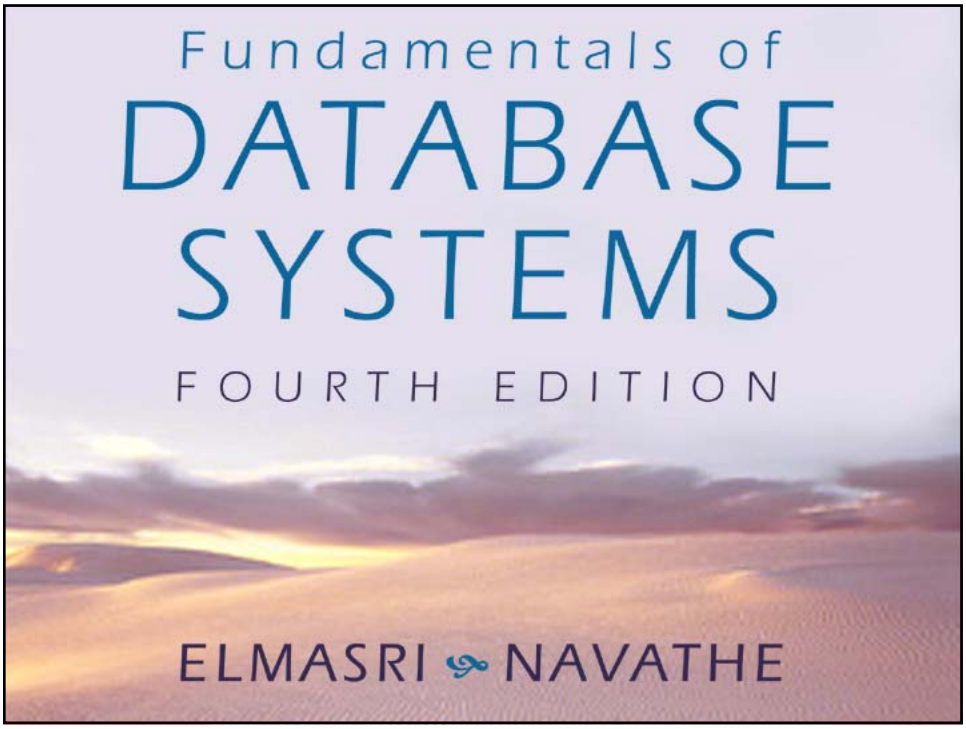

Chapter 13

Disk Storage, Basic File Structures, and Hashing.

Chapter Outline

- Disk Storage Devices
- Files of Records
- Operations on Files
- Unordered Files
- Ordered Files
- Hashed Files
  - Dynamic and Extendible Hashing Techniques
- RAID Technology

Disk Storage Devices (cont.)

- Preferred secondary storage device for high storage capacity and low cost.
- Data stored as magnetized areas on magnetic disk surfaces.
- A *disk pack* contains several magnetic disks connected to a rotating spindle.
- Disks are divided into concentric circular *tracks* on each disk *surface*. Track capacities vary typically from 4 to 50 Kbytes.

Disk Storage Devices (cont.)

Because a track usually contains a large amount of information, it is divided into smaller blocks or sectors.

- The division of a track into *sectors* is hard-coded on the disk surface and cannot be changed. One type of sector organization calls a portion of a track that subtends a fixed angle at the center as a sector.
- A track is divided into *blocks*. The block size B is fixed for each system. Typical block sizes range from B=512 bytes to B=4096 bytes. Whole blocks are transferred between disk and main memory for processing.

Disk Storage Devices (cont.)

INSERT FIGURE 13.2 here

Disk Storage Devices (cont.)

- A *read-write* head moves to the track that contains the block to be transferred. Disk rotation moves the block under the read-write head for reading or writing.
- A physical disk block address consists of a surface number, track number (within surface), and block number (within track).
- Reading or writing a disk block is time consuming because of the seek time s and rotational delay (latency) **rd**.
- Double buffering can be used to speed up the transfer of contiguous disk blocks.

Disk Storage Devices (cont.)

INSERT FIGURE 13.1 here

Files of Records

- A file is a *sequence* of records, where each record is a collection of data values (or data items).
- A *file descriptor* (or *file header*) includes information that describes the file, such as the *field names* and their *data types*, and the addresses of the file blocks on disk.
- Records are stored on disk blocks. The *blocking factor* BFR for a file is the (average) number of file records stored in a disk block.
- A file can have *fixed-length* records or *variable-length* records.

Files of Records (cont.)

- File records can be *unspanned* (no record can span two blocks) or *spanned* (a record can be stored in more than one block).
- The physical disk blocks that are allocated to hold the records of a file can be *contiguous*, *linked*, or *indexed*.
- In a file of fixed-length records, all records have the same format. Usually, unspanned blocking is used with such files.
- Files of variable-length records require additional information to be stored in each record, such as *separator characters* and *field types*. Usually spanned blocking is used with such files.

Operation on Files

Typical file operations include:

- **OPEN:** Readies the file for access, and associates a pointer that will refer to a *current* file record at each point in time.
- **FIND:** Searches for the first file record that satisfies a certain condition, and makes it the current file record.
- **FINDNEXT:** Searches for the next file record (from the current record) that satisfies a certain condition, and makes it the current file record.
- **READ:** Reads the current file record into a program variable.
- **INSERT:** Inserts a new record into the file, and makes it the current file record.

Operation on Files (cont.)

- **DELETE:** Removes the current file record from the file, usually by marking the record to indicate that it is no longer valid.
- **MODIFY:** Changes the values of some fields of the current file record.
- **CLOSE:** Terminates access to the file.
- **REORGANIZE:** Reorganizes the file records. For example, the records marked deleted are physically removed from the file or a new organization of the file records is created.
- **READ_ORDERED:** Read the file blocks in order of a specific field of the file.

Unordered Files

- Also called a *heap* or a *pile* file.
- New records are inserted at the end of the file.
- To search for a record, a *linear search* through the file records is necessary. This requires reading and searching half the file blocks on the average, and is hence quite expensive.
- Record insertion is quite efficient.
- Reading the records in order of a particular field requires sorting the file records.

Ordered Files

- Also called a *sequential file*.
- File records are kept sorted by the values of an *ordering field*.
- Insertion is expensive: records must be inserted in the *correct order*. It is common to keep a separate unordered *overflow* (or *transaction*) file for new records to improve insertion efficiency; this is periodically merged with the main ordered file.
- A *binary search* can be used to search for a record on its *ordering field value*. This requires reading and searching $\log_2$ of the file blocks on the average, an improvement over linear search.
- Reading the records in order of the ordering field is quite efficient.

Ordered Files (cont.)

INSERT FIGURE 13.7

Hashed Files

- The file blocks are divided into M equal-sized *buckets*, numbered bucket0, $bucket_1$, ..., $bucket_{M-1}$. Typically, a bucket corresponds to one (or a fixed number of) disk block.
- One of the file fields is designated to be the hash key of the file.
- The record with hash key value K is stored in bucket i, where i=h(K), and h is the *hashing function*.
- Search is very efficient on the hash key.
- Collisions occur when a new record hashes to a bucket that is already full. An overflow file is kept for storing such records. Overflow records that hash to each bucket can be linked together.

Hashed Files (cont.)

There are numerous methods for collision resolution, including the following:

- ***Open addressing:*** Proceeding from the occupied position specified by the hash address, the program checks the subsequent positions in order until an unused (empty) position is found.
- ***Chaining:*** For this method, various overflow locations are kept, usually by extending the array with a number of overflow positions. In addition, a pointer field is added to each record location. A collision is resolved by placing the new record in an unused overflow location and setting the pointer of the occupied hash address location to the address of that overflow location.
- ***Multiple hashing:*** The program applies a second hash function if the first results in a collision. If another collision results, the program uses open addressing or applies a third hash function and then uses open addressing if necessary.

Hashed Files (cont.)

Insert figure 13.9

Hashed Files (cont.)

- To reduce overflow records, a hash file is typically kept 70-80% full.
- The hash function h should distribute the records uniformly among the buckets; otherwise, search time will be increased because many overflow records will exist.
- Main disadvantages of static external hashing:
  - Fixed number of buckets M is a problem if the number of records in the file grows or shrinks.
  - Ordered access on the hash key is quite inefficient (requires sorting the records).

Hashed Files (cont.)

INSERT FIGURE 13.10

Dynamic And Extendible Hashed Files

Dynamic and Extendible Hashing Techniques

- Hashing techniques are adapted to allow the dynamic growth and shrinking of the number of file records.
- These techniques include the following: *dynamic hashing* , *extendible hashing* , and *linear hashing* .
- Both dynamic and extendible hashing use the *binary representation* of the hash value h(K) in order to access a *directory*. In dynamic hashing the directory is a binary tree. In extendible hashing the directory is an array of size 2^d where d is called the *global depth.*

Dynamic And Extendible Hashing (cont.)

- The directories can be stored on disk, and they expand or shrink dynamically. Directory entries point to the disk blocks that contain the stored records.
- An insertion in a disk block that is full causes the block to split into two blocks and the records are redistributed among the two blocks. The directory is updated appropriately.
- Dynamic and extendible hashing do not require an overflow area.
- Linear hashing does require an overflow area but does not use a directory. Blocks are split in *linear order* as the file expands.

Extendible Hashing

INSERT FIGURE 13.11

Parallelizing Disk Access using RAID Technology.

- Secondary storage technology must take steps to keep up in performance and reliability with processor technology.
- A major advance in secondary storage technology is represented by the development of **RAID**, which originally stood for **Redundant Arrays of Inexpensive Disks.**
- The main goal of raid is to even out the widely different rates of performance improvement of disks against those in memory and microprocessors.

RAID Technology (cont.)

- A natural solution is a large array of small independent disks acting as a single higher-performance logical disk. A concept called **data striping** is used, which utilizes *parallelism* to improve disk performance.
- Data striping distributes data transparently over multiple disks to make them appear as a single large, fast disk.

Insert Figure 13.12

RAID Technology (cont.)

Different raid organizations were defined based on different combinations of the two factors of granularity of data interleaving (striping) and pattern used to compute redundant information.

- Raid level 0 has no redundant data and hence has the best write performance.
- Raid level 1 uses mirrored disks.
- Raid level 2 uses memory-style redundancy by using Hamming codes, which contain parity bits for distinct overlapping subsets of components. Level 2 includes both error detection and correction.
- Raid level 3 uses a single parity disk relying on the disk controller to figure out which disk has failed.
- Raid Levels 4 and 5 use block-level data striping, with level 5 distributing data and parity information across all disks.
- Raid level 6 applies the so-called $P + Q$ redundancy scheme using Reed-Soloman codes to protect against up to two disk failures by using just two redundant disks.

Use of RAID Technology (cont.)

Different raid organizations are being used under different situations

- Raid level 1 (mirrored disks)is the easiest for rebuild of a disk from other disks
  - It is used for critical applications like logs
- Raid level 2 uses memory-style redundancy by using Hamming codes, which contain parity bits for distinct overlapping subsets of components. Level 2 includes both error detection and correction.
- Raid level 3 (single parity disks relying on the disk controller to figure out which disk has failed) and level 5 (block-level data striping) are preferred for Large volume storage, with level 3 giving higher transfer rates.
- Most popular uses of the RAID technology currently are: Level 0 (with striping), Level 1 (with mirroring) and Level 5 with an extra drive for parity.
- Design Decisions for RAID include – level of RAID, number of disks, choice of parity schemes, and grouping of disks for block-level striping.