nodes m with `pre`(m) > n }
→ `PrePreceding`(n) = { nodes m with `pre`(m) < n }



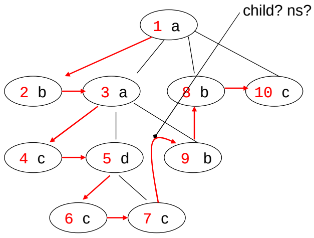
pre	foll	prec
1	2-10	-
2	3-10	1
3	4-10	1-2
4	5-10	1-3
5	6-10	1-4
6	7-10	1-5
7	8-10	1-6
8	9-10	1-7
9	10	1-8
10	-	1-9

Pre-Order

From `pre( )` …useful??

we can compute
→ `PreFollowing`(n) = { nodes m with `pre`(m) > n }
→ `PrePreceding`(n) = { nodes m with `pre`(m) < n }

Not "tree (navigation) complete" ☹



pre
1
2
3
4
5
6
7
8
9
10

XML to RDBMS Encoding

Relational XML processors (2)

Our approach to **relational XQuery processing:**

- The XQuery data model—ordered, unranked trees and ordered item sequences—is, in a sense, alien to a relational database kernel.
- A **relational tree encoding** $\mathcal{E}$ is required to map trees into the relational domain, *i.e.*, tables.

Relational tree encoding $\mathcal{E}$

What makes a good (relational) (XML) tree encoding?

Hard requirements:

1. $\mathcal{E}$ is required to reflect **document order** and **node identity.**
   - *Otherwise:* cannot enforce XPath semantics, cannot support << and `is`, cannot support node construction.
2. $\mathcal{E}$ is required to encode the **XQuery DM node properties.**
   - *Otherwise:* cannot support XPath axes, cannot support XPath node tests, cannot support atomization, cannot support validation.
3. $\mathcal{E}$ is able to encode any well-formed **schema-less** XML fragment (*i.e.*, $\mathcal{E}$ is "**schema-oblivious**", see below).
   - *Otherwise:* cannot process non-validated XML documents, cannot support arbitrary node construction.

What makes a good (relational) (XML) tree encoding?

Soft requirements (primarily motivated by performance concerns):

1. **Data-bound operations** on trees (potentially delivering/copying lots of nodes) should map into efficient database operations.
   - *XPath location steps* (12 axes)
2. Principal, recurring **operations imposed by the XQuery semantics** should map into efficient database operations.
   - *Subtree traversal* (atomization, element construction, serialization).

For a relational encoding, "database operations" always mean "table operations" …

XML to RDBMS Encoding

`pre( )` is not enough

Other possibilities: (1) large (unparsed) text block
(2) Schema-based encoding
(3) Adjacency-based encoding

Dead Ends
***No** good…*

Questions Why is (1) a dead end?

Dead end #2: Schema-based encoding

XML address database (excerpt)

```
<person>
  <name><first>John</first><last>Foo</last></name>
  <address><street>13 Main St</street>
           <zip>12345</zip><city>Miami</city>
  </address>
</person>
<person>
  <name><first>Erik</first><last>Bar</last></name>
  <address><street>42 Kings Rd</street>
           <zip>54321</zip><city>New York</city>
  </address>
</person>
```

Schema-based relational encoding: table person

id	first	last	street	zip	city
0	John	Foo	13 Main St	12345	Miami
1	Erik	Bar	42 Kings Rd	54321	New York

Dead end #2: Schema-based encoding

Irregular hierarchy

```
<a no="0">
  <b><c>X</c><c/></b>
</a>
<a no="1">
  <b><c>Y</c></b>
</a>
<a><b/></a>
<a no="3"/>
```

A relational encoding

id	@no	b
0	0	α
3	1	β
5	NULL^a	γ
6	3	NULL^b

id	b	c
1	α	X
2	α	NULL^c
4	β	Y

Issues:

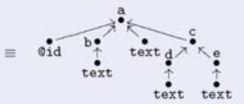
- Number of encoding tables depends on nesting depth.
- Empty element `c` encoded by NULL^c, empty element `b` encoded by absence of γ (will need *outer join* on column `b`).
- NULL^a encodes absence of attribute, NULL^b encodes absence of element.
- Document order/identity of `b` elements only implicit.

Dead end #3: Adjacency-based encoding

Adjacency-based encoding of XML fragments

```
<a id="0">
  <b>fo</b>o
  <c>
    <d>b</d><e>ar</e>
  </c>
</a>
```

≡



Resulting relational encoding

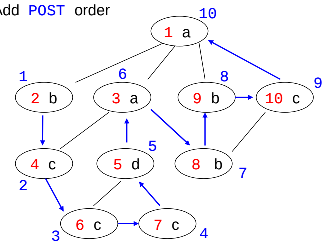
id	parent	tag	text	val
0	NULL	a	NULL	NULL
1	0	@id	NULL	"0"
2	0	b	NULL	NULL
3	2	NULL	"fo"	NULL
4	0	NULL	"o"	NULL
5	0	c	NULL	NULL
⋮				

Dead end #3: Adjacency-based encoding

- **Pro:**
  - Since this captures all adjacency, kind, and content information, we can—in principle—**serialize the original XML fragment.**
  - **Node identity** and **document order** is adequately represented.
- **Contra:**
  - The XQuery processing model is not well-supported: subtree traversals require **extra-relational** queries (**recursion**).
  - This is completely `parent-child` centric. How to support `descendant`, `ancestor`, `following`, or `preceding`?

Pre/Post Encoding

➔ Add `POST` order

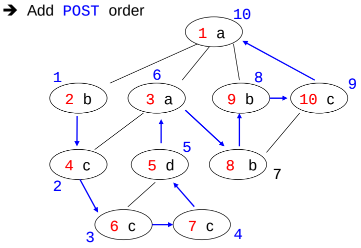


PRE	POST	lab
1	10	a
2	1	b
3	6	a
4	2	c
5	5	d
6	3	c
7	4	c
8	7	b
9	8	b
10	9	c

```
CREATE VIEW descendant AS
SELECT r1.pre,r2.pre FROM R r1, R r2
              WHERE r1.pre<r2.pre
                AND r1.post>r2.post
```

Pre/Post Encoding

➔ Add POST order



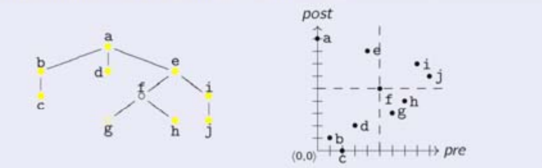

```
PRE   POST  lab
-------------
1     10    a
2      1    b
3      6    a
4      2    c
5      5    d
6      3    c
7      4    c
8      7    b
9      8    b
10     9    c
```

```
CREATE VIEW descendant AS
SELECT r1.pre,r2.pre FROM R r1, R r2
               WHERE r1.pre<r2.pre
                 AND r1.post>r2.post
```

"structural join"

XPath axes in the pre/post plane

Plane partitions ≡ XPath axes, ∘ is arbitrary!



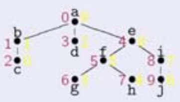
Pre/post plane regions ≡ major XPath axes

The **major XPath axes** `descendant`, `ancestor`, `following`, `preceding` correspond to rectangular **pre/post plane windows.**

XPath Accelerator encoding

XML fragment *f* and its skeleton tree

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



Pre/post encoding of *f*: table accel

pre	post	par	kind	tag	text
0	9	NULL	elem	a	NULL
1	1	0	elem	b	NULL
2	0	1	text	NULL	c
3	2	0	com	NULL	d
4	8	0	elem	e	NULL
5	5	4	elem	f	NULL
6	3	5	elem	g	NULL
7	4	5	pi	NULL	h
8	7	4	elem	i	NULL
9	6	8	text	NULL	j

Pre/Post Encoding

Straightforward how to compute, for a given node,

→ descendants
→ ancestors
→ following
→ preceding

Questions

How to do

→ lastChild
→ parent
→ childNodes

Can you find corresponding SQL queries?

END
Lecture 3