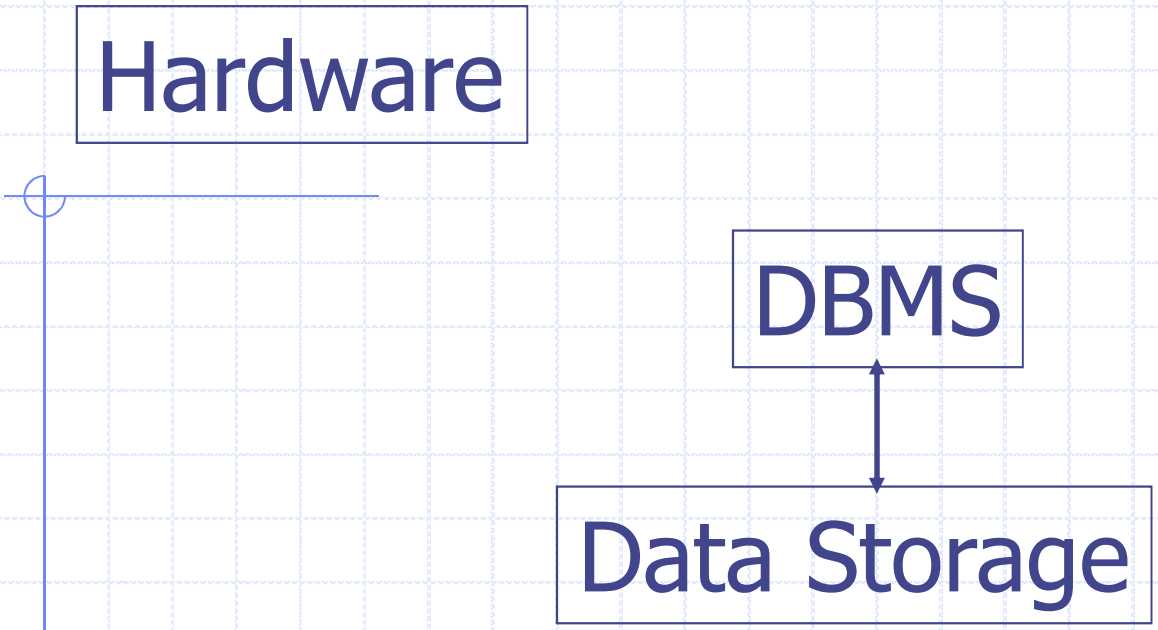
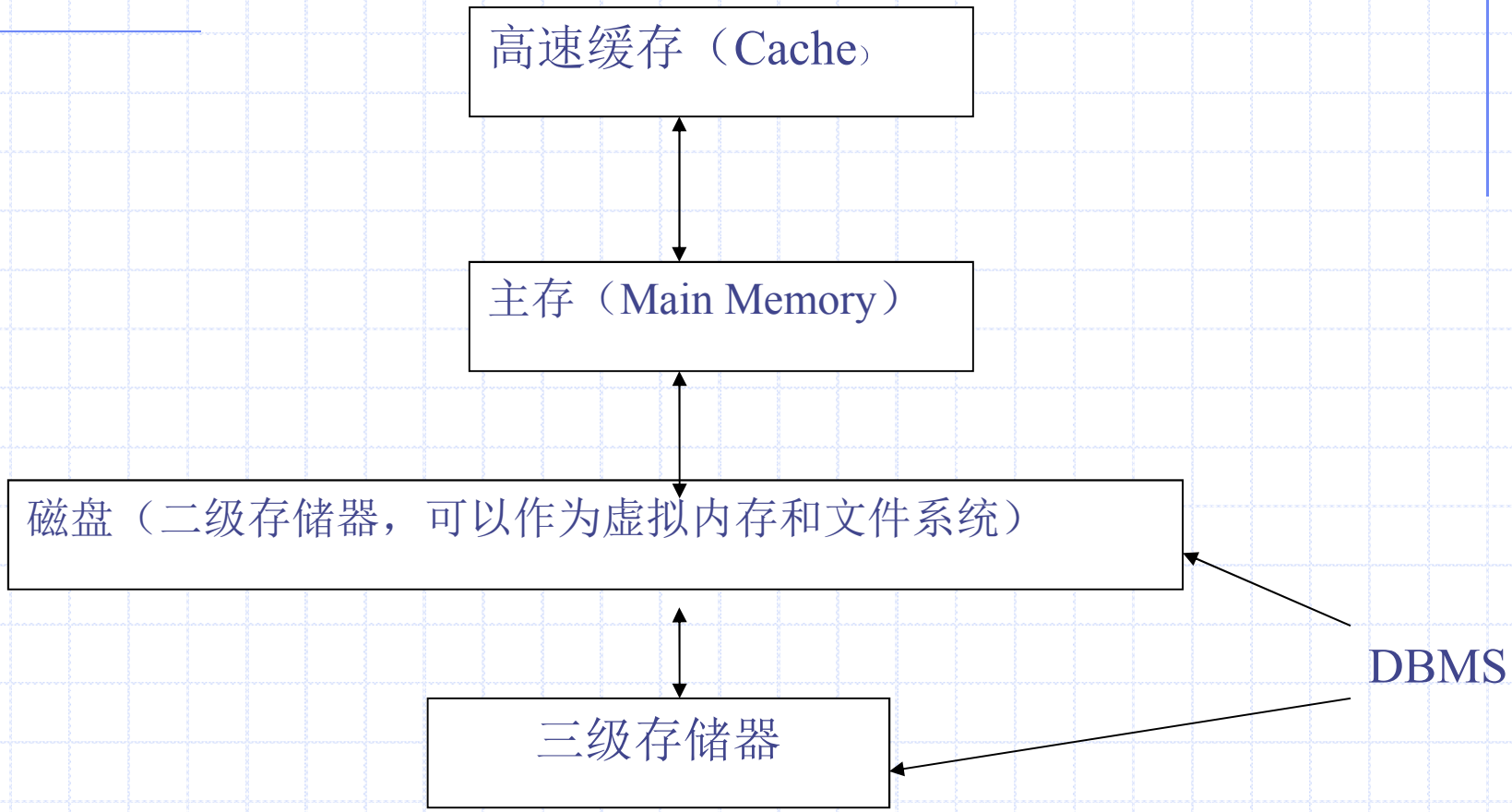
Database System Principles

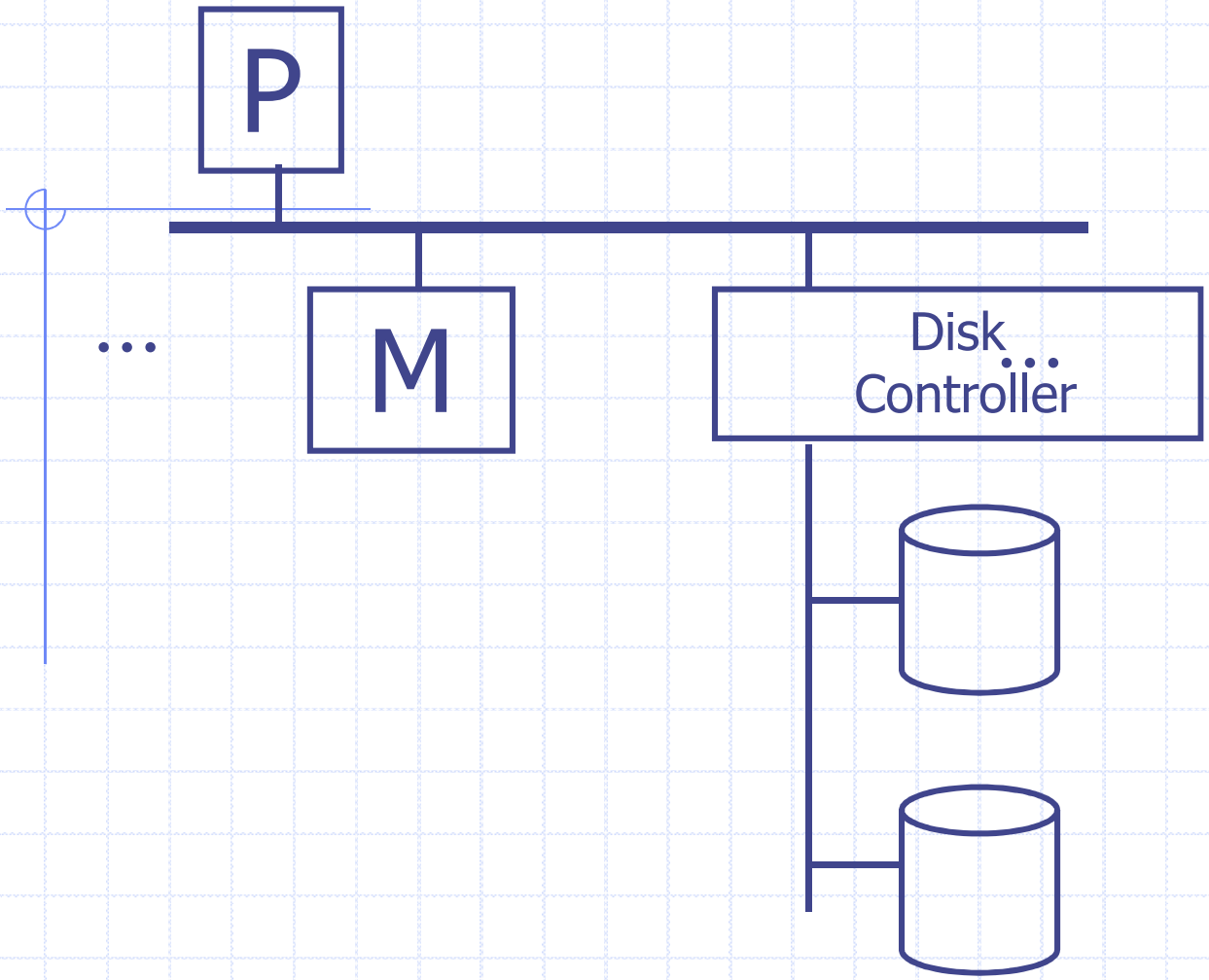
chapter 2: Data storage

Outline

- Hardware: Disks
- Access Times
- Optimizations
- Other Topics:
  - Storage costs
  - Using secondary storage
  - Disk failures


Hardware
DBMS
Data Storage


高速缓存（Cache）
主存（Main Memory）
磁盘（二级存储器，可以作为虚拟内存和文件系统）
三级存储器
DBMS



Typical Computer

Secondary Storage

Processor

Fast, reduced instruction set, with cache

Speed: 100 → 500 → 1000 MIPS

处理器的频率目前在3GHz到4GHz之间，能达到10,000 -100,000MIPS数量级。Intel Core i7 4770k 处理器，3.9GHz频率，127,273 MIPS。

Memory

Fast, slow, non-volatile, read-only,…

Access time: 10^{-6} → 10^{-9} sec.

1 μs → 1 ns

Notes: MIPS (million instructions per second)

Secondary storage

- Disk: Floppy
  Removable Packs
  Optical, CD-ROM...
  Arrays
- Tape

机械硬盘读取速度有150M/s-300M/s，写速度在100M/s以内。

磁盘和文件

- DBMS把数据存放在硬盘上 ("hard") disks.
- DBMS的主要功能
  - 读READ: 把数据从磁盘读到内存 (RAM).
  - 写WRITE: 把数据从内存写到磁盘.
  - 相对于内存中的操作，读些操作都是很耗时的，在设计DBMS时，需要认真计划!

为什么不把所有的内容放在内存?

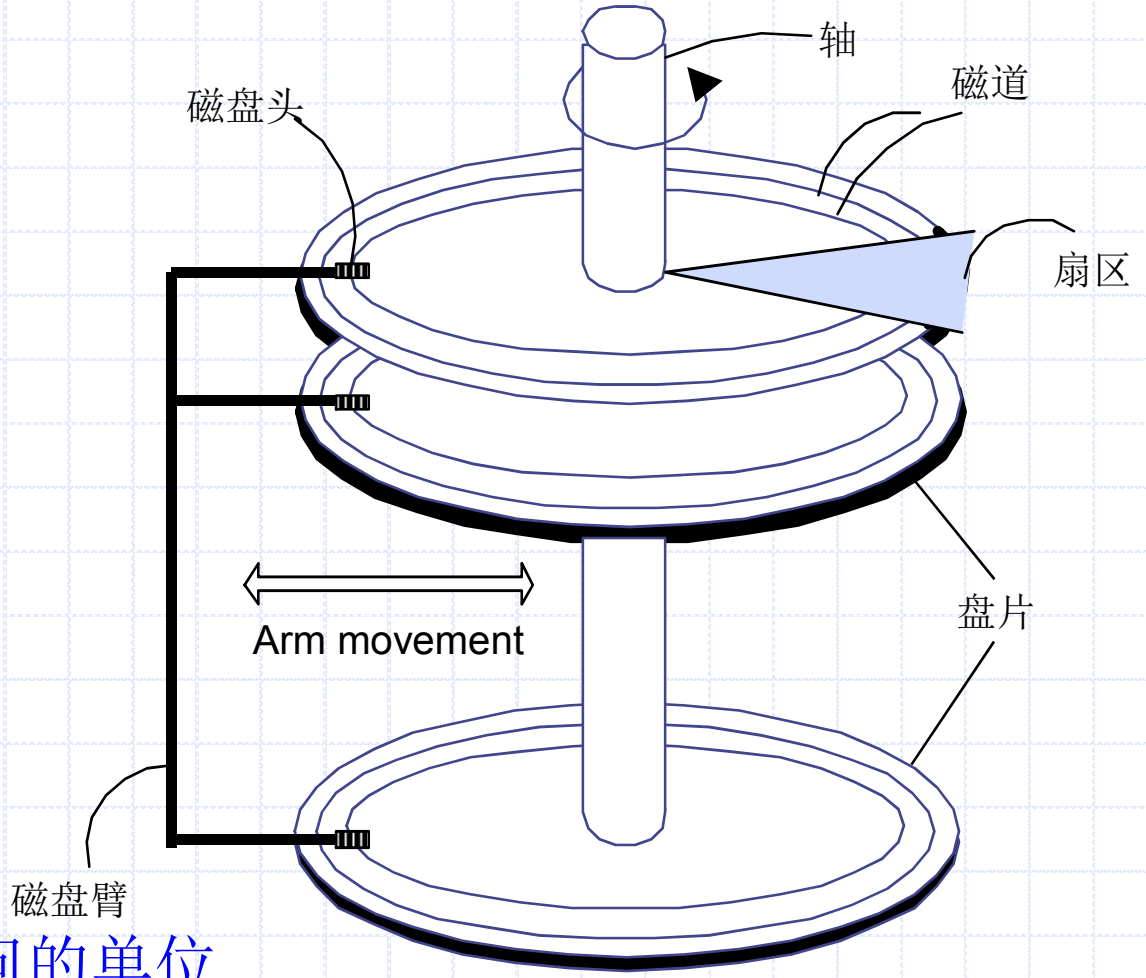
- 花销大.
- 内存是数据是挥发的. 掉电后，数据就丢失了
- 典型的存储结构:
  - 内存 (RAM)：临时使用的数据.
  - 磁盘：二级存储.
  - 磁带：数据库中数据的归档.

磁盘

- 二级存储设备.
- 磁盘vs.磁带：随机存取vs. 顺序读取.
- 存取的数据单元：磁盘块、页面*pages*.

磁盘的组成

- 盘片绕轴旋转.
- 一次只能读或写
- *扇区大小是固定的.*访问的单位为磁盘块，磁盘块可由多个扇区组成

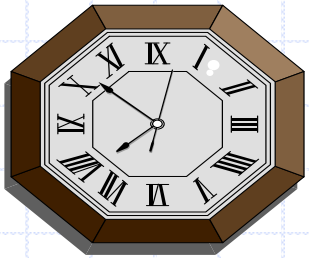


存取一个页面

- 读写时间:
  - *寻道时间seek time*
  - *旋转延迟rotational delay* (waiting for block to rotate under head)
  - *传输时间transfer time*
- 寻道时间和旋转延迟占主要部分.
  - 寻道时间大约 1微秒到 20msec
  - 旋转延迟0微秒到 10msec
  - 传输时间每 4KB大约1msec
- I/O的主要影响因素: 减少寻道和旋转延迟!

Disk Access Time

I want block X

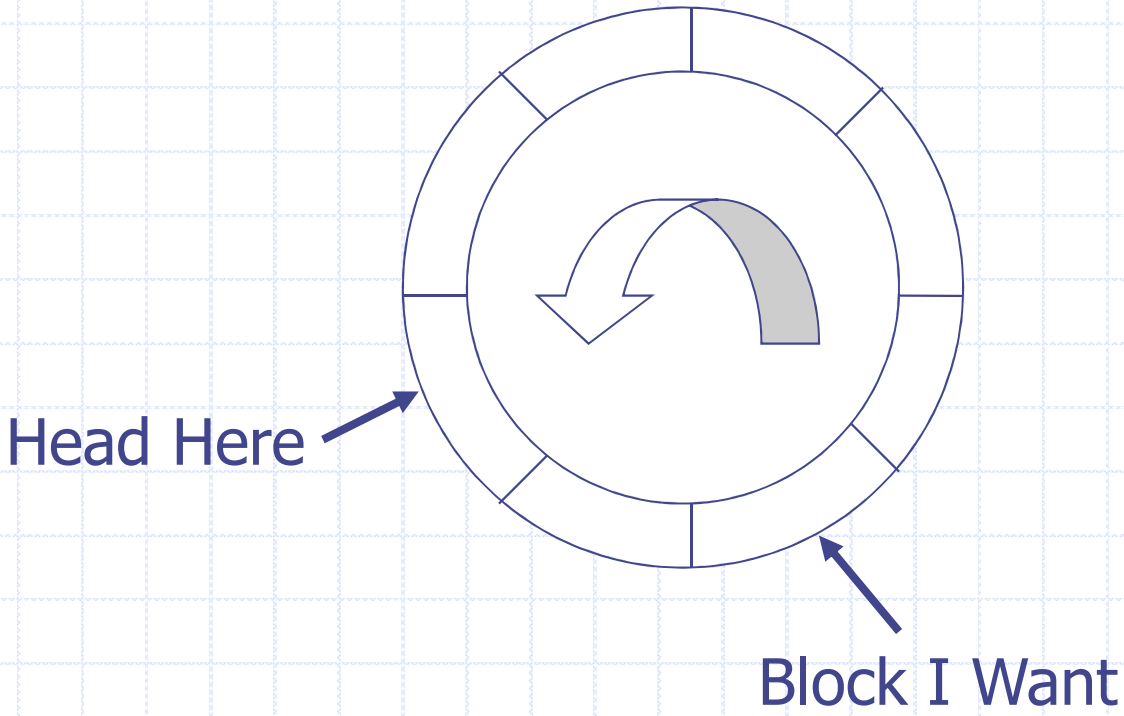


?

block x in memory

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

Rotational Delay



Other Delays

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

"Typical" Value: 0

Block Address:

- Physical Device
- Cylinder #
- Surface #
- Sector

Outline

- Hardware: Disks
- Access Times
- Optimizations
- Other Topics
  - Storage Costs
  - Using Secondary Storage
  - Disk Failures

Optimizations (in controller or O.S.)

- Cylinder-based Organization
- Disk Scheduling Algorithms
  - e.g., elevator algorithm
- Double Buffer
- Pre-fetch
- Mirrored Disks

磁盘数据的组织

- 相邻块:
  - blocks on same cylinder
  - blocks on same track
- 文件尽量在硬盘上为相邻块

Single Buffer Solution

(1) Read B1 → Buffer
(2) Process Data in Buffer
(3) Read B2 → Buffer
(4) Process Data in Buffer ...

Say P = time to process/block

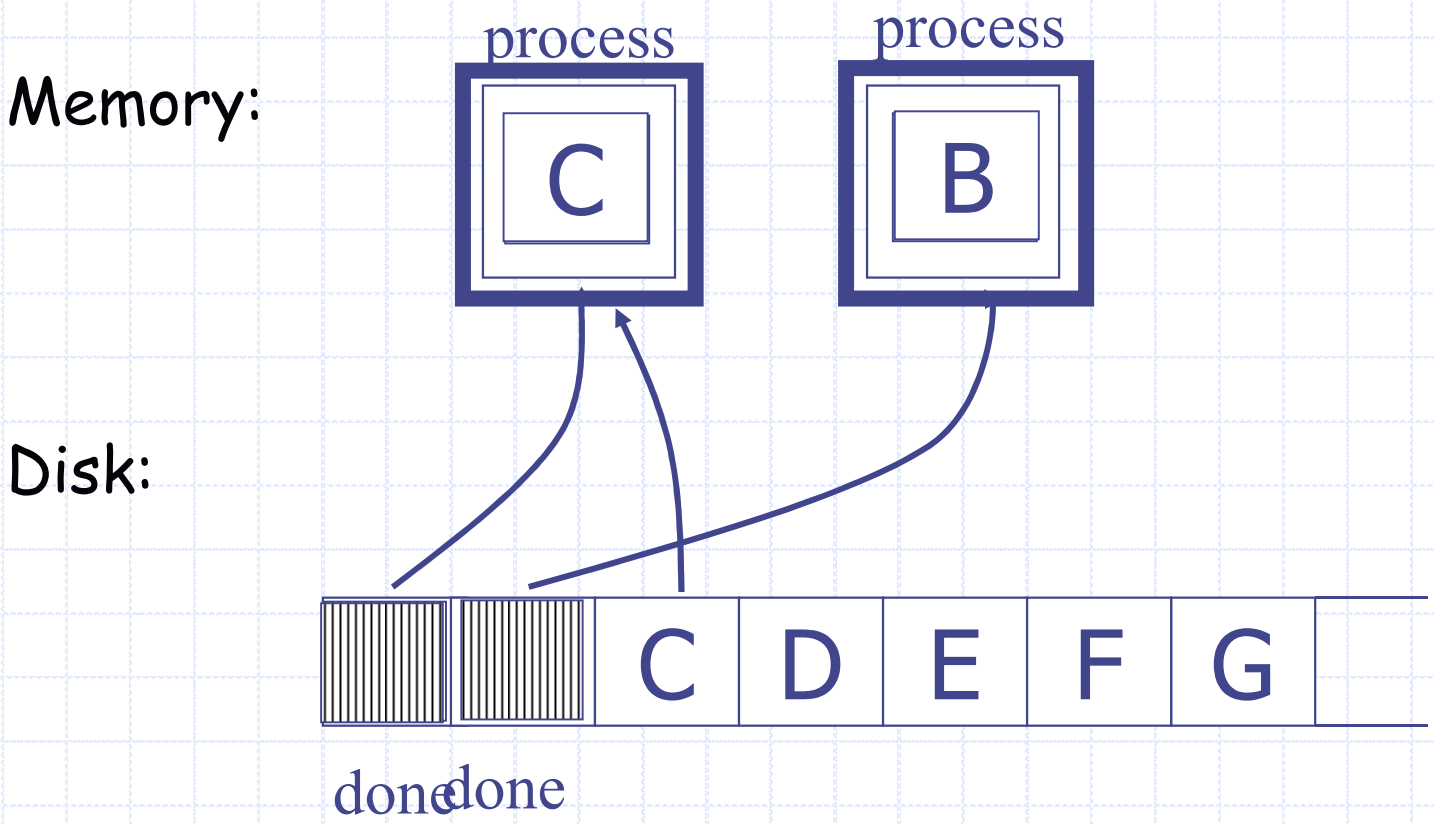
R = time to read in 1 block

n = # blocks

Single buffer time

= n(P+R)

Double Buffering



Say $P \geq R$

P = Processing time/block
R = IO time/block
n = # blocks

What is processing time?

- Double buffering time = R + nP
- Single buffering time = n(R+P)

Block Size Selection?

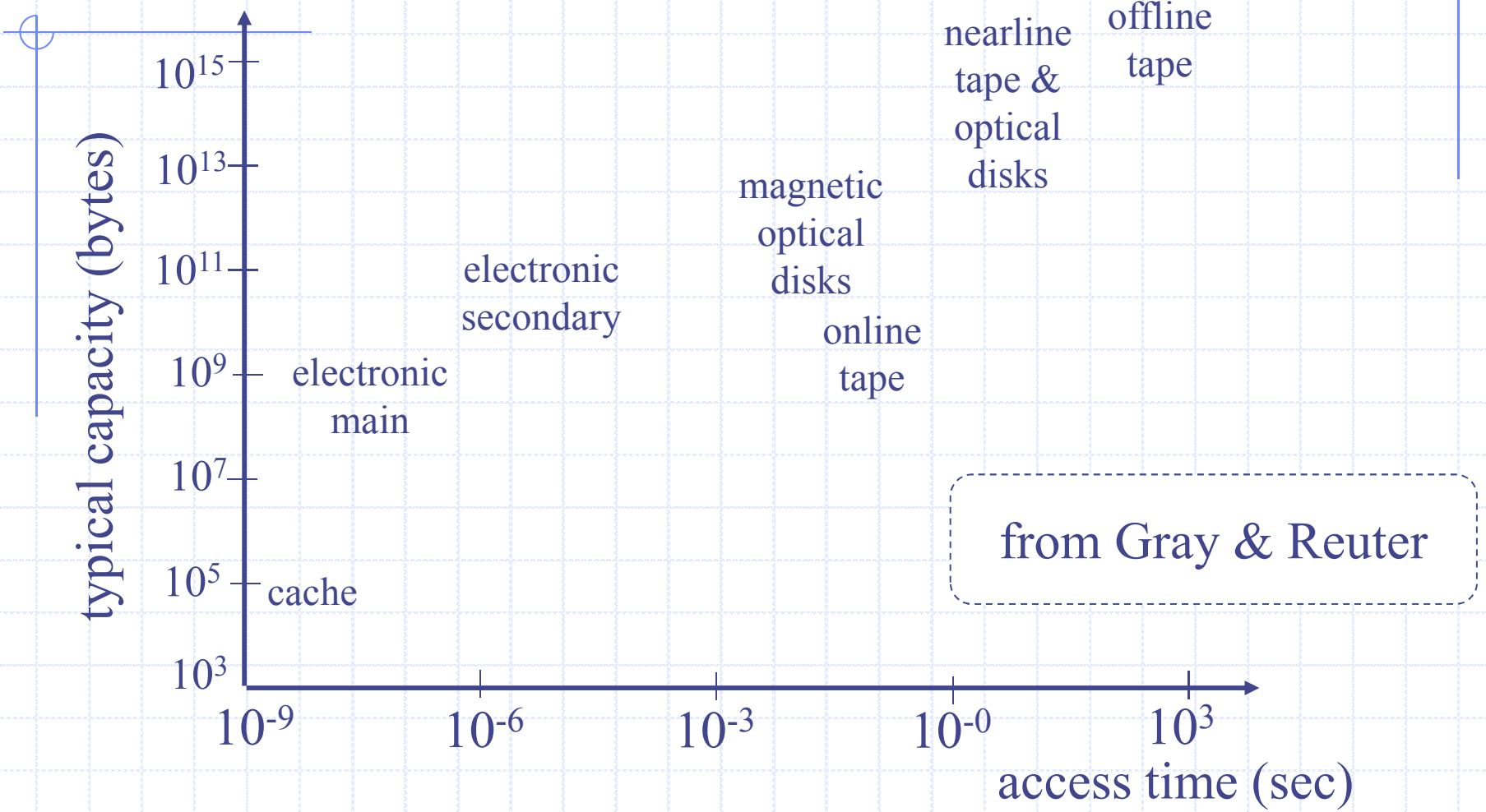
- Big Block $\rightarrow$ Amortize I/O Cost

- Big Block $\Rightarrow$ Read in more useless stuff!
  and takes longer to read

Trend

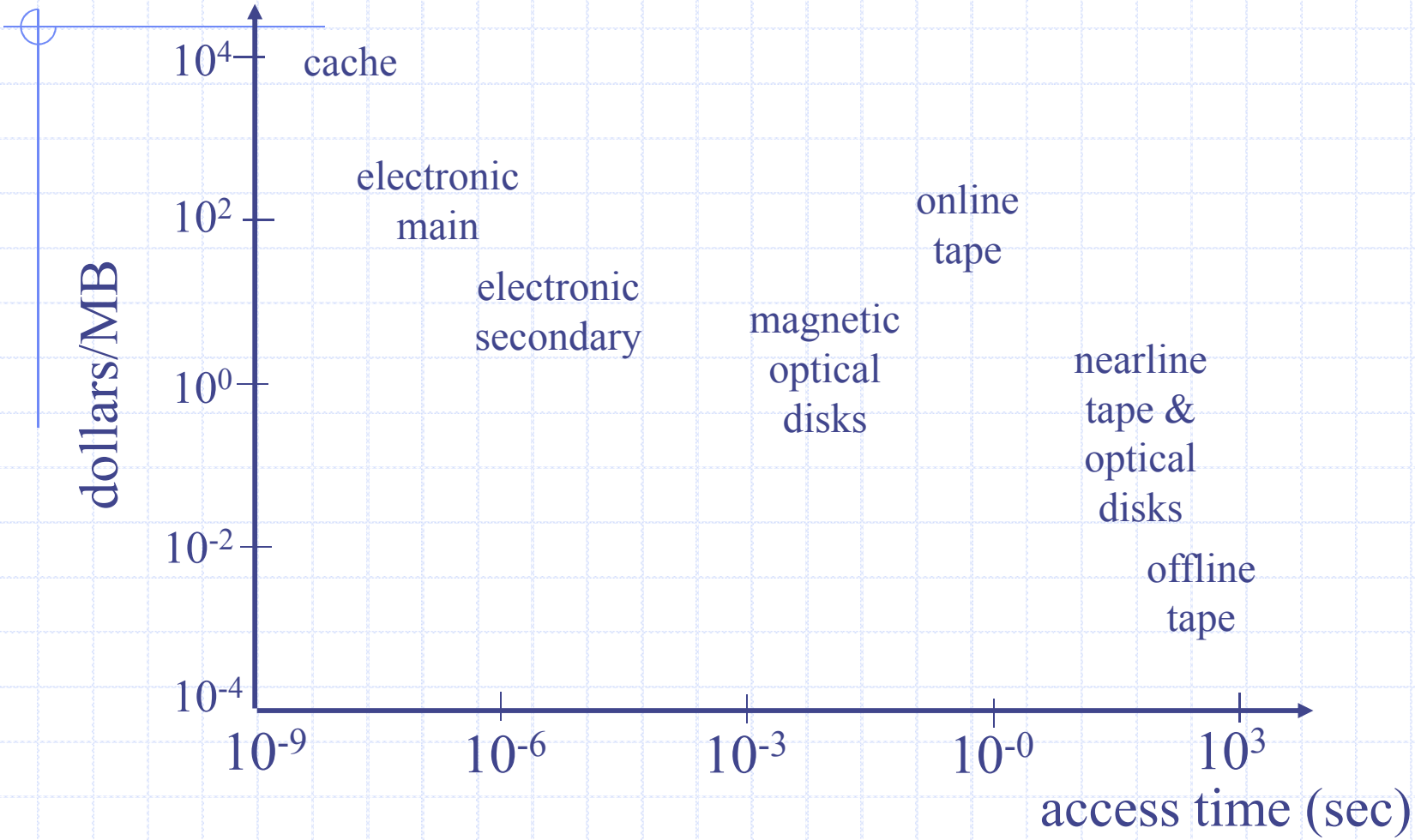
- As memory prices drop, blocks get bigger ...

Storage Cost



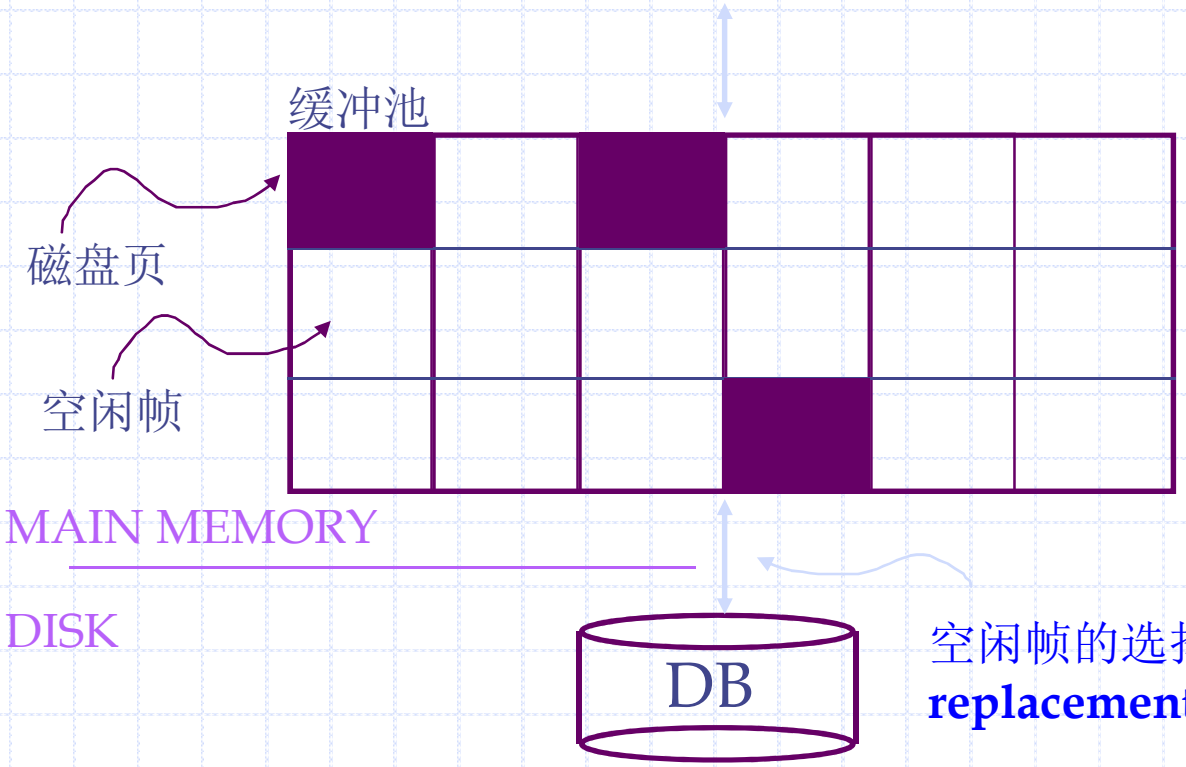
Storage Cost

from Gray & Reuter



Buffer Management缓冲区管理

来自高层次代码的页请求



- *数据必须在主存中，才能被DBMS所处理!*
- *系统维护表 <frame#, pageid,pin-count,Dirty>.*

页面请求

- 当页面不在缓冲池中:
  - 首先选择一个替换帧*replacement*
  - 如果帧的dirty位是真,把该帧写到磁盘上
  - 把请求的页读入替换帧
- *把替换帧的主存地址返回给申请者*

*如果可以预测请求（例如：顺序扫描），
*那么页面可以被预取*pre-fetched*!

缓冲区替换策略

- *替换策略replacement policy:*
  - 最近最少使用策略Least-recently-used (LRU)（链表实现）
  - 时钟替换Clock
  - 最近经常使用策略MRU等.

Using secondary storage effectively (Sec. 2.3)

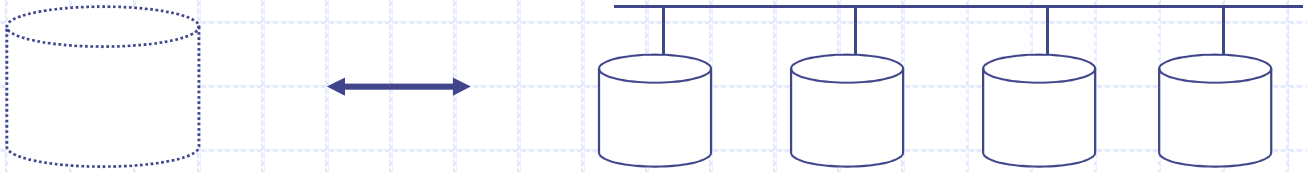
- Example: Sorting data on disk
- Conclusion:
  - I/O costs dominate
  - Design algorithms to reduce I/O
- Merge Sort
  - Two-phase, Multiway merge sort

Disk Failures (Sec 2.5)

- Coping with Disk Failures
  - Detection
    - e.g. Checksum
  - Correction
    - ⇒ Redundancy

At what level do we cope?

- Single Disk
  - e.g., Error Correcting Codes
- Disk Array



Logical

Physical

RAID

- 磁盘阵列: 把几个磁盘组织在一起的一种形式.
- 目标: 提高性能和可靠性.
- 两种主要技术:
  - 数据划分:数据给分成大小相等的段；不同数据段写在不同的磁盘上.
  - 冗余: 重复信息允许数据重现.

Summary

- Secondary storage, mainly disks
- I/O times
- I/Os should be avoided,
  especially random ones.....

Any question?