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

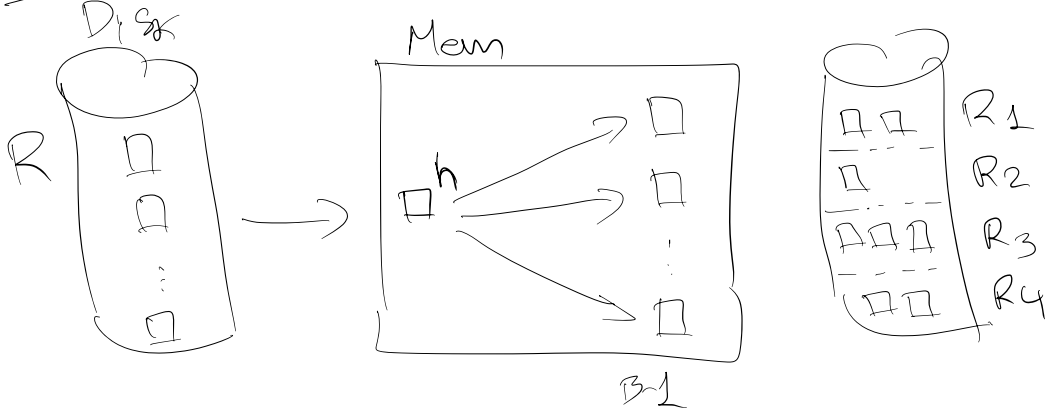
for $l = 1, 2, \ldots K$

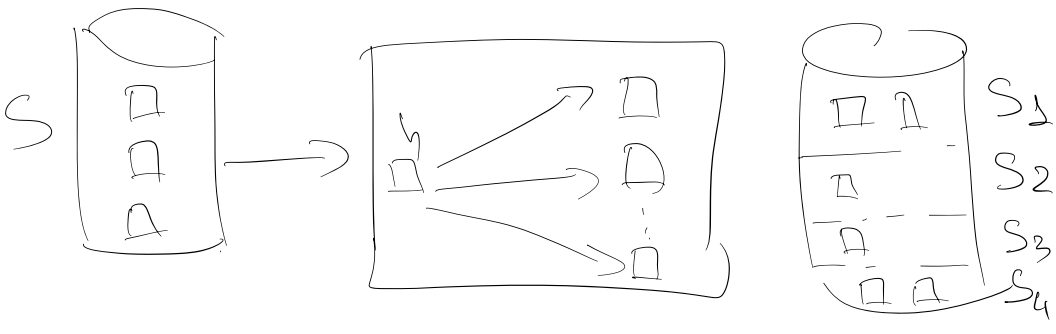
$\forall r \in R_l$
read r and insert into in-memory HT using $h_2(r_i)$

$\forall s \in S_l$
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



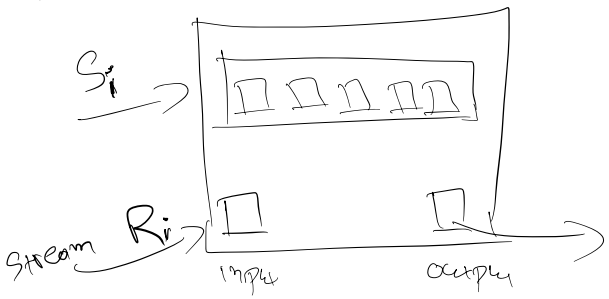


cost

$2 \cdot M$

$2 \cdot N$

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 algorithm recursively

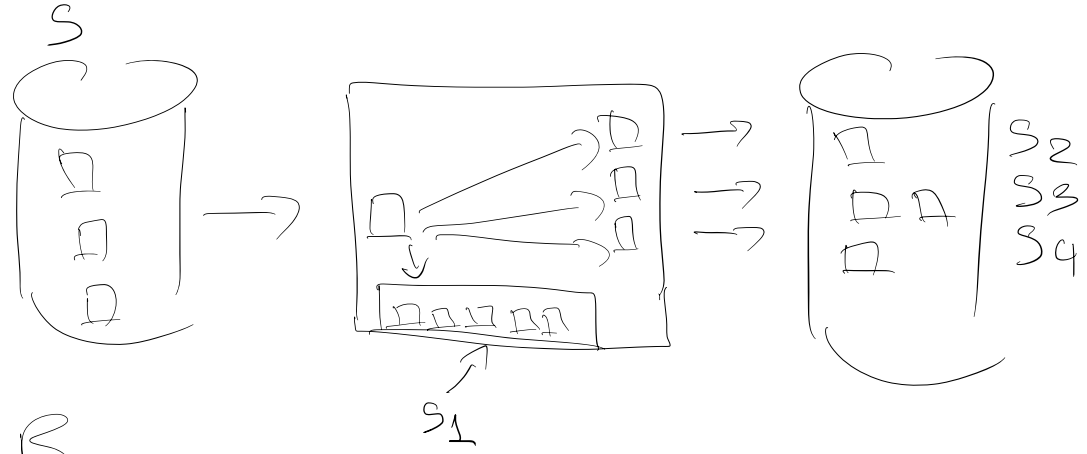
→ read, repartition S_i, R_i with h_3 ($\neq h_2, \neq h$)

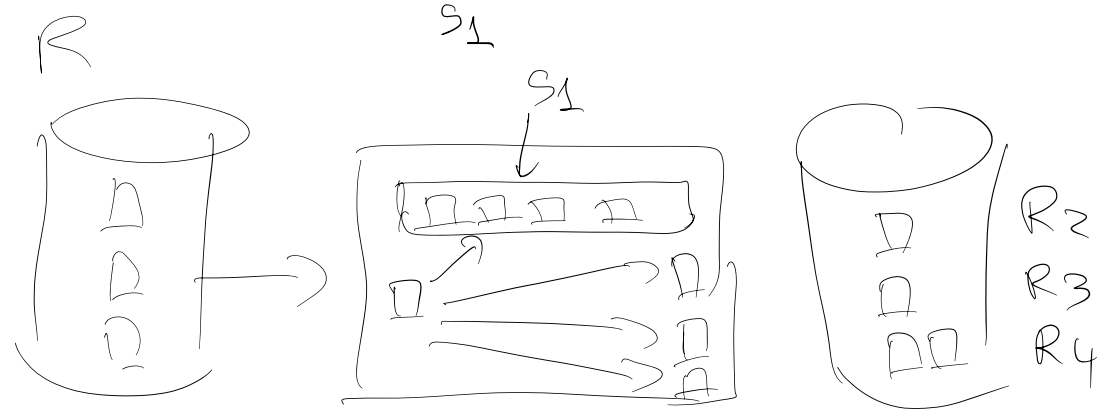
→ matching per subpartition (mem. is enough)

* 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

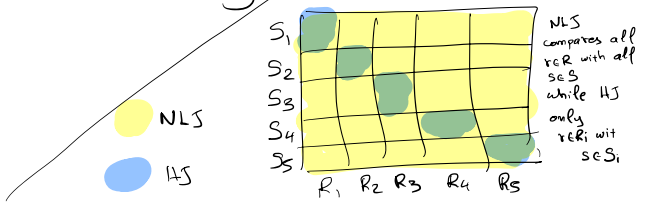
if $B = 600$

read S once + build hash table

Scan R once probe S on-the-fly

HJ vs NLJ

Work done during matching



Hash Join vs SMJ

cost

memory requirement (m.r.)

$3(M+N)$ | $3(M+N)$

$B > \sqrt{f \cdot N}$ ← smaller | $B > \sqrt{M}$ ← larger

example: $B > \sqrt{1.04 \cdot 500} = 23$ | $B > \sqrt{1000} = 32$

$\sqrt{fN} \leq B < \sqrt{M}$ | HJ exploits additional mem: $3(M+N) - 2(\text{sizeof}(R_1) - \text{sizeof}(S_1))$ | needs additional passes (cost is $> 3(M+N)$) $3(M+N)$

$\sqrt{M} \leq B < N$ | $M+N$ | $M+N$ sorted

$B > N$ | | $M+N$

output

if input sorted | $3(M+N)$

BUT sensitive to data skew

(a) equality join 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

→ refinement also applies

→ 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 cached by BP
SNLJ B>N ✓
B<N LRU → sequential flooding
MRU ✓
BNLJ replacement policy hang no impact
INLJ → sort the outer relation