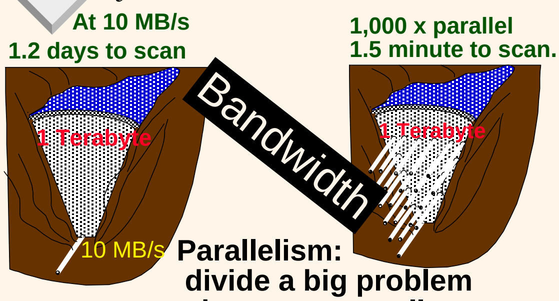
Parallel DBMS

Chapter 22, Part A

Slides by Joe Hellerstein, UCB, with some material from Jim Gray, Microsoft Research. See also:
http://www.research.microsoft.com/research/BARC/Gray/PDB95.ppt

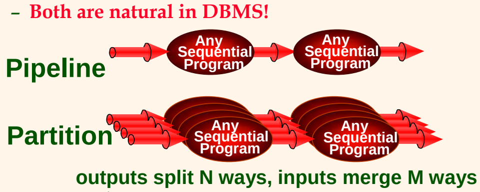
Why Parallel Access To Data?



Parallelism:
divide a big problem
into many smaller ones
to be solved in parallel.

Parallel DBMS: Intro

- Parallelism is natural to DBMS processing
  - *Pipeline parallelism:* many machines each doing one step in a multi-step process.
  - *Partition parallelism:* many machines doing the same thing to different pieces of data.
  - **Both are natural in DBMS!**

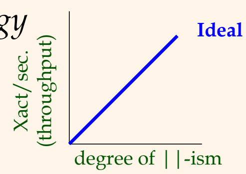


DBMS: ***The*** || *Success Story*

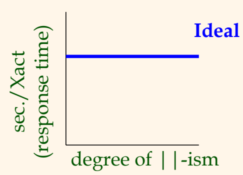
- DBMSs are the most (only?) successful application of parallelism.
  - Teradata, Tandem vs. Thinking Machines, KSR..
  - Every major DBMS vendor has some || server
  - Workstation manufacturers now depend on || DB server sales.
- Reasons for success:
  - Bulk-processing (= partition ||-ism).
  - Natural pipelining.
  - Inexpensive hardware can do the trick!
  - Users/app-programmers don't need to think in ||

Some || Terminology

- Speed-Up
  - More resources means proportionally less time for given amount of data.

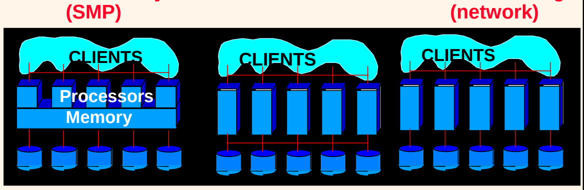


- Scale-Up
  - If resources increased in proportion to increase in data size, time is constant.



Architecture Issue: Shared What?

Shared Memory (SMP) | **Shared Disk** | **Shared Nothing (network)**



Easy to program
Expensive to build
Difficult to scaleup

Hard to program
Cheap to build
Easy to scaleup

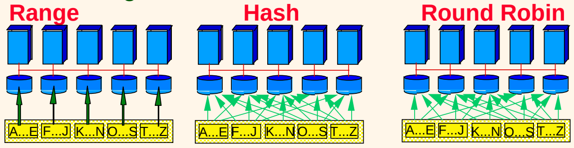
Different Types of DBMS ||-ism

- Intra-operator parallelism
  - get all machines working to compute a given operation (scan, sort, join)
- Inter-operator parallelism
  - each operator may run concurrently on a different site (exploits pipelining)
- Inter-query parallelism
  - different queries run on different sites
- We'll focus on intra-operator ||-ism

Automatic Data Partitioning

Partitioning a table:

Range **Hash** **Round Robin**



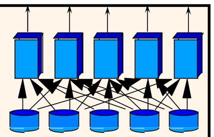
Good for equijoins, range queries group-by **Good for equijoins** **Good to spread load**

Shared disk and memory less sensitive to partitioning, Shared nothing benefits from "good" partitioning

Parallel Scans

- Scan in parallel, and merge.
- Selection may not require all sites for range or hash partitioning.
- Indexes can be built at each partition.
- Question: How do indexes differ in the different schemes?
  - Think about both lookups and inserts!
  - What about unique indexes?

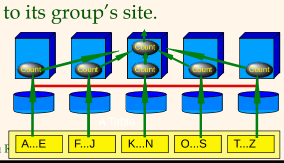
Parallel Sorting



- Current records:
  - 8.5 Gb/minute, shared-nothing; Datamation benchmark in 2.41 secs (UCB students! http://now.cs.berkeley.edu/NowSort/)
- Idea:
  - Scan in parallel, and range-partition as you go.
  - As tuples come in, begin "local" sorting on each
  - Resulting data is sorted, and range-partitioned.
  - Problem: ***skew!***
  - Solution: "sample" the data at start to determine partition points.

Parallel Aggregates

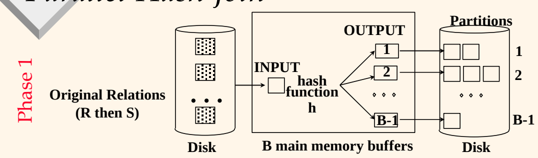
- For each aggregate function, need a decomposition:
  - **count**(S) = Σ **count**(s(i)), ditto for **sum**()
  - **avg**(S) = (Σ **sum**(s(i))) / Σ **count**(s(i))
  - and so on...
- For groups:
  - Sub-aggregate groups close to the source.
  - Pass each sub-aggregate to its group's site.
    - Chosen via a hash fn.



Parallel Joins

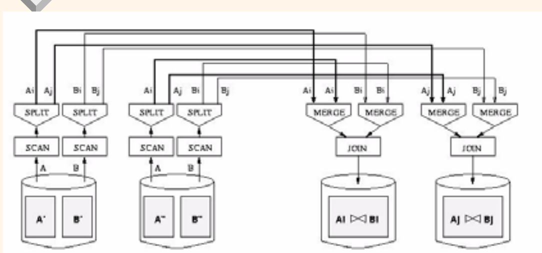
- Nested loop:
  - Each outer tuple must be compared with each inner tuple that might join.
  - Easy for range partitioning on join cols, hard otherwise!
- Sort-Merge (or plain Merge-Join):
  - Sorting gives range-partitioning.
    - But what about handling 2 skews?
  - Merging partitioned tables is local.

Parallel Hash Join



- In first phase, partitions get distributed to different sites:
  - A good hash function *automatically* distributes work evenly!
- Do second phase at each site.
- Almost always the winner for equi-join.

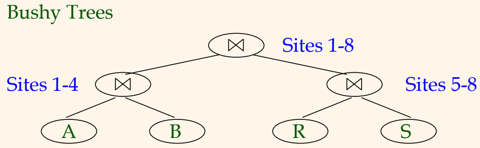
Dataflow Network for || Join



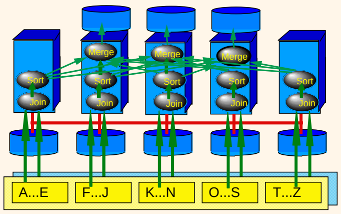
- Good use of split/merge makes it easier to build parallel versions of sequential join code.

Complex Parallel Query Plans

- Complex Queries: Inter-Operator parallelism
  - Pipelining between operators:
    - note that sort and phase 1 of hash-join block the pipeline!!
  - Bushy Trees



N×M-way Parallelism



N inputs, M outputs, no bottlenecks.

Partitioned Data
Partitioned and Pipelined Data Flows

Observations

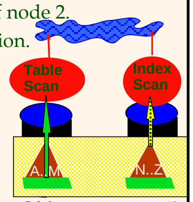
- It is relatively easy to build a fast parallel query executor
- It is hard to write a robust and world-class parallel query optimizer.
  - There are many tricks.
  - One quickly hits the complexity barrier.
  - Still open research!

Parallel Query Optimization

- Common approach: 2 phases
  - Pick best sequential plan (System R algorithm)
  - Pick degree of parallelism based on current system parameters.
- "Bind" operators to processors
  - Take query tree, "decorate" as in previous picture.

What's Wrong With That?

- Best serial plan != Best | | plan! Why?
- Trivial counter-example:
  - Table partitioned with local secondary index at two nodes
  - Range query: all of node 1 and 1% of node 2.
  - Node 1 should do a scan of its partition.
  - Node 2 should use secondary index.
- SELECT *
  FROM telephone_book
  WHERE name < "NoGood";



Parallel DBMS Summary

- | |-ism natural to query processing:
  - Both pipeline and partition | |-ism!
- Shared-Nothing vs. Shared-Mem
  - Shared-disk too, but less standard
  - Shared-mem easy, costly. Doesn't scaleup.
  - Shared-nothing cheap, scales well, harder to implement.
- Intra-op, Inter-op, & Inter-query | |-ism all possible.

| | DBMS Summary, cont.

- Data layout choices important!
- Most DB operations can be done partition-| |
  - Sort.
  - Sort-merge join, hash-join.
- Complex plans.
  - Allow for pipeline-| |ism, but sorts, hashes block the pipeline.
  - Partition | |-ism acheived via bushy trees.

|| DBMS Summary, cont.

- Hardest part of the equation: optimization.
  - 2-phase optimization simplest, but can be ineffective.
  - More complex schemes still at the research stage.
- We haven't said anything about Xacts, logging.
  - Easy in shared-memory architecture.
  - Takes some care in shared-nothing.