15-721 Database Management Systems

Future of Parallel DBMS

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Citation

Parallel Database systems: The future of high performance database systems David DeWitt and Jim Gray, CACM 35(6): 85-98 (1992)

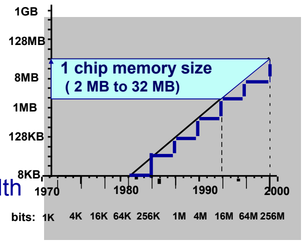
Main Message

- Technology trends give
  - Many processors and storage units
  - Inexpensively
- Parallelism in DBs came from a failed idea
  - (namely, use special purpose hardware)
- To analyze large quantities of data
  - Parallel is faster (trades time for money)
  - Relational algorithms exploit parallelism

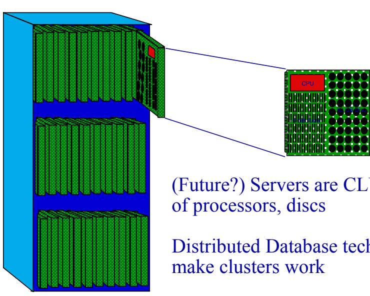
Moore's Law

XXX doubles every 18 months
60% increase per year

- Microprocessor speeds
- Chip density
- Magnetic disk density
- Communication bandwidth
  - WAN approaches LAN



Implication of Hardware Trends: Clusters



(Future?) Servers are CLUSTERS of processors, discs

Distributed Database techniques make clusters work

Implications

- **Tech trends => pipeline & partition parallelism**
  - Lots of bytes & bandwidth per dollar
  - Lots of latency
  - Lots of MIPS per dollar
  - Lots of processors

Implications cont'd

- **Scaleable Networks and Platforms**
  - Build clusters of commodity processors & storage
  - Commodity Cluster Operating System is key
  - Fault isolation and tolerance is key
  - Automatic Parallel Programming is key (hard!)

Outline

- Introduction
- **Requirements / performance metrics**
- Parallelism in database systems
  - Partitioning: data, index
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  - Optimization
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The Software Challenge

- Automatic data placement
  - How to partition: randomly or organized
- Automatic parallel programming
  - Essentially: process placement
- Parallel concepts, algorithms & tools
- Parallel Query Optimization
- Execution Techniques
  - load balancing
  - checkpoint/restart
  - multi-programming

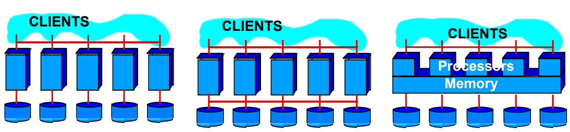
Parallelism: Goal=Performance

Law 1: parallel system should be
faster than serial system

Law 2: parallel system should give
near-linear scaleup
or near-linear speedup or
both.

Architecture: Shared What?

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



Program?
Build?
Scaleup?

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Build?
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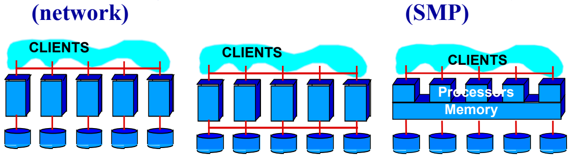


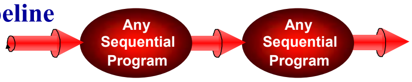
Program: Hard
Build: Cheap
Scaleup: Easy
Tandem, Teradata, SP2

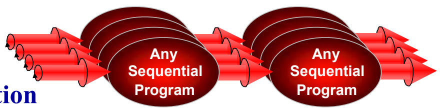
VMScluster, Sysplex

Program: Easy
Build: Expensive
Scaleup: Hard
Sequent, SGI, Sun

Kinds of Parallel Execution

Pipeline





Partition

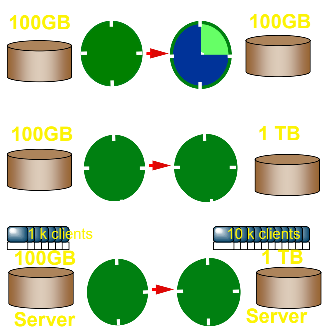
outputs split N ways
inputs merge M ways

Parallelism: Speedup & Scaleup

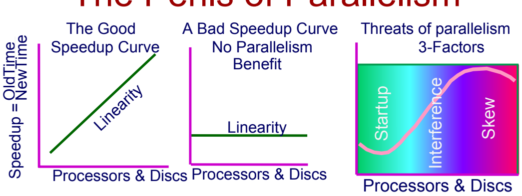
Speedup:
Same Job,
More Hardware
Less time

Scaleup:
Bigger Job,
More Hardware
Same time

Transaction Scaleup:
more clients/servers
Same response time



The Perils of Parallelism



Startup: Creating processes
Opening files
Optimization

Interference: Device (cpu, disc, bus)
logical (lock, hotspot, server, log,...)

Skew: If tasks get very small, variance > service time

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Why are Relational Operators So Successful for Parallelism?

Why are Relational Operators So Successful for Parallelism?

Relational data model uniform operators
on uniform data stream
closed under composition

Each operator consumes 1 or 2 input streams
Each stream is a uniform collection of data
Sequential data in and out: Pure dataflow

partitioning some operators (e.g. aggregates, non-equi-join, sort,..)
requires innovation

Types of DB parallelism

- What kind of parallelism can we do wrt
- OPERATORS?
- QUERIES?

Types of DB parallelism

- Intra-operator
  - All machines work to execute one operator
- Inter-operator
  - Each operator may run concurrently on different sites
  - (exploits pipelining)
- Inter-query
  - Different queries run on different sites

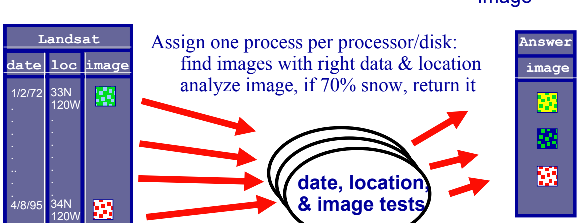
Example: Automatic Parallel OR DB

```
Select image
from landsat
where date between 1970 and 1990
and overlaps(location, :Rockies)
and snow_cover(image) >.7;
```

Temporal

Spatial

Image



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Automatic Data Partitioning

Split a SQL table to subset of nodes & disks

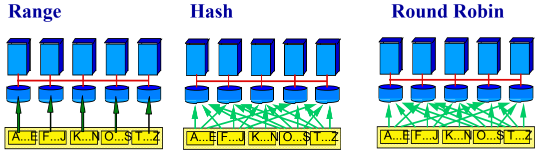
How??

Automatic Data Partitioning

Split a SQL table to subset of nodes & disks

Partition within set:

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



Queries?

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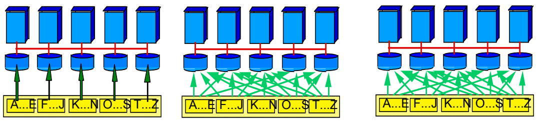

Good for equi-joins,
range queries
group-by

Queries?

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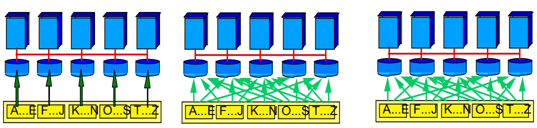

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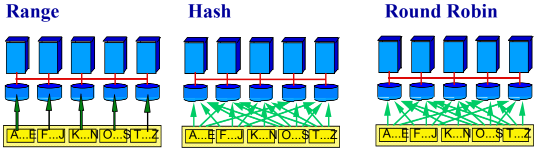

Good for equi-joins,
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group-by

Good for equi-joins

Good to spread load

Sensitivity to partitioning:
Shared disk / memory ?
Shared nothing ?

Automatic Data Partitioning

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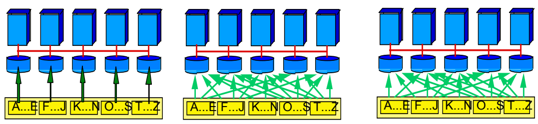

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Shared disk and memory less sensitive to partitioning,
Shared nothing benefits from "good" partitioning

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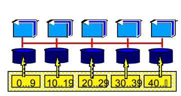
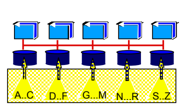
Index Partitioning

Hash indices partition by hash



B-tree indices partition as a forest of trees.
One tree per range



Primary index clusters data

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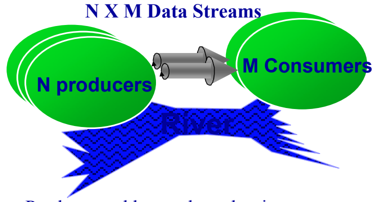
Data Rivers: Split + Merge Streams

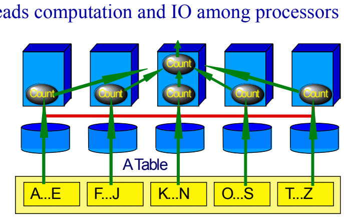
N X M Data Streams



Producers add records to the river,
Consumers consume records from the river
Purely sequential programming.
River does flow control and buffering
does partition and merge of data records
River = Split/Merge in Gamma =
Exchange operator in Volcano.

Partitioned Execution

Spreads computation and IO among processors

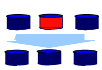


Partitioned data gives NATURAL parallelism

'Split' operator

- E.g., for hashing

Picking Data Ranges



Disk Partitioning
For range partitioning, sample load on disks.
Cool hot disks by making range smaller
For hash partitioning,
Cool hot disks
by mapping some buckets to others

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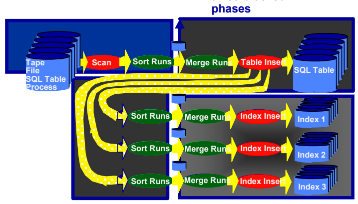
Blocking Operators=Short Pipelines

An operator is blocking,
  if it does not produce any output,
  until it has consumed all its input

Database Load
Template has
three blocked
phases



Examples?

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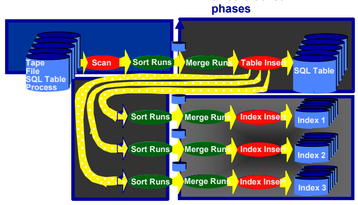

Examples:
  Sort,
  Aggregates,
  Hash-Join (reads all of one operand)
Blocking operators kill pipeline parallelism
Bushy trees?

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Simple Aggregates (sort or hash?)

Simple aggregates?

GROUP BY aggregates?

Simple Aggregates (sort or hash?)

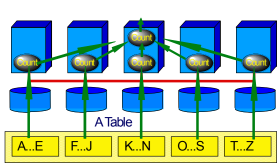
Simple aggregates (count, min, max, ...) can use indices
- More compact
- Sometimes have aggregate info.

GROUP BY aggregates
- scan in category order if possible (use indices)
- Else
  - If categories fit in RAM
    - use RAM category hash table
  - Else
    - make temp of <category, item>
    - sort by category,
    - do math in merge step.

Parallel Aggregates

For aggregate function, need a decomposition strategy:
- $count(S) = \Sigma\ count(s(i))$, ditto for sum()
- $avg(S) = (\Sigma\ sum(s(i))) / \Sigma\ count(s(i))$
- and so on...

For groups,
- sub-aggregate groups close to the source
- drop sub-aggregates into a hash river.



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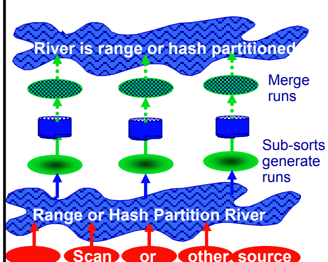
Parallel Sort



M inputs N outputs

Disk and merge not needed if sort fits in memory

Sort is benchmark from hell for shared nothing machines
net traffic = disk bandwidth, no data filtering at the source

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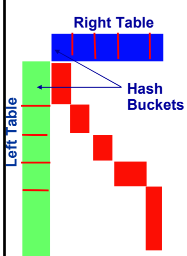
Hash Join: Combining Two Tables

How parallelize hash join?

Hash Join: Combining Two Tables



Hash smaller table into N buckets (hope N=1)
If N=1 read larger table, hash to smaller
Else, hash outer to disk then
bucket-by-bucket hash join.

Purely sequential data behavior

Always beats sort-merge and nested
unless data is clustered.
Good for equi, outer, exclusion join
Lots of papers!

Hash reduces skew

Parallel Hash Join

- ICL implemented hash join with bitmaps in CAFS machine (1976)!
- Kitsuregawa pointed out the parallelism benefits of hash join in early 1980's (it partitions beautifully)
- Hashing minimizes skew, requires little thinking for redistribution
- Hashing uses massive main memory

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Parallel Query Optimization

- Relatively easy to build a parallel executor
- Hard to write a robust optimizer
  - Tricks
  - Complexity barrier
  - Open research!
- Common approach: 2 phases
  - Pick best sequential plan
  - Pick degree of parallelism
  - Bind operators to processors (decorate tree)
- What's wrong with that?

Parallel Query Optimization

- Best parallel plan != best serial plan
- Example?

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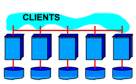
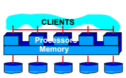
What Systems Work This Way



Shared Nothing

Teradata:	**400 nodes**
	80x12 nodes
Tandem:	**110 nodes**
IBM / SP2 / DB2:	**128 nodes**
Informix/SP2	**100 nodes**
ATT & Sybase	**8x14 nodes**



Shared Memory

Informix	**9 nodes**
RedBrick	**? nodes**

Summary

- **Why Parallelism:**
  - technology push
  - application pull
- **Parallel Database Techniques**
  - partitioned data
  - partitioned and pipelined execution
  - parallel relational operators
- **Optimization still open problem**