CS315: Principles of Database Systems
Physical Design

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Tue, Fri 1530-1700 at CS101

Physical storage media

- Cache (primary storage)
  - Fastest
  - Most costly
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- Flash memory (secondary storage, online storage)
  - Non-volatile
  - Read is quite fast
  - Write is slower due to erase
  - Supports a fixed number of write/erase cycles
  - Cheaper than main memory

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  - Direct-access: can read and write any location
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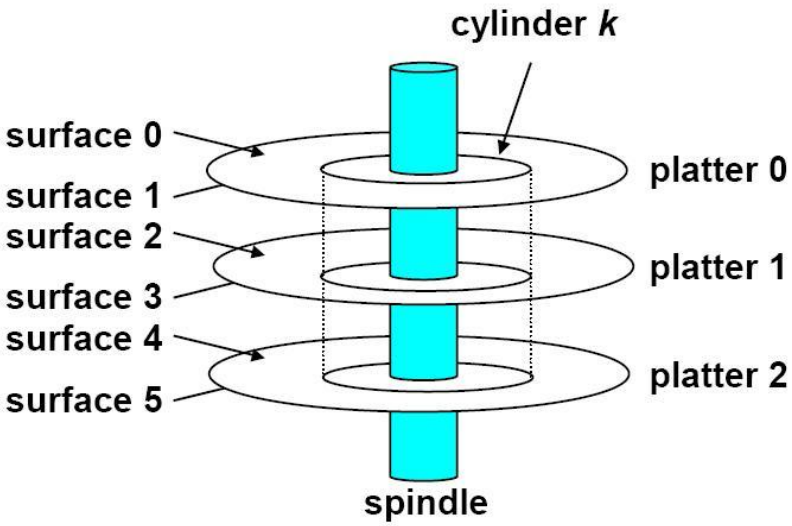
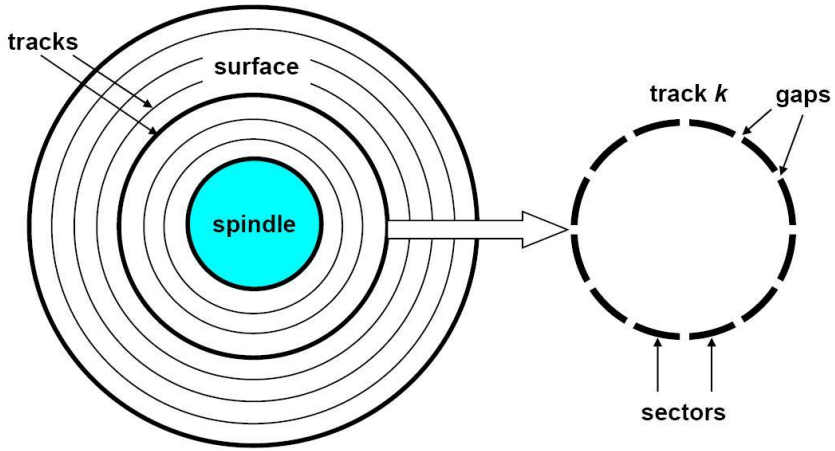
- Magnetic tape (tertiary storage, offline storage)
  - Sequential access
  - Much slower
  - Very high capacity
  - Much cheaper

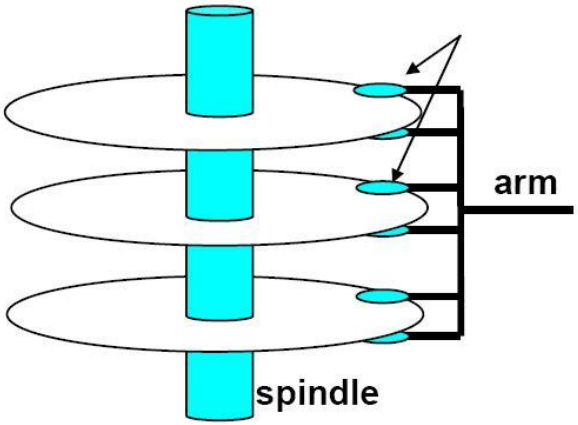
Disks

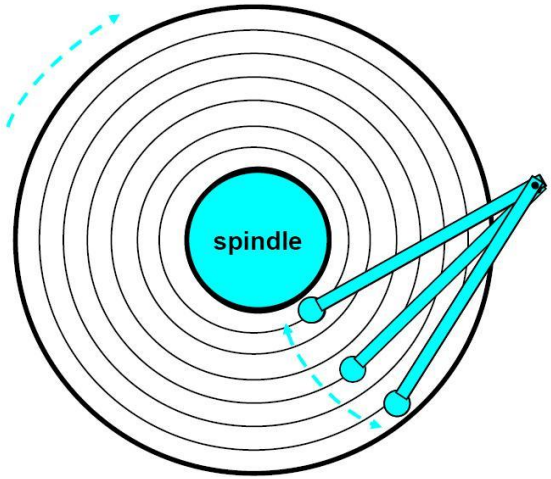
- Physically, disks consist of circular platters
- Both surfaces of a platter can be accessed
- Each surface contains concentric tracks
- Tracks are divided into sectors separated by gaps
- Aligned tracks form a cylinder

Disk access


cylinder k
surface 0
surface 1
surface 2
surface 3
surface 4
surface 5
platter 0
platter 1
platter 2
spindle


tracks
surface
track k
gaps
spindle
sectors


arm
spindle


spindle

Disk access time

- *Smallest* unit of information that can be read from or written to disk is a sector
- Block or page is a logical unit read from or written to by O/S
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- Access time T_{access}: Time to access a particular sector

$$T_{access} = T_{seek} + T_{rotation} + T_{transfer}$$

- Seek time T_{seek}: Time to position arm heads over cylinder containing the target sector
  - Typical seek time: 8 ms
- Rotational latency $T_{rotation}$: (Average) time to rotate r/w head to the first bit of the sector
  - $T_{rotation}$ = (1 / 2) $\times$ (1 / rpm) $\times$ (60 s / 1 min)
- Transfer time $T_{transfer}$: Time to read bits from the sector
  - $T_{transfer}$ = (1 / (#sectors / track)) $\times$ (60 / rpm)

Typical disk parameters

- Average seek times from 4-10 ms
- Rotational speeds are 60, 90, 120, 250 revolutions per second, i.e., 3600, 5400, 7200, 15000 rpm respectively
- Sector sizes vary between 512 bytes and 1024 bytes
- 400 to 1000 sectors per track
- 20,000 to 50,000 tracks per surface
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- Example
  - Rotational speed = 7200 rpm
  - Average seek time T_{seek} = 8 ms
  - Average #sectors / track = 400
  - $T_{rotation} = (1 / 2) \times (1 / 7200) \times 60 = 4.17$ ms
  - $T_{transfer} = (1 / 400) \times (1 / 7200) \times 60 = 0.02$ ms
  - $\therefore T_{access} = 8 + 4.17 + 0.02 = 12$ ms

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- Disk access time is dominated by seek time and rotational latency
- Sequential access algorithms exploit the (almost) free access time of later bits heavily
- Most algorithms aim to avoid random I/Os

Optimization of disk block access

- *Disk arm scheduling*: schedule such that movement of disk arm head is minimized
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- *Deferred writes*: Postpone and perform writes batchwise
  - Use non-volatile write buffers, e.g., flash memory
  - Maintain logs for correctness

Data redundancy and parallelism

- Redundancy improves reliability
- RAID: Redundant arrays of independent disks
- Uses mirroring or shadowing
  - Failure only if both fail
- Mean time to data loss depends on mean time to failure for each disk and mean time to repair

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- Two main ways
- Bit-level striping: Each bit of a byte is stored in a separate disk
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- Job of buffer manager in memory to store disk blocks

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- Variable-length records use slotted page structure
- Header of a slotted page (block) contains
  - Number of record entries
  - Address and size of each record
  - Address of start of free space
- Records are placed contiguously in the block

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- Generally, a single relation is organized as a single file
- Sometimes, records from multiple relations are placed in the same file
- Suppose, two relations are joined frequently
- Records pertaining to the same value of the joined attrbute are stored in the same block
- This is called multi-table clustering file organization

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- Large objects need pointers and buffer management