



# Chapter 6

## 数据库模式设计之层次结构

# 处理层次结构 (Hierarchical Data)

- 树状结构 (Tree Structures)
  - 历史...
    - 层次数据库
    - 网状数据库
    - 关系型数据库
  - 直到关系理论出现，数据库设计是“科学 (science)”而非“工艺 (craft)”
    - 层次性数据广泛存在 (XML, LDAP, BOM...)
  - 层次结构复杂度在于
    - 访问树的方式

# 树状结构VS.主从结构

- 父子结构 (parent/child link) --tree structure
- 主从结构 (master/detail relationship)
- 差异
  - 树状结构保存只需要一张表
  - 深度
  - 所有权
  - 多重父节点
- 参考书籍: Fabian Pascal: Practical Issues in Database Management (Addison Wesley)

# 层次结构的实际案例

- Risk exposure
- 档案位置
- 原料使用
- .....
- 不同的案例具有不同的基本特征
- 通常，树中的节点数量偏小。实际上，这也是树的优点，便于高效检索

# 层次结构的实际案例

```
select building.name building,  
       floor.name floor,  
       room.name room,  
       alley.name alley,  
       cabinet.name cabinet,  
       shelf.name shelf,  
       box.name box,  
       folder.name folder  
from inventory,  
     location folder,  
     location box,  
     location shelf,  
     location cabinet,  
     location alley,  
     location room,  
     location floor,  
     location building  
where inventory.id = 'AZE087564609'  
and inventory.folder = folder.id  
and folder.located_in = box.id  
and box.located_in = shelf.id  
and shelf.located_in = cabinet.id  
and cabinet.located_in = alley.id  
and alley.located_in = room.id  
and room.located_in = floor.id  
and floor.located_in = building.id
```

# 用SQL数据库描述树结构

- 只要对象的类型相同，而对象的层树可变，其关系就应该被建模为树结构
- 在数据库设计中，树通常三种模型
  - Adjacency model-邻接模型
  - Materialized path model-物化路径模型
  - Nested set model-嵌套集合模型
    - Joe Celko发明
    - Vadim Tropashko 提出过nested interval model

数据来源<http://www.kessler-web.co.uk>

# 树的实际实现：邻接模型

## ADJACENCY\_MODEL

Name	Null?	Type
ID	NOT NULL	NUMBER
PARENT_ID		NUMBER
DESCRIPTION	NOT NULL	VARCHAR2(120)
COMMANDER		VARCHAR2(120)

表的每一行描述一个部队，parent\_id指向树中的上级部队

# 树的实际实现：物化路径模型

## MATERIALIZED\_PATH\_MODEL

Name	Null?	Type
MATERIALIZED_PATH	NOT NULL	VARCHAR2(25)
DESCRIPTION	NOT NULL	VARCHAR2(120)
COMMANDER		VARCHAR2(120)

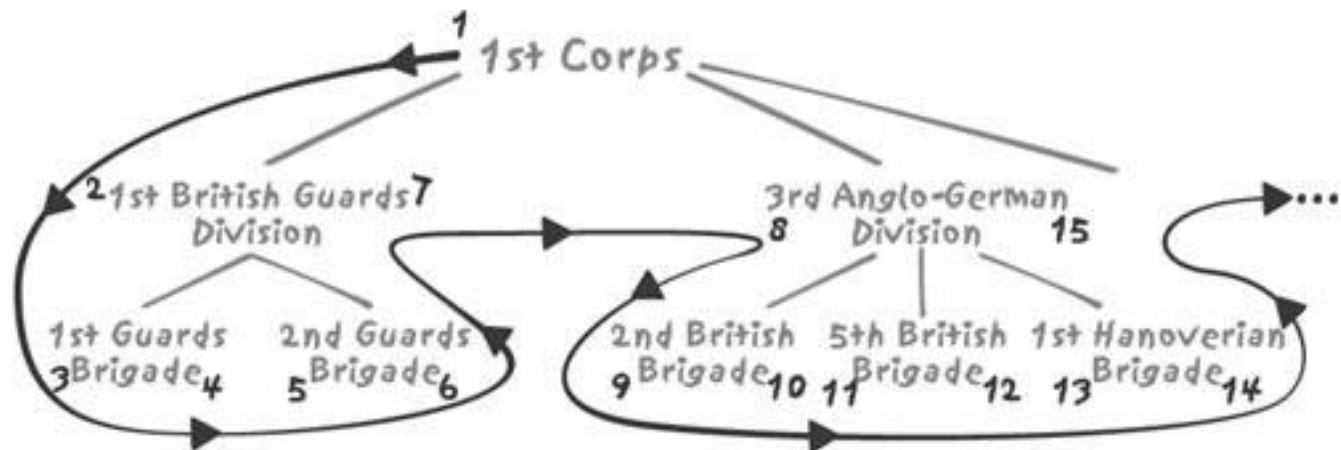
表中有两个索引，在materialized\_path上的唯一性索引以及在commander上的索引，正确的设计应该增加id字段。



# 树的实际实现：嵌套集合模型

## NESTED\_SETS\_MODEL

Name	Null?	Type
DESCRIPTION		VARCHAR2(120)
COMMANDER		VARCHAR2(120)
LEFT_NUM	NOT NULL	NUMBER
RIGHT_NUM	NOT NULL	NUMBER



# 用SQL访问树结构

- 为了检查效率和性能，分别用不同模型解决如下两个问题：
- 法国将军Dominique Vandamme指挥哪些部队，以缩排方式或简单列表的方式显示他们。注意，所有的commander字段都构建了索引（简称Vandamme查询）
- Scottish Highlanders的每个团各属于哪个部队（自底向上的查询）。在部队的名称（description字段）上没有索引，唯一的方法是在description字段中查找“Highland”字符串，在没有任何全文索引的情况下，这个问题简称highland问题
  - 注：层次结构Corp-division-brigade-regiment
  - Oracle

# 自顶向下查询：Vandamme查询

- 邻接模式

- connect by <a column of the current row> = prior <a column of the previous row> ,
- connect by <a column of the previous row> = prior <a column of the current row>

```
select lpad(description, length(description) + level) description,  
       commander  
from adjacency_model  
connect by parent_id = prior id  
start with commander = 'Général de Division Dominique Vandamme'
```

# 邻接模式

DESCRIPTION	COMMANDER
III Corps	Général de Division Dominique Vandamme
8th Infantry Division	Général de Division Baron Etienne-Nicolas Lefol
2nd Brigade	Général de Brigade Baron Corsin
37th Rgmt de Ligne	Colonel Cornebise
1st Brigade	Général de Brigade Billard (d.15th)
23rd Rgmt de Ligne	Colonel Baron Vernier
15th Rgmt Léger	Colonel Brice
...	
10th Infantry Division	Général de Division Baron Pierre-Joseph Habert
2nd Brigade	Général de Brigade Baron Dupeyroux
70th Rgmt de Ligne	Colonel Baron Maury
22nd Rgmt de Ligne	Colonel Fantin des Odoards
2nd (Swiss) Infantry Rgmt	Colonel Stoffel
1st Brigade	Général de Brigade Baron Gengoult
88th Rgmt de Ligne	Colonel Baillon
34th Rgmt de Ligne	Colonel Mouton
Division Artillery	
18/2nd Foot Artillery	Captain Guérin

40 rows selected.

# 邻接模式:递归实现

- STEP 1: define starting point

```
select 1 level,  
       id,  
       description,  
       commander  
from adjacency_model  
where commander = 'Général de Division Dominique Vandamme'
```

- STEP 2: define how each child row relates to its parent row

```
select parent.level + 1,  
       child.id,  
       child.description,  
       child.comander  
from recursive_query parent, adjacency_model child  
where parent.id = child.parent_id
```

# 邻接模式:递归实现

```
with recursive_query(level, id, description, commander)
as (select 1 level,
        id,
        description,
        commander
    from adjacency_model
    where commander = 'Général de Division Dominique Vandamme'
    union all
    select parent.level + 1,
        child.id,
        child.description,
        child.commander
    from recursive_query parent,
        adjacency_model child
    where parent.id = child.parent_id)
select char(concat(repeat(' ', level), description), 60) description,
        commander
from recursive_query
```

# 邻接模式:递归实现

```
with recursive_query(level, id, rank, description, commander)
as (select 1,
      id,
      cast(1 as double),
      description,
      commander
 from adjacency_model
 where commander = 'Général de Division Dominique Vandamme'
 union all
 select parent.level + 1,
        child.id,
        parent.rank + ranking.sn / power(100.0, parent.level),
        child.description,
        child.commander
 from recursive_query parent,
      (select id,
       row_number( ) over (partition by parent_id
                          order by description) sn
       from adjacency_model) ranking,
      adjacency_model child
 where parent.id =child.parent_id
       and child.id = ranking.id)
 select char(concat(repeat(' ', level), description), 60) description,
        commander
 from recursive_query
 order by rank
```

# 邻接模式:递归实现

## DESCRIPTION

## COMMANDER

III Corps	Général de Division Dominique Vandamme
10th Infantry Division	Général de Division Baron Pierre-Joseph Habert
1st Brigade	Général de Brigade Baron Gengoult
34th Rgmt de Ligne	Colonel Mouton
88th Rgmt de Ligne	Colonel Baillon
2nd Brigade	Général de Brigade Baron Dupeyroux
22nd Rgmt de Ligne	Colonel Fantin des Odoards
2nd (Swiss) Infantry Rgmt	Colonel Stoffel
70th Rgmt de Ligne	Colonel Baron Maury
Division Artillery	
18/2nd Foot Artillery	Captain Guérin
11th Infantry Division	Général de Division Baron Pierre Berthézène
...	
23rd Rgmt de Ligne	Colonel Baron Vernier
2nd Brigade	Général de Brigade Baron Corsin
37th Rgmt de Ligne	Colonel Cornebise
Division Artillery	
7/6th Foot Artillery	Captain Chauveau
Reserve Artillery	Général de Division Baron Jérôme Doguereau
1/2nd Foot Artillery	Captain Vollée
2/2nd Rgmt du Génie	



# 物化路径模型

- 查询编写不困难
- 计算由路径导出的层次不方便
- 假设mp\_depth()函数返回当前节点深度

```
select lpad(a.description, length(a.description)
          + mp_depth(...)) description,
       a.commander
from materialized_path_model a,
     materialized_path_model b
where a.materialized_path like b.materialized_path || '%'
     and b.commander = 'Général de Division Dominique Vandamme')
order by a.materialized_path
```

# 嵌套集合模型

- 很简单，某节点的后代的left\_num和right\_num都会在该节点的left\_num和right\_num范围内

```
select a.description,  
       a.commander  
from nested_sets_model a,  
     nested_sets_model b  
where a.left_num between b.left_num and b.right_num  
      and b.commander = 'Général de Division Dominique  
Vandamme'
```

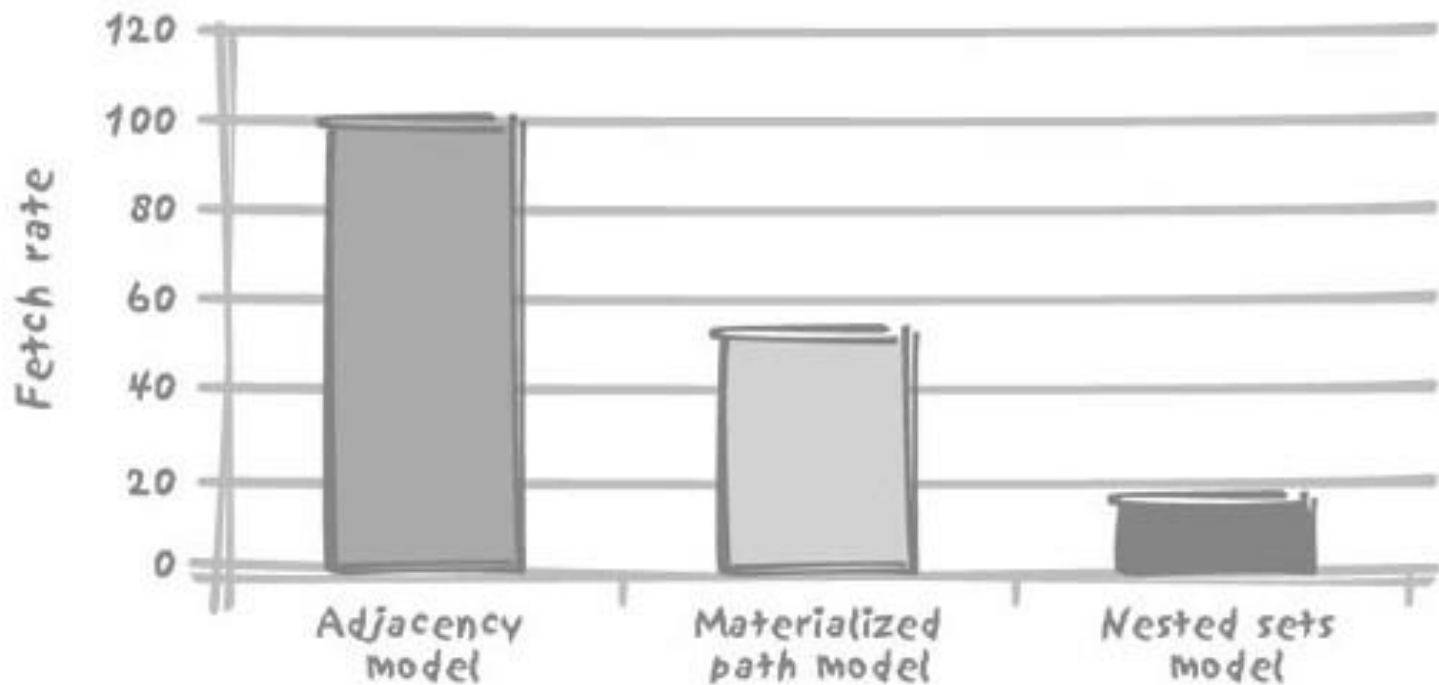
# 嵌套集合模型

- 缩排怎么办.....

```
select lpad(description, length(description) + depth) description,  
       commander  
from (select count(c.left_num) depth,  
            a.description,  
            a.commander,  
            a.left_num  
from nested_sets_model a,  
     nested_sets_model b,  
     nested_sets_model c  
where a.left_num between c.left_num and c.right_num  
     and c.left_num between b.left_num and b.right_num  
     and b.commander = 'Général de Division Dominique Vandamme'  
group by a.description,  
         a.commander,  
         a.left_num)  
order by left_num
```

# 比较各模型下的Vandamme模型

- 返回40条记录，循环执行每个查询5000次，比较每秒返回的记录数



# 自底向上访问：Highland查询

- 在description字段中查找“Highland”字符串
- 必然导致完整的表扫描
- 不同模型下Highland查询的差异

# 邻接模式

- Connect by相当容易实现

```
select lpad(description, length(description) + level) description,  
       commander  
from adjacency_model  
connect by id = prior parent_id  
start with description like '%Highland%'
```

## DESCRIPTION

## COMMANDER

2/73rd (Highland) Rgmt of Foot	Lt-Colonel William George Harris
5th British Brigade	Major-General Sir Colin Halkett
3rd Anglo-German Division	Lt-General Count Charles von Alten
I Corps	Prince William of Orange
The Anglo-Allied Army of 1815	Field Marshal Arthur Wellesley, Duke of Wellington
1/71st (Highland) Rgmt of Foot	Lt-Colonel Thomas Reynell
British Light Brigade	Major-General Frederick Adam
2nd Anglo-German Division	Lt-General Sir Henry Clinton
II Corps	Lieutenant-General Lord Rowland Hill
The Anglo-Allied Army of 1815	Field Marshal Arthur Wellesley, Duke of Wellington
1/79th (Highland) Rgmt of Foot	Lt-Colonel Neil Douglas
8th British Brigade	Lt-General Sir James Kempt
5th Anglo-German Division	Lt-General Sir Thomas Picton (d.18th)
General Reserve	Duke of Wellington
The Anglo-Allied Army of 1815	Field Marshal Arthur Wellesley, Duke of Wellington
1/42nd (Highland) Rgmt of Foot	Colonel Sir Robert Macara (d.16th)
9th British Brigade	Major-General Sir Denis Pack
5th Anglo-German Division	Lt-General Sir Thomas Picton (d.18th)
General Reserve	Duke of Wellington
The Anglo-Allied Army of 1815	Field Marshal Arthur Wellesley, Duke of Wellington
1/92nd (Highland) Rgmt of Foot	Lt-Colonel John Cameron
9th British Brigade	Major-General Sir Denis Pack
5th Anglo-German Division	Lt-General Sir Thomas Picton (d.18th)
General Reserve	Duke of Wellington
The Anglo-Allied Army of 1815	Field Marshal Arthur Wellesley, Duke of Wellington

25 rows selected.

# 物化路径模型

- 仅找出适当的记录并缩排显示算容易

```
select lpad(a.description, length(a.description)
          + mp_depth(b.materialized_path)
          - mp_depth(a.materialized_path)) description,
       a.commander
from materialized_path_model a,
     materialized_path_model b
where b.materialized_path like a.materialized_path || '%'
     and b.description like '%Highland%')
```

- 重复记录的问题
- 顺序的问题



# 物化路径模型

```
select description, commander
from (select distinct lpad(a.description, length(a.description)
    + mp_depth(b.materialized_path)
    - mp_depth(a.materialized_path)) description,
    a.commander,
    a.materialized_path
from materialized_path_model a,
    materialized_path_model b
where b.materialized_path like a.materialized_path || '%'
    and b.description like '%Highland%')
order by materialized_path desc
```

much nicer and more compact result

DESCRIPTION	COMMANDER
-----	-----
1/92nd (Highland) Rgmt of Foot	Lt-Colonel John Cameron
1/42nd (Highland) Rgmt of Foot	Colonel Sir Robert Macara (d.16th)
9th British Brigade	Major-General Sir Denis Pack
1/79th (Highland) Rgmt of Foot	Lt-Colonel Neil Douglas
8th British Brigade	Lt-General Sir James Kempt
5th Anglo-German Division	Lt-General Sir Thomas Picton (d.18th)
General Reserve	Duke of Wellington
1/71st (Highland) Rgmt of Foot	Lt-Colonel Thomas Reynell
British Light Brigade	Major-General Frederick Adam
2nd Anglo-German Division	Lt-General Sir Henry Clinton
II Corps	Lieutenant-General Lord Rowland Hill
2/73rd (Highland) Rgmt of Foot	Lt-Colonel William George Harris
5th British Brigade	Major-General Sir Colin Halkett
3rd Anglo-German Division	Lt-General Count Charles von Alten
I Corps	Prince William of Orange
The Anglo-Allied Army of 1815	Field Marshal Arthur Wellesley, Duke of Wellington

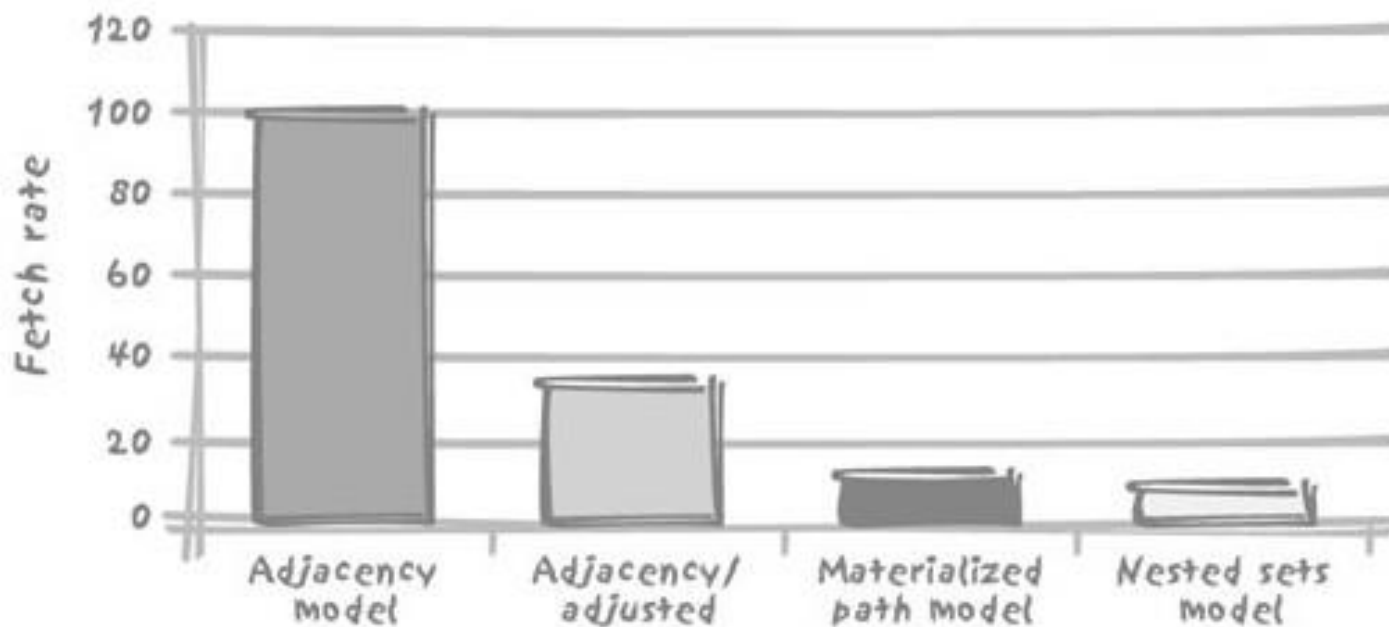
16 rows selected.

# 嵌套集合模型

- 动态计算深度依旧是个问题
- 不要显示人造根节点
- 硬编码最大深度（为了缩排显示）

```
select lpad(description, length(description) + 6 - depth) description,  
       commander  
from (select distinct b.description,  
                    b.commander,  
                    b.left_num,  
                    (select count(c.left_num)  
                     from nested_sets_model c  
                     where b.left_num between c.left_num  
                        and c.right_num) depth  
from nested_sets_model a,  
     nested_sets_model b  
where a.description like '%Highland%'  
     and a.left_num between b.left_num and b.right_num  
     and b.left_num > 1)  
order by left_num desc
```

# 比较各种模型下的Highland查询



# 一些问题

- 物化路径不该是KEY，即使他们有唯一性
- 物化路径不该暗示任何兄弟节点的排序
- 所选择的编码方式不需要完全中立

# 对保存于叶节点中的值做聚合

- 为人数建模
  - 叶节点包含更多的信息
  - 采用先前的例子，并限定法国第三军，构建UNITS表，记录一个团、一个师或一个旅，不包含关联

ID	NAME	COMMANDER
1	III Corps	Général de Division Dominique Vandamme
2	8th Infantry Division	Général de Division Baron Etienne-Nicolas Lefol
3	1st Brigade	Général de Brigade Billard
4	2nd Brigade	Général de Brigade Baron Corsin
5	10th Infantry Division	Général de Division Baron Pierre-Joseph Habert
6	1st Brigade	Général de Brigade Baron Gengoult
7	2nd Brigade	Général de Brigade Baron Dupeyroux
8	11th Infantry Division	Général de Division Baron Pierre Berthézène
9	1st Brigade	Général de Brigade Baron Dufour
10	2nd Brigade	Général de Brigade Baron Logarde
11	3rd Light Cavalry Division	Général de Division Baron Jean-Simon Domont
12	1st Brigade	Général de Brigade Baron Dommanget
13	2nd Brigade	Général de Brigade Baron Vinot
14	Reserve Artillery	Général de Division Baron Jérôme Doguereau

# 关联关系的存储

UNIT\_LINK\_ADJACENCY

ID    PARENT\_ID

2	1
3	2
4	2
5	1
6	5
7	5
8	1
9	8
10	8
11	1
12	11
13	11
14	1

UNIT\_LINKS\_PATH

ID    PATH

1	1
2	1.1
3	1.1.1
4	1.1.2
5	1.2
6	1.2.1
7	1.2.2
8	1.3
9	1.3.1
10	1.3.2
11	1.4
12	1.4.1
13	1.4.2
14	1.5

unit\_strength

ID                      MEN

3	2952
4	2107
6	2761
7	2823
9	2488
10	2050
12	699
13	318
14	152

# 计算每一层的人数

- 对于邻接模型
  - 第三军的总人数

```
select sum(men)
from unit_strength
where id in (select id
             from unit_links_adjacency
             connect by prior id = parent_id
             start with parent_id = 1)
```

- 每级战斗单位的人数

```
select u.name,
       u.commander,
       (select sum(men)
        from unit_strength
        where id in (select id
                     from unit_links_adjacency
                     connect by parent_id = prior id
                     start with parent_id = u.id)
        or id = u.id) men
from units u
```



# 计算每一层的人数

- 对于物化路径模型

- 第一步，构建视图EXPLODED\_LINKS\_PATH

```
SQL> select * from exploded_links_path;
```

ID	ANCESTOR	DEPTH
14	1	1
13	1	2
12	1	2
11	1	1
10	1	2
9	1	2
8	1	1
7	1	2
6	1	2
5	1	1
4	1	2
3	1	2
2	1	1
4	2	1
3	2	1
7	5	1
6	5	1
10	8	1
9	8	1
13	11	1
12	11	1

# 计算每一层的人数

- 然后做sum操作，不考虑叶节点

```
select u.name, u.commander, sum(s.men) men
from units u,
     exploded_links_path el,
     unit_strength s
where u.id = el.ancestor
     and el.id = s.id
group by u.name, u.commander
```

NAME	COMMANDER	MEN
-----	-----	-----
III Corps	Général de Division Dominique Vandamme	16350
8th Infantry Division	Général de Division Baron Etienne-Nicolas Lefol	5059
10th Infantry Division	Général de Division Baron Pierre Joseph Habert	5584
11th Infantry Division	Général de Division Baron Pierre Berthézène	4538
3rd Light Cavalry Division	Général de Division Baron Jean-Simon Domont	1017

# 计算每一层的人数

- 执行查询5000次，比较单位时间返回的记录数

