Data Structures and Algorithms (9)

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Higher Education Press, 2008.6 (the "Eleventh Five-Year" national planning textbook)

https://courses.edx.org/courses/PekingX/04830050x/2T2014/

Chapter 9 File management and External Sorting

- ## 9.1 Primary vs. Secondary Storage

- ## 9.2 File Organization and File management

  - 9.2.1 File Organization

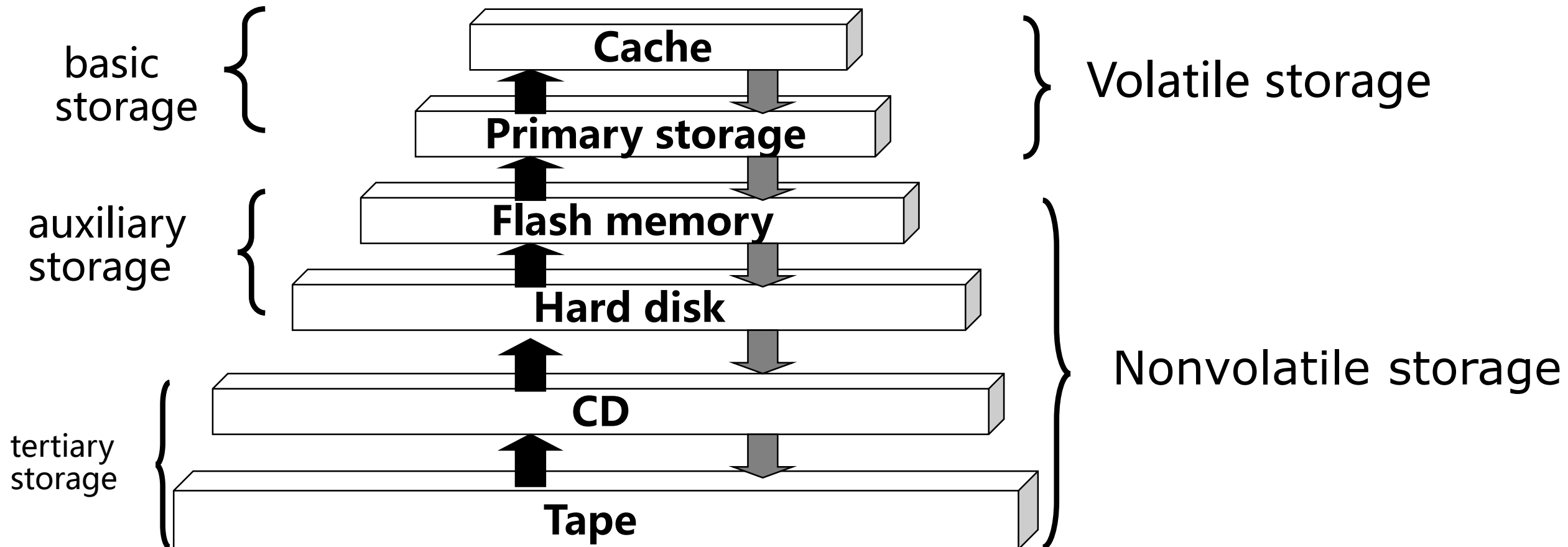 - 9.2.2 Stream File of C++

- ## 9.3 External Sorting

Primary vs. Secondary Storage

- Two main kinds of computer storage:

  - Primary/main memory
    - Random Access Memory (RAM)
    - Cache
    - Video memory

  - Peripheral/secondary storage
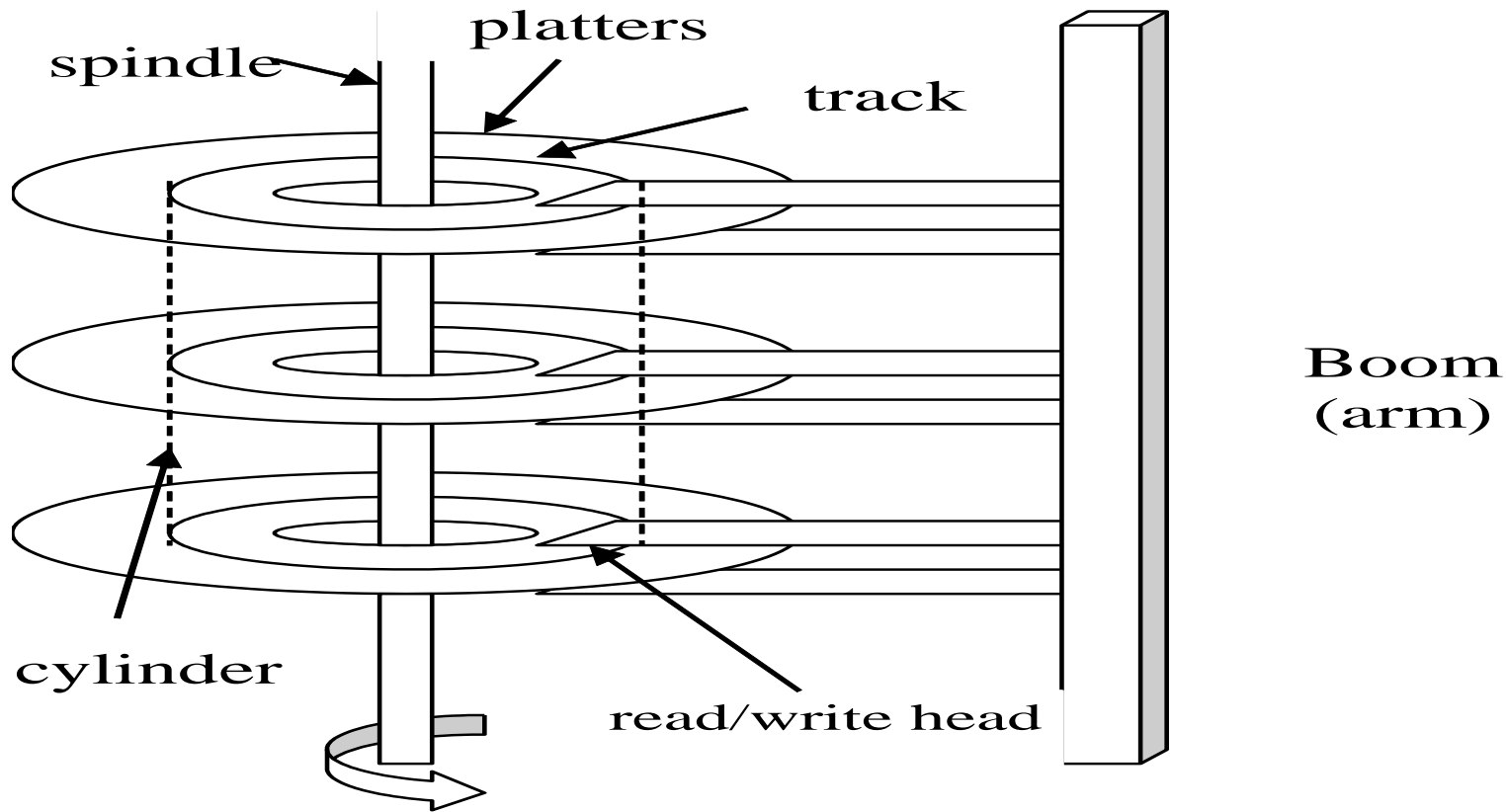   - Hard disk (100 GB – 100 TB, 10^{12}B)
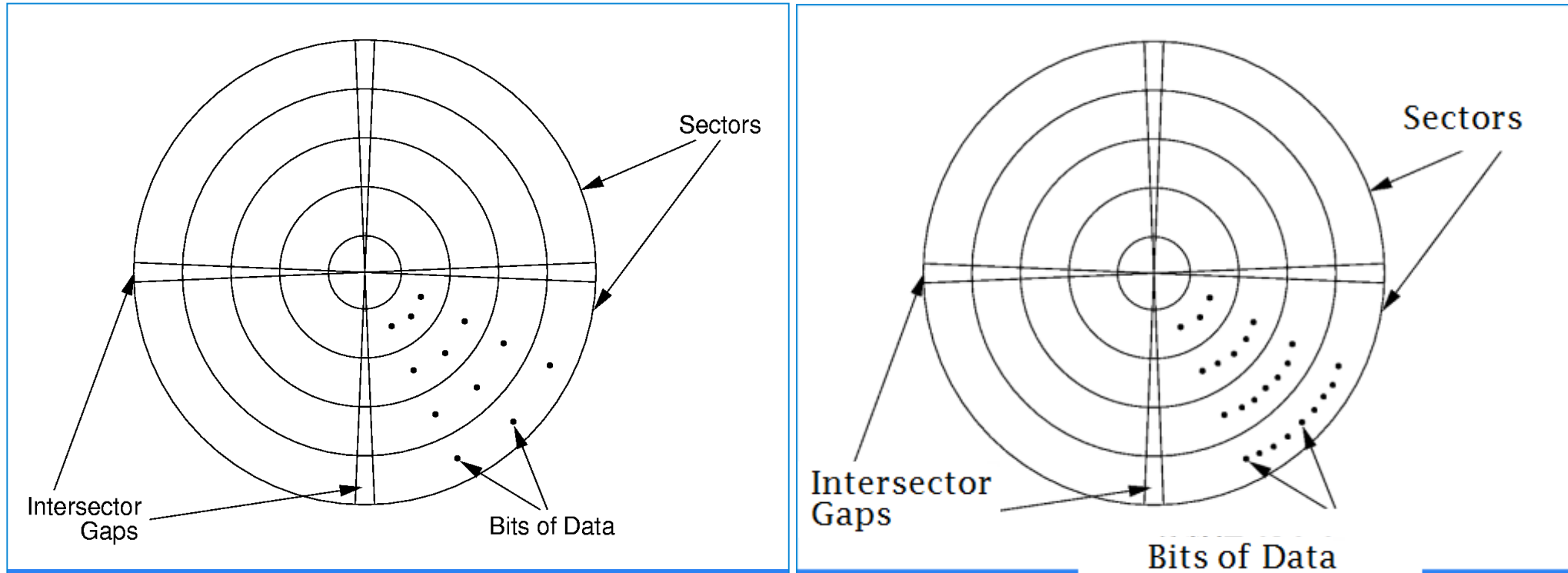   - Tape (100 PB, 10^{15}B)

Physical Storage Medium Overview

basic
storage

auxiliary
storage

tertiary
storage

| Cache |
| Primary storage |
| Flash memory |
| Hard disk |
| CD |
| Tape |

Volatile storage

Nonvolatile storage

Disk Drive Architecture

spindle

platters

track

Boom (arm)

cylinder

read/write head

Platter Organization

Track Organization (Interleaving)

- 512 or 1024 bytes per page
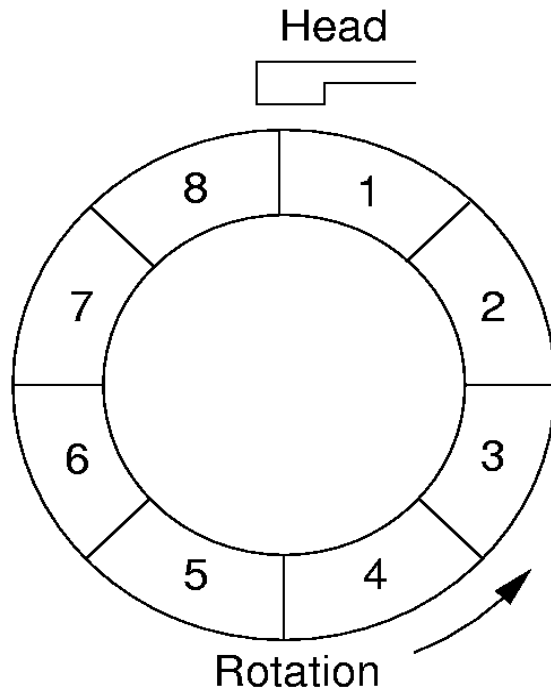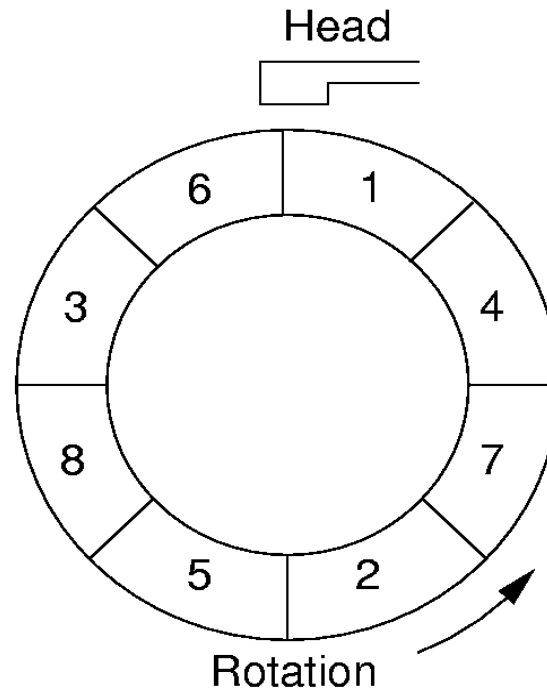
(a) sectors are sequential;   (b) interleave factor is 3

Pros and Cons of Primary Storage

- Pros: the access speed is fast
- Cons: expensive, small size, lose data when power is off
- CPU interacts with primary storage directly, so the access time of primary storage can be assumed as a small constant

Pros and Cons of Secondary Storage

- Pros: cheap, nonvolatile, portable

- Cons: the access speed is low
  - Generally, the unit of access time of primary storage is in **nanosecond**, 1 ns = 10^{-9}s
  - The unit of access time of secondary storage is in **millisecond**, or even second, 1 ms = 10^{-3} s

- When a computer program involves secondary storage, we should **reduce the times of access**, to reduce the execution time

9.1 Primary vs. Secondary Storage

- KB (kilo byte) 10^3B (page)
- MB (mega byte) 10^6B (cache)
- GB (giga) 10^9B (memory, disk)
- TB (tera) 10^{12}B (RAID)
- PB (peta) 10^{15}B (tape library)
- EB = 10^{18}B ; ZB = 10^{21}B ; YB = 10^{24}B
- Googol is 10^{100}

Logical Structure of Files

- ## File is a set of records

  - The records of the file are arranged in a specific order, so that they form a linear relation between themselves naturally.

- ## Thus, file is a linear structure.

File Organization and File Management

- ## Logical file
  - ### For programmer using high-level programming languages
  - ### Records are made up of contiguous bytes, and logical files are made up of records
- ## Physical file
  - ### Stored in disk block by block
- ## File manager
  - ### Part of the operating system or database system
    - The records in an OS file do not have an explicit structure, while a database file consists of structured records
  - ### Map logical position to specific physical position in disk drive

File Organization

- 3 kinds of logical file organization
  - Fixed-length records of sequential structure
  - Variable-length records of sequential structure
  - Records accessed by key values

- General physical file organization
  - Sequential structure (sequential file)
  - Address-calculation structure (hash file)
  - Index structure (index file)
    - Inverted index is a special kind of index

Operations of File

- Retrieval. Find a record which meets certain conditions in the file

- Modify. Update the value of a record; if you update its key value, it is equivalent to delete an old record and insert a new one

- Insert. Add a new record to the file

- Delete. Remove a record from the file

- Sort. Rearrange the records according to specific data fields; usually rearrange by the key values

Standard I/O Stream Class in C++

- ## Standard I/O stream class
  - – istream: a base class of input stream classes
  - – ostream: a base class of output stream classes
  - – iostream: a base class of input/output stream classes

- ## 3 file classes used to manipulate files
  - – ifstream: derived from istream, supporting the input of a file on the disk
  - – ofstream: derived from ostream, supporting the output of a file on the disk
  - – fstream: derived from iostream, supporting the input and output of a file on the disk

Major Methods of fstream Class

Seek the "get"/"put" positions;
Read from the "get" position; **Write** to the "put" position

```
#include <fstream.h>                          // fstream = ifstream + ofstream
void fstream::open(char*name, openmode mode);
                                              // open the file
fstream::read(char*ptr, int numbytes);  // read bytes from the current position of the file
fstream::write(char*ptr, int numbtyes); // write bytes to the current position of the file

// seekg and seekp: move the current position of the file
// so that we can read/write bytes anywhere we want
fstream::seekg(int pos);                      // set the "get" position for reading
fstream::seekg(int pos, ios::curr);
fstream::seekp(int pos);                      // set the "put" position for writting
fstream::seekp(int pos, ios::end);
void fstream::close();                        // close the file
```

Buffer and Buffer Pool

- Purpose: reduce the disk access latency
- Method: buffering or caching
  - Retain as many blocks as possible in the primary storage
  - Increase the possibility that the blocks to access stay in the primary storage
- The data stored in the same buffer form a page, which is the unit of file I/O
- A collection of buffers forms a buffer pool

Strategies for Buffer Replacement

- When a new page requests for a buffer, release an old buffer that may not be used again, and store the new page in this buffer
  - "First-In-First-Out" (FIFO)
  - "Least Frequently Used" (LFU)
  - "Least Recently Used" (LRU)

Thinking

1. Find the price per byte of the storage devices, such as main memory, disk drives, tapes, cache, etc.

2. Find the performance indicators of mainstream disks
   - Capacity (GB)
   - Revolutions per minute (rpm)
   - Interleave factor
   - Seek time
   - Rotational delay time

Data Structures and Algorithms

Thanks