CS 443
External Sorting
Chapters 13

Slides adapted from
Ramakrishnan & Gerhke
pages.cs.wisc.edu/~dbbook/

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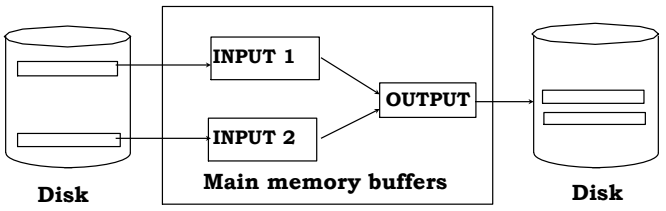
Why Sort?

- A classic problem in computer science!
- Data requested in sorted order
  - e.g., find students in increasing *gpa* order
- Sorting is first step in *bulk loading* B+ tree index.
- Sorting useful for eliminating *duplicate copies* in a collection of records (Why?)
- *Sort-merge* join algorithm involves sorting.
- Problem: sort 1Gb of data with 1Mb of RAM.
  - Why not virtual memory?

2-Way Sort: Requires 3 Buffers

- Pass 1: Read a page, sort it, write it.
  - only one buffer page is used
- Pass 2, 3, …, etc.:
  - three buffer pages used.



Two-Way External Merge Sort

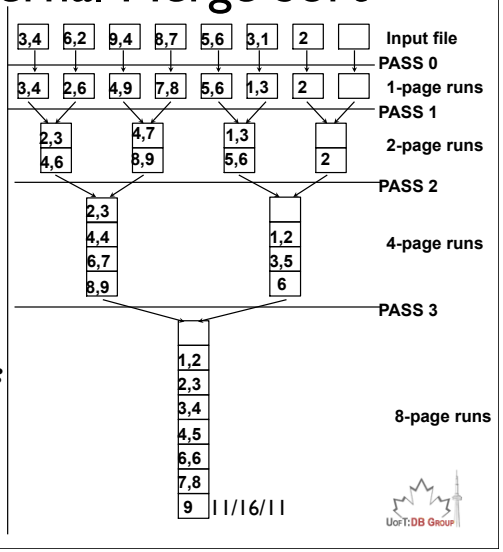
- Each pass we read + write each page in file.
- N pages in the file => the number of passes

$$= \lceil \log_2 N \rceil + 1$$

- So toal cost is:

$$2N\left(\lceil \log_2 N \rceil + 1\right)$$

- *Idea:* ***Divide and conquer:*** sort subfiles and merge



General External Merge Sort

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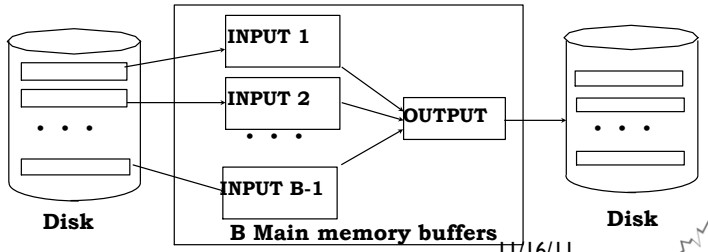
☛ *More than 3 buffer pages. How can we utilize them?*

- To sort a file with *N* pages using *B* buffer pages:
  - Pass 0: use *B* buffer pages. Produce $\lceil N / B \rceil$ sorted runs of *B* pages each.
  - Pass 2, …, etc.: merge *B-1* runs.



Cost of External Merge Sort

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- Number of passes: $1 + \lceil \log_{B-1} \lceil N / B \rceil \rceil$
- Cost = 2N * (# of passes)
- E.g., with 5 buffer pages, to sort 108 page file:
  - Pass 0: $\lceil 108 / 5 \rceil$ = 22 sorted runs of 5 pages each (last run is only 3 pages)
  - Pass 1: $\lceil 22 / 4 \rceil$ = 6 sorted runs of 20 pages each (last run is only 8 pages)
  - Pass 2: 2 sorted runs, 80 pages and 28 pages
  - Pass 3: Sorted file of 108 pages

Number of Passes of External Sort

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N	B=3	B=5	B=9	B=17	B=129	B=257
100	7	4	3	2	1	1
1,000	10	5	4	3	2	2
10,000	13	7	5	4	2	2
100,000	17	9	6	5	3	3
1,000,000	20	10	7	5	3	3
10,000,000	23	12	8	6	4	3
100,000,000	26	14	9	7	4	4
1,000,000,000	30	15	10	8	5	4

Using B+ Trees for Sorting

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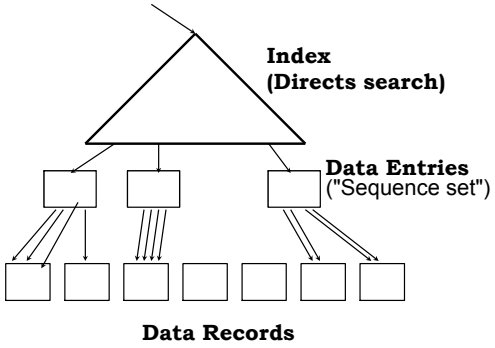
- Scenario: Table to be sorted has B+ tree index on sorting column(s).
- Idea: Can retrieve records in order by traversing leaf pages.
- ***Is this a good idea?***
- Cases to consider:
  - B+ tree is clustered — ***Good idea!***
  - B+ tree is not clustered — ***Could be a very bad idea!***

Clustered B+ Tree Used for

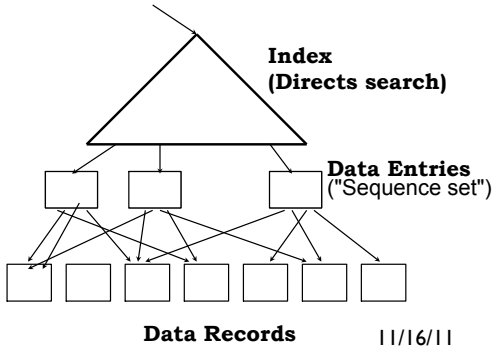
- Cost: root to the left-most leaf, then retrieve all leaf pages



☛ *Always better than external sorting!*

Unclustered B+ Tree Used for Sorting

- For data entries; each data entry contains *rid* of a data record. In general, one I/O per data record!



External Sorting vs. Unclustered

N	Sorting	p=1	p=10	p=100
100	200	100	1,000	10,000
1,000	2,000	1,000	10,000	100,000
10,000	40,000	10,000	100,000	1,000,000
100,000	600,000	100,000	1,000,000	10,000,000
1,000,000	8,000,000	1,000,000	10,000,000	100,000,000
10,000,000	80,000,000	10,000,000	100,000,000	1,000,000,000

☛ *p*: # of records per page
☛ *B=1,000 and block size=32 for sorting*
☛ *p=100 is the more realistic value.*

Summary

- External sorting is important; DBMS may dedicate part of buffer pool for sorting!
- External merge sort minimizes disk I/O cost:
  - Pass 0: Produces sorted ***runs*** of size ***B*** (# buffer pages). Later passes: ***merge*** runs.
  - # of runs merged at a time depends on ***B***, and ***block size***.
  - Larger block size means less I/O cost per page.
  - Larger block size means smaller # runs merged.
  - In practice, # of runs rarely more than 2 or 3.

Summary, cont.

- Choice of internal sort algorithm may matter:
  - Quicksort: Quick!
  - Heap/tournament sort: slower (2x), longer runs
- The best sorts are wildly fast:
  - Despite 40+ years of research, we're still improving!
- Clustered B+ tree is good for sorting; unclustered tree is usually very bad.