CH06 External Memory

- Magnetic Disk
- RAID
- Optical Memory
- Magnetic Tape

Types of External Memory

- Magnetic Disk
  - RAID
  - Removable
- Optical
  - CD-ROM
  - CD-Writable (WORM)
  - CD-R/W
  - DVD
- Magnetic Tape

Magnetic Disk

- Metal or plastic disk coated with magnetizable material (iron oxide…rust)
- Range of packaging
  - Floppy
  - Winchester hard disk
  - Removable hard disk

Data Organization and Formatting

- Concentric rings or tracks
  - Gaps between tracks
  - Reduce gap to increase capacity
  - Same number of bits per track (variable packing density)
  - Constant angular velocity
- Tracks divided into sectors
- Minimum block size is one sector
- May have more than one sector per block

Disk Data Layout

Fixed/Movable Head Disk

- Fixed head
  - One read write head per track
  - Heads mounted on fixed ridged arm
- Movable head
  - One read write head per side
  - Mounted on a movable arm
Fixed and Movable Heads

Removable or Not

- Removable disk
  - Can be removed from drive and replaced with another disk
  - Provides unlimited storage capacity
  - Easy data transfer between systems
- Nonremovable disk
  - Permanently mounted in the drive

Floppy Disk

- 8", 5.25", 3.5"
- Small capacity
  - Up to 1.44Mbyte (2.88M never popular)
- Slow (disk rotate at 300 and 600 rpm, average delay 100/2 and 200/2 ms.)
- Universal
- Cheap

Winchester Hard Disk (1)

- Developed by IBM in Winchester (USA)
- Sealed unit
- One or more platters (disks)
- Heads fly on boundary layer of air as disk spins (crash into disk!)
- Very small head to disk gap
- Getting more robust

Winchester Hard Disk (2)

- Universal
- Cheap
- Fastest external storage (typically rotate 3600 rpm, newer faster, average rotational delay 8.3 ms.)
- Getting larger all the time
  - Multiple Gigabyte now usual

Removable Hard Disk

- ZIP
  - Cheap
  - Very common
  - Only 100M
- JAZ
  - Not cheap
  - 1G
- L-120 (α: drive)
  - Also reads 3.5" floppy
  - Becoming more popular?
Finding Sectors
• Must be able to identify start of track and sector
• Format disk
  ➔ Additional information not available to user
  ➔ Marks tracks and sectors

ST506 format (old!)

Characteristics
• Fixed (rare) or movable head
• Removable or fixed
• Single or double (usually) sided
• Single or multiple platter
• Head mechanism
  ➔ Contact (Floppy)
  ➔ Fixed gap
  ➔ Flying (Winchester)

Multiple Platter
• One head per side
• Heads are joined and aligned
• Aligned tracks on each platter form cylinders
• Data is striped by cylinder
  ➔ reduces head movement
  ➔ Increases speed (transfer rate)

Speed
• Seek time
  ➔ Moving head to correct track
• (Rotational) latency
  ➔ Waiting for data to rotate under head
• Access time = Seek + Latency
• Transfer rate T = (number of bytes to be transferred)/(rotation speed)/(number of bytes on a track) = \( b/(rN) \)
• total access time \( T_a = T_s + 1/(2r) + b/(rN) \)

Sequential organization vs. random access e.g.
➢ e.g. a hard disk has average seek time of 20 ms, a transfer rate of 1 M byte/s, and 512 byte sectors with 32 sectors per track. Need to read a file consisting 256 sectors for a total of 128 K bytes. What is the total time for the transfer?
• Case 1: Sequential Organization (256 sectors on 8 tracks x 32 sectors/tracks)
  ➢ Average seek time = 20.0 ms
  ➢ Rotational delay = 8.3 ms
  ➢ Read 32 sections (one track) = 16.7 ms
  ➢ total time to read first track = 45 ms
  ➢ Total time = 45 ms + 7*(8.3 + 16.7) ms = 0.22 s
Time required for random access on highly fragmented organization

- Case 2: random access rather than sequential access
  - Average seek time = 20.0 ms
  - Rotational delay = 8.3 ms
  - Read 1 sector = 16.7/32 = 0.5 ms
  - Time to read one sector = 28.8 ms
  - Total time = 256 * 28.8 ms = 7.37 s

- De-fragment your hard disk!

Optical Storage CD-ROM

- Originally for audio
- 650 Mbytes giving over 70 minutes audio
- Polycarbonate coated with highly reflective coat, usually aluminum
- Data stored as pits
- Read by reflecting laser
- Constant packing density
- Constant linear velocity

Constant Angular Velocity vs. Constant Linear Velocity

CD-ROM Drive Speeds

- Audio is single speed
  - Constant linear velocity
  - 1.2 ms⁻¹
  - Track (spiral) is 5.27 km long
  - Gives 4391 seconds = 73.2 minutes
  - Data rate 176.4 K bytes/s total capacity 774.57 M Bytes

- Other speeds are quoted as multiples
  - e.g. 24x ~ 4 M Bytes/s (data transfer rate)
  - The quoted figure is the maximum the drive can achieve

CD-ROM Format

- Mode 0: blank data field
- Mode 1: 2048 byte data + error correction
- Mode 2: 2336 byte data

Random Access on CD-ROM

- Difficult
- Move head to rough position
- Set correct speed
- Read address
- Adjust to required location
- (Yawn!)
CD-ROM for & against
- Large capacity (?)
- Easy to mass produce
- Removable
- Robust

- Expensive for small runs
- Slow
- Read only

Other Optical Storage
- CD-Writable
  - WORM
  - Now affordable
  - Compatible with CD-ROM drives
- CD-RW
  - Erasable
  - Getting cheaper
  - Mostly CD-ROM drive compatible

DVD - what’s in a name?
- Digital Video Disk
  - Used to indicate a player for movies
  - Only plays video disks
- Digital Versatile Disk
  - Used to indicate a computer drive
  - Will read computer disks and play video disks
- Dogs Veritable Dinner
- Officially - nothing!!!

DVD - technology
- Multi-layer
- Very high capacity (4.7G per layer)
- Dual-layer (single-sided ?) hold 8.5 Gbytes ~ 4hr movie
- Full length movie on single disk
  - Using MPEG compression
- Finally standardized (honest!)
- Movies carry regional coding
- Players only play correct region films

DVD - Writable
- Loads of trouble with standards
- First generation DVD drives may not read first generation DVD-W disks
- First generation DVD drives may not read CD-RW disks
- Wait for it to settle down before buying!

Foreground Reading
- Check out optical disk storage options
- Check out Mini Disk
**Magnetic Tape**
- Serial access
- Slow
- Very cheap
- Backup and archive

**Digital Audio Tape (DAT)**
- Uses rotating head (like video)
- High capacity on small tape
  - 4Gbyte uncompressed
  - 8Gbyte compressed
- Backup of PC/network servers

**RAID**
- Redundant Array of Independent Disks
- Redundant Array of Inexpensive Disks
- 6 levels in common use
- Not a hierarchy
- Set of physical disks viewed as single logical drive by O/S
- Data distributed across physical drives
- Can use redundant capacity to store parity information

**RAID Levels 0, 1, 2**

**RAID Levels 3, 4**

**RAID Levels 5, 6**
RAID 0
- No redundancy
- Data striped across all disks
- Round Robin striping
- Increase speed
  - Multiple data requests probably not on same disk
  - Disks seek in parallel
  - A set of data is likely to be striped across multiple disks

RAID 1
- Mirrored Disks
- Data is striped across disks
- 2 copies of each stripe on separate disks
- Read from either
- Write to both
- Recovery is simple
  - Swap faulty disk & re-mirror
  - No down time
- Expensive

RAID 2
- Disks are synchronized
- Very small stripes
  - Often single byte/word
- Error correction calculated across corresponding bits on disks
- Multiple parity disks store Hamming code error correction in corresponding positions
- Lots of redundancy
  - Expensive
  - Not used

RAID 3
- Similar to RAID 2
- Only one redundant disk, no matter how large the array
- Simple parity bit for each set of corresponding bits
- Data on failed drive can be reconstructed from surviving data and parity info
- Very high transfer rates

RAID 4
- Each disk operates independently
- Good for high I/O request rate
- Large stripes
- Bit by bit parity calculated across stripes on each disk
- Parity stored on parity disk

RAID 5
- Like RAID 4
- Parity striped across all disks
- Round robin allocation for parity stripe
- Avoids RAID 4 bottleneck at parity disk
- Commonly used in network servers
RAID 6

- Two different parity calculations are carried out and
- stored in separate blocks on different disks.
- Able to regenerate data even if two disks containing user data fail