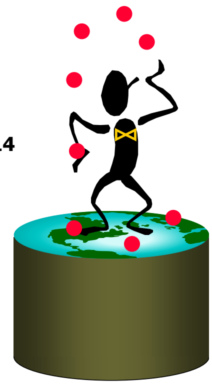
Implementation of Relational Operations (Part 2)

R&G - Chapters 12 and 14



An Alternative to Sorting: Hashing!

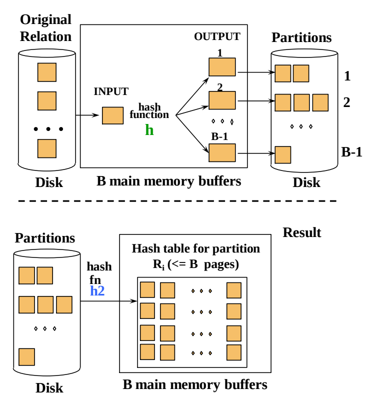
- **Idea:**
  - Many of the things we use sort for don't exploit the *order* of the sorted data
  - e.g.: removing duplicates in DISTINCT
  - e.g.: finding matches in JOIN
- **Often good enough to match all tuples with equal values**
- **Hashing does this!**
  - And may be cheaper than sorting! (Hmmm…!)
  - But how to do it for data sets bigger than memory??

General Idea

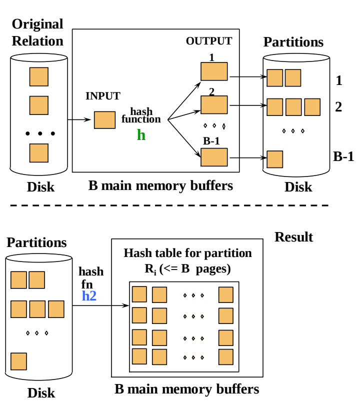
- **Two phases:**
  - Partition: use a hash function *h* to split tuples into partitions on disk.
    - Key property: all matches live in the same partition.
  - ReHash: for each partition on disk, build a main-memory hash table using a hash function *h2*

Two Phases

- **Partition:**
- **Rehash:**

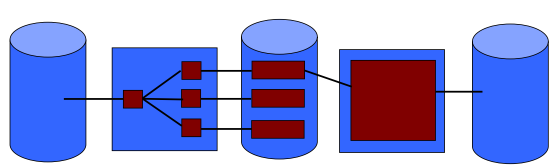


Duplicate Elimination using Hashing



- **read one bucket at a time**
- **for each group of identical tuples, output one**

Cost of External Hashing



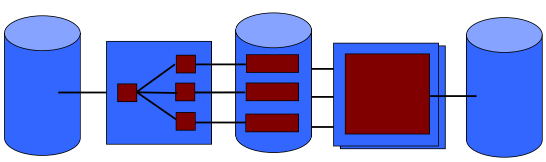
cost = 4*[R] IO's

Memory Requirement

- **How big of a table can we hash in two passes?**
  - B-1 “partitions” result from Phase 0
  - Each should be no more than B pages in size
  - Answer: B(B-1).
    Said differently:
    We can hash a table of size N pages in about $\sqrt{N}$ space
  - *Note: assumes hash function distributes records evenly!*
- **Have a bigger table? Recursive partitioning!**

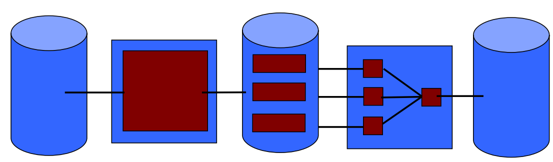
How does this compare with external sorting?

Cost of External Hashing Sorting



cost = 4*[R] IO’s

Cost of External Sorting



cost = 4*[R] IO’s

Memory Requirement for External Sorting

- **How big of a table can we <u>sort</u> in two passes?**
  - Each “sorted run” after Phase 0 is of size B
  - Can merge up to B-1 sorted runs in Phase 1
  - Answer: B(B-1).
    Said differently:
    We can sort a table of size N pages in about $\sqrt{N}$ space
- **Have a bigger table? Additional merge passes!**

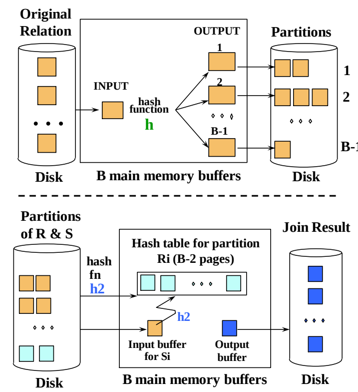
So which is better ??

- **Based on our simple analysis:**
  - Same memory requirement for 2 passes
  - Same IO cost
- **Digging deeper …**
- **Sorting pros:**
  - Great if input already sorted (or *almost* sorted)
  - Great if need output to be sorted anyway
  - Not sensitive to “data skew” or “bad” hash functions
- **Hashing pros:**
  - Highly <u>parallelizable</u> *(will discuss later in semester)*
    - So is sorting, with some work
  - Can exploit extra memory to reduce # IOs *(stay tuned…)*

before we optimize hashing further …

Q: Can we use hashing for JOIN ?

Hash Join



Cost of Hash Join

- **Partitioning phase: read+write both relations**
  ⇒ 2([R]+[S]) I/Os
- **Matching phase: read both relations, write output**
  ⇒ [R]+[S] + [output] I/Os

- **Total cost of 2-pass hash join = 3([R]+[S])+[output]**

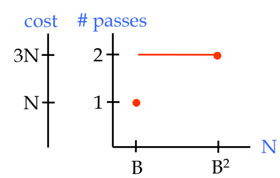
Q: what is cost of 2-pass *sort join*?

Q: how much memory needed for 2-pass *sort join*?

Q: how much memory needed for 2-pass *hash join*?

An important optimization to hashing

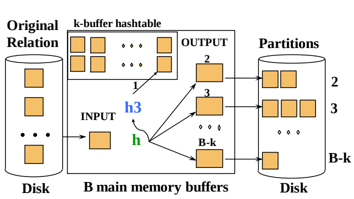
- **Have B memory buffers**
- **Want to hash relation of size N**



If B < N < B2, will have unused memory …

Hybrid Hashing

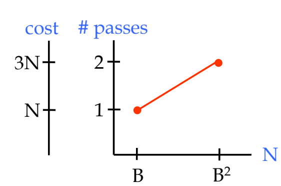
- **Idea: keep one of the hash buckets in memory!**



Q: how do we choose the value of *k*?

Cost reduction due to hybrid hashing

- **Now:**



Summary: Hashing vs. Sorting

- **Sorting pros:**
  - Good if input already sorted, or need output sorted
  - Not sensitive to data skew or bad hash functions

- **Hashing pros:**
  - Often cheaper due to hybrid hashing
  - For join: # passes depends on size of *smaller* relation
  - Highly parallelizable