Multimedia Systems:
Lecture 2 -- Storage Devices

- Today: storage system basics
- Next time: disk arrays, striped tape systems
- Next week: efficient data layout schemes for video

Magnetic Disks
Magnetic Tape
Optical Disk
Magneto-optical Disk
Holographic Storage
Optical Tape

Magnetic Disk Technology

- Platters
  - Aluminum
  - Covered with magnetic material
  - Rotates at constant angular velocity
- Actuator moves arms radialy across surface
- Moves read/write heads
- Heads move collectively
- Only a single head reads/writes at a time
- Track: Circular swath
- Cylinder: Vertical collection of tracks
- Sectors: Small arcs, smallest unit of data transfer

Typical Disk Performance

- Seek operation
  - Time to move head to correct radial position
  - 1 to 30 msec
- Rotational Latency
  - Time for sector to rotate under disk head
  - Full rotation: 8 to 28 msec
- Transfer time
  - Depends on data transfer rate: 1 to 5 MB/sec
  - A function of:
    - » rotation rate
    - » density of magnetic media
    - » radial distance of head from center of platter

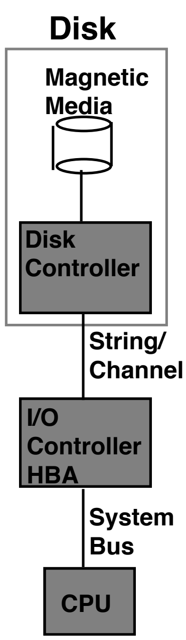
Typical Disk Parameters

- Form factors: 3.5" or smaller (diameter)
- Capacity
  - Hundreds of megabytes to 3 gigabytes
  - Increasing 50% per year
- Cost
  - $ 0.50 per megabyte
  - Dropping 50% per year
- Bytes per sector: 512
- Sectors per track: approx. 100
- Tracks per cylinder: approx: 20
- Cylinders per platter: approx. 2600

Types of I/O

- Slow head positioning time
- Fast data transfer rate
- Performance depends on size, relative locations
  - Large, sequential accesses: high data rate
  - Small, random accesses: high I/O rate

Data Path



- Data encoded on platter surface as flux reversals
- Sense, amplify, digitize
- Pulses decoed into separate data bits
- Bits aligned into bytes
- Error-correction codes applied
- On-disk controllers perform speed-matching
- Track buffers perform caching
- Deliver bytes to host over peripheral bus (SCSI)
- Data path between disk and host bus adaptor:
  - Channel
  - String: devices share data path
- Transferred to host memory from host bus adaptor

Magnetic Tape

- **Thin, flexible plastic substrate**
  - **thinner: more caacity**
  - **thicker: more durable**
- **Magnetic layer**
  - **Metal Particle: coating 2 to 5 microns thick**
  - **Metal Evaporated: 100 nanometers**
    - **superior recording characteristics**
- **Back coating for protection against static**

Linear Recording

- **Data written in tracks parallel to tape edges**
- **Stationary, multitrack heads**
  - **read/write entire width of tape simultaneously**
  - **gaps left between tracks**
- **Serpentine drives**
  - **read/write a few tracks at a time**
  - **then reverse direction**

Helical Scan Drives

- **Read and write heads on a drum**
- **Drum rotates at high speed (2000 rpm)**
- **Slow-moving tape (1/2-inch per second)**
- **Tracks written at small angle (10-20 degrees)**
- **Servo information written on edges of track**
- **Tracks with little/no overlap**

Linear vs. Helical Scan

- **Linear: less abrasive head-to-tape interface**
  - **longer-lived heads, tapes**
- **Helical scan: relatively slow normal tape speed**
  - **fast search, rewind operations**

Tape Issues

- Append-only
  - random access would cause wear
  - high rate of errors: rewrite data
- A few update-in-place
  - leave wide zones for erase operations
  - formatted like disks; waste capacity
- Rewind required before tapes can be ejected
  - eject operations cause wear
  - some cassettes have a single reel
- Maintain streaming mode of operation
  - starts/stops cause wear
  - to avoid wear, release tension during idle periods

Tape Robots

- Higher capacity, bandwidth
- Tape libraries
  - hundreds or thousands of tapes
  - small number of tape drives
- Variety of sizes
  - stacker (10 tapes, 1 drives)
  - carousel (50 tapes, 2 drives)
  - library (6000 tapes, 16 drives)

Tape Performance

- **Robot grab operation: 5-20 seconds**
- **Insert tape into tape drive: 5 to 60 seconds**
- **Forward search to data transfer position**
  - **constant overhead for acceleration (15 sec)**
  - **then constant search rate (15-200 MB/sec)**
- **Data transfer time**
  - **Depends on density of tracks, speed of tape**
  - **0.2 to 20 MB/sec**

- **Tape switch operation**
  - **remove tape from drive, insert another tape**
  - **on average several minutes**

Tape Characteristics

- **Tape capacity: 1-90 gigabytes**
- **$ 0.0015 per megabyte (media cost)**
- **$ 0.15 per megabyte (robot cost)**

- **Trends:**
  - **Similar to disks**
  - **Capacity, throughput double every two years**

Optical Disk Drive

- **Laser stores information by forming pits**
  - **Plastic substrate**
  - **Reflective aluminum layer**
  - **Transparent dielectric layer**
  - **Thin metal layer**
- **Write operation:**
  - **Laser melts small region of metal layer**
  - **Opens a hole or pit**
- **Read operation:**
  - **Lower-intensity laser beam reflected off surface**
  - **Pits and “land” reflect differently**
  - **Bits encoded as alternating regions of pits, land**

Features

- **Write-once**
- **Single spiral track (CDROM) or concentric circles**
- **Several servos:**
  - **tracking**
  - **focusing**
  - **controlling speed for constant data rate**

Magneto-Optical Devices

- **Thermo-magnetic recording**
- **Store material in magnetic material using a laser**
  - **Plastic disk**
  - **Magneto-optical film layer**
- **Write operation**
  - **Laser heats spot on magnetic material above a critical temperature**
  - **Allows spot to cool in magnetic field**
  - **Different directions for one vs. zero**
- **Read operation**
  - **Optical principle (Kerr effect)**
  - **Reflect a linearly polarized laser beam**
  - **Polarized beam will rotate differently for 1 vs. 0**

Magneto-Optical Features

- **Rewriteable**
  - **Usually a separate erase phase**
  - **Then can repeat write process**

- **Robots: Optical disk jukeboxes**

Optical and Magneto-Optical

- **Random-access devices**
  - **seek, rotation times**
  - **slower than magnetic disk**
  - **average >100 msec seek**
- **Data transfer rates**
  - **CDROM: 150 KB/sec to 600 KB/sec**
  - **magneto-optical: up to 3 MB/sec**
- **Media costs: $ 0.003 to $0.28 per megabyte**
- **Jukebox prices: $ 0.50 per megabyte**

- **Question: what is future of optical disk?**
  - **CD-ROM: distribution of software; commodity**

Future: Holographic Storage

- **Stores data as a pattern of charges in photorefractive crystallite material**
- **Strontium barium niobate doped with cerium**
- **Divide crystals into two-dimensional "pages"**
- **Write procedure:**
  - **Create pattern of dark, light spots (ones, zeros)**
  - **Superimpose onto laser beam**
  - **Shine through crystal array**
  - **Write interference grating on photorefractive material**
  - **Modify charges stored in crystallite**

Holographic Storage

- Read procedure:
  - Shine a reference beam through crystal
  - Particular angle corresponds to page
  - Focus resulting bit pattern onto detector array
  - Reproduce original digital signals
- Projected targets
  - 1 megabit per page
  - 100 pages per crystallite
  - 1000 crystallites per module (10 x 10 x 0.5 cm)
  - 100 gigabytes per module
  - 100 nsec to read; 10 microseconds to write
  - 1 terabyte per second

Optical Tape

- Similar to optical disks
- Substrate is flexible plastic (like magnetic tape)
  - polyester base film
  - smoothing layer
  - metallic reflective layer
  - infrared-absorbing dye-polymer layer tuned to wavelength of laser
  - protective overcoat
  - backing coat

Optical Tape

- **Write procedure:**
  - **Laser melts small spot of dye-polymer layer**
  - **Forms physical pit**
- **Read procedure:**
  - **Low-power laser beam**
  - **Pits vs. land have different reflectivity**

- **Creo product**
  - **Reel: 12-in diameter, 35-mm wide**
  - **Holds 1 terabyte of data**
  - **Average access time 1 minute**