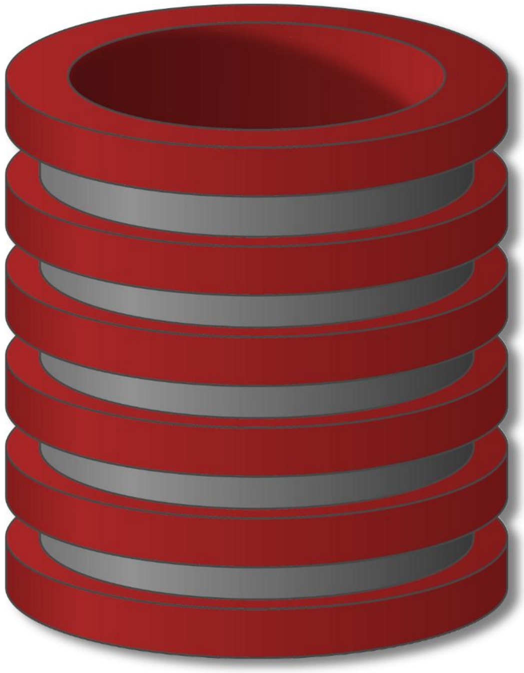


Recursion in SQL

Nonlinear and Mutual Recursion

Jennifer Widom

SQL With Recursive Statement

```
With Recursive
      R1 As (query-1),        R1
      R2 As (query-2),
      ...
      Rn As (query-n)
<query involving R1,…,Rn (and other tables)>
```

SQL `With Recursive` Statement

```
With Recursive
      R As ( base query
                  Union
             recursive query )
<query involving R (and other tables)>
```

Linear Recursion

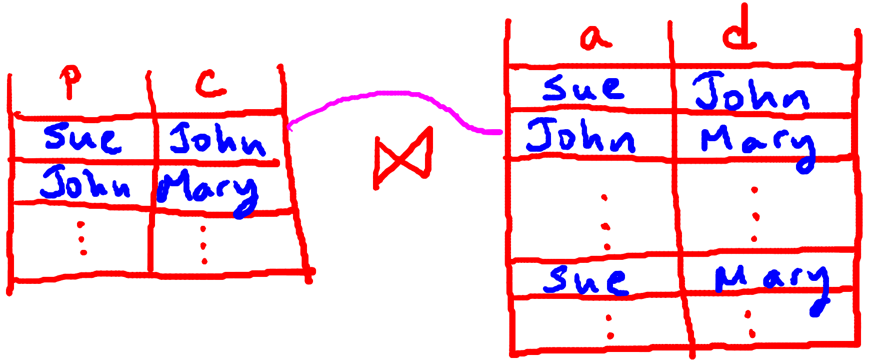
```
With Recursive
      R  As  ( base query
                    Union
               recursive query )
<query involving R (and other tables)>
```

one reference to R

Example: Ancestors

`ParentOf(parent,child)`　　***Find all of Mary's ancestors***

```
with recursive
  Ancestor(a,d) as (select parent as a, child as d from ParentOf
                    union
                    select Ancestor.a, ParentOf.child as d
                    from Ancestor, ParentOf
                    where Ancestor.d = ParentOf.parent)
select a from Ancestor where d = 'Mary';
```



p	c
Sue	John
John	Mary
⋮	⋮

$\bowtie$

a	d
Sue	John
John	Mary
⋮	⋮
Sue	Mary
⋮	⋮

Example: Ancestors

`ParentOf(parent,child)` ***Find all of Mary's ancestors***

```
with recursive
  Ancestor(a,d) as (select parent as a, child as d from ParentOf
                    union
                    select A1.a, A2.d
                    from Ancestor A1, Ancestor A2
                    where A1.d = A2.a)
select a from Ancestor where d = 'Mary';
```

Nonlinear

p	c
Sue	John
John	Mary
⋮	⋮

a	d
Sue	John
John	Mary
⋮	⋮
Sue	Mary

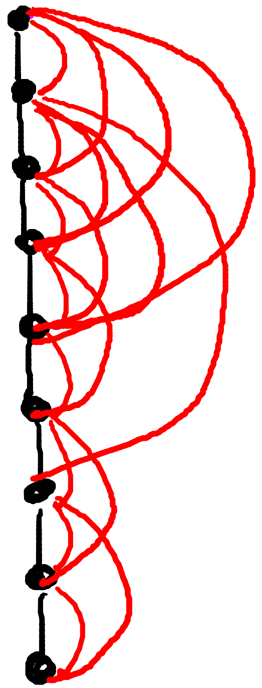
$\bowtie$

Example: Ancestors

`ParentOf(parent,child)`

Find all of Mary's ancestors

- ❖ Nonlinear (versus linear)
  - + Query looks cleaner
  - + Converges faster
  - – Harder to implement
  - SQL standard only requires linear



SQL With Recursive Statement

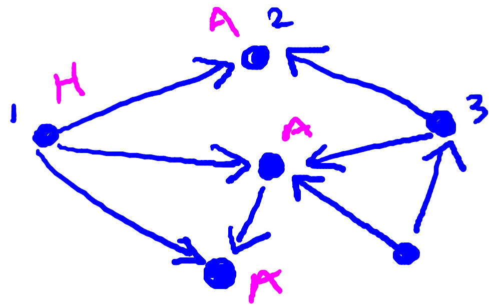
```
With Recursive
     R1 As (query-1),
     R2 As (query-2),
     ...
     Rn As (query-n)
<query involving R1,…,Rn (and other tables)>
```

Mutual Recursion

```
With Recursive
    R1 As (query-1),  ← R2
    R2 As (query-2),  ← R1
    ...
    Rn As (query-n)
<query involving R1,…,Rn (and other tables)>
```

Example: Hubs & Authorities

```
Link(src,dest)
HubStart(node) AuthStart(node)
```



Hub points to ≥ 3 Authority

Authority pointed to ≥ 3 Hub

☆

Example: Hubs & Authorities

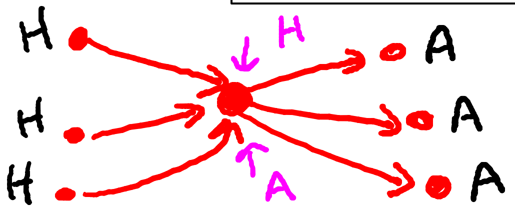
```
Link(src,dest)
HubStart(node) AuthStart(node)
```

```
with recursive
  Hub(node) as (select node from HubStart
                union
                select src as node from Link L
                where dest in (select node from Auth)
                group by src having count(*) >= 3),
  Auth(node) as (select node from AuthStart
                 union
                 select dest as node from Link L
                 where src in (select node from Hub)
                 group by dest having count(*) >= 3)
select * from Hub;
```

point to ≥ 3 Auth.

pointed to ≥ 3 Hubs

Example: Hubs & Authorities



Depends negatively on other relation

```
with recursive
  Hub(node) as (select node from HubStart
                union
     X    *     select src as node from Link L
                where src not in (select node from Auth)
                and dest in (select node from Auth)
                group by src having count(*) >= 3),
  Auth(node) as (select node from AuthStart
                 union
       *   X     select dest as node from Link L
                 where dest not in (select node from Hub)
                 and src in (select node from Hub)
                 group by dest having count(*) >= 3)
select * from Hub;
```

Example: Recursion with Aggregation

P(x) ←

```
with recursive
  R(x) as (select x from P
           union
           select sum(x) from R)
select * from R;
```

R: P , sum(P)

P: 1 , 2

R: 1 , 2 , ~~3~~ , ~~6~~ 9

SQL With Recursive Statement

```
With Recursive
    R1 As (query-1),
    R2 As (query-2),
    ...
    Rn As (query-n)
<query involving R1,…,Rn (and other tables)>
```

R1

Extends expressiveness of SQL

- Basic functionality: linear recursion
- Extended functionality: nonlinear recursion, mutual recursion
- Disallowed: recursive subqueries (negative), aggregation