

# ***Introduction to Database Systems***

## **Execution Plans in PostgreSQL**

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# Execution Plans in PostgreSQL

Call EXPLAIN in psql

```
wdb=> EXPLAIN
wdb-> SELECT d.loc
wdb-> FROM   emp e, dept d, salgrade s
wdb-> WHERE  e.deptno = d.deptno AND
wdb->         e.sal BETWEEN s.losal AND s.hisal AND
wdb->         s.grade = 2;
```

EXPLAIN can also be called from pgAdmin

# EXPLAIN Returns a Query Plan

Hash Join (cost=1.09..3.53 rows=2 width=7)

Hash Cond: (e.deptno = d.deptno)

-> Nested Loop (cost=0.00..2.41 rows=2 width=4)

Join Filter: ((e.sal >= s.losal) AND (e.sal <= s.hisal))

-> Seq Scan on salgrade s (cost=0.00..1.06 rows=1 width=8)

Filter: (grade = 2)

-> Seq Scan on emp e (cost=0.00..1.14 rows=14 width=8)

-> Hash (cost=1.04..1.04 rows=4 width=11)

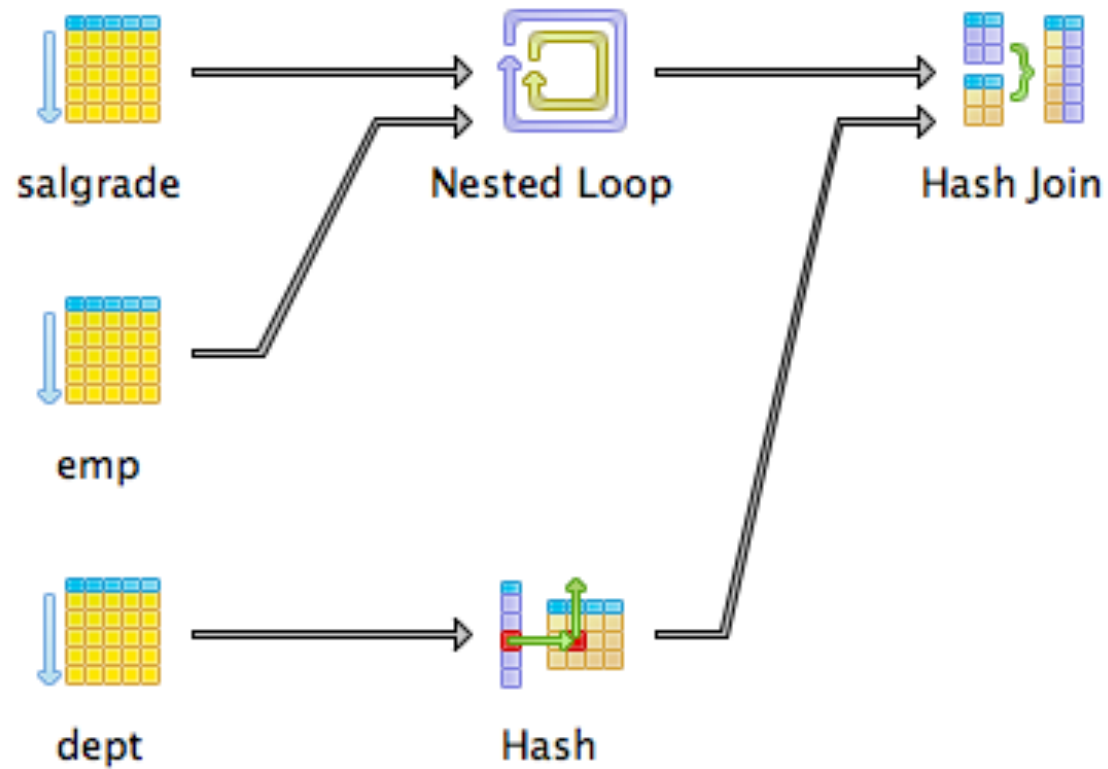
-> Seq Scan on dept d (cost=0.00..1.04 rows=4 width=11)

# Principles

- Each **operator**, except the top one, is marked by ->
- The tree structure is indicated by **indentation**
- For each step the plan contains the operator applied and **estimates** of
  - the time needed to produce the first tuple (= **start-up time**), measured in disk page fetches
  - the time needed to produce **all tuples**
  - the number of **result tuples**
  - the **size** of result tuples

*There is a graphical representation of plans in pgAdmin*

# Graphical Plan



# Explain Analyze

Runs the query and confronts the expected values in the plan with the real ones

Hash Join (cost=1.09..3.53 rows=2 width=7)  
(actual time=0.074..0.107 rows=3 loops=1)  
Hash Cond: (e.deptno = d.deptno)  
-> Nested Loop (cost=0.00..2.41 rows=2 width=4)  
(actual time=0.037..0.063 rows=3 loops=1)  
Join Filter: ((e.sal >= s.losal) AND (e.sal <= s.hisal))  
-> Seq Scan on salgrade s (cost=0.00..1.06 rows=1 width=8)  
(actual time=0.016..0.018 rows=1 loops=1)  
Filter: (grade = 2)  
-> Seq Scan on emp e (cost=0.00..1.14 rows=14 width=8)  
(actual time=0.003..0.014 rows=14 loops=1)  
-> Hash (cost=1.04..1.04 rows=4 width=11)  
(actual time=0.018..0.018 rows=4 loops=1)  
-> Seq Scan on dept d (cost=0.00..1.04 rows=4 width=11)  
(actual time=0.003..0.007 rows=4 loops=1)

# Operators: Query 1

```
EXPLAIN SELECT e.ename
FROM      emp1 e, salgrade s
WHERE     e.sal BETWEEN s.losal AND s.hisal AND
          s.grade = 2;
```

# Operators: Plan 1

Nested Loop (cost=0.00..35.06 rows=111 width=10)

Join Filter: ((e.sal >= s.losal) AND (e.sal <= s.hisal))

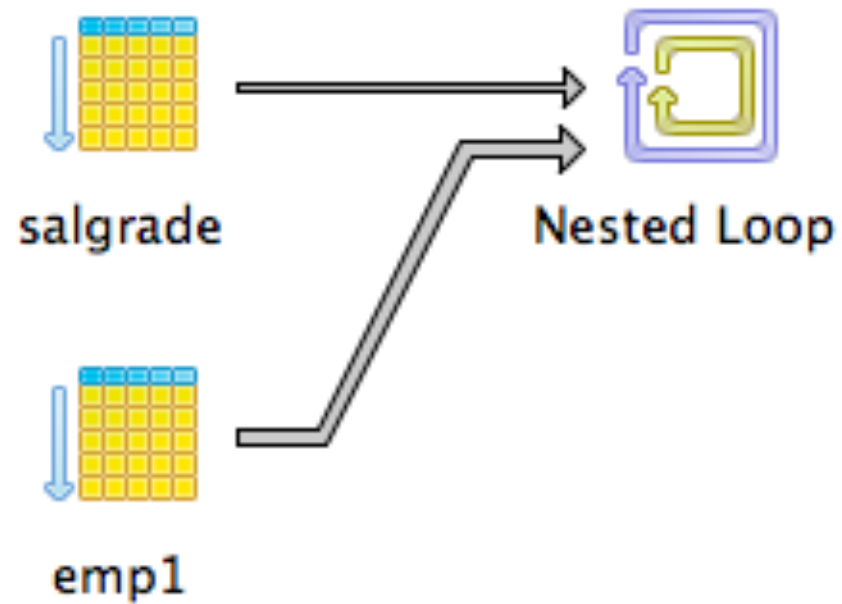
-> Seq Scan on salgrade s (cost=0.00..1.06 rows=1 width=8)

Filter: (grade = 2)

-> Seq Scan on emp1 e (cost=0.00..19.00 rows=1000 width=14)



# Operators: Graphical Plan 1

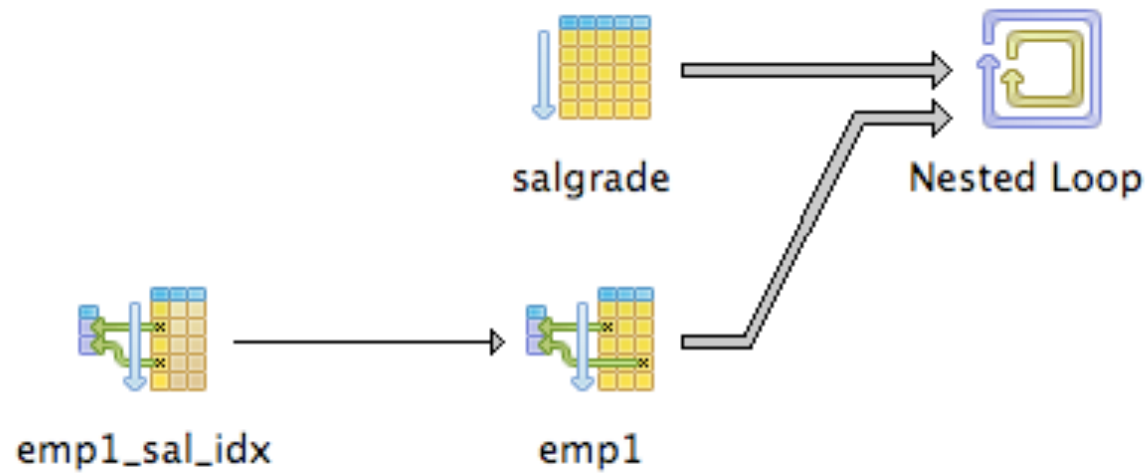


## Operators: Query 2

```
CREATE INDEX emp1_sal_idx on emp1(sal);
```

```
EXPLAIN SELECT e.ename  
FROM emp1 e, salgrade s  
WHERE e.sal BETWEEN s.losal AND s.hisal AND  
s.grade = 2;
```

# Operators: Graphical Plan 2



# Operators: Plan 2

Nested Loop (cost=5.39..18.23 rows=111 width=10)

-> Seq Scan on salgrade s (cost=0.00..1.06 rows=1 width=8)

Filter: (grade = 2)

-> Bitmap Heap Scan on emp1 e (cost=5.39..15.50 rows=111 width=14)

Recheck Cond: ((e.sal >= s.losal) AND (e.sal <= s.hisal))

-> Bitmap Index Scan on emp1\_sal\_idx (cost=0.00..5.36 rows=111 width=0)

Index Cond: ((e.sal >= s.losal) AND (e.sal <= s.hisal))

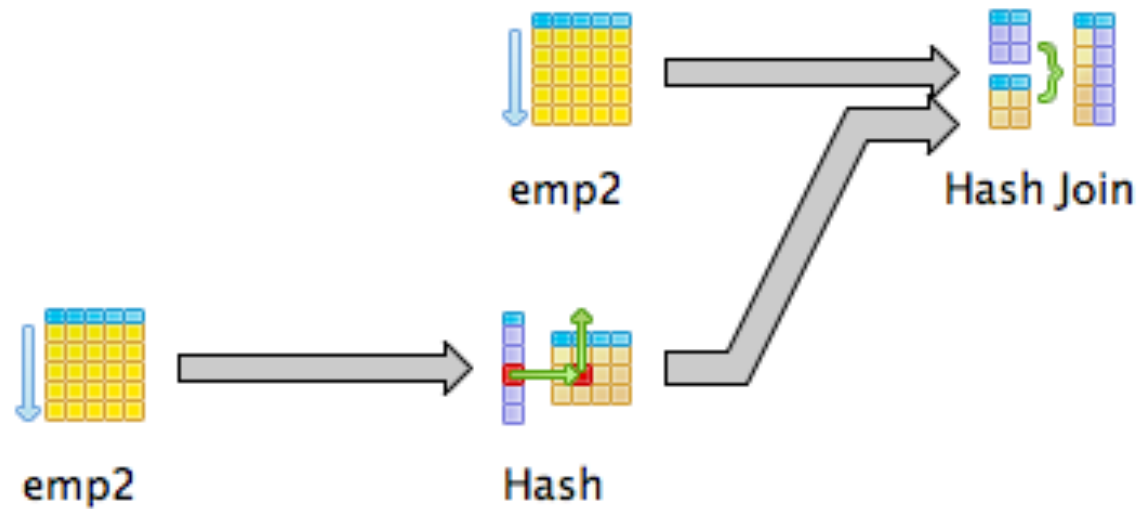
# Hash Join vs. Sort Merge Join

emp2 has 10,000 tuples, emp3 has 100,000 tuples

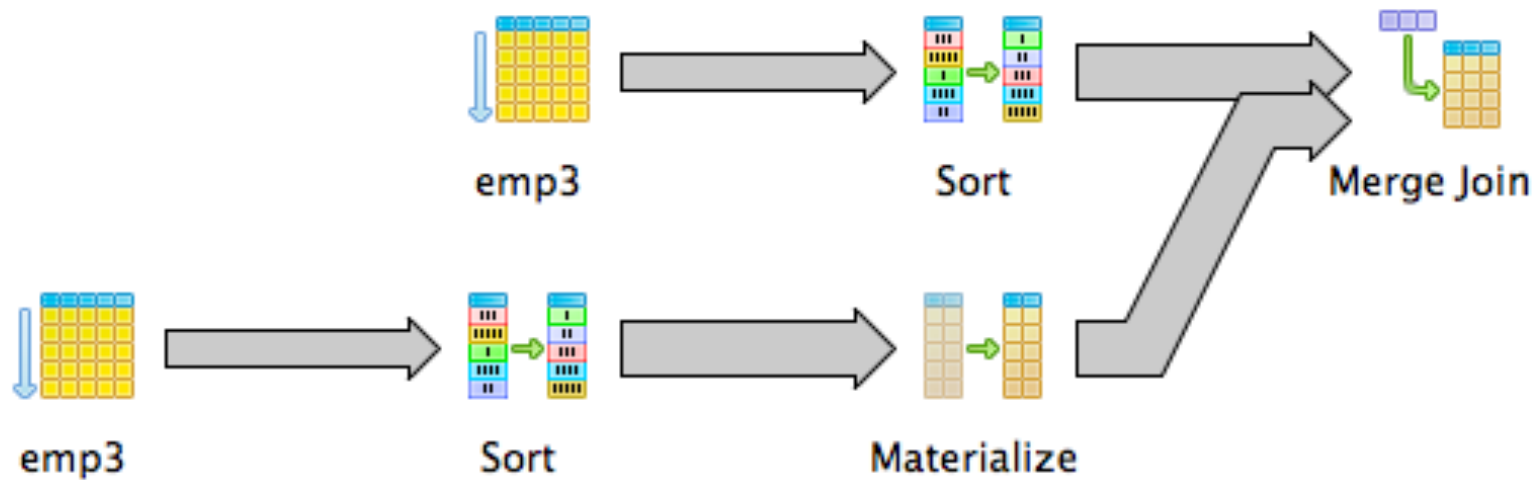
```
SELECT e1.ename, e2.ename
FROM   emp2 e1, emp2 e2
WHERE  e1.mgr = e2.mgr;
```

```
SELECT e1.ename, e2.ename
FROM   emp3 e1, emp3 e2
WHERE  e1.mgr = e2.mgr;
```

# Joining emp2: Graphical Plan



# Joining emp3: Graphical Plan



# Hash Join vs. Sort Merge Join

Hash Join (cost=312.00..1778.32 rows=26682 width=18)

Hash Cond: (e1.mgr = e2.mgr)

-> Seq Scan on emp2 e1 (cost=0.00..187.00 rows=10000 width=13)

-> Hash (cost=187.00..187.00 rows=10000 width=13)

-> Seq Scan on emp2 e2 (cost=0.00..187.00 rows=10000 width=13)

Merge Join (cost=23754.82..29777.58 rows=368208 width=18)

Merge Cond: (e1.mgr = e2.mgr)

-> Sort (cost=11877.32..12127.32 rows=100000 width=13)

Sort Key: e1.mgr

-> Seq Scan on emp3 e1 (cost=0.00..1861.00 rows=100000 width=13)

-> Materialize (cost=11877.32..13127.32 rows=100000 width=13)

-> Sort (cost=11877.32..12127.32 rows=100000 width=13)

Sort Key: e2.mgr

-> Seq Scan on emp3 e2 (cost=0.00..1861.00 rows=100000 width=13)}<sub>6</sub>



# Speeding Up Selections

```
SELECT COUNT (ename)
FROM   emp3 e
WHERE  e.sal = 4000;
```

## Example

- **emp3** has 100,000 tuples
- salaries are between 5 and 4000
- there are 3959 distinct values of **sal**
- there are 27 tuples with **sal=4000**
- relation **emp3** has size 7Mb

# Selection without Index

Aggregate (cost=2111.07..2111.07 rows=1 width=9)

(actual time=85.711..85.712 rows=1 loops=1)

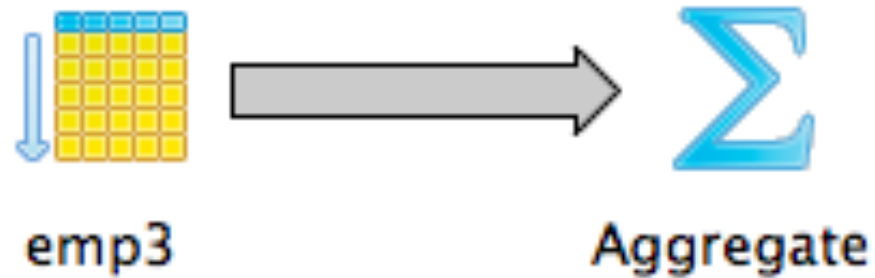
-> Seq Scan on emp3 e (cost=0.00..2111.00 rows=25 width=9)

(actual time=0.781..85.574 rows=27 loops=1)

Filter: (sal = 4000)

Total runtime: 85.776 ms

# Selection Without Index: Graphical Plan



# Selection with Index

```
CREATE INDEX emp3_sal_idx ON emp3 (sal);
```

Aggregate (cost=92.05..92.06 rows=1 width=9)

(actual time=0.553..0.553 rows=1 loops=1)

-> Bitmap Heap Scan on emp3 e (cost=4.45..91.99 rows=25 width=9)

(actual time=0.206..0.489 rows=27 loops=1)

Recheck Cond: (sal = 4000)

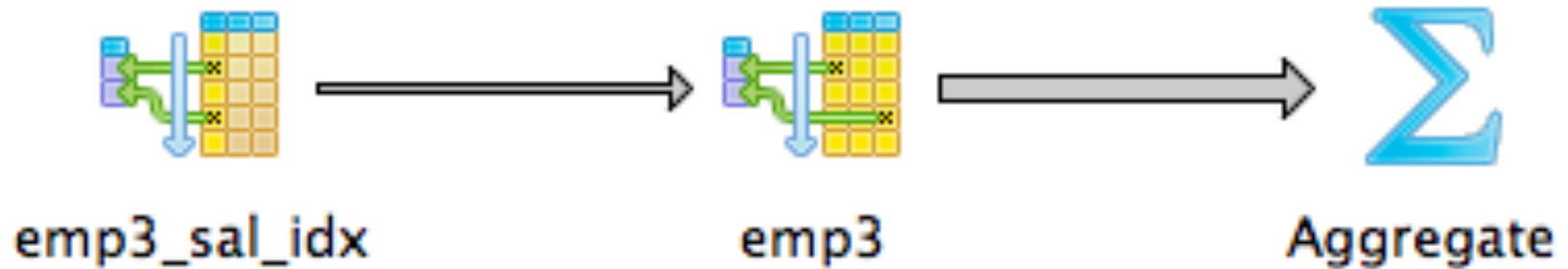
-> Bitmap Index Scan on emp3\_sal\_idx (cost=0.00..4.45 rows=25 width=0)

(actual time=0.181..0.181 rows=27 loops=1)

Index Cond: (sal = 4000)

Total runtime: 0.632 ms

# Selection with Index: Graphical Plan



# Selection and Join on Primary Keys

```
EXPLAIN ANALYZE
SELECT *
FROM   emp3 NATURAL JOIN dept3
WHERE  empno = 54321;
```

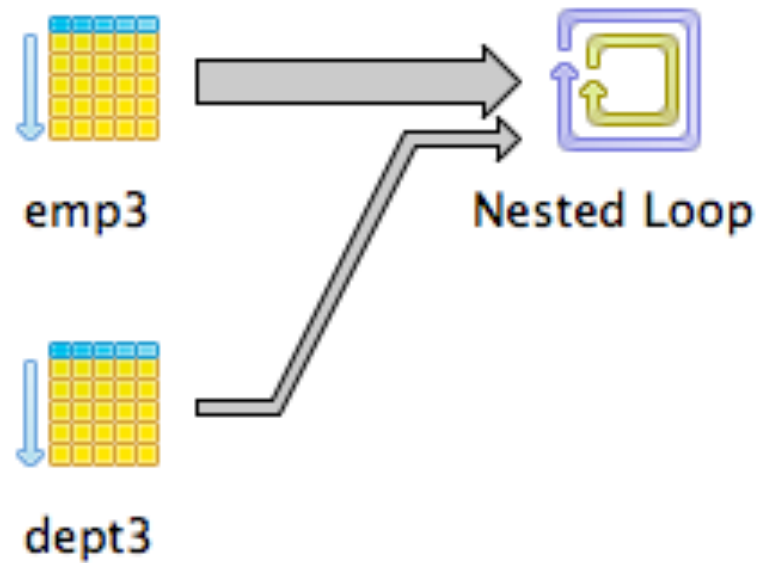
Statistics:

- emp3 has 100,000 tuples
- dept3 has 1,000 tuples

# Without Indexes on the Primary Keys

Nested Loop (cost=0.00..2140.50 rows=1 width=60)  
(actual time=25.113..47.055 rows=1 loops=1)  
Join Filter: (emp3.deptno = dept3.deptno)  
-> Seq Scan on emp3 (cost=0.00..2111.00 rows=1 width=43)  
(actual time=23.250..45.006 rows=1 loops=1)  
Filter: (empno = 54321)  
-> Seq Scan on dept3 (cost=0.00..17.00 rows=1000 width=21)  
(actual time=0.085..1.157 rows=1000 loops=1)  
Total runtime: 47.128 ms

# Without Indexes: Graphical Plan





# With Indexes on the Primary Keys

```
CREATE INDEX emp3_empno_idx ON emp3(empno);
```

```
CREATE INDEX dept3_deptno_idx ON dept3(deptno);
```

Nested Loop (cost=0.00..16.56 rows=1 width=60)

(actual time=0.218..0.226 rows=1 loops=1)

-> Index Scan using emp3\_empno\_idx on emp3 (cost=0.00..8.28 rows=1  
width=43)

(actual time=0.094..0.095 rows=1 loops=1)

Index Cond: (empno = 54321)

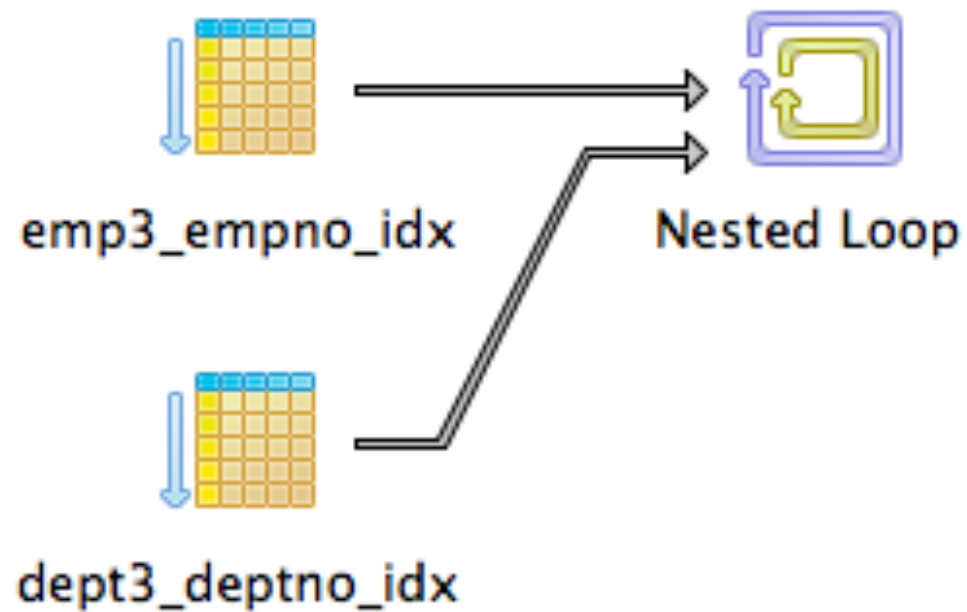
-> Index Scan using dept3\_deptno\_idx on dept3 (cost=0.00..8.27 rows=1  
width=21)

(actual time=0.109..0.113 rows=1 loops=1)

Index Cond: (dept3.deptno = emp3.deptno)

Total runtime: 0.271 ms

# With Indexes: Graphical Plan



# Controlling the Join Order (1)

```
SELECT e.ename
FROM   dept d natural join emp e, salgrade s
WHERE  e.sal BETWEEN s.losal AND s.hisal AND
       s.grade = 2 AND
       d.loc = 'Boston';
```

Suppose we want that **salgrade** and **emp** are joined first

# The Standard Plan

Nested Loop (cost=1.06..3.42 rows=1 width=6)

Join Filter: ((e.sal >= s.losal) AND (e.sal <= s.hisal))

-> Seq Scan on salgrade s (cost=0.00..1.06 rows=1 width=8)

Filter: (grade = 2)

-> Hash Join (cost=1.06..2.29 rows=4 width=10)

Hash Cond: (e.deptno = d.deptno)

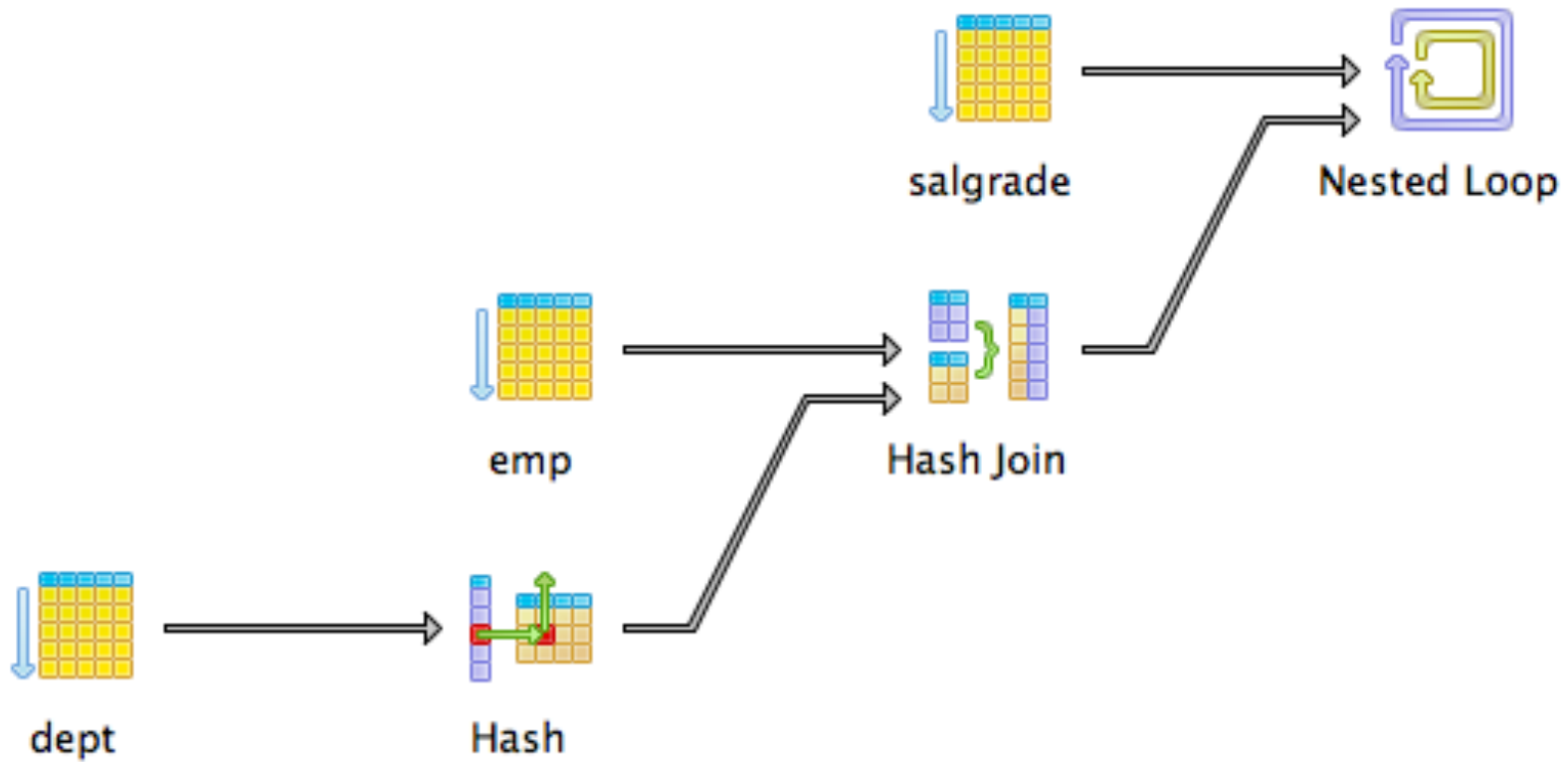
-> Seq Scan on emp e (cost=0.00..1.14 rows=14 width=14)

-> Hash (cost=1.05..1.05 rows=1 width=4)

-> Seq Scan on dept d (cost=0.00..1.05 rows=1 width=4)

Filter: ((loc)::text = 'Boston'::text)

# The Standard Plan (2)



# Controlling the Join Order (3)

By default, joins in the **FROM** clause are translated into

- tables in the **FROM** clause
- conditions in the **WHERE** clause

In a session, we can set the parameter `join_collapse_limit`, which limits the number of relations in the **FROM** clause

```
SET join_collapse_limit = 1;
```

# The Modified Query

```
SELECT e.ename
FROM   (emp e JOIN salgrade s
        ON e.sal BETWEEN s.losal AND s.hisal)
       NATURAL JOIN dept d
WHERE  s.grade = 2 AND
       d.loc = 'Boston';
```

# Controlling the Join Order (4)

Nested Loop (cost=0.00..3.49 rows=1 width=6)

Join Filter: (e.deptno = d.deptno)

-> Seq Scan on dept d (cost=0.00..1.05 rows=1 width=4)

Filter: ((loc)::text = 'Boston'::text)

-> Nested Loop (cost=0.00..2.41 rows=2 width=10)

Join Filter: ((e.sal >= s.losal) AND (e.sal <= s.hisal))

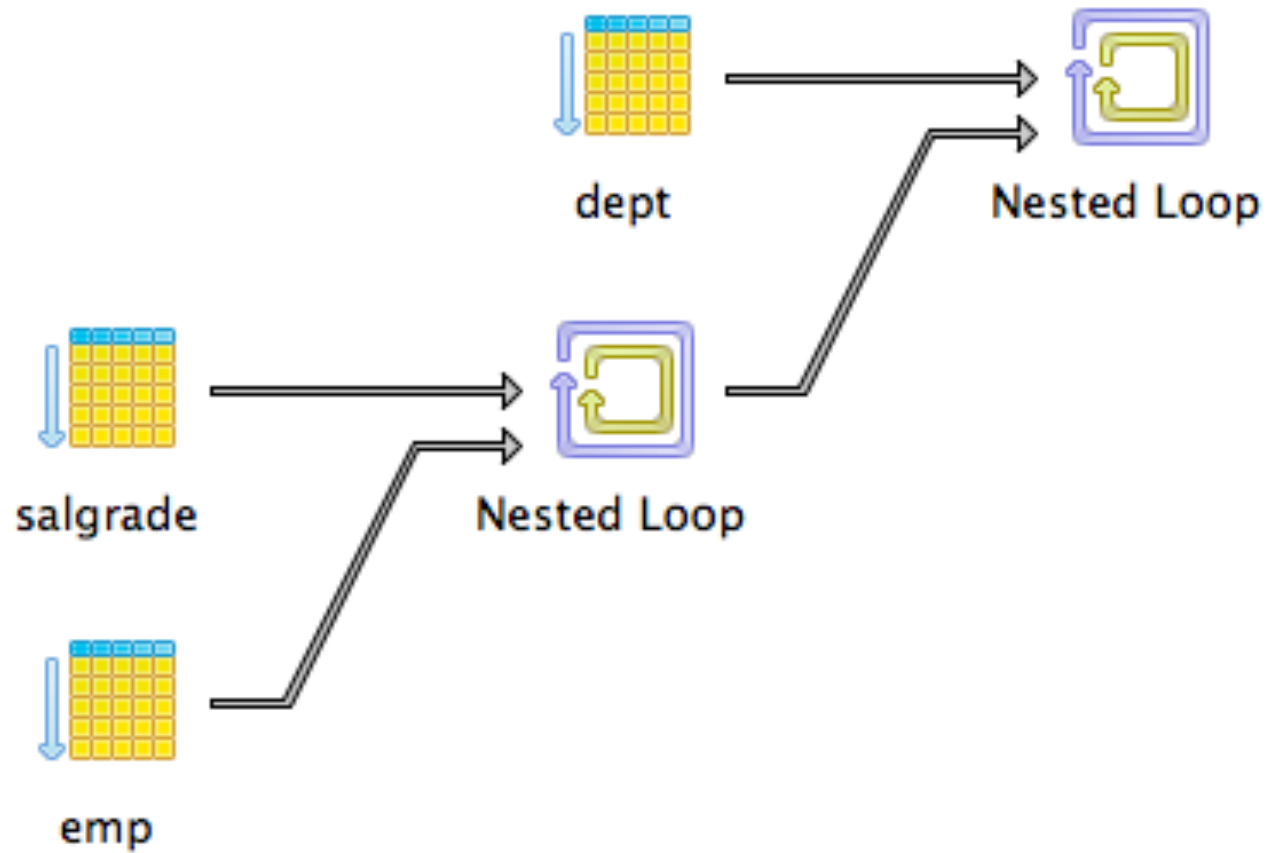
-> Seq Scan on salgrade s (cost=0.00..1.06 rows=1 width=8)

Filter: (grade = 2)

-> Seq Scan on emp e (cost=0.00..1.14 rows=14 width=14)



# Modified Query: Graphical Plan



# Which One Was Faster?

Nested Loop (cost=1.06..3.42 rows=1 width=6) (actual time=0.350..0.350 rows=0 loops=1)  
Join Filter: ((e.sal >= s.losal) AND (e.sal <= s.hisal))  
-> Seq Scan on salgrade s (cost=0.00..1.06 rows=1 width=8) (actual time=0.164..0.165 rows=1 loops=1)  
Filter: (grade = 2)  
-> Hash Join (cost=1.06..2.29 rows=4 width=10) (actual time=0.173..0.173 rows=0 loops=1)  
Hash Cond: (e.deptno = d.deptno)  
-> Seq Scan on emp e (cost=0.00..1.14 rows=14 width=14) (actual time=0.077..0.084 rows=14 loops=1)  
-> Hash (cost=1.05..1.05 rows=1 width=4) (actual time=0.057..0.057 rows=1 loops=1)  
-> Seq Scan on dept d (cost=0.00..1.05 rows=1 width=4) (actual time=0.045..0.047 rows=1 loops=1)  
Filter: ((loc)::text = 'Boston'::text)  
Total runtime: 0.429 ms

Nested Loop (cost=0.00..3.49 rows=1 width=6) (actual time=0.078..0.078 rows=0 loops=1)  
Join Filter: (e.deptno = d.deptno)  
-> Seq Scan on dept d (cost=0.00..1.05 rows=1 width=4) (actual time=0.018..0.019 rows=1 loops=1)  
Filter: ((loc)::text = 'Boston'::text)  
-> Nested Loop (cost=0.00..2.41 rows=2 width=10) (actual time=0.021..0.049 rows=3 loops=1)  
Join Filter: ((e.sal >= s.losal) AND (e.sal <= s.hisal))  
-> Seq Scan on salgrade s (cost=0.00..1.06 rows=1 width=8) (actual time=0.006..0.008 rows=1 loops=1)  
Filter: (grade = 2)  
-> Seq Scan on emp e (cost=0.00..1.14 rows=14 width=14) (actual time=0.003..0.013 rows=14 loops=1)  
Total runtime: 0.140 ms

# References

For the preparation of these slides I have used the PostgreSQL Manual at

<http://www.postgresql.org/docs/manuals/>