Query Processing
Hash-based (Optional)

CS348 Spring 2024

Outline

- Scan
  - Selection, duplicate-preserving projection, nested-loop join
- Index
  - Selection, index nested-loop join, zig-zag join
- Sort
  - External merge sort, sort-merge join, union (set), difference, intersection, duplicate elimination, grouping and aggregation
- Hash (Optional)

Operators that benefit from sorting

- Union (set), difference, intersection
  - More or less like SMJ
- Duplication elimination
  - External merge sort
    - Eliminate duplicates in sort and merge
- Grouping and aggregation
  - External merge sort, by group-by columns
    - Trick: produce "partial" aggregate values in each run, and combine them during merge
      - This trick doesn't always work though
        - Examples: SUM(DISTINCT …), MEDIAN(…)

Outline

- Scan
  - Selection, duplicate-preserving projection, nested-loop join
- Index
  - Selection, index nested-loop join, zig-zag join
- Sort
  - External merge sort, sort-merge join, union (set), difference, intersection, duplicate elimination, grouping and aggregation
- Hash (Optional)
  - Hash join, union (set), difference, intersection, duplicate elimination, grouping and aggregation

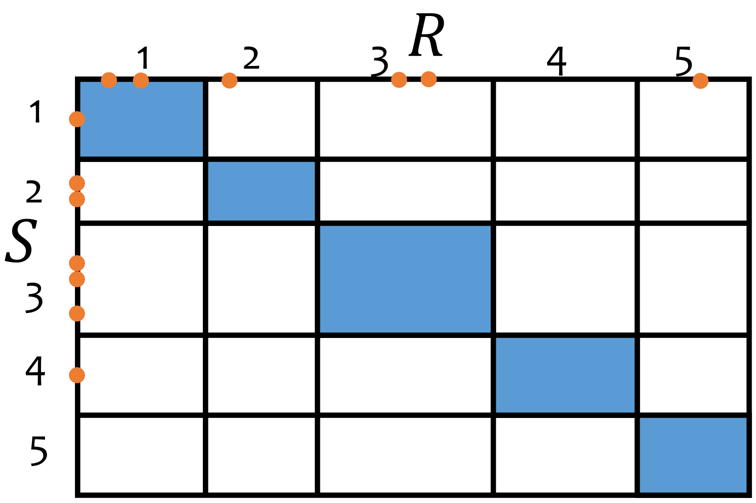
Hashing-based algorithms

http://global.rakuten.com/en/store/citygas/item/041233/

Hash join

$R \bowtie_{R.A=S.B} S$

- Main idea
  - Partition R and S by hashing their join attributes, and then consider corresponding partitions of R and S
  - If $r.A$ and $s.B$ get hashed to different partitions, they don't join

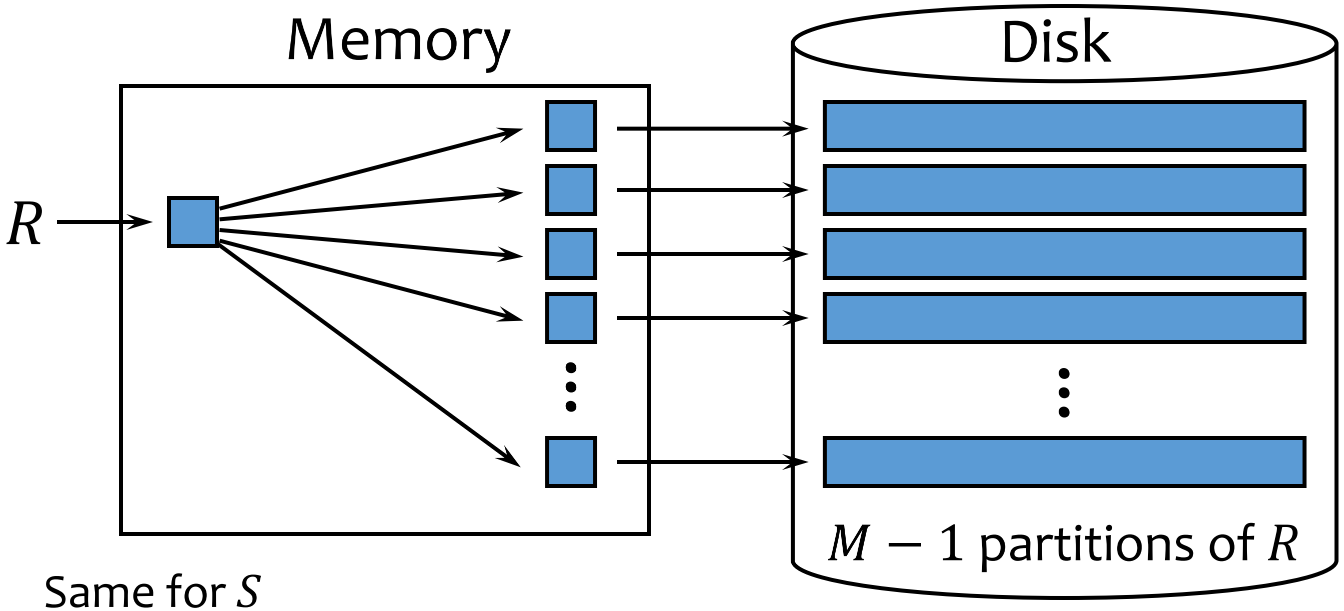


Nested-loop join considers all slots

Hash join considers only those along the diagonal!

Partitioning phase

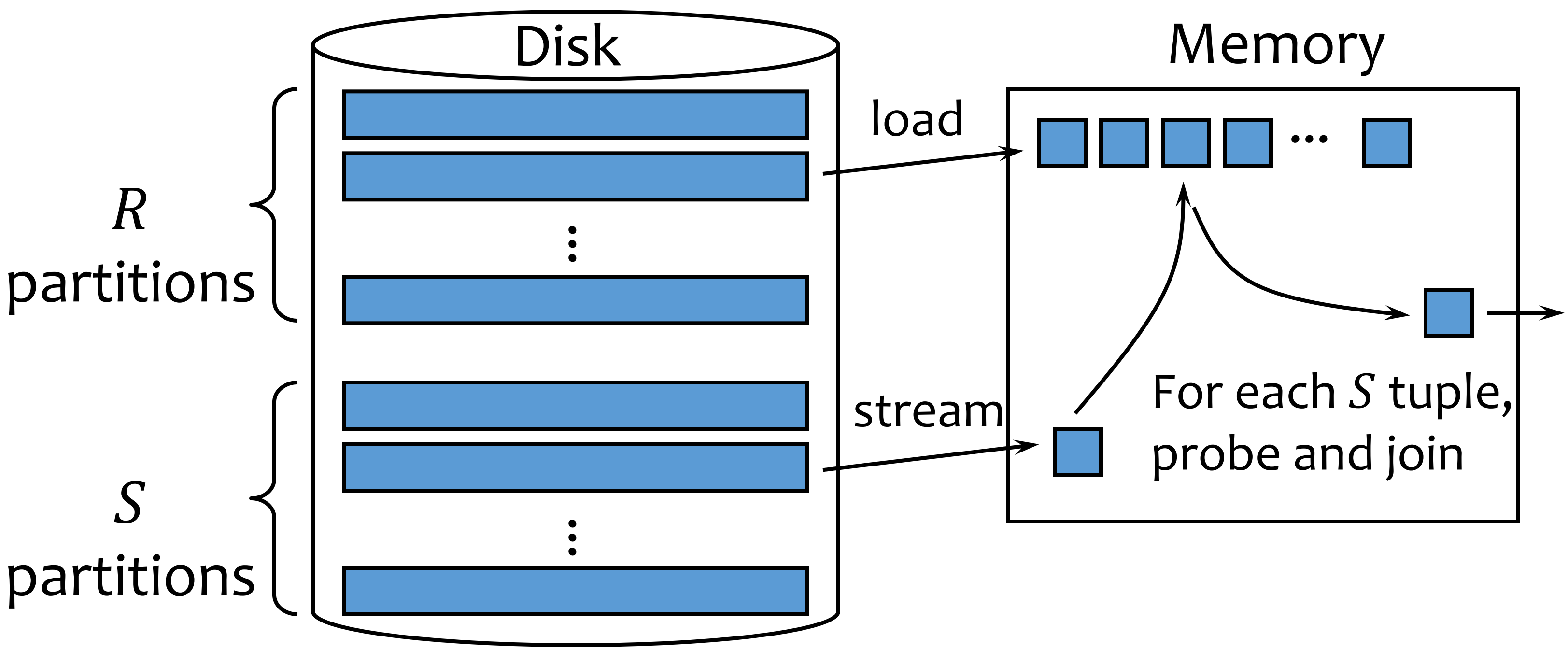
- Partition R and S according to the same hash function on their join attributes



Each partition has a size of B(R)/(M-1)

Probing phase

- Read in each partition of R, stream in the corresponding partition of S, join
  - Typically build a hash table for the partition of R
    - Not the same hash function used for partition, of course!



Performance of (two-pass) hash join

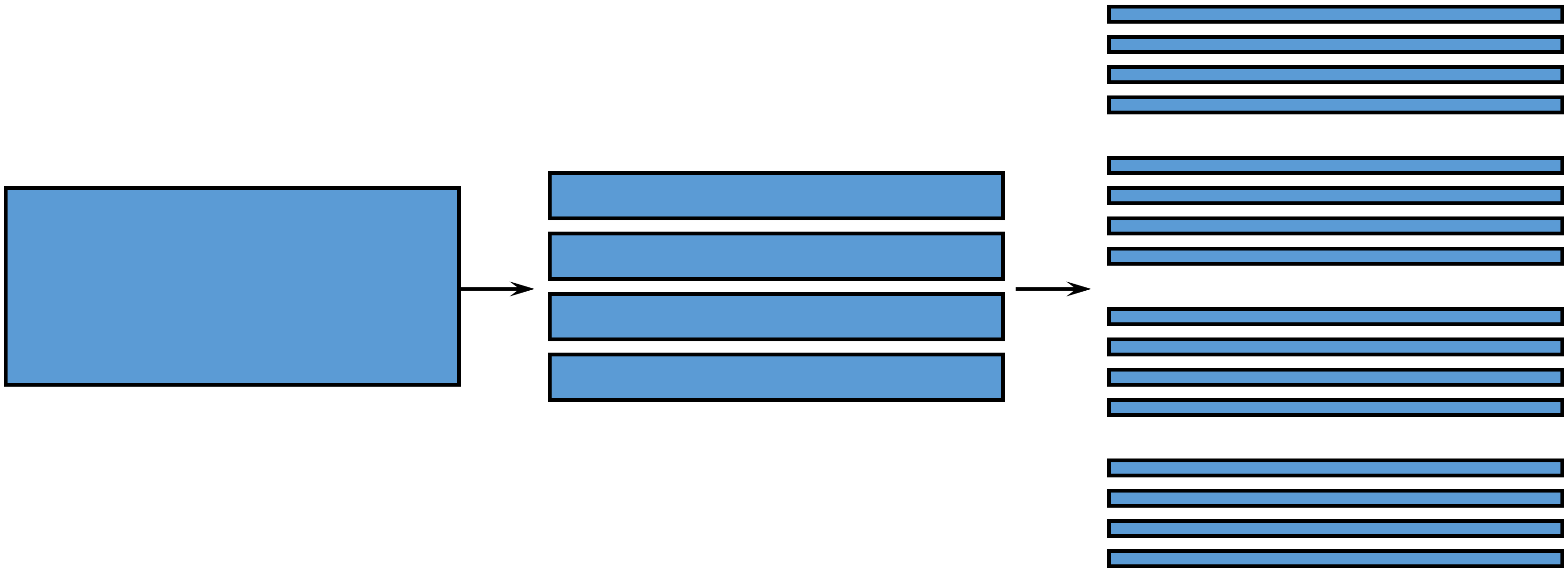
- If hash join completes in two phases:
  - I/O's: $3 \cdot \big(B(R) + B(S)\big)$
    - 1st phase: read B(R) + B(S) into memory to partition and write partitioned B(R) +B(S) to disk
    - 2nd phase: read B(R) + B(S) into memory to merge and join

  - Memory requirement:
    - In the probing phase, we should have enough memory to fit one partition of *R*: $M - 1 > \frac{B(R)}{M-1}$
    - $M > \sqrt{B(R)} + 1$
    - We can always pick R to be the smaller relation, so:

$$M > \sqrt{\min\big(B(R), B(S)\big)} + 1$$

Generalizing for larger inputs

- What if a partition is too large for memory?
  - Read it back in and partition it again!
  - Re-partition $O\left(\log_M B(R)\right)$ times



Hash join versus SMJ

(Assuming two-pass)

- I/O's: same
- Memory requirement: hash join is lower
  - $\sqrt{\min\big(B(R), B(S)\big)} + 1 < \sqrt{B(R) + B(S)}$
  - Hash join wins when two relations have very different sizes
- Other factors
  - Hash join performance depends on the quality of the hash
    - Might not get evenly sized buckets
  - SMJ can be adapted for inequality join predicates
  - SMJ wins if R and/or S are already sorted
  - SMJ wins if the result needs to be in sorted order

What about nested-loop join?

- May be best if many tuples join
  - Example: non-equality joins that are not very selective
- Necessary for black-box predicates
  - Example: WHERE *user_defined_pred*$(R.A, S.B)$

Other hash-based algorithms

- Union (set), difference, intersection
  - More or less like hash join
- Duplicate elimination
  - Check for duplicates within each partition/bucket
- Grouping and aggregation
  - Apply the hash functions to the group-by columns

Summary of techniques

- Scan
  - Selection, duplicate-preserving projection, nested-loop join
- Index
  - Selection, index nested-loop join, zig-zag join
- Sort (Optional)
  - External merge sort, sort-merge join, union (set), difference, intersection, duplicate elimination, grouping and aggregation
- Hash (Optional)
  - Hash join, union (set), difference, intersection, duplicate elimination, grouping and aggregation

Another view of techniques

- Selection
  - Scan without index (linear search): $\mathrm{O}(B(R))$
  - Scan with index – selection condition must be on search-key of index
    - B+ index: $\mathrm{O}(\log(B(R))$
    - Hash index: $\mathrm{O}(1)$
- Projection
  - Without duplicate elimination: $\mathrm{O}(B(R))$
  - With duplicate elimination
    - Sorting-based: $O\left(B(R) \cdot \log_M B(R)\right)$
    - Hash-based: $\mathrm{O}(B(R) + t)$where t is the result of the hashing phase
- Join
  - Block-based nested loop join (scan table): $\mathrm{O}(B(R) \cdot \frac{B(S)}{M})$
  - Index nested loop join $\mathrm{O}(B(R) + |R| \cdot (\text{index lookup}))$
  - Sort-merge join $O\left(B(R) \cdot \log_M B(R) + B(S) \cdot \log_M B(S)\right)$
  - Hash join $O\left(B(R) \cdot \log_M B(R) + B(S) \cdot \log_M B(S)\right)$