OPERATING SYSTEMS: FILE SYSTEMS

Directories

Goals

- To know the concepts of file and directory and their characteristics.
- To use file and directory management services offered by de operating system.
- To understand a file system structure.
- To understand the mechanisms supporting a file server and to apply them to simple exercises.

Content

- **Directories**
- Structure alternatives
- Name interpretation
- Directory handling.

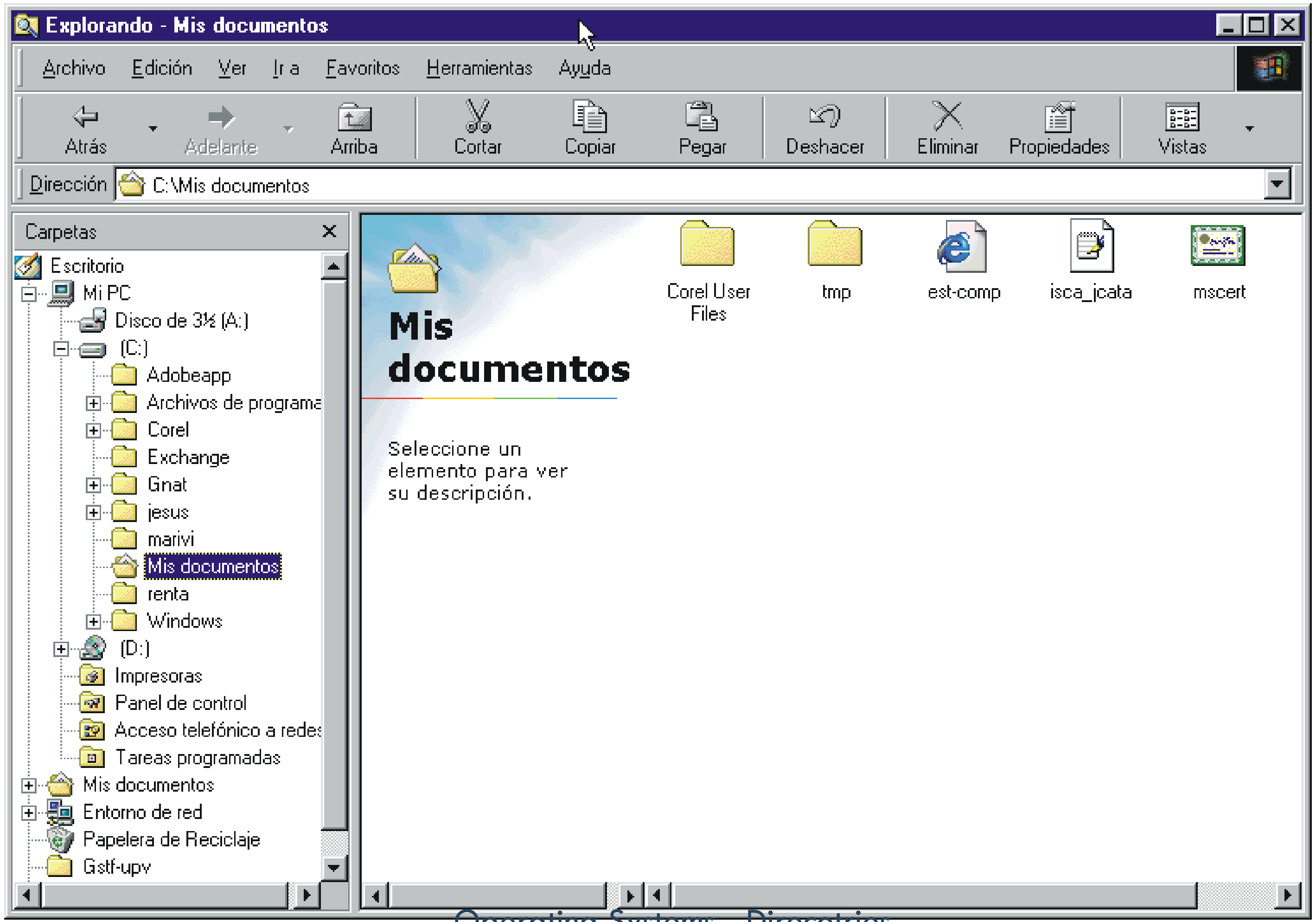
File organization

- A file system may store a great number of files.
- Mechanism needed to organize and locate files.
  - **Extensions**: Organization by file type.
  - **Directory**: Folder with documents metaphor.

Concept

- **Directory:**
  - Object uniquely relating a user file name with an internal file descriptor.
- Organize and provide information about structure of file systems.
- A directory has an entry per stored file.
- Entry information:
  - Internal file descriptor.
  - Possible, some file attributes.

Example: Windows explorer



Seleccione un elemento para ver su descripción.

Directories: logical view

- Hierarchical approach.
- When a file is opened the OS looks for the name in the directory structure.

- Operations on directories:
  - Create and erase directories.
  - Open and close directories.
  - Rename directory.
  - Read directory entries.

- Directory hierarchical organization:
  - Simplifies file naming (unique names).
  - Provides distribution management => group files logically (same user, same application, same task, …)

Content

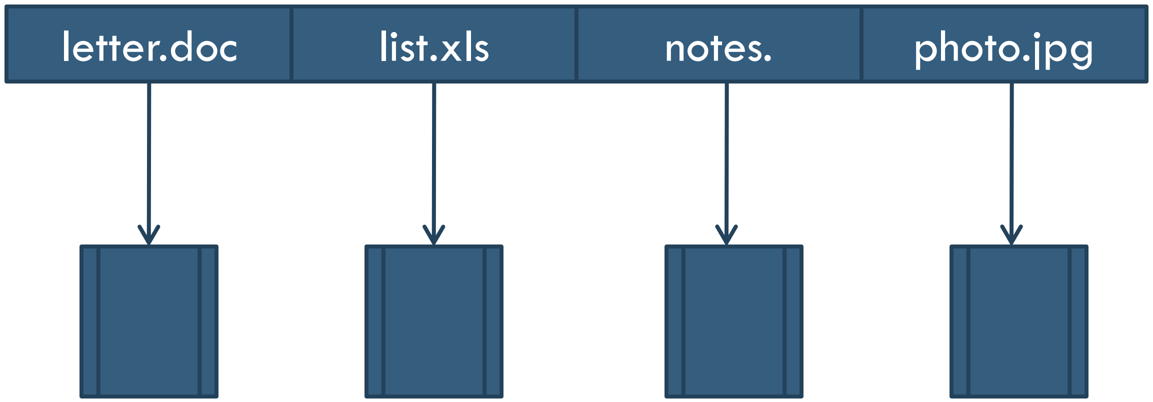
- Directories
- **Structure alternatives**
- Name interpretation
- Directory handling.

Structure alternatives

- Single level directory.
- Two-levels directory.
- Tree structure directory.
- DAG (directed acyclic graph) structure directory.
- Generalized graph structure directory.

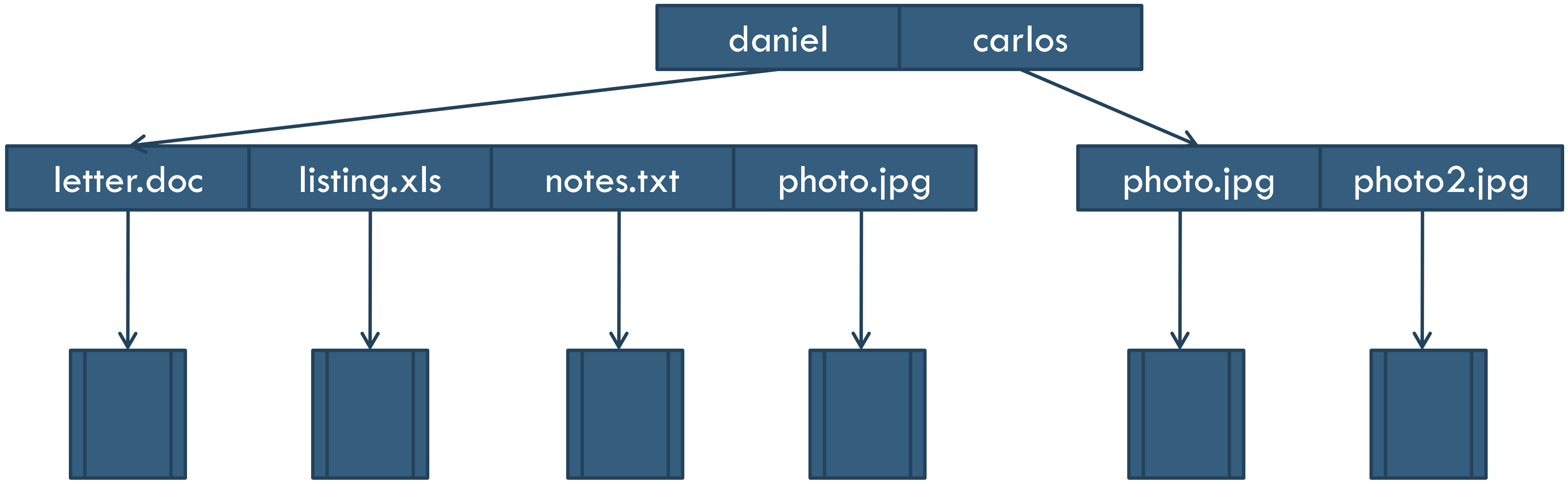
Single level directory

- A single directory for all users.
- Problems with file naming.
  - High probability of name coincidence.



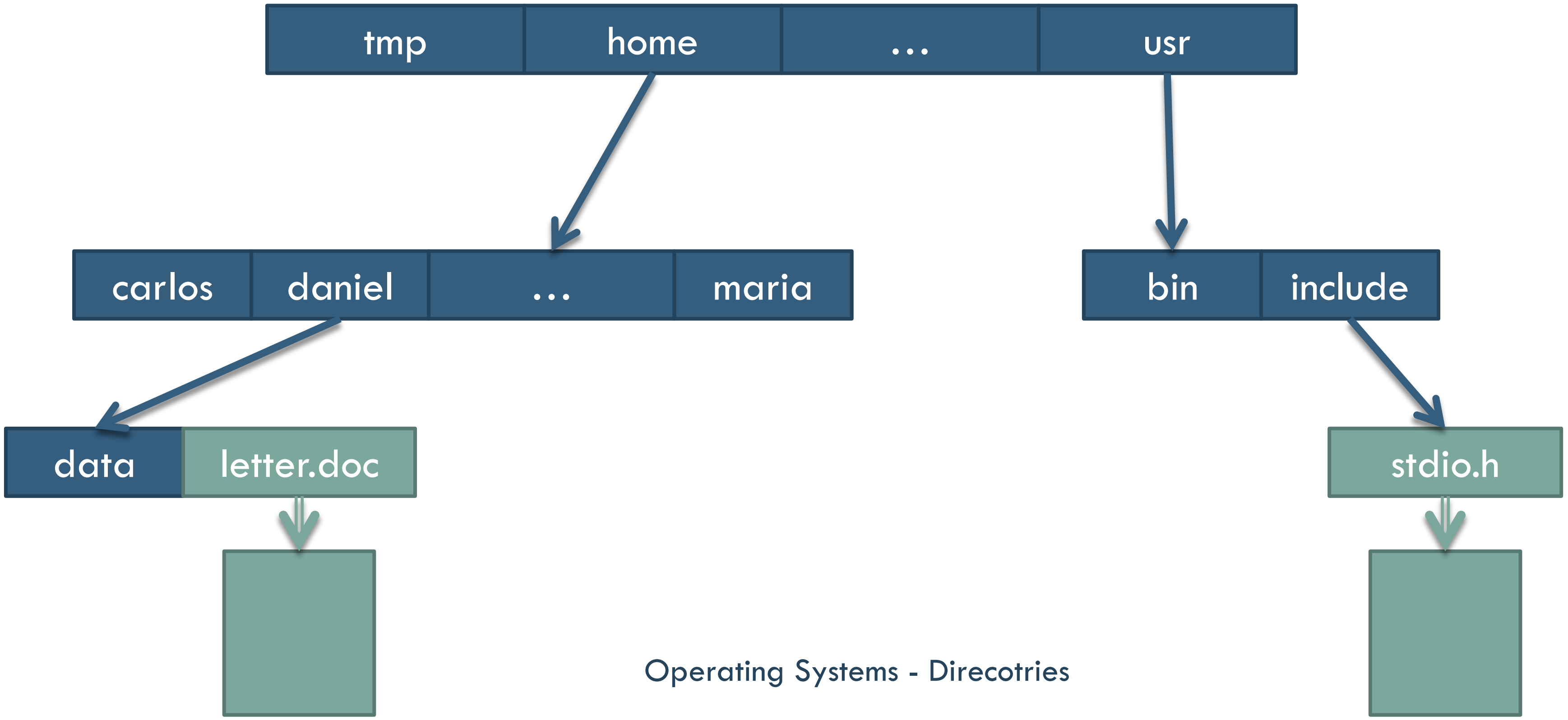
Two-levels directory

- A directory per user.
- Automated or manual path.
- Same file name for multiple users is valid.
- Efficient lookup, but grouping problems.



Tree structure directory

- Efficient lookup.
- Relative and absolute naming -> working directory.



Tree structure directory

- Absolute names contain the full path.
- Relative names start from working (or current) directory.
- Directory change:

  cd /spell/mail/prog

  cd prog
- Erase file: **rm** <filename>
- Create directory: **mkdir** <dir-name>
- Example:

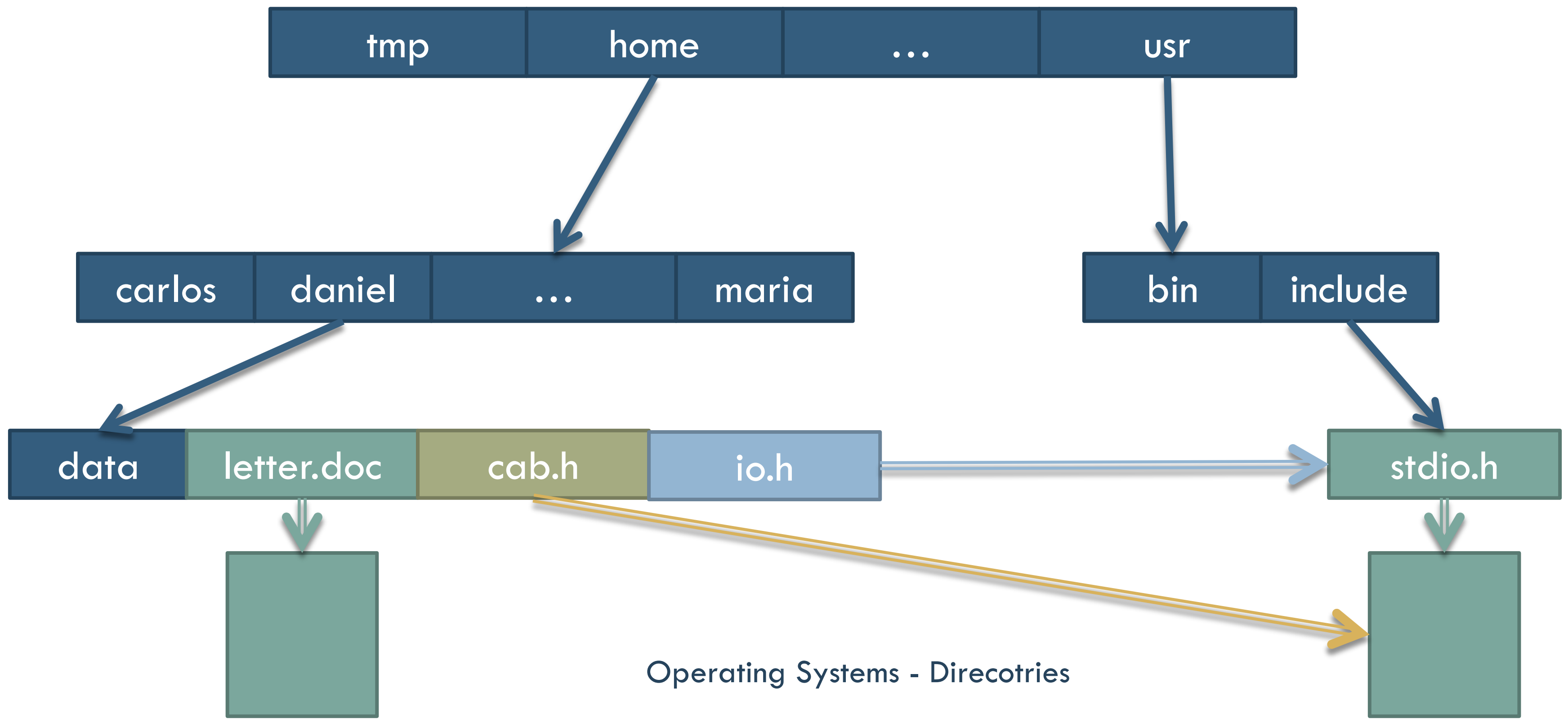
  cd /spell/mail

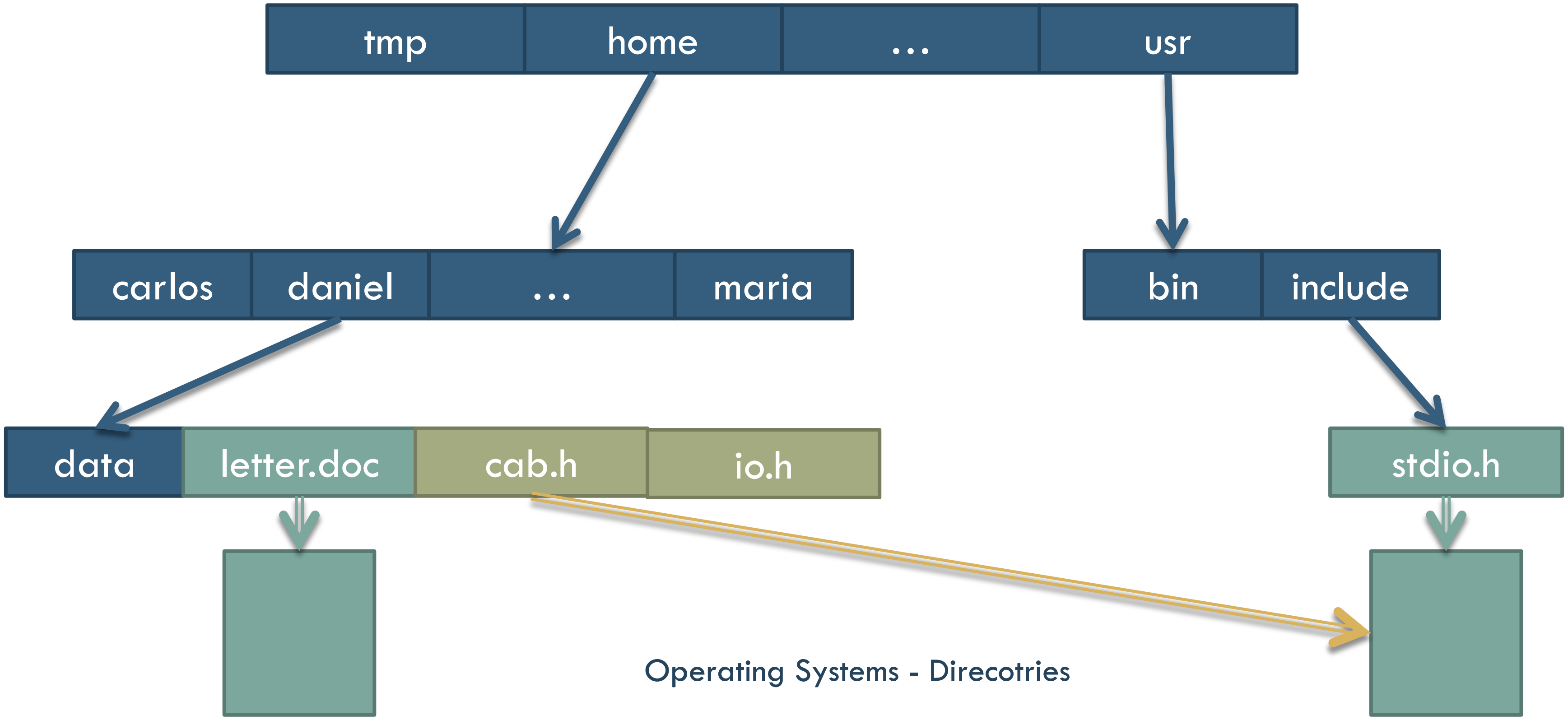
  mkdir count

  ls /spell/mail/count
- Erase directory: **rm** -r mail

Acyclic graph structure directory

- Has shared files and directories.
- Concept not visible to Windows users.




tmp
home
…
usr
carlos
daniel
…
maria
bin
include
data
letter.doc
cab.h
io.h
stdio.h

Acyclic graph directory

- **link**: A file with multiple names -> link control
  - A single file with link count in descriptor (physical link).
  - New file type with target name in file content (symbolic link).
- Link removal:
  A. Decrement counter; if 0 erase file.
  B. Traverse links and erase all.
  C. Erase only link and leave the rest.
- Problem: Loops in tree.
- Solutions:
  - Allow only links to files, but not for directories.
  - Loop finding algorithm whne link is created.

- UNIX implementation limitation: physical links only within same file system.

Directory structure

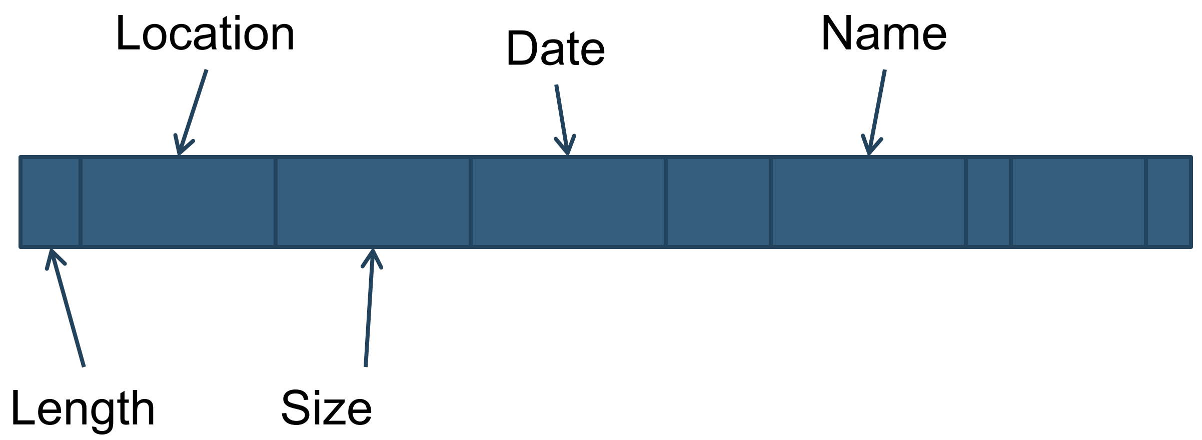
- Directory structure and files stored in disks.
- Implementation alternatives for directories:
  - Use special block with directory information.
  - Use file whose content is the directory.
- Information in directory: name, type, address, max and current length, access and modification time, owner, …
  - In case of using a file, most are file metadata.

Directory structure: alternatives

- Directories for contiguous files.
  - Assume all files are stored with contiguous allocation.
- Directories for linked files.
  - Assume all files are stored with non-contiguous allocation and blocks are represented as a linked list.
- Directories for indexed files.
  - Assume all files are stored with non-contiguous allocation and blocks or extents are represented through an indexed structure.

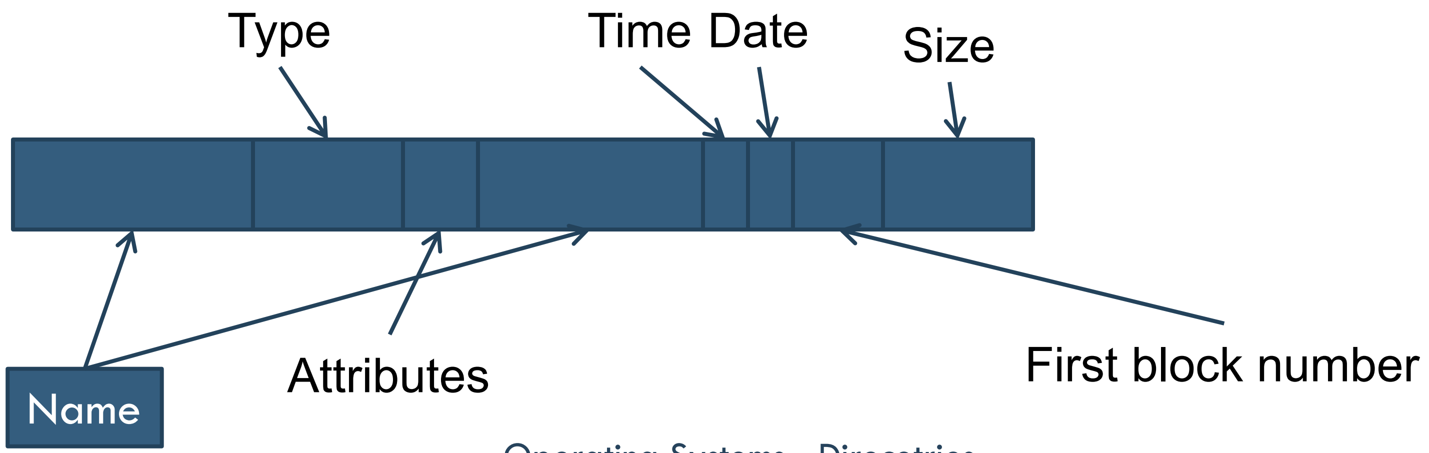
Directories for contiguous files

- Directory entry:
  - File attributes in directory entry.
  - File first block identifier.
  - File size.
- Example: ISO-9660 format for CD-ROM



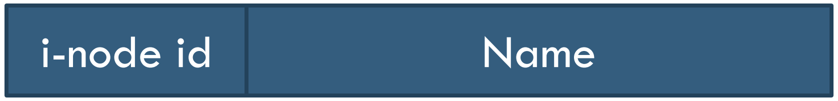
Directory for linked files

- Directory entry:
  - File attributes.
  - First block number.
  - File size.
- Example: FAT



Directory for indexed files

- Most used alternative
- Directory entry:
  - Name.
  - Metada identifier for file (i-node, MFT entry, …)



Directories for indexed files.

- Advantages:
  - No need to modify directory to change file attributes.
  - No need to modify directory when file changes its length.
  - An i-node may represent a directory or a file.
    - Simplified construction of hierarchical systems.
  - Name length is not prefixed.
  - Easy creation of name synonyms for a file name.

Directory organization

- Efficiency: fast file lookup.
- Naming: Convenient and easy for users.
  - Two users may have the same name for different files.
  - Same file may have different names.
  - Variable length names.
- Grouping:
  - Logical grouping for files according to properties (e.g. c++ programs, games, …)
- Structuring:
  - Clearly defined operations and hiding.
- Simplification:
  - Directory entre must be as simple as possible.

Hierarchical naming

- Absolute name: Path from root directory (/ in GNU/Linxu, \ in Windows).
- Relative name Path from directory different from root.
  - Example: (you are in /users/) daniel/keys
  - Relative to working directory (*pwd*)
- Special directories:
  - . Working directory. Example: cp / users/daniel/keys.
  - .. Parent directory. Example: ls ..
  - `HOME`: Base directory for user.

Content

- Directories
- Structure alternatives
- **Name interpretation**
- Directory handling.

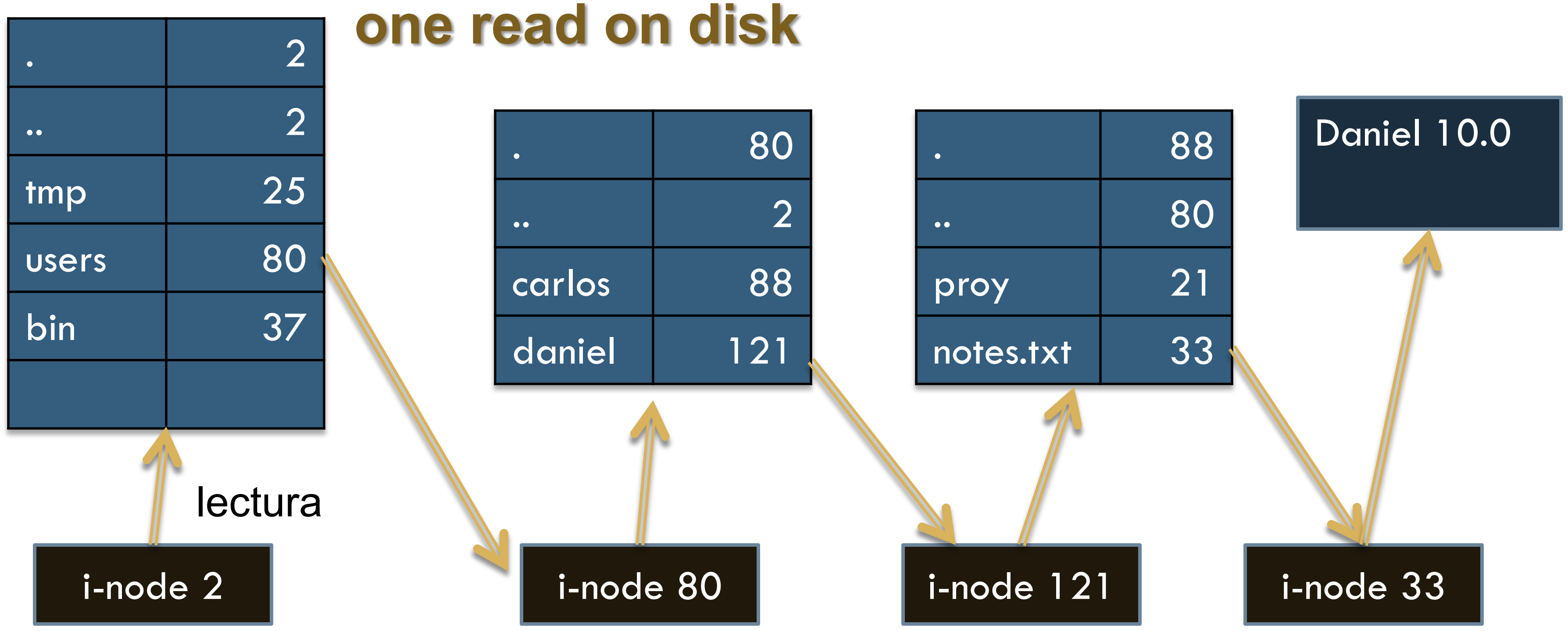
Name interpretation in UNIX

- Each directory is stored as a file with pairs <i-node number, file-name>.
- Initially in memory directory for /.
- How many disk blocks does a directory needs for storage?
  - Depends on number of files in directory and length of names.
- Lookup in directory is sequential.

Name interpretation in UNIX

- Find i-node for file /users/daniel/notes.txt.

Directory traversing many lead to more than one read on disk



Directory hierarchy

- Single directory tree?
  - Per logical device in Windows (c:\users\carlos\keys, j:\joe\tmp, ...)
  - System wide in UNIX (/users/carlos/keys, /joe/tmp, …)

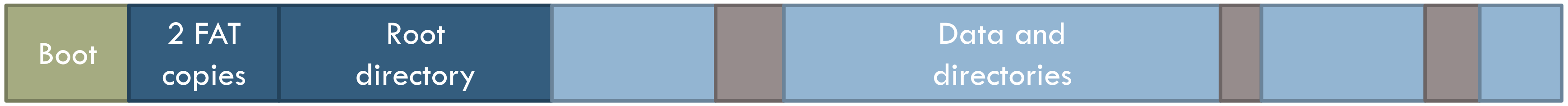
- Services for building hierarchy are needed: **mount** and **umount**.
  - mount /dev/hda /users
  - umount /users

- **Advantages**:
  - Single system image and hiding device type.
- **Drawbacks**:
  - More complex name translation.
  - Problems with physical file links.

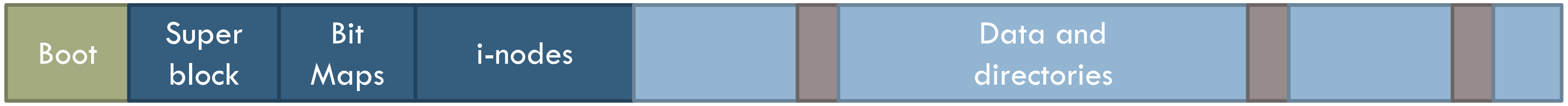
File systems and partitions

- Volume:
  - Set of coherent metainformation and data.

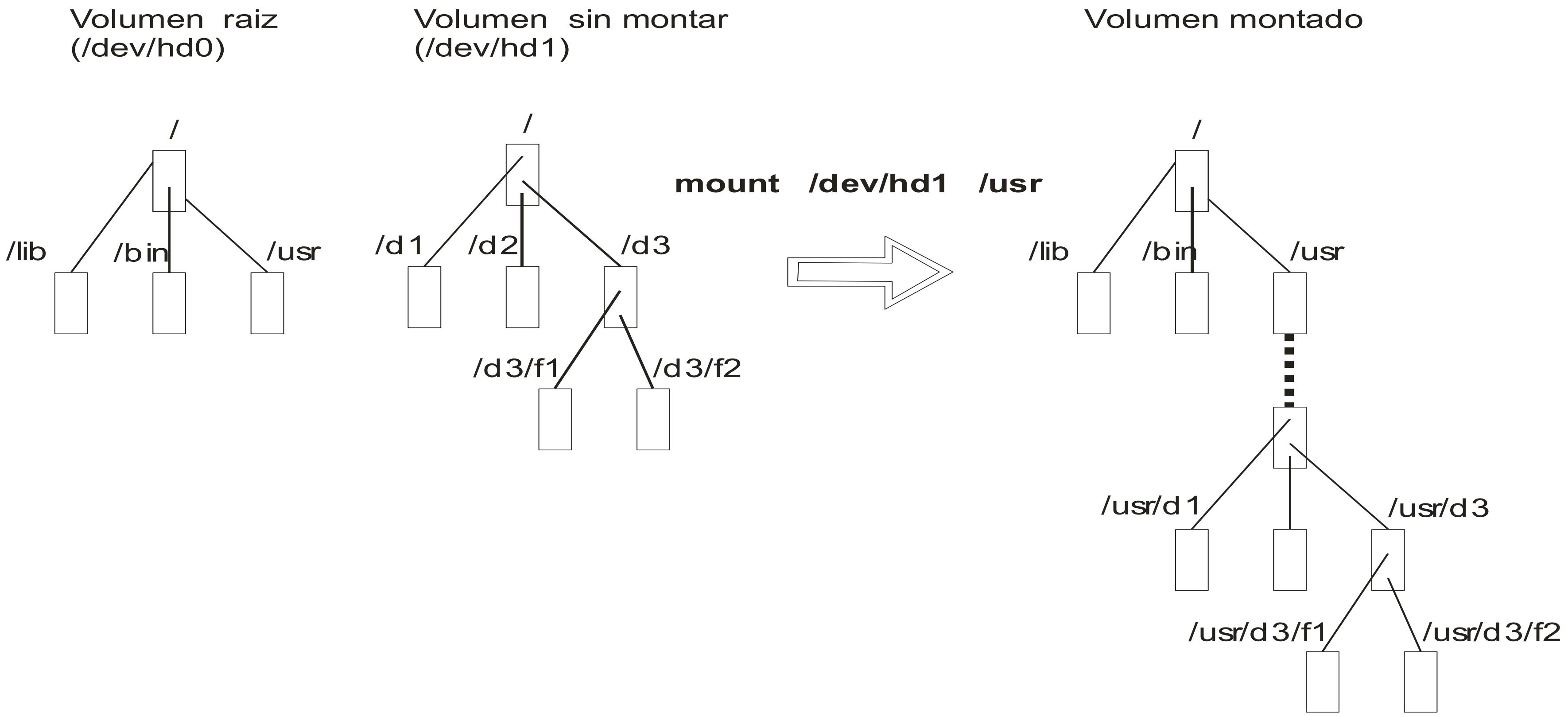
FAT



UNIX



Mounting partitions



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- **Directory handling.**

Example: directory handling

- Services for handling files representing directories.
- How does one know if a name corresponds to a file or a directory?
- Service:

```
#include <sys/types.h>
#include <sys/stat.h>
int stat(char *name, struct stat *buf);
int fstat(int fd, struct stat *buf);
…
cond = S_ISDIR(s.st_mode) /* true for directories*/
```

Mkdir – Create directory

- Service:

```
#include <sys/types.h>
#include <dirent.h>
int mkdir(const char *name, mode_t mode);
```

- Arguments:
  - **name**: directory name.
  - **mode**: protection bits.

- Returns:
  - Zero or -1 on error.

- Description:
  - Creates a directory named **name**.
  - Owner UID = effective UID.
  - Owner GID = effective GID.

Rmdir – Remove directory

- Service:

```
#include <sys/types.h>
int rmdir(const char *name);
```

- Arguments:
  - **name**: Directory name.
- Returns:
  - Zero or -1 on error.
- Decription:
  - Remove directory if it is empty.
  - Otherwise directory is not removed.

Opendir – Open a directory

- Service:

```
#include <sys/types.h>
#include <dirent.h>
DIR *opendir(char * name);
```

- Arguments:
  - **dirname**: Directory name.
- Returns:
  - A pointor to be used with **readdir()** or **closedir()**.
  - NULL on error.
- Description:
  - Opens a directory as a sequence of entries.
  - Places pointer in first entry.

Closedir – Cerrar un directorio

- Service:

```
#include <sys/types.h>
#include <dirent.h>
int closedir(DIR *dirp);
```

- Arguments:
  - **dirp**: Pointer returned by opendir().
- Returns:
  - Zero or -1 if error.
- Description:
  - Closes association between **dirp** and directory entry sequence.

Readdir – Read directory entries

- Service:

```
#include <sys/types.h>
#include <dirent.h>
struct dirent *readdir(DIR *dirp);
```

- Arguments:
  - **dirp**: pointer returned by **opendir**().

- Returns:
  - A pointer to an object of type **struct dirent** representing directory.
  - **NULL** on error.

- Description:
  - Returns next entry in directory associated to dirp and advances pointer.
  - Structure is implementation dependent but you can assume it has a member **char* d_name**.

Rewindir – Position directory pointer

- Service:

```
#include <sys/types.h>
#include <dirent.h>
void rewindir(DIR *dirp);
```

- Arguments:
  - **dirp**: pointer returned by opendir().

- Description:
  - Sets directory position pointer to the first entry.

Link – Create a directory entry

- Service:
```
#include <unistd.h>
int link(const char *existing, const char *new);
int symlink(const char *existing, const char *new);
```
- Arguments:
  - **existing**: Name of existing file.
  - **new**: name of new entry that will be linked to existing file.
- Returns:
  - Zero or -1 if error.
- Description:
  - Create a new physical or symbolic link to an existing file.
  - The OS does not record which is the original file and which is the new one.

Unlink – Remove directory entry

- Service:

```
#include <sys/types>
int unlink(char *name);
```

- Arguments:
  - **name**: File name.
- Returns:
  - Zero or -1 if error.
- Description:
  - Removes entry to directory and decrements number of links to file.
  - When number of links equals zero and no process keeps it open, space if freed and file is no longer accessible.

Chdir – Change current directory

- Service:

```
int chdir(char *name);
```

- Arguments:
  - **name**: directory name
- Returns:
  - Zero or –1 if error.
- Description:
  - Modifies current directory used to form relative paths.

Rename – Change file name

- **Service:**

```
#include <unistd.h>
int rename(char *old, char *new);
```

- **Arguments:**
  - **old**: Name of existing file.
  - **new**: New file name.

- **Returns:**
  - Zero or -1 if error.

- **Description:**
  - Change name of file **old**.
  - New name is **new**.

Getcwd – Get name of current directory

- Service:

```
char *getcwd(char *buf, size_t size);
```

- Arguments:
  - **buf**: pointer to buffer to store name of current directory.
  - **size**: Length in byts of buffer.

- Returns:
  - Pointer to **buf** or **NULL** if error.

- Description:
  - Gets name of current directory.

Example: Directory listing

```
#include <sys/types.h>
#include <dirent.h>
#include <stdio.h>

#define MAX_BUF   256

void main(int argc, char **argv) {
  DIR *dirp;
  struct dirent *dp;
  char buf[MAX_BUF];

  /* print current directory*/
  getcwd(buf, MAX_BUF);
  printf(“Current directory: %s\n", buf);
```

Example: Directory listing

```
 /* Open directory argument */
 dirp = opendir(argv[1]);

 if (dirp == NULL)  {
   fprintf(stderr,“Cannot open %s\n", argv[1]);
 }
 else {
   /* read entry by entry*/
   while ( (dp = readdir(dirp)) != NULL)
     printf("%s\n", dp->d_name);
   closedir(dirp);
 }
 exit(0);
}
```