Class 18 : Joins I

Summary $\quad$ #pages M $\quad \begin{pmatrix} N \\ P_S \end{pmatrix}$

#rows per page P_R

S (sid, sname, rating, age)

$N = 500 \quad P_S = 80$

R (sid, bid, day, rname)

$M = 1000 \quad P_R = 100$

Selection (a) i) cheapest access path
ii) retrieve tuples
iii) apply remaining selection conditions

(b) i) get rids from all matching indexes
ii) intersection rids
iii) retrieve tuples & apply remaining sel. cond.

unsorted	M I/Os
sorted	$\log_2 M + f \cdot M$
clustered	$\log_F M + f \cdot M$
unclustered	$\log_F M + f \cdot M \cdot P_R$

Projection
Sort + discard unwanted fields & duplicates
hash + "

cost: $\quad M + 2 \cdot T \leftarrow$ pages after removing unwanted fields

Joins : Nested-Loop Joins
Sort-Merge Joins $\quad$ today
Hash Joins
Remaining op (joins + agg)

any interesting query contains a join

SELECT * FROM R, S WHERE R.sid = S.sid

$R \bowtie S$ discuss as # I/Os discard output

$\cancel{\sigma_{R.sid=S.sid}(R \times S)}$

- Simple Nested-Loop Join $R \bowtie_{i=j} S$

```
$\forall r \in R$ ← outer
    $\forall s \in S$ ← inner
        if $r_i == s_j$ then add $\langle r,s \rangle$ to the result
```

Cost

$$(M \cdot p_R) \cdot N + M = (1000 \cdot 100) \cdot 500 + 1000 = \boxed{50,001,000} \text{ \# I/Os}$$

$\Downarrow$

rows of R   1 I/O → 2ms $\boxed{28h}$

R $M = 1000 \rightarrow 4MB$

S $N = 500 \rightarrow 2MB$

swap R with S

$$(N \cdot p_S) \cdot M + N = \boxed{40,000,500} \text{ IOs}$$

- Page-oriented Nested-Loop Join

```
$\forall$ page $b_r$ in R
    $\forall$ page $b_s$ in S
        $\forall$ tuple r in $b_r$
            $\forall$ tuple s in $b_s$
                if $r_i == s_j$ then add $\langle r,s \rangle$ to the result
```

Cost

$$M \cdot N + M = 1000 \cdot 500 + 1000 = \boxed{501,000} \rightarrow \boxed{17 \text{min}}$$

smaller outer?

$$N \cdot M + N = 500 \cdot 1000 + 500 = \boxed{500,500}$$

- Index Nested Loop Join

```
∀ tuple r in R
    probe index to fetch s such that $s_i == r_j$
        add <r,s> to result
```

Cost

$M + M \cdot p_R \cdot$ cost of finding matching tuples through the index

$\rightarrow$ Hash index 1.2 I/Os

$\rightarrow$ B^+-Tree 2-4 I/Os

clustered → 1 I/O per page of matching tuples

unclustered → 1 I/O per matching tuple

Example 1: hash idx on sid of S

```
Scan R: (M)
∀ each tuple in R
    fetch data entry (1.2)
        goto file (1)
```

$$M + M \cdot p_R \cdot (1.2 + 1) \rightarrow \overset{1000+}{1000} \cdot 100 (2.2) = \boxed{221,000} \rightarrow \boxed{7 \text{min}}$$

Example 2: hash idx on sid of R

$$\frac{M \cdot p_R}{N \cdot p_S} = \frac{100k}{40k} = 2.5 \ \frac{res}{sailor}$$

Scan S (N)

```
∀ s probe hash idx (1.2)
    find matching tuples 2.5
```

$N = N \cdot p_S (1.2 + 2.5) = 500 + 500 \cdot 80 \cdot (3.7) = \boxed{148,500} \rightarrow \boxed{5 \text{ min}}$

- Block Nested Loop Joins

→ 1 page for streaming the inner S
1 page for output
k pages for holding blocks (of k) of outer R

```
∀ block of k pages of R
    ∀ page bs in S
        ∀ tuple r in k pages of R
            ∀ tuple s in bs
                if $r_i == s_j$ add <r, s> to the result
```

Cost

Scan outer R: M I/Os
Scan inner for each block of R

$$M + \frac{M}{k} \cdot N \longrightarrow 1000 + \frac{500 \cdot 1000}{k} \qquad k = 100 \text{ pages}$$

$$\rightarrow \boxed{6000} \ I/Os \ \boxed{12sec}$$

$$N + \frac{N}{k} \cdot M \longrightarrow 500 + \frac{500 \cdot 1000}{k} \longrightarrow \boxed{5500} \rightarrow \boxed{11sec}$$

- Sort-Merge Join

→ both sorted on the join attribute

useful : ① both or one relations sorted on join attr.

② output should be sorted on join attr.

→ many duplicates may lead to backtracking

Cost Sort R + Sort S + M + N

worst case? M·N if all is equal

cost $(M+N)\cdot 2\cdot \#\text{passes} + M + N$

2 passes ?

$$\left\lceil \frac{N}{B} \right\rceil = B-1 \approx \frac{N}{B} = B-1 \Rightarrow B^2 - B - N = 0$$

$$B \approx \lceil \sqrt{N} \rceil + 1 = 33$$

$$\text{Cost} = (M+N)\cdot 5 = 1500 \cdot 5 = \boxed{7500} \text{ I/Os} \rightarrow \boxed{15 \text{ sec}}$$

BNLJ w/ 33 buffers $M + \frac{M\cdot N}{K} = 1000 + \frac{500\cdot 1000}{33} \approx \boxed{1000+15151}$

$N + \frac{M\cdot N}{K} = 500 + \frac{500\cdot 1000}{33} \approx \boxed{500+15151}$

if $K=100$ SMJ cannot do better than $\boxed{7500}$

BNLJ will do as low as $\boxed{5500}$

• Refined Sort - Merge Join

assume $B > \sqrt{M}$ and $B > \sqrt{N}$

after pass 0

$R \rightarrow \frac{M}{B}$ runs $\quad B > \sqrt{M} \Rightarrow \frac{1}{B} < \frac{1}{\sqrt{M}} \Rightarrow \frac{M}{B} < \sqrt{M} < B$

$S \rightarrow \frac{N}{B}$ runs $\quad B > \sqrt{N} \Rightarrow \frac{N}{B} < \sqrt{N} < B$

after pass 0 either R, S # runs $< B$

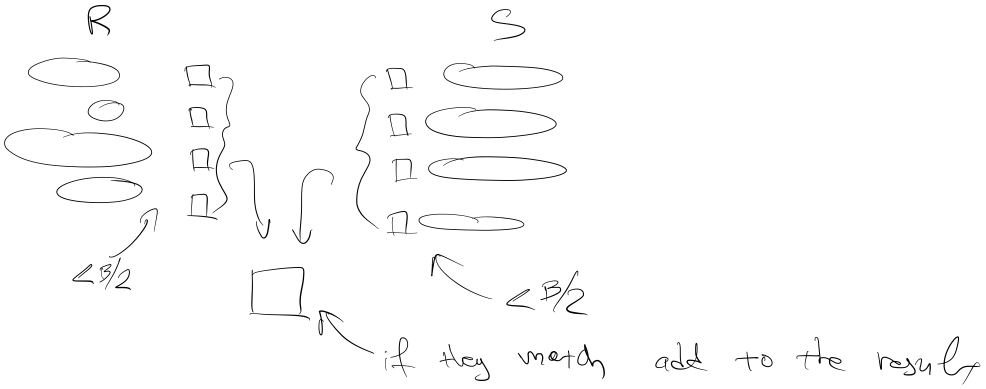
consider using replacement sort

it results to runs with size $\simeq 2B$

sorted runs after pass 0 using replacement sort

$R \rightarrow \frac{M}{2B} < \frac{B}{2} \qquad S \rightarrow \frac{N}{2B} < B/2$

we allocate a buffer per sorted run per file



cost $= (M+N) \cdot 3$

Read R → writing $< B/2$ # runs of R $\quad 2 \cdot M$

Read S → writing $< B/2$ # runs of S $\quad 2 \cdot N$

Read R and S and merge on the fly : $M+N$

$(M+N) \cdot 3 = \boxed{4500}$ I/Os → $\boxed{9s}$