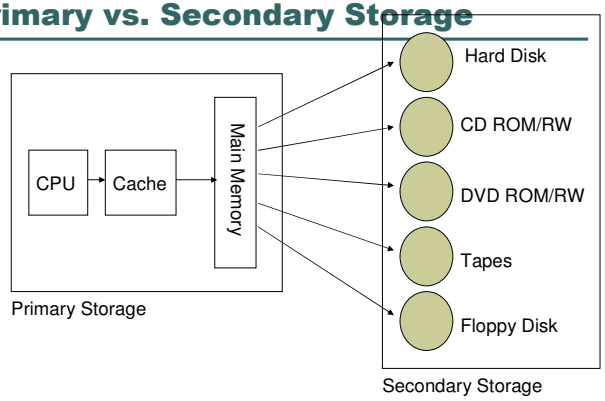
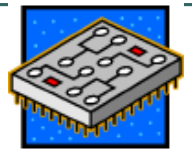
Secondary Storage

Disk Organisation

Primary vs. Secondary Storage



Primary Storage



- Primary Storage is …
  - Limited
  - Volatile
  - Expensive
- However, it is also …
  - Fast (May be accessed directly from the CPU)

Secondary Storage

- Secondary Storage is …
  - Extendible
  - Persistent
  - Cheap
- However, it is …
  - Relatively slow (must be copied to main memory before being accessed by the CPU)

Why do we use secondary storage?

Primary storage (RAM) costs more than disk space

- We like to switch our computers off and on again
- CPUs can't address all the data we need it to

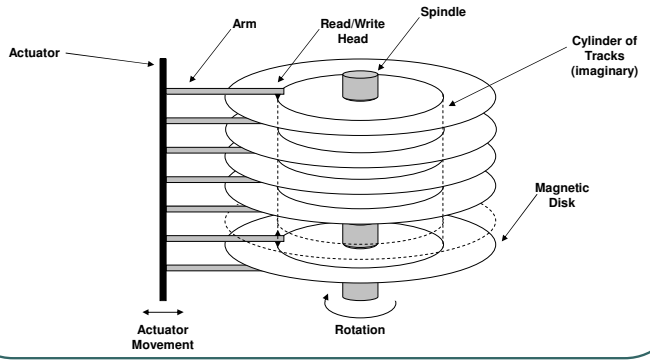
But secondary storage is slow

- Retrieving a single character from RAM takes about 150 nanoseconds (150 billionths of a second)
- Retrieving the same character from disk takes about 75 milliseconds (thousandths of a second)
- 75 msec is 500,000 times longer than 150 ns.

Disk Storage Devices

- Direct Access Storage
  - As opposed to Tape drives, which are serial devices
- Offer high storage capacity and low cost
- Data stored as magnetized areas on magnetic platters surfaces
- Each disk has one or more platters
- A disk pack contains several magnetic platters connected to a rotating spindle

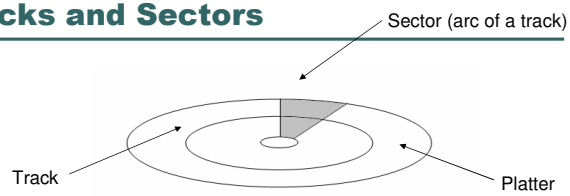
Disk Pack with Read/Write H/W



Movable vs Fixed-head Disks

- Some disks have fixed-heads
  - As many read/write heads as there are tracks on the platter
  - Track is selected electronically and is therefore much faster
  - Cost of additional read/write heads is the limiting factor to production
- Disks with an actuator are called moveable-head disks
  - Actuator moves the (single) read/write head per platter to the appropriate track

Tracks and Sectors



- Disks are divided into concentric circular tracks on each platter surface
- Track capacities vary typically from 4 to 50 Kbytes

Sectors

- Subtended at fixed angle at the centre of a platter are sectors (figure previous slide)
- The division of the disk into sectors is hard-coded and may not be changed
- Not all disks have their tracks divided into sectors

Cylinder

- Tracks directly above and below one another form a cylinder
- All information on a cylinder can be accessed without moving the arm (called seeking) that holds the read/write heads
  - A cylinder consists of a group of tracks
  - A track consists of a group of sectors
  - A sector consists of a group of bytes

Estimating Capacities

- Track capacity = #sectors per track * bytes per sector
- Cylinder capacity = #tracks per cylinder * Track capacity
- Drive capacity = #cylinders * Cylinder capacity
- Knowing these relationships allows us to compute the amount of disk space a file is likely to require

Example

- How many cylinders to store a file with 20,000 fixed length records of 256 bytes each on a disk with –
  - 512 bytes per sector
  - 40 sectors per track
  - 11 tracks per cylinder

Answer

- The file is 20,000 * 256 = 5,120,000 bytes
- 5,120,000 / 512 = 10,000 sectors
- 10,000 / 40 = 250 tracks
- 250 / 11 = 22.72 cylinders
- If 22.72 physically contiguous cylinders are not available then the file will have to be spread out over the disk (fragmentation)

Blocks

- A track is divided into blocks or pages
- Block size (generally) fixed for each operating system
- Typical block sizes range from 512 bytes to 4096 bytes
- A disk with hard-coded sectors often has the sectors further subdivided onto blocks
- Why are they important?
  - Whole blocks are transferred between disk and main memory for processing

Disk I/O

- Input/Output (I/O) from/to a Disk …
  - A read-write head moves to the track that contains the block to be transferred *(seek)*
  - Disk rotation moves the block under the read-write head for reading and writing *(rotational delay or latency)*
  - Entire block read/written from/to an area in RAM called a buffer
    - Time taken to transfer the block (block transfer time)

Seek

- Move head to desired cylinder
- *mechanical operation - slow*
- Seek time consists of:
  - initial start-up time
  - \+ time taken to traverse the cylinders (which is proportional to # of cylinders to be traversed)
- Average seek time for **random** accesses is based on traversing **one third** of the cylinders.
- Typical average 25 ms.

Rotational Delay

- Wait for required bytes (i.e. sector) to come under r/w head.
- Average rotational delay is time for half a revolution.
- e.g. 3600 revs/min => 16.66 ms/rev =>
- average delay = 16.66/2 ms = 8.3 ms

Transfer Time

- Time required for passing data under a r/w head until it is read.
- Transfer time =

  $$\frac{\text{\# bytes transferred}}{\text{\# bytes on a track}} * \text{Rotation time.}$$

- Transfer time for 1 sector =

  $$\frac{\text{rotation time}}{\text{\# sectors per track}}$$

- These are nominal times because data is not usually laid on the disk in contiguous sector order.

Why do we care about disk organisation?

- Time needed to read or write data depends on location of the data
  - Access time = seek time + rotational delay + transfer time
- Data storage affects time taken for file access operations
- If 2 data records in DBMS used frequently together then we should try to place as "close" as possible to each other..
  - In same data block
  - In same track
  - In same cylinder
  - In adjacent cylinder

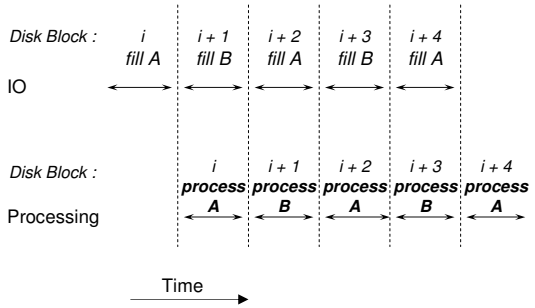
Decreasing order of closeness

Buffers

- When several blocks need to be transferred from disk to main memory (and all the block addresses are known beforehand) several buffers can be reserved in main memory to speed the transfer
  - CPU processes data in a buffer while another is being read/written
- Facilitated by independent Input/Output processor
  - Can transfer data block to/from main memory independent of and in parallel to CPU processor
  - This technique is referred to as double buffering

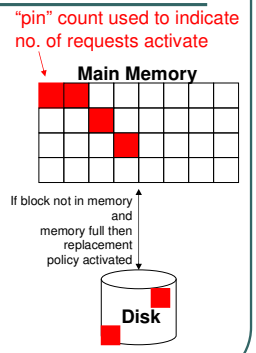
Example of Double Buffering

Use of two buffers, A and B, for reading from disk



Buffer Management in DBMS

- Buffer Manager is needed to so that needed data block is brought into main memory and decide on which existing data block to replace using a **replacement policy**
  - Least Frequently Used (LRU) policy
  - Clock policy
- DBMS sounds like "virtual memory", as both trying to manage access to more data that can fit in memory
- Differences
  - DBMS can often predict the order in which blocks accessed
  - DBMS needs control over when a block is written to disk



Review

- Compared to RAM disk accesses are slow, but cheap!
- Disks facilitate persistent storage of data
- Disks enable direct access
- Anatomy of a Disk
  - Platters, tracks, cylinders, sectors, blocks
- Physical components of a Disk
  - Magnetic disks, actuator, arm, read/write heads, spindle
- Estimating Capacities
- Disk I/O and Buffering
- Sector Organisation and Clustering