PURDUE UNIVERSITY

CS54100: Database Systems

Building a DBMS
10 February 2012
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Slides adapted from those developed by Stanford University Prof. Hector Garcia-Molina

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Isn't Implementing a Database System Simple?

Relations ⇨ Statements ⇨ Results

Introducing the

MEGATRON 3000

Database Management System

- The latest from Megatron Labs
- Incorporates latest relational technology
- UNIX compatible

Megatron 3000 Implementation Details

! First sign non-disclosure agreement !

Megatron 3000 Implementation Details

- Relations stored in files (ASCII)
  e.g., relation R is in /usr/db/R

```
Smith # 123 # CS
Jones # 522 # EE
  ⋮
```


Megatron 3000 Implementation Details

- Directory file (ASCII) in /usr/db/directory

```
R1 # A # INT # B # STR …
R2 # C # STR # A # INT …
  ⋮
```

Megatron 3000 Sample Sessions

```
% MEGATRON3000
   Welcome to MEGATRON 3000!
&
  :
  :
& quit
%
```


Megatron 3000 Sample Sessions

```
& select *
  from R #

    Relation R
   A        B     C
   SMITH   123    CS

&
```

Megatron 3000 Sample Sessions

```
& select A,B
  from R,S
  where R.A = S.A and S.C > 100 #

   A     B
  123   CAR
  522   CAT

&
```


Megatron 3000 Sample Sessions

```
& select *
  from R | LPR #
&
```

Result sent to LPR (printer).

Megatron 3000 Sample Sessions

```
& select *
  from R
  where R.A < 100 | T #
&
```

New relation T created.

Megatron 3000

- To execute "**`select * from R where condition`**":
  - (1) Read dictionary to get R attributes
  - (2) Read R file, for each line:
    - (a) Check condition
    - (b) If OK, display

Megatron 3000

- To execute "**`select * from R where condition | T`**":
  - (1) Process select as before
  - (2) Write results to new file T
  - (3) Append new line to dictionary

Megatron 3000

- To execute "**`select A,B from R,S where condition`**":
  - (1) Read dictionary to get R,S attributes
  - (2) Read R file, for each line:
    - (a) Read S file, for each line:
      - (i) Create join tuple
      - (ii) Check condition
      - (iii) Display if OK

What's wrong with the Megatron 3000 DBMS?

- Tuple layout on disk
  - Change string from 'Cat' to 'Cats' and we have to rewrite file
  - ASCII storage is expensive
  - Deletions are expensive
- Search expensive; no indexes
  - Cannot find tuple with given key quickly
  - Always have to read full relation

What's wrong with the Megatron 3000 DBMS?

- No buffer manager
  - Need caching
- Brute force query processing
  - select *
    from R,S
    where R.A = S.A and S.B > 1000
  - Do select first?
  - More efficient join?

What's wrong with the Megatron 3000 DBMS?

- No concurrency control
- No reliability
  - Can lose data
  - Can leave operations half done
- No security
  - File system insecure
  - File system security is coarse

What's wrong with the Megatron 3000 DBMS?

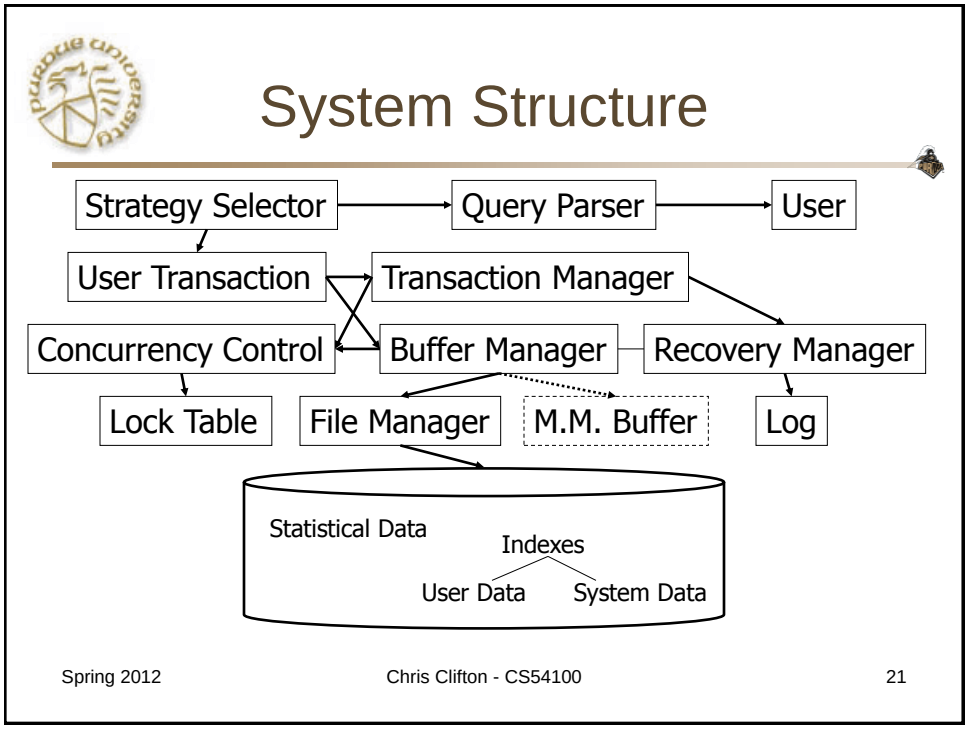
- No application program interface (API)
  - How can a payroll program get at the data?
- No GUI
- Cannot interact with other DBMSs.
- Poor dictionary facilities
  - How do we know what is in the database?
- Lousy salesman!!

What do we need to know?

- File & System Structure
  Records in blocks, dictionary, buffer management,…
- Indexing & Hashing
  B-Trees, hashing,…
- Query Processing
  Query costs, join strategies,…
- Crash Recovery
  Failures, stable storage,…

What do we need to know?

- Concurrency Control
  Correctness, locks,…
- Transaction Processing
  Logs, deadlocks,…
- Security & Integrity
  Authorization, encryption,…
- Distributed Databases
  Interoperation, distributed recovery,…


System Structure
Strategy Selector
Query Parser
User
User Transaction
Transaction Manager
Concurrency Control
Buffer Manager
Recovery Manager
Lock Table
File Manager
M.M. Buffer
Log
Statistical Data
Indexes
User Data
System Data
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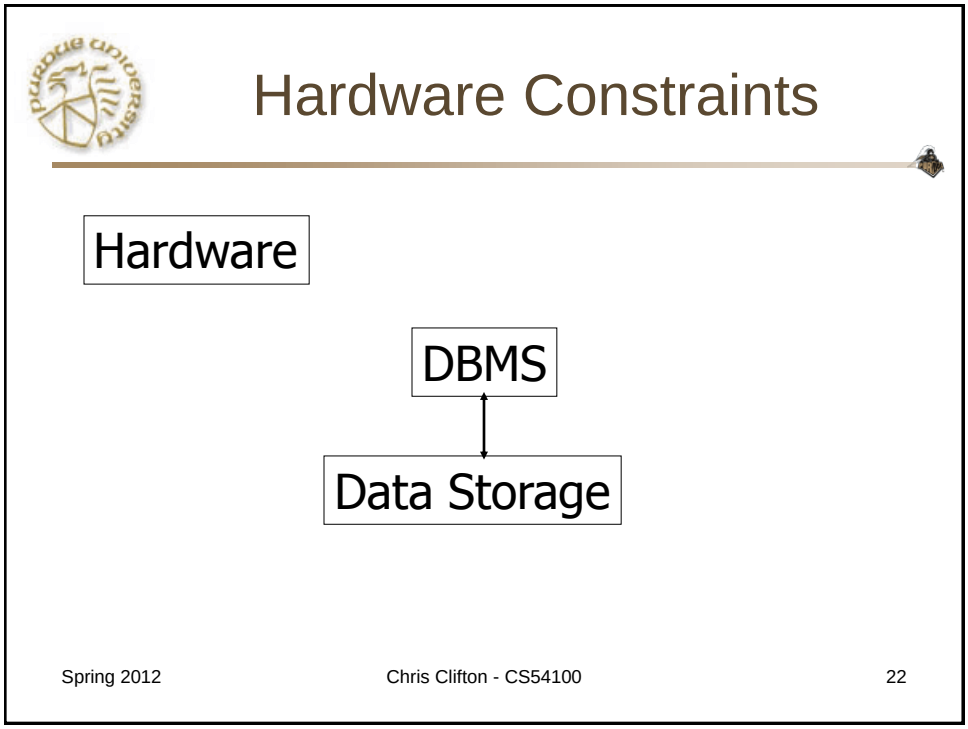
Hardware Constraints
Hardware
DBMS
Data Storage
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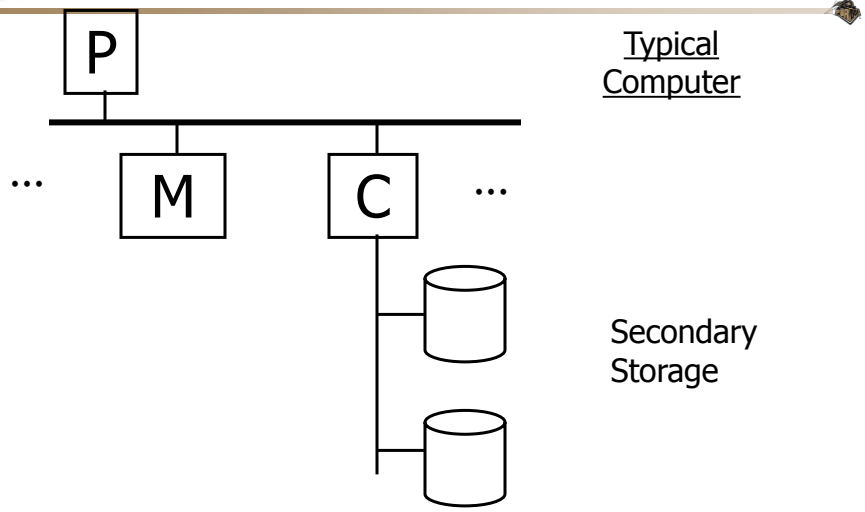


Processor

Fast, slow, reduced instruction set, with cache, pipelined…

Speed: 100 → 500 → 1000 MIPS

Memory

Fast, slow, non-volatile, read-only,…

Access time: 10^{-6} → 10^{-9} sec.

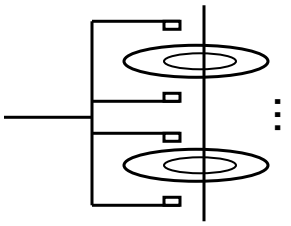
1 μs → 1 ns

Secondary storage

Many flavors:

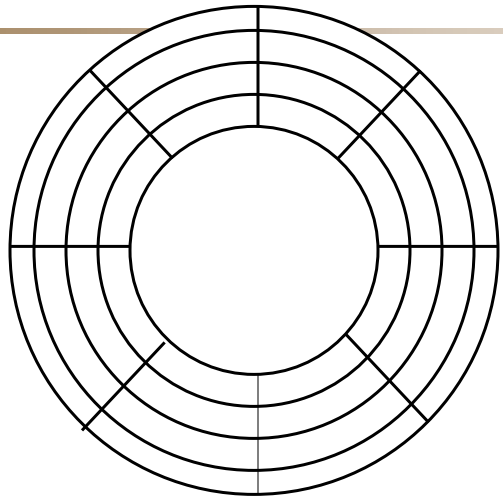
- Disk: Floppy (hard, soft)
  Removable Packs
  Winchester
  Ram disks
  Optical, CD-ROM…
  Arrays
- Tape Reel, cartridge
  Robots

Focus on: "Typical Disk"



Terms: Platter, Head, Actuator
Cylinder, Track
Sector (physical),
Block (logical), Gap

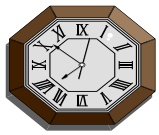
Top View



"Typical" Numbers

Diameter:	1 inch → 15 inches
Cylinders:	100 → 2000
Surfaces:	1 (CDs) →
(Tracks/cyl)	2 (floppies) → 30
Sector Size:	512B → 50K
Capacity:	360 KB (old floppy)
	→ TB

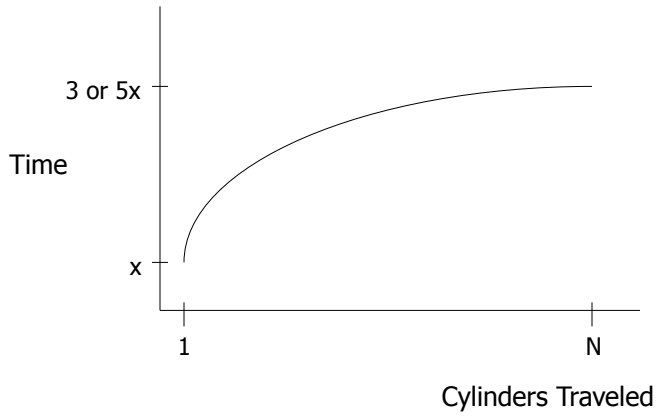
Disk Access Time

I want block X →  → block x in memory

?

Time = Seek Time +
Rotational Delay +
Transfer Time +
Other

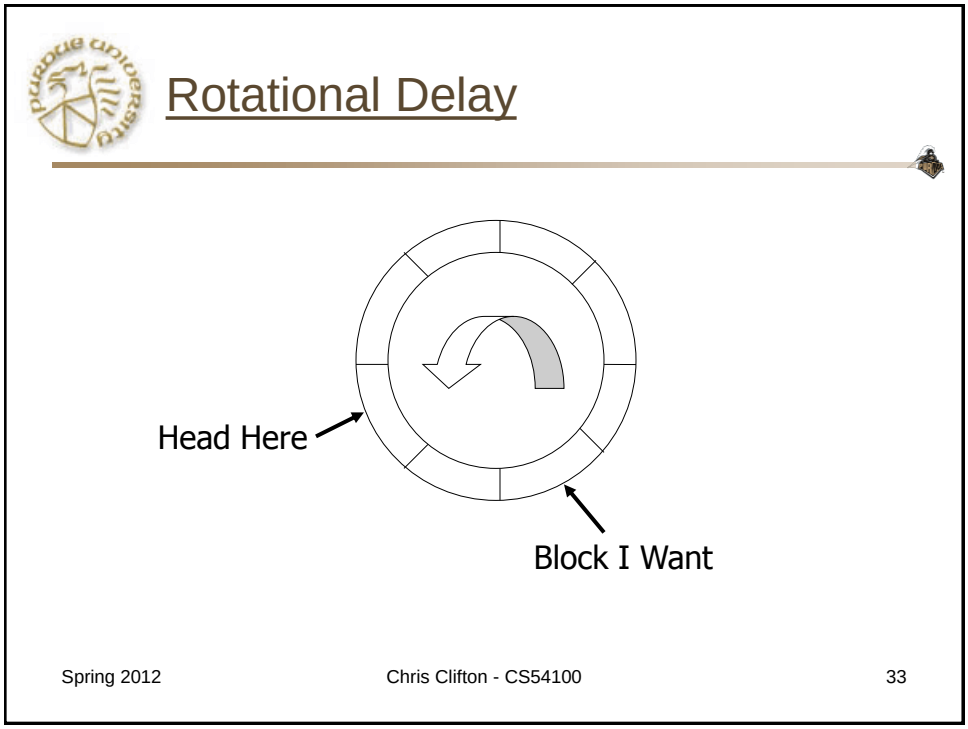
Seek Time

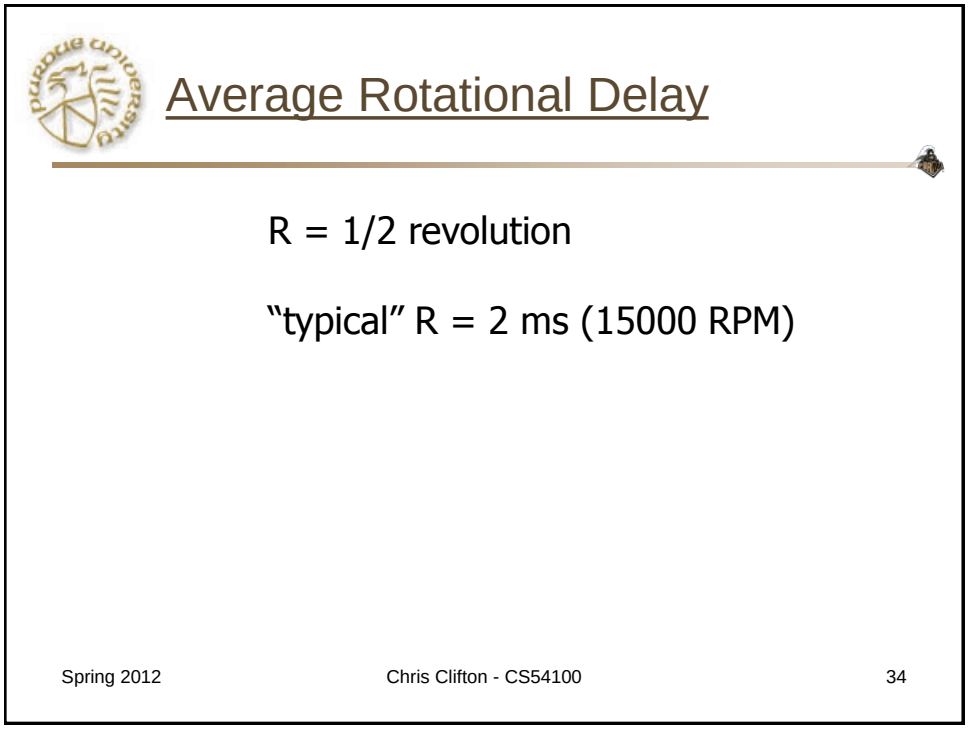


Average Random Seek Time

$$S = \frac{\sum_{i=1}^{N} \sum_{\substack{j=1 \\ j \neq i}}^{N} \text{SEEKTIME}(i \rightarrow j)}{N(N-1)}$$

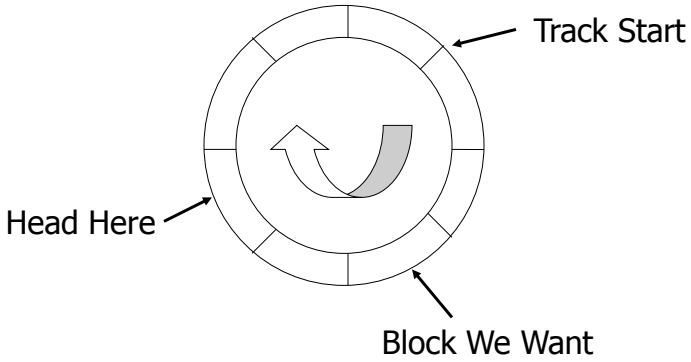
"Typical" S: 5 ms → 10 ms





Complication

- May have to wait for start of track before we an read desired block



Transfer Rate: t

- "typical" t: 1 → 3 MB/second
- transfer time: $\frac{\text{block size}}{t}$

Other Delays

- CPU time to issue I/O
- Contention for controller
- Contention for bus, memory

"Typical" Value: 0

- So far: Random Block Access
- What about: Reading "Next" block?

If we do things right

(e.g., Double Buffer, Stagger Blocks…)

Time to get block = Block Size / t + Negligible

- skip gap
- switch track
- once in a while, next cylinder

Rule of Thumb

Random I/O: Expensive
Sequential I/O: Much less

- Ex: 1 KB Block
  - » Random I/O: ~ 10 ms.
  - » Sequential I/O: ~ 1 ms.

Cost for Writing similar to Reading

…. unless we want to verify!
need to add (full) rotation + Block size
t

To Modify a Block?

To Modify Block:

(a) Read Block
(b) Modify in Memory
(c) Write Block
[(d) Verify?]

Block Address:

- Physical Device
- Cylinder #
- Surface #
- Sector

Complication: Bad Blocks

- Messy to handle
- May map via software to integer sequence