Class 17: Joins II

Last time

Relation S, $N = 500$ pages $P_S = 80$
R, $M = 1000$ pages $P_R = 100$

Nested-Loop Joins

Simple	$(P_R \cdot M) \cdot N + M$	w/ R outer
Page-oriented	$M \cdot N + M$	
Block-based	$\frac{M \cdot N}{K} + M$	w/ K buffer
Index	$M + M \cdot P_R \cdot (\text{index\_access\_cost} + \text{data\_access\_cost})$	

index_access_cost: hash ~1.2, B^+-tree 2–4

data_access_cost: clustered → 1 I/O per page of matching tuples; unclustered → 1 I/O per matching tuple

Sort-Merge Joins

$3 \cdot (M+N)$ if $B > \sqrt{M}$ where M is # pages of the larger relation

$M+N$ if $B > N$ where N corresponds to the smallest relation

Today

- Hash Joins
- General Join Conditions
- Aggregates

Hash Joins

- Use a hash function h to create partitions of both relations — **hashing (building)**
- match tuples only between the corresponding partitions — **probing (matching)**

B buffers

h hash function

$R \bowtie S$ $i=j$

Building

$\forall r \in R$
read r and add it to buffer $h(r_i)$

$\forall s \in R$
read S and add it to buffer $h(s_j)$

Matching

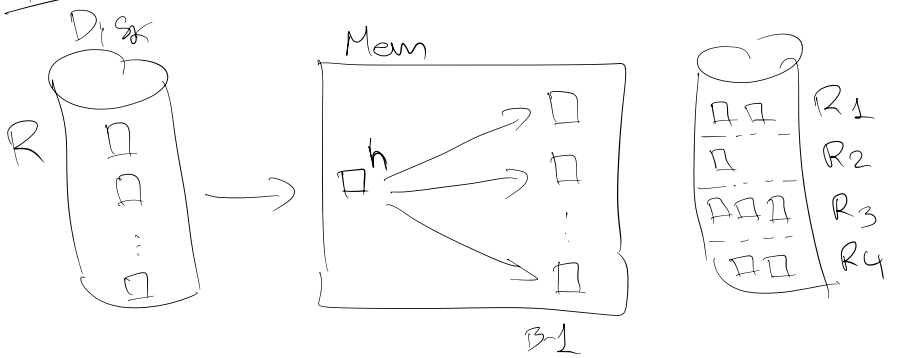
for $l = 1, 2, \ldots K$

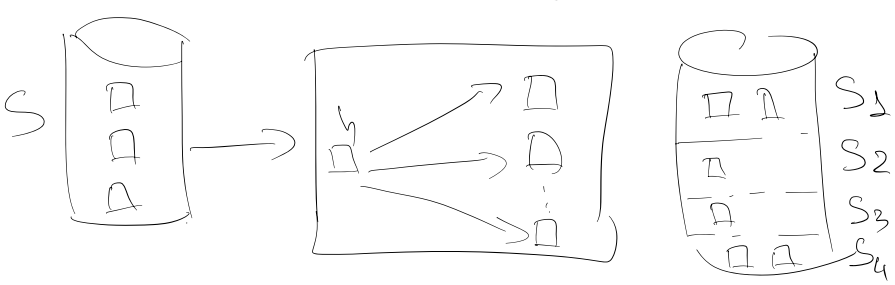
$\forall r \in R_l$
read r and insert into in-memory HT using $h_2(r_i)$

$\forall s \in S_l$
read S and probe HT using $h_2(s_j)$
if match found add $\langle r, s \rangle$ to the result

clear hash table from memory to proceed with next pair of partitions

Building



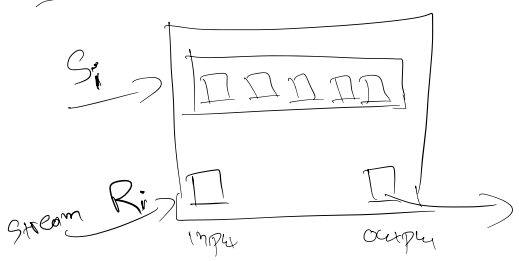


cost

$2 \cdot M$

$2 \cdot N$

Matching



read every partition once

in-memory HT w/ h_2 ($\neq h$)

Search in S_i as we stream R_i

Cost: $M+N$

total cost of Hash Join $= 3(M+N) = 4500 \rightarrow 45$

Memory Requirements

→ enough buffers for the largest partition of the smaller relation (S)

→ Input page for the other relation

→ Output page

→ a few pages of hash metadata

Fudge factor f (for example $f = 1.04$)

if $h \rightarrow$ uniform

size of a partition $\sim \frac{N}{B-1}$

$$B > \frac{f \cdot N}{B-1} + 2 \Rightarrow B > \sqrt{f \cdot N}$$

What if not enough memory? (for S_i to fit in memory)

→ apply the same algorith recursively

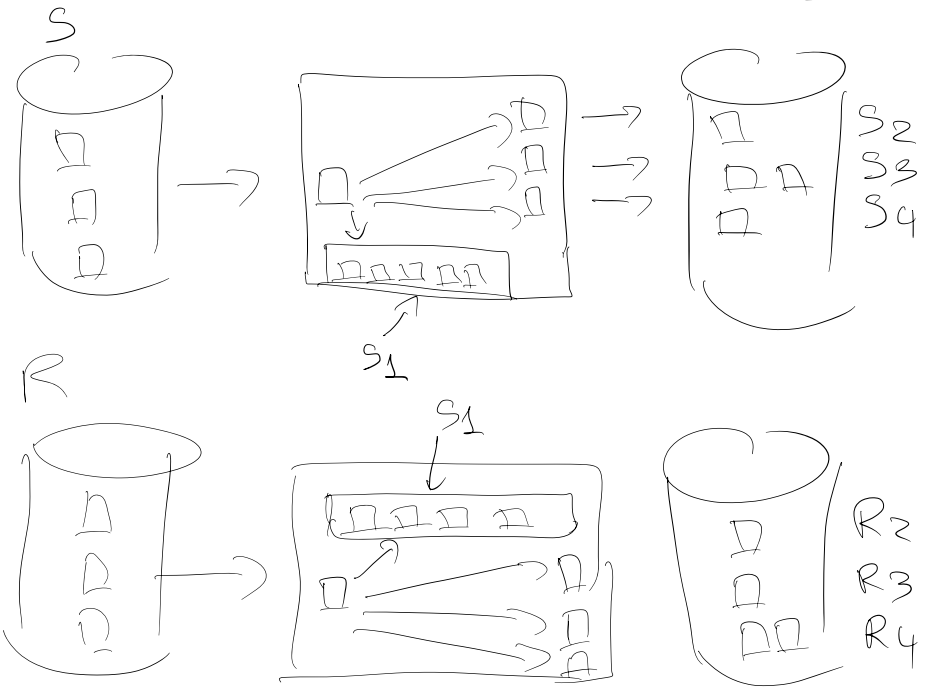
→ read, repartition S_i, R_i with h_3 ($\neq h_2, \neq h$)

→ matching per subpartition (mem. is enough)

* if not, again recursion

What if we have more memory?

Hybrid Hash Join



Cost

→ hashing S $N + N - \text{sizeof}(S_1)$

→ hashing R $M + M - \text{sizeof}(R_1)$

→ matching $M - \text{sizeof}(R_1) + N + \text{sizeof}(S_1)$

total $3(M+N) - 2(\text{sizeof}(S_1) + \text{sizeof}(R_1))$

B = 300
M = 1000
N = 500

$3(1000+500) - 2(500+250) = 4500 - 1500 = 3000$

GS

if B = 600

read S once + build hash table

Scan R once probe S on-the-fly

	Hash Join	vs	SMJ
cost	$3(M+N)$		$3(M+N)$
mem. req.	$B > \sqrt{f \cdot N}$ ← smaller		$B > \sqrt{M}$ ← larger
	$B > \sqrt{1.04 \cdot 500} = 23$		$B > \sqrt{1000} = 32$
$B(\text{sm.r.}) < N$	$3(M+N) - 2(\text{sizeof}(R_1) - \text{sizeof}(S_1))$		$3(M+N)$
$B > N$	$M+N$		$M+N$
output			sorted
if input sorted	$3(M+N)$		$M+N$

BUT sensitive to data skew

(a) equality joins on several attributes

(b) inequality joins

→ (a) for INLJ we need index with all attributes in join conditions

→ sort/hash use combination of all attributes

→ (b) INLJ w/ B+-Tree (not Hash Index)

HJ/SMJ cannot work

Block NLJ the best approach

Set

UNION / EXCEPT (set difference)

→ Sorting

→ sort S+R on all attributes

→ merging → discard duplicates (UNION)

→ set-difference

→ hashing
→ partition R + S
→ ∀ S-part probe corr. R-part,
→ discard duplicates (UNION)
→ set_difference

→ Intersection → special case of Join
Equality across all attributes

Aggregation
→ SELECT AVG(sal) FROM E
→ SCAN once

→ GROUP BY
< age, avg_salary >

hash (age) ⟶ < age, salary, count >

sort (age) Calculate "running info" of aggregation on-the-fly

⟶ if we have an index on < Group-by, select, where >
can use only the index WAY FASTER

⟶ Buffering
many thing in parallel
tough to estimate what is asked by BP

SNLJ B > N ✓
B < N LRU → sequential flooding
MRU ✓

INLJ → sort the outer relation