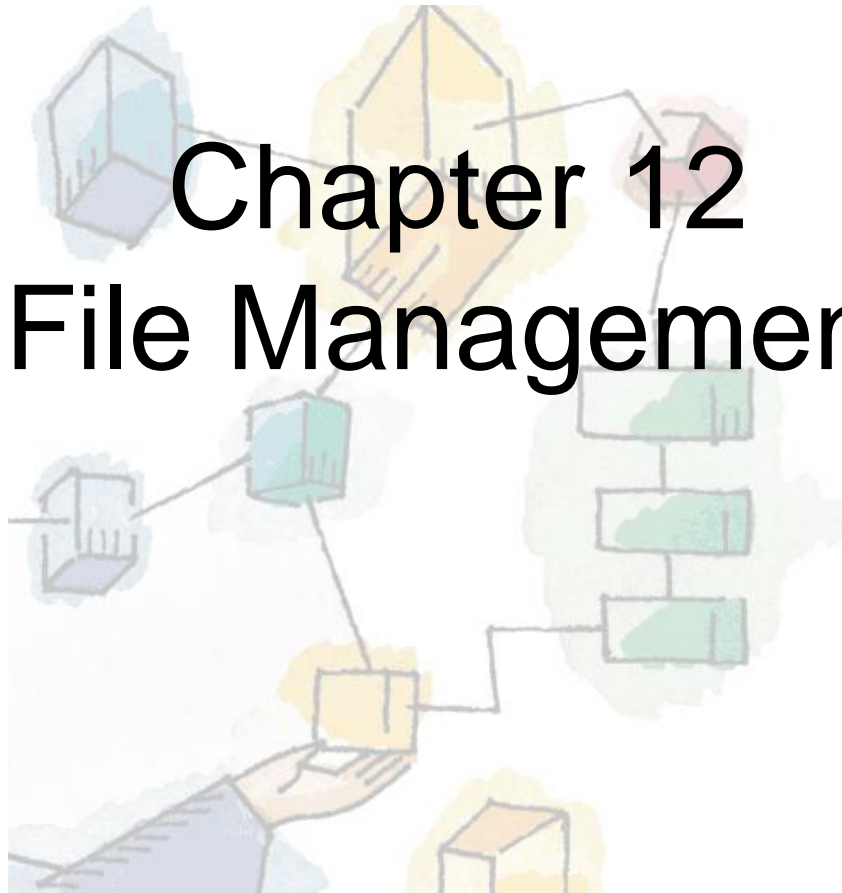*Operating Systems:*
Internals and Design Principles, 6/E
William Stallings

Chapter 12
File Management

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Roadmap

Overview

- File organisation and Access
- File Directories
- File Sharing
- Record Blocking
- Secondary Storage Management
- File System Security
- Unix File Management
- Linux Virtual File System
- Windows File System

Files

- Files are the central element to most applications
- The File System is one of the most important part of the OS to a user
- Desirable properties of files:
  - Long-term existence
  - Sharable between processes
  - Structure
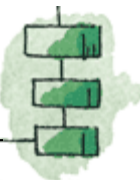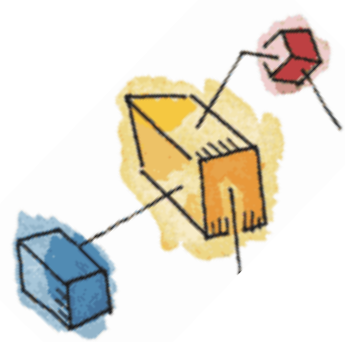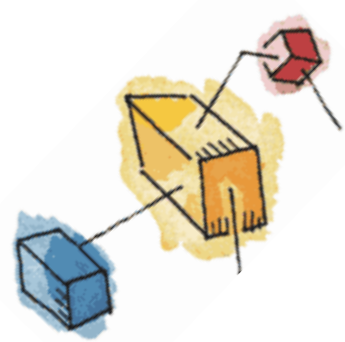
File Management

- File management system consists of system utility programs that run as privileged applications

- Concerned with secondary storage

Typical Operations

- File systems also provide functions which can be performed on files, typically:
    - Create
    - Delete
    - Open
    - Close
    - Read
    - Write

Terms

- Four terms are in common use when discussing files:
  - Field
  - Record
  - File
  - Database

Fields and Records

- Fields
  - Basic element of data
  - Contains a single value
  - Characterized by its length and data type
- Records
  - Collection of related fields
  - Treated as a unit

File and Database

- File
  - Have file names
  - Is a collection of similar records
  - Treated as a single entity
  - May implement access control mechanisms
- Database
  - Collection of related data
  - Relationships exist among elements
  - Consists of one or more files

File Management Systems

- Provides services to users and applications in the use of files
  - The way a user or application accesses files
- Programmer does not need to develop file management software

Objectives for a File Management System

- Meet the data management needs of the user

- Guarantee that the data in the file are valid

- Optimize performance

- Provide I/O support for a variety of storage device types

- Minimize lost or destroyed data

- Provide a standardized set of I/O interface routines to user processes

- Provide I/O support for multiple users (if needed)
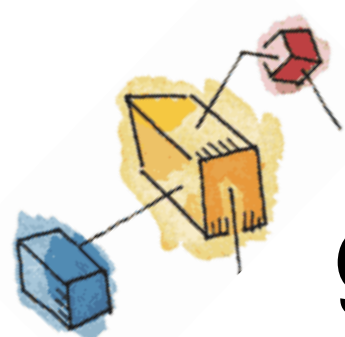
Requirements for a general purpose system

1. Each user should be able to create, delete, read, write and modify files

2. Each user may have controlled access to other users' files

3. Each user may control what type of accesses are allowed to the users' files

4. Each user should be able to restructure the user's files in a form appropriate to the problem

Requirements cont.

5. Each user should be able to move data between files

6. Each user should be able to back up and recover the user's files in case of damage

7. Each user should be able to access the user's files by using symbolic names
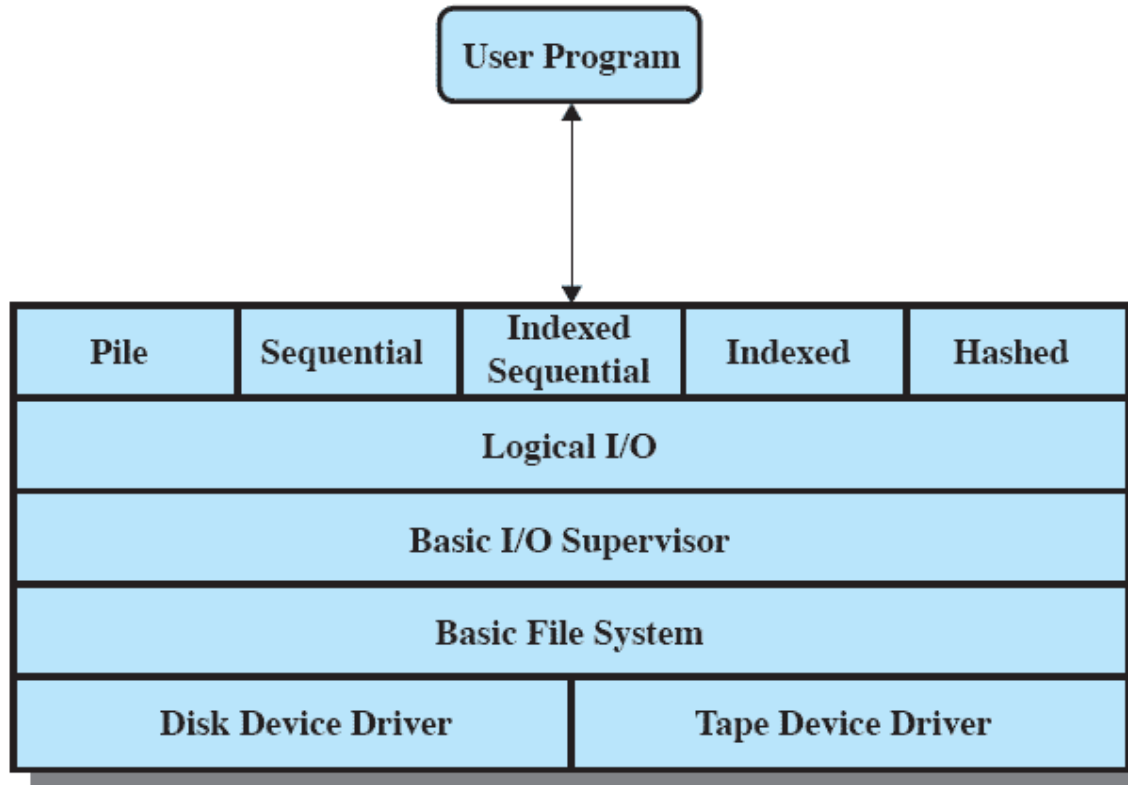
Typical software organization

User Program

Pile	Sequential	Indexed Sequential	Indexed	Hashed
Logical I/O				
Basic I/O Supervisor				
Basic File System				
Disk Device Driver		Tape Device Driver		

Figure 12.1   File System Software Architecture

Device Drivers

- Lowest level
- Communicates directly with peripheral devices
- Responsible for starting I/O operations on a device
- Processes the completion of an I/O request

Basic File System

- Physical I/O
- Primary interface with the environment outside the computer system
- Deals with exchanging blocks of data
- Concerned with the placement of blocks
- Concerned with buffering blocks in main memory

Basic I/O Supervisor

- Responsible for all file I/O initiation and termination.

- Control structures deal with
  - Device I/O,
  - Scheduling,
  - File status.

- Selects and schedules I/O with the device

Logical I/O

- Enables users and applications to access records

- Provides general-purpose record I/O capability

- Maintains basic data about file

Access Method

- Closest to the user

- Reflect different file structures

- Provides a standard interface between applications and the file systems and devices that hold the data

- Access method varies depending on the ways to access and process data for the device.
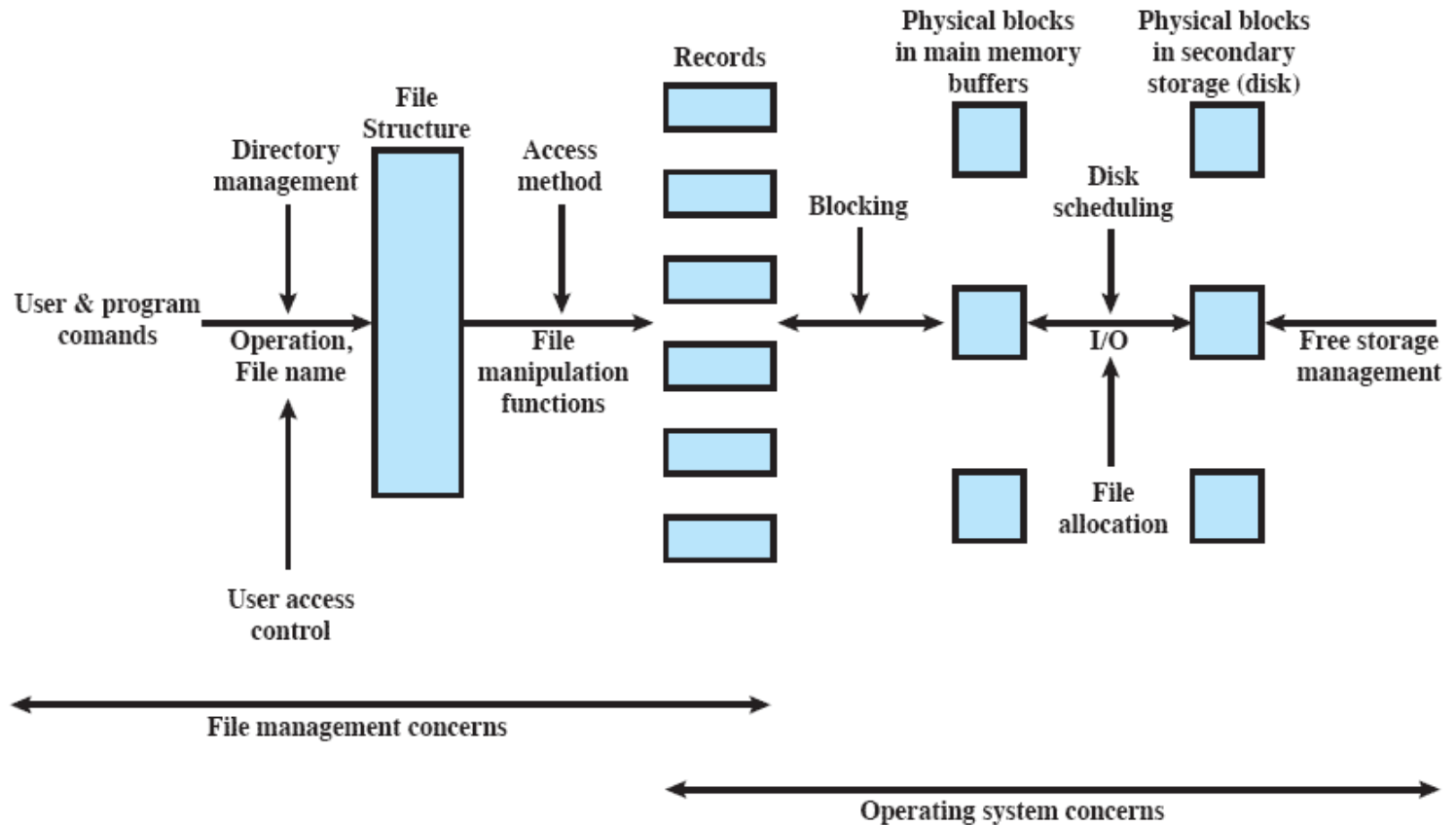
Elements of File Management

Figure 12.2   Elements of File Management

Roadmap

- Overview

→ File organisation and Access

- File Directories

- File Sharing

- Record Blocking

- Secondary Storage Management

- File System Security

- Unix File Management

- Linux Virtual File System

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File Organization

- File Management Referring to the logical structure of records
  - Physical organization discussed later
- Determined by the *way* in which files are accessed

Criteria for
File Organization

- Important criteria include:
    - Short access time
    - Ease of update
    - Economy of storage
    - Simple maintenance
    - Reliability
- Priority will differ depending on the use (e.g. read-only CD vs Hard Drive)
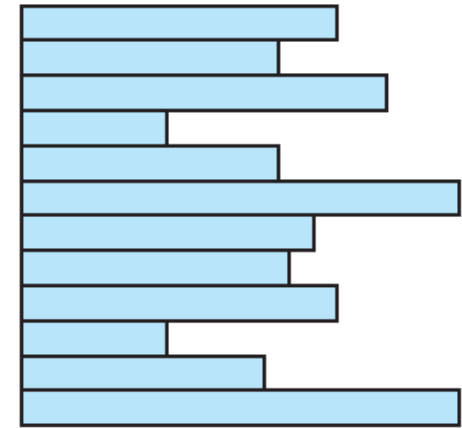   - Some may even conflict

File Organisation Types

- Many exist, but usually variations of:
  - Pile
  - Sequential file
  - Indexed sequential file
  - Indexed file
  - Direct, or hashed, file

The Pile

- Data are collected in the order they arrive
  - No structure
- Purpose is to accumulate a mass of data and save it
- Records may have different fields
- Record access is by exhaustive search

Variable-length records
Variable set of fields
Chronological order

(a) Pile File

The Sequential File

- Fixed format used for records

- Records are the same length

- All fields the same (order and length)

- Field names and lengths are attributes of the file

- Key field

  – Uniquely identifies the record

  – Records are stored in key sequence

Fixed-length records
Fixed set of fields in fixed order
Sequential order based on key field
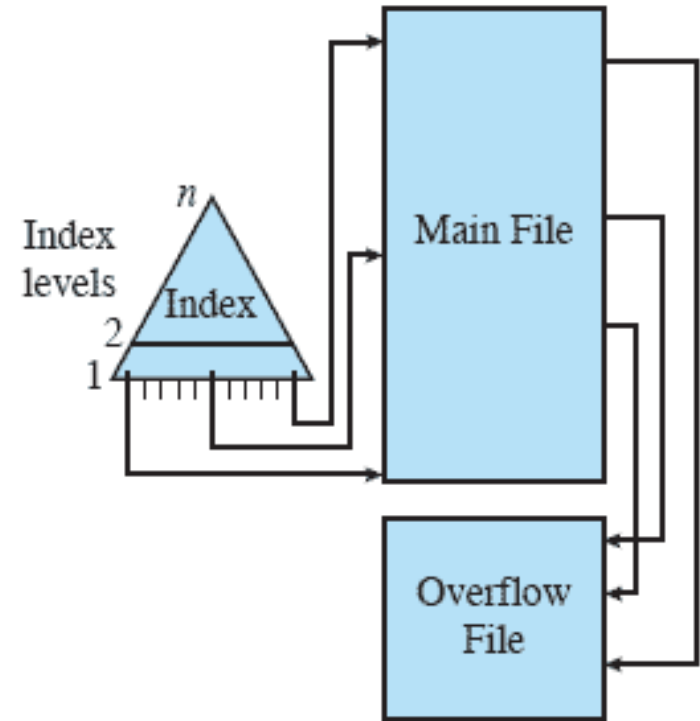
(b) Sequential File
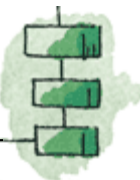
Indexed Sequential File

- Maintains the key characteristic of the sequential file:

  - records are organized in sequence based on a key field.

Two features are added:

  - an index to the file to support random access,

  - and an overflow file.

(c) Indexed Sequential File

Indexed File

- Uses multiple indexes for different key fields
  - May contain an exhaustive index that contains one entry for every record in the main file
  - May contain a partial index
- When a new record is added to the main file, all of the index files must be updated.

Exhaustive index Exhaustive index Partial index

Primary File
(variable-length records)
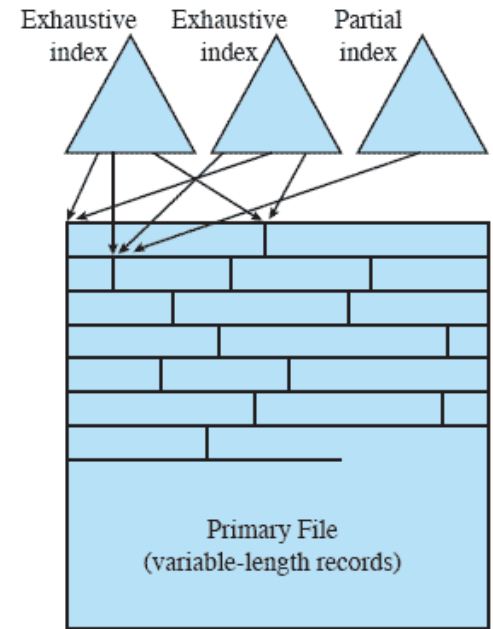
(d) Indexed File

File Organization

- Access directly any block of a known address.

- The Direct or Hashed File
  - Directly access a block at a known address
  - Key field required for each record

Performance

Table 12.1 Grades of Performance for Five Basic File Organizations [WIED87]

File Method	Space Attributes		Update Record Size		Retrieval		
	Variable	Fixed	Equal	Greater	Single record	Subset	Exhaustive
Pile	A	B	A	E	E	D	B
Sequential	F	A	D	F	F	D	A
Indexed sequential	F	B	B	D	B	D	B
Indexed	B	C	C	C	A	B	D
Hashed	F	B	B	F	B	F	E

A = Excellent, well suited to this purpose $\approx O(r)$
B = Good $\approx O(o \times r)$
C = Adequate $\approx O(r \log n)$
D = Requires some extra effort $\approx O(n)$
E = Possible with extreme effort $\approx O(r \times n)$
F = Not reasonable for this purpose $\approx O(n^{>1})$

where

r = size of the result
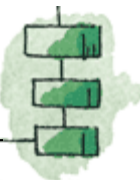o = number of records that overflow
n = number of records in file

Roadmap

- Overview
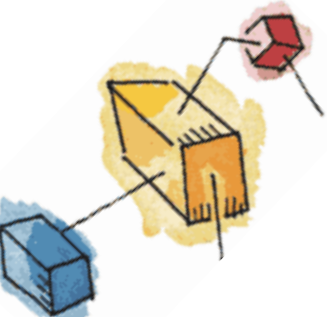- File organisation and Access
- **File Directories**
- File Sharing
- Record Blocking
- Secondary Storage Management
- File System Security
- Unix File Management
- Linux Virtual File System
- Windows File System

Contents

- Contains information about files
  - Attributes
  - Location
  - Ownership
- Directory itself is a file owned by the operating system
- Provides mapping between file names and the files themselves
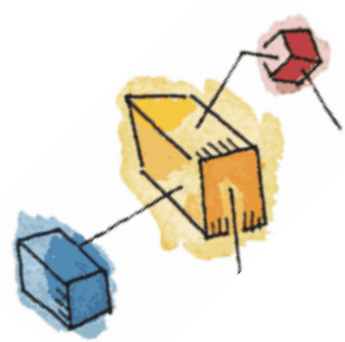
Directory Elements: Basic Information

- File Name
  - Name as chosen by creator (user or program).
  - Must be unique within a specific directory.
- File type
- File Organisation
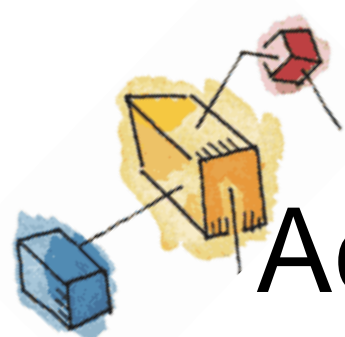 - For systems that support different organizations

Directory Elements: Address Information

- Volume
  - Indicates device on which file is stored
- Starting Address
- Size Used
  - Current size of the file in bytes, words, or blocks
- Size Allocated
  - The maximum size of the file

Directory Elements:
Access Control Information

- Owner
  - The owner may be able to grant/deny access to other users and to change these privileges.

- Access Information
  - May include the user's name and password for each authorized user.

- Permitted Actions
  - Controls reading, writing, executing, transmitting over a network

Directory Elements: Usage Information

- Date Created

- Identity of Creator

- Date Last Read Access

- Identity of Last Reader

- Date Last Modified

- Identity of Last Modifier

- Date of Last Backup

- Current Usage
  - Current activity, locks, etc

Simple Structure for a Directory

- The method for storing the previous information varies widely between systems
- Simplest is a list of entries, one for each file
  - Sequential file with the name of the file serving as the key
  - Provides no help in organizing the files
  - Forces user to be careful not to use the same name for two different files
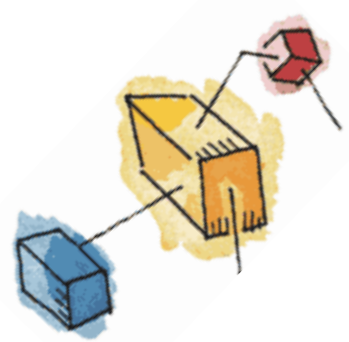
Operations Performed on a Directory

- A directory system should support a number of operations including:
  - Search
  - Create files
  - Deleting files
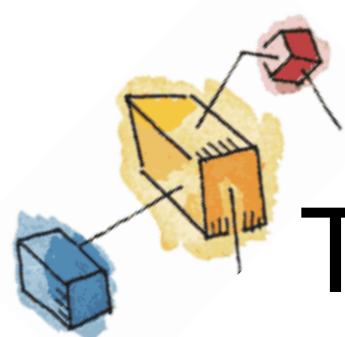 - Listing directory
  - Updating directory
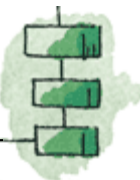
Two-Level Scheme for a Directory

- One directory for each user and a master directory
  - Master directory contains entry for each user
  - Provides address and access control information
- Each user directory is a simple list of files for that user
  - Does not provide structure for collections of files

Hierarchical, or Tree-Structured Directory

- Master directory with user directories underneath it

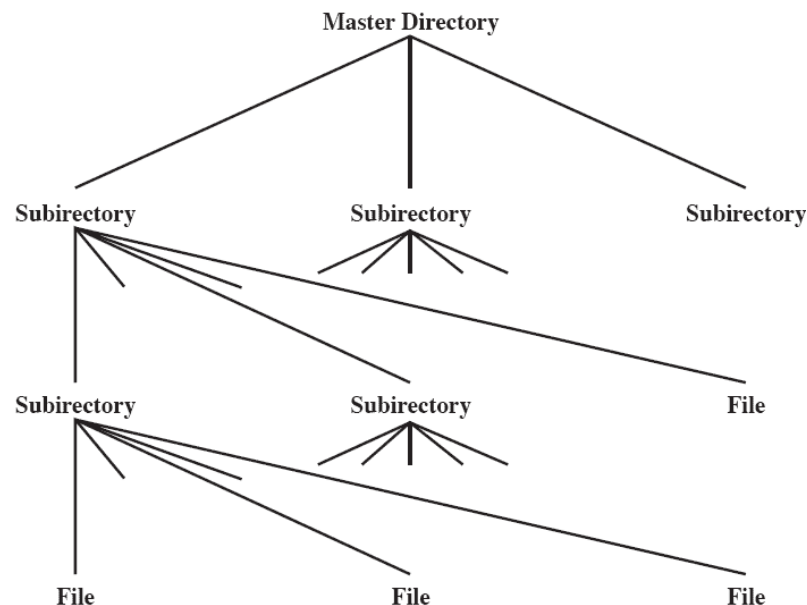- Each user directory may have subdirectories and files as entries

Master Directory

Subirectory   Subirectory   Subirectory

Subirectory   Subirectory   File

File   File   File

Figure 12.4 Tree-Structured Directory

Naming

- Users need to be able to refer to a file by name
  - Files need to be named uniquely, but users may not be aware of all filenames on a system
- The tree structure allows users to find a file by following the directory path
  - Duplicate filenames are possible if they have different pathnames
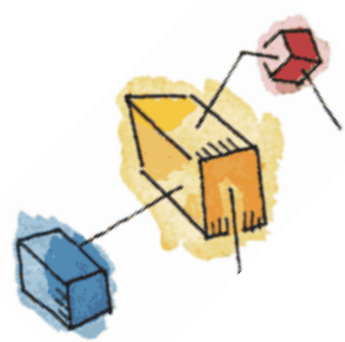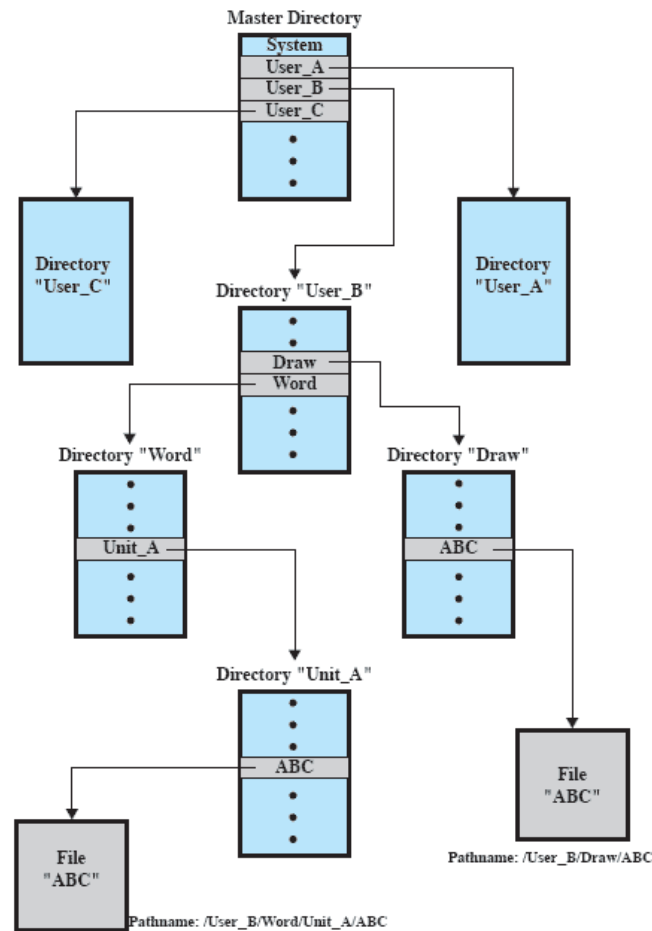
Example of Tree-Structured Directory

Figure 12.5 Example of Tree-Structured Directory

Working Directory

- Stating the full pathname and filename is awkward and tedious

- Usually an interactive user or process is associated with a **current** or **working directory**
  - All file names are referenced as being relative to the working directory unless an explicit full pathname is used

Roadmap

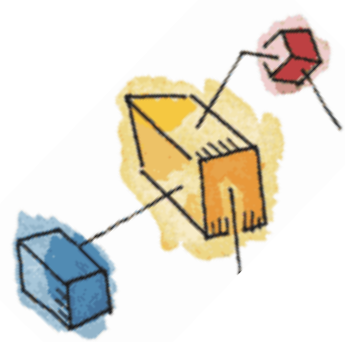- Overview
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File Sharing

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File Sharing

- In multiuser system, allow files to be shared among users

- Two issues
  - Access rights
  - Management of simultaneous access

Access Rights

- A wide variety of access rights have been used by various systems
  - often as a hierarchy where one right implies previous
- None
  - User may not even know of the files existence
- Knowledge
  - User can only determine that the file exists and who its owner is

Access Rights cont…

- Execution
  - The user can load and execute a program but cannot copy it

- Reading
  - The user can read the file for any purpose, including copying and execution

- Appending
  - The user can add data to the file but cannot modify or delete any of the file's contents

Access Rights cont…

- Updating
  - The user can modify, delete, and add to the file's data.

- Changing protection
  - User can change access rights granted to other users

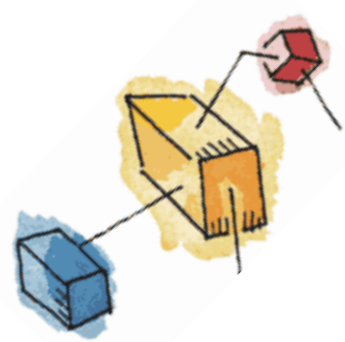- Deletion
  - User can delete the file

User Classes

- Owner
  - Usually the files creator, usually has full rights
- Specific Users
  - Rights may be explicitly granted to specific users
- User Groups
  - A set of users identified as a group
- All
  - everyone

Simultaneous Access

- User may lock entire file when it is to be updated

- User may lock the individual records during the update

- Mutual exclusion and deadlock are issues for shared access

Roadmap

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→ Record Blocking

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