Week 10
Project 3: An Introduction to File Systems

Classes COP4610 / CGS5765

Florida State University

Introduction

- The goal of project 3 is to understand
  - basic file system design and implementation
  - file system testing
  - data serialization/de-serialization
- At the end of the project, you will feel like a file system expert!

Outline

- Background
  - Setting up your environment
  - Mounting file systems
- Project 3
  - Specification
  - Downloading and testing file system image
  - General FAT32 data structures
  - Endian-ness

Environment Setup

Get ready for Project 3!

Project 3 Environment

- Must develop inside Linux environment with root access
  - Use Debian virtual machine or lab machine from project 2
- I will be grading your projects inside of my copy of the class virtual machine

Project Environment

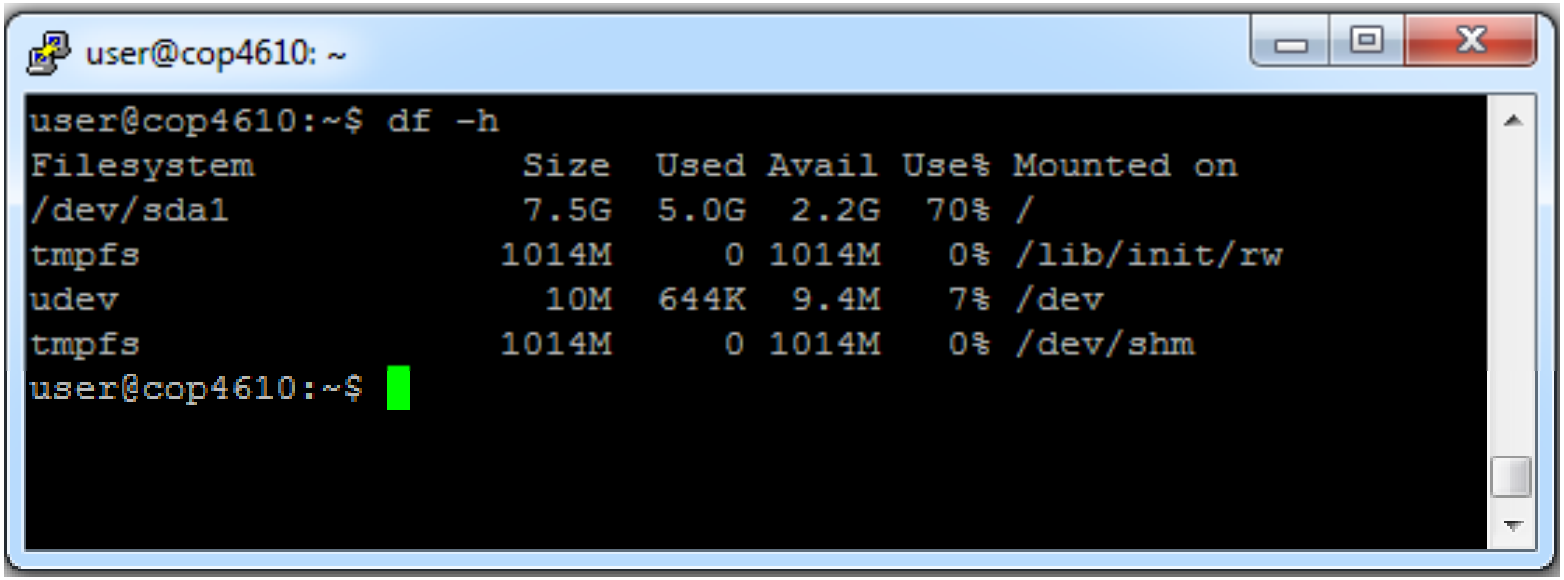
- Kernel version no longer matters
  - Can go back to the default 2.6.26 version if you trust it more
- Entire project will be in userspace, not kernel!
  - Please use debuggers, they will save you time
    - gdb, ddd, others…
- Programming language is still C

Running out of room?

- You must have at least 64MB free plus room for your source code
- To see how much room you have left inside your machine, issue the following command:

```
$> df -h
```

df -h



- /dev/sda is root file system mounted on "/"
  - Has 2.2GB currently available

Cleaning up space

- If you need to clean up some more space
  - Issue ‘make clean’ inside of your 2.6.32 kernel source
  - Delete the 2.6.26 kernel source

Mounting File Systems

Unix File Hierarchy

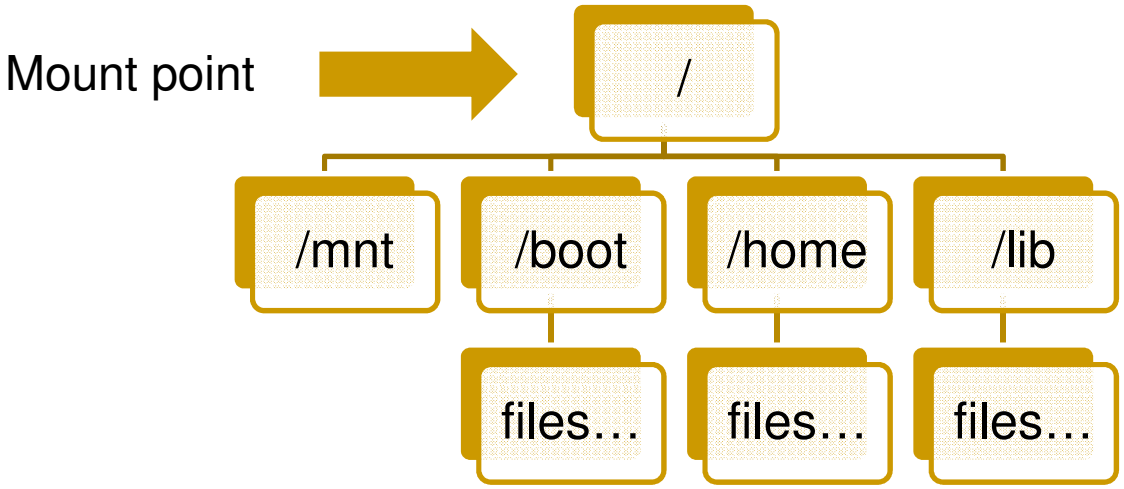
- All files accessible in a Unix system are arranged in one big tree
  - Also called the ***file hierarchy***
  - Tree is rooted (starts) at /
- These files can be spread out over several devices
- The **mount** command serves to attach the file system found on some device to the big file tree

‘mount’ command

- `mount`
- `mount <device> <mount directory>`

- Typing ‘mount’ without arguments shows you what is mounted and where
- Second example attaches a device or partition to a directory
  - Must have root privileges

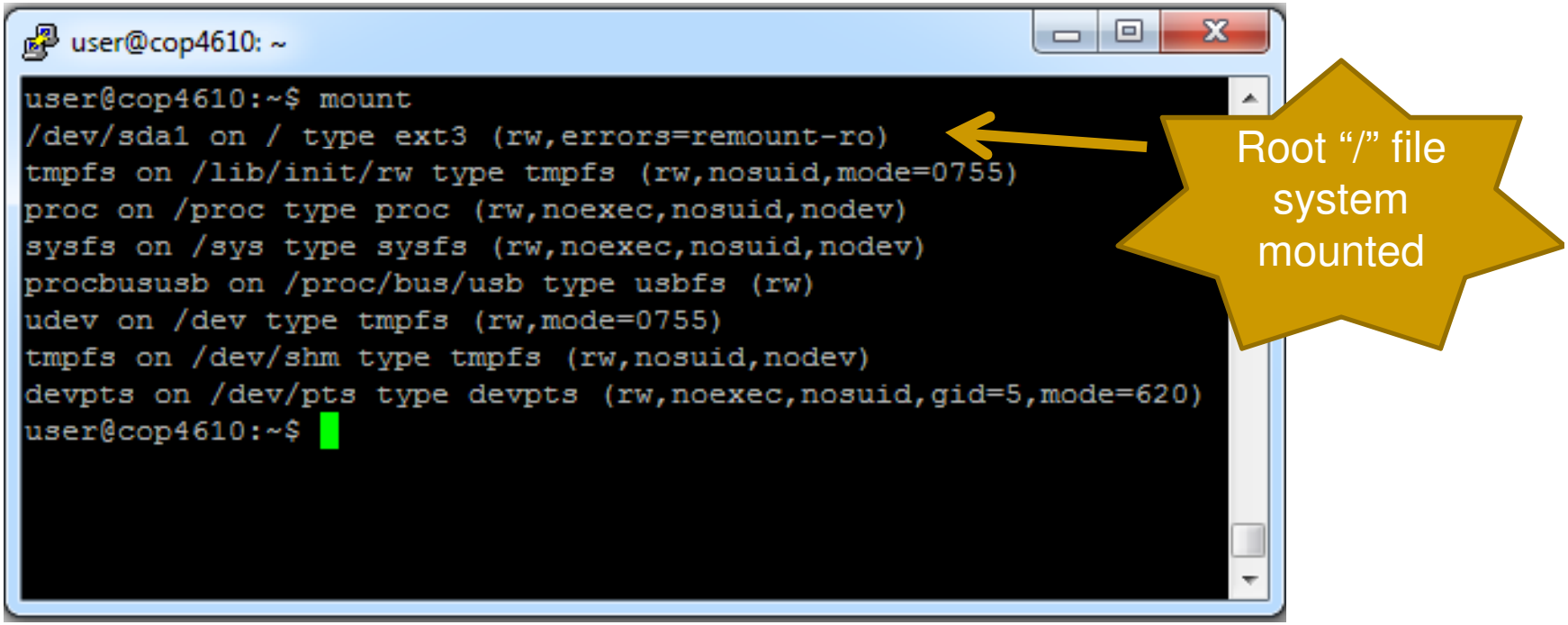
Mount Example



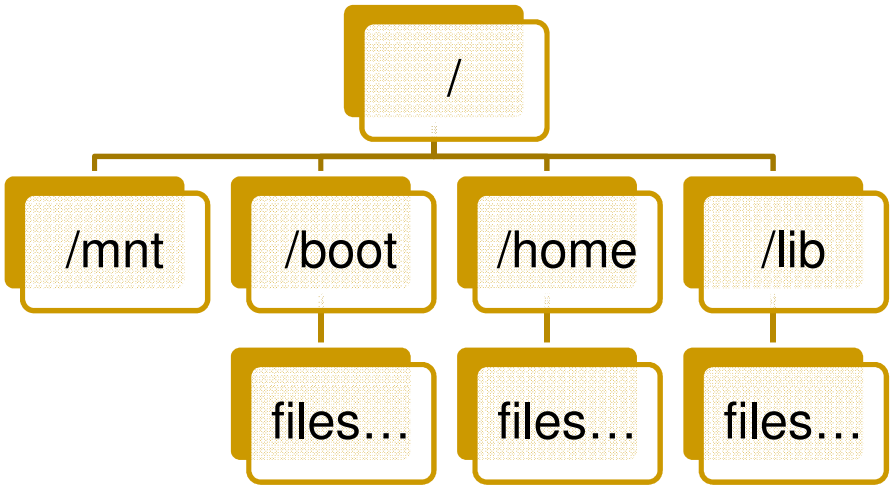
The device sda partition 1 is mounted at “/”. All files and dirs below “/” come from this device.

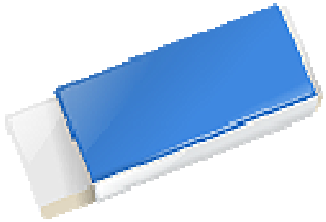
Mount Example

- Type command ‘mount’ without any arguments to see what is mounted and where



Mount Example

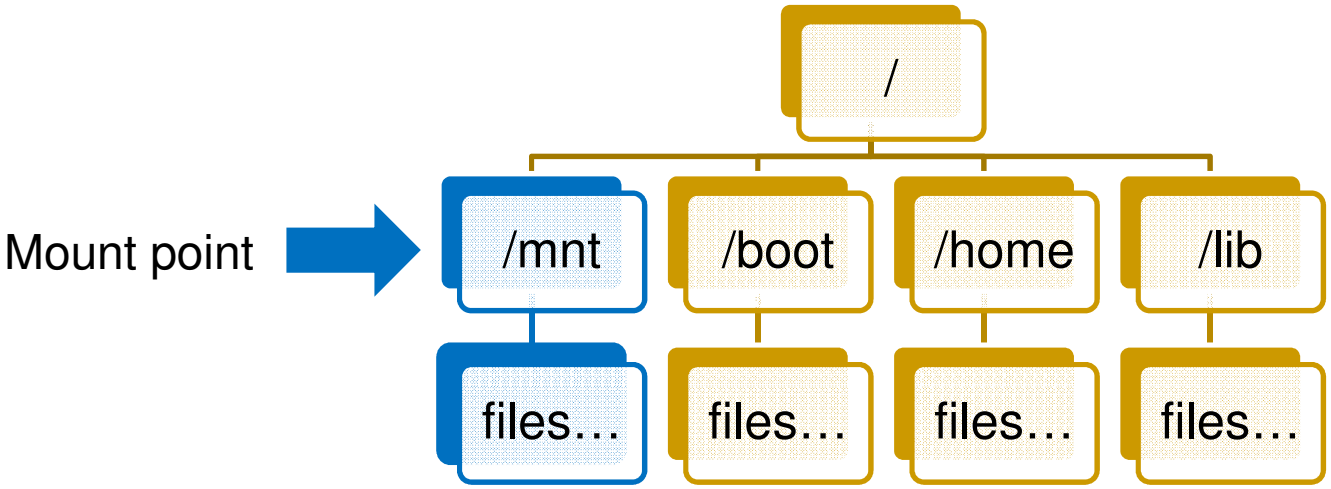


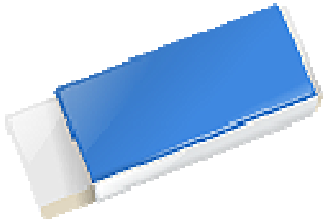


/dev/sdb1

Now suppose we attach a thumb drive and want our thumb drive files accessible under /mnt…

File Hierarchy Example



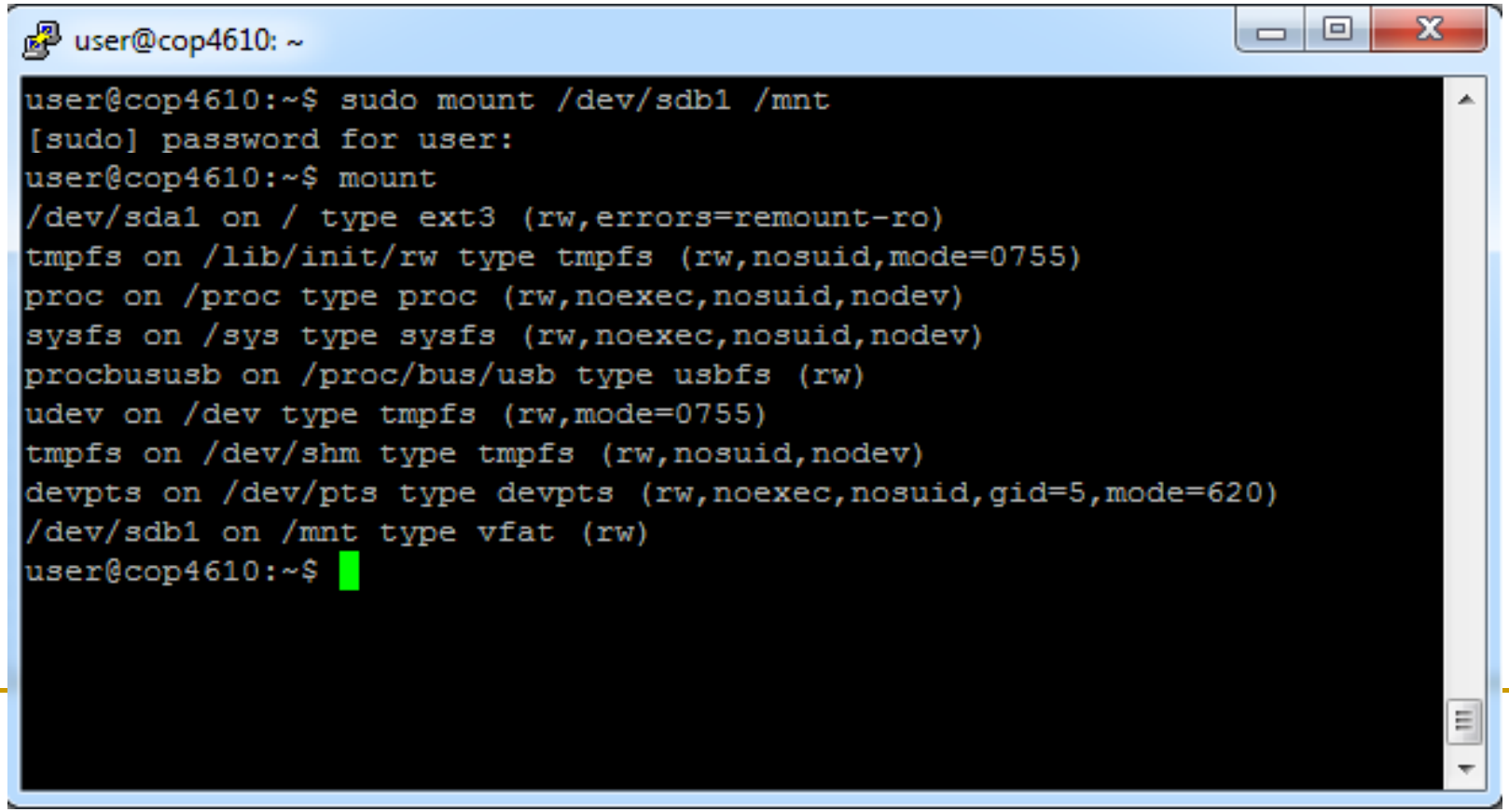


/dev/sdb1

Files from the thumb drive are now accessible under /mnt

Mount Example

- The ‘mount’ command can dynamically attach new devices to new mount points



Mount Example

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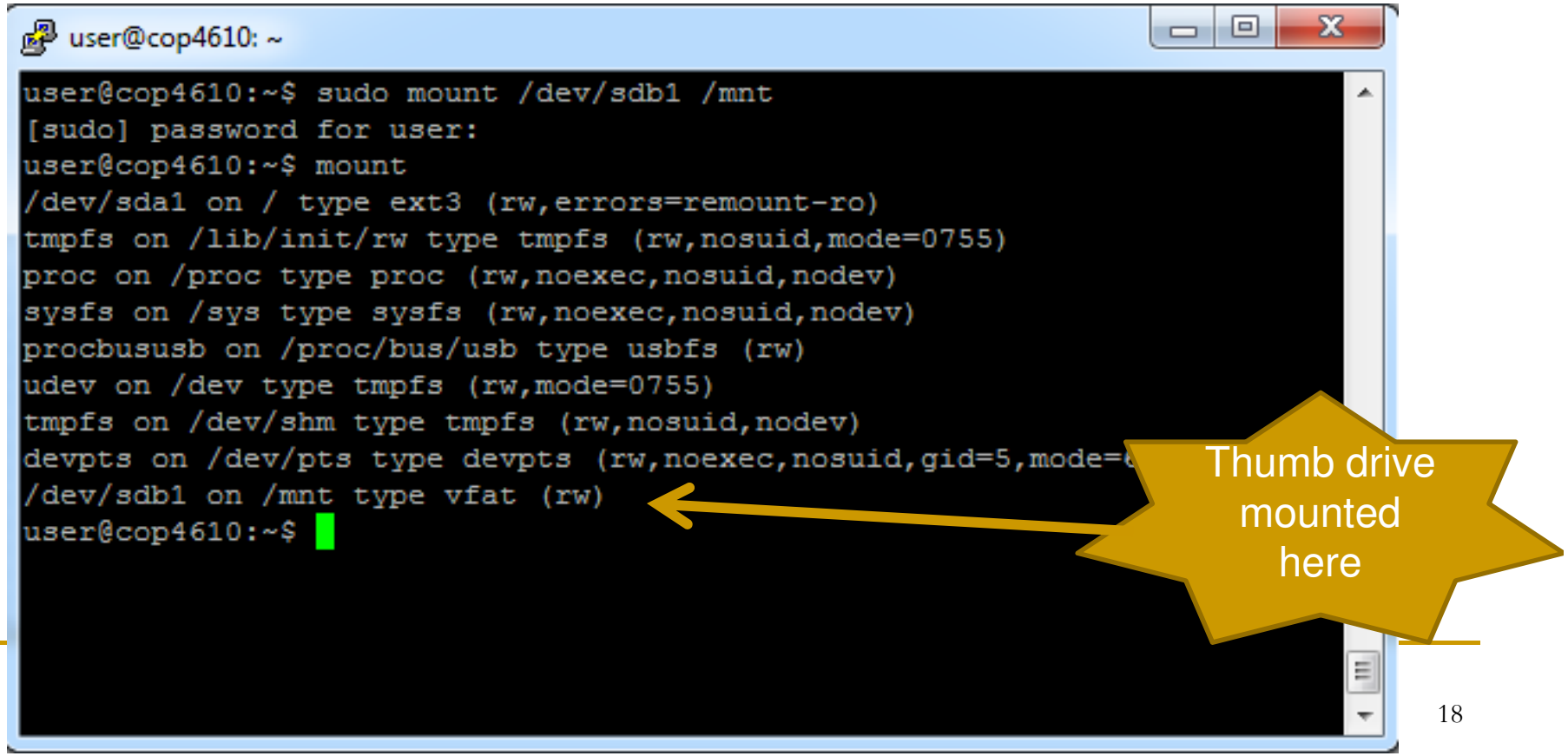


Un-mount Command

- `umount <dir>`

- In our example where the thumb drive was mounted at /mnt, we can issue
  - `$> umount /mnt`
  - Must have root privileges

Figuring out names of devices

- /etc/fstab – Has list of devices and file systems that get auto-mounted on boot
- ‘dmesg’ command shows output when plugging in a dynamic device

Project 3

More than you wanted to know about FAT32..

Project 3

- You will create a user-space utility to manipulate a FAT32 file system image
  - No more kernel programming!
- Utility must understand a few basic commands to allow simple file system manipulation
- Utility must not corrupt the file system and should be robust

FAT32 Manipulation Utility

Utility only recognizes the following built-in commands:

- open
- close
- create
- rm
- size
- cd
- ls
- mkdir
- rmdir
- read
- write

File System Image

- Manipulation utility will work on a pre-configured FAT32 ***file system image***
  - Actually a file
- File system image will have raw FAT32 data structures inside
  - Just like looking at the raw bytes inside of a disk partition

File System Image

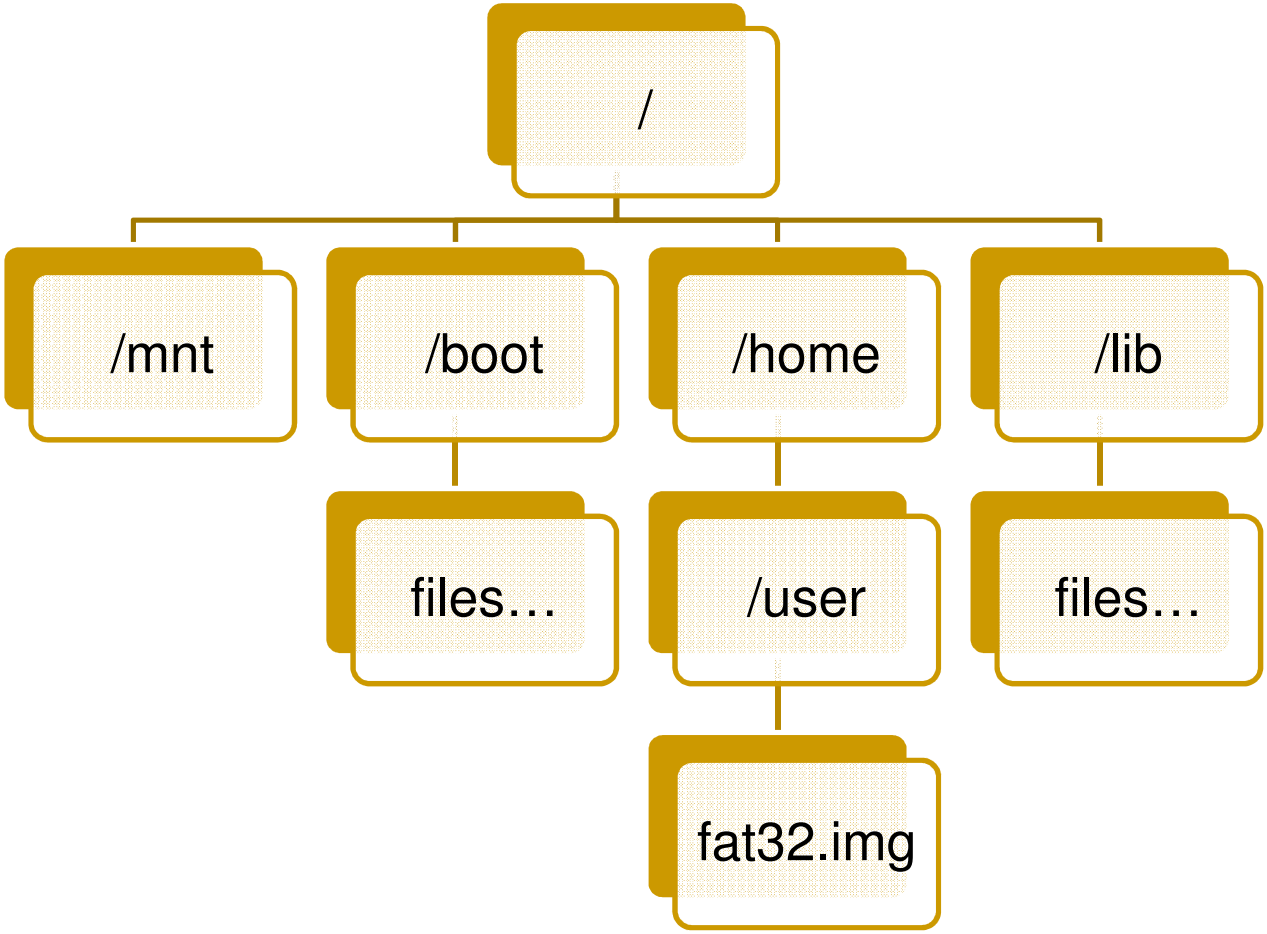
- Your FAT32 manipulation utility will have to
  - Open the FAT32 file system image
  - Read parts of the FAT32 file system image and interpret the raw bytes inside to service your utility's file system commands…

…just like a file system!

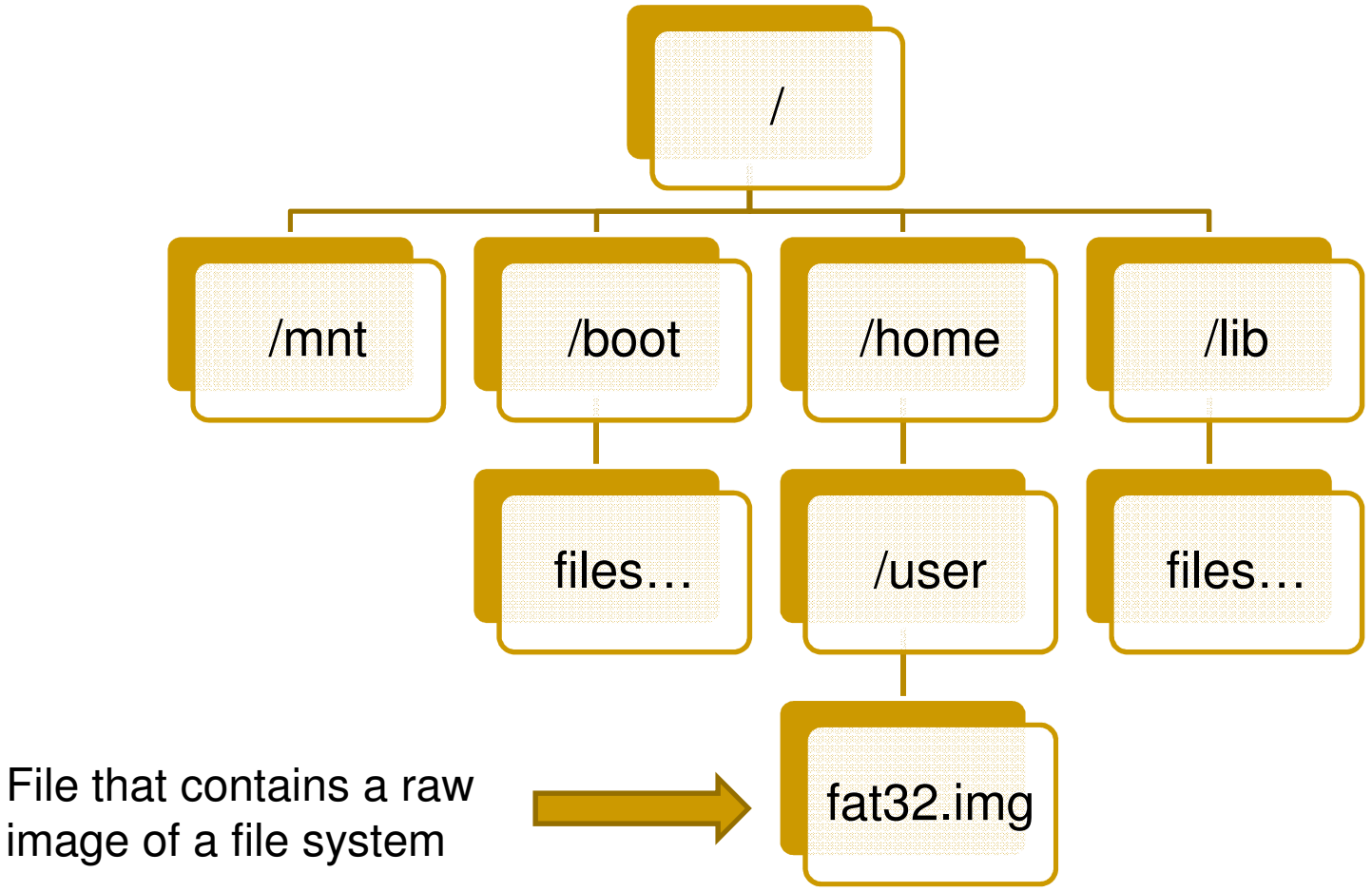
File System Image

- Sometimes you may want to check that you haven't corrupted your file system image, or that you can add or write files successfully
  - Mount your file system image with the OS FAT32 driver
  - Just like the file system image is a device

File System Image Mount Example

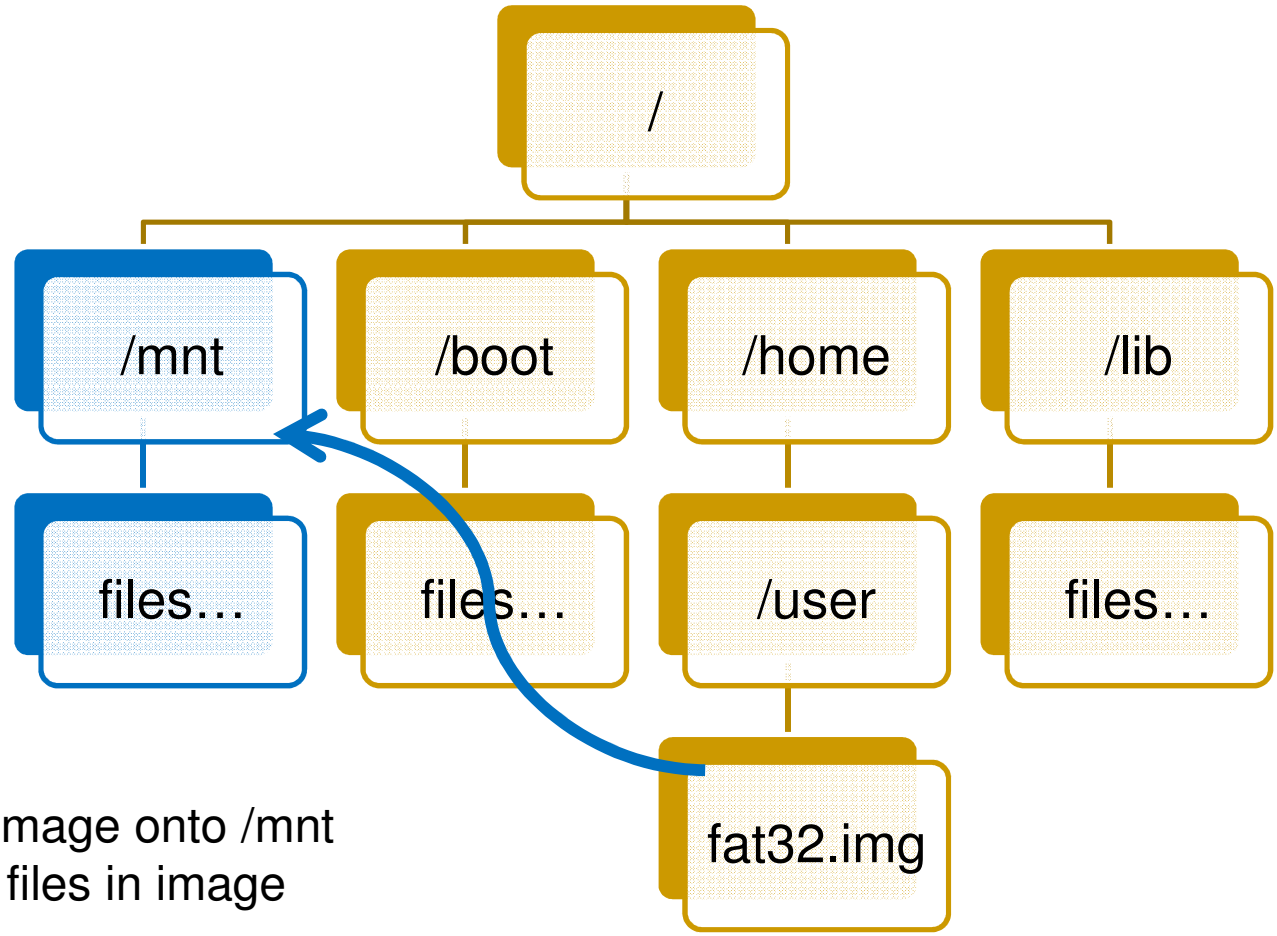


File System Image Mount Example



File that contains a raw image of a file system

File System Image Mount Example



Mount image onto /mnt
to read files in image

File System Image Mount Example

```
$> sudo mount -o loop fat32.img /mnt
$> cd /mnt
```

- `fat32.img` is your image file
- `/mnt` is your mounting directory
- Once the file is mounted, you can go into the /mnt directory and issue all your normal file system commands like:
  - ls, cat, cd, …

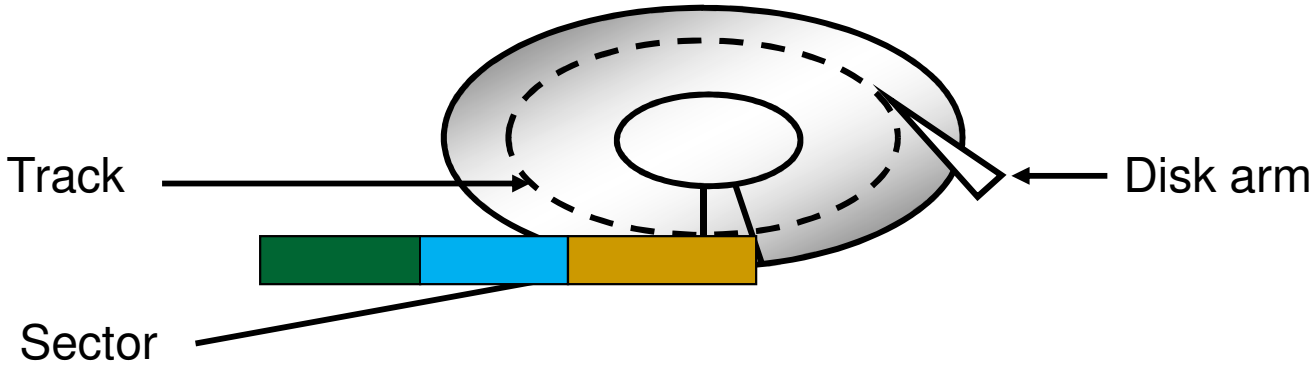
General FAT32 Data Structures

Terminology

- ***Byte*** – 8 bits of data, the smallest addressable unit in modern processors
- ***Sector*** – Smallest addressable unit on a storage device. Usually this is 512 bytes
- ***Cluster*** – FAT32-specific term. A group of sectors representing a chunk of data
- ***FAT*** – Stands for *file allocation table* and is a map of files to data

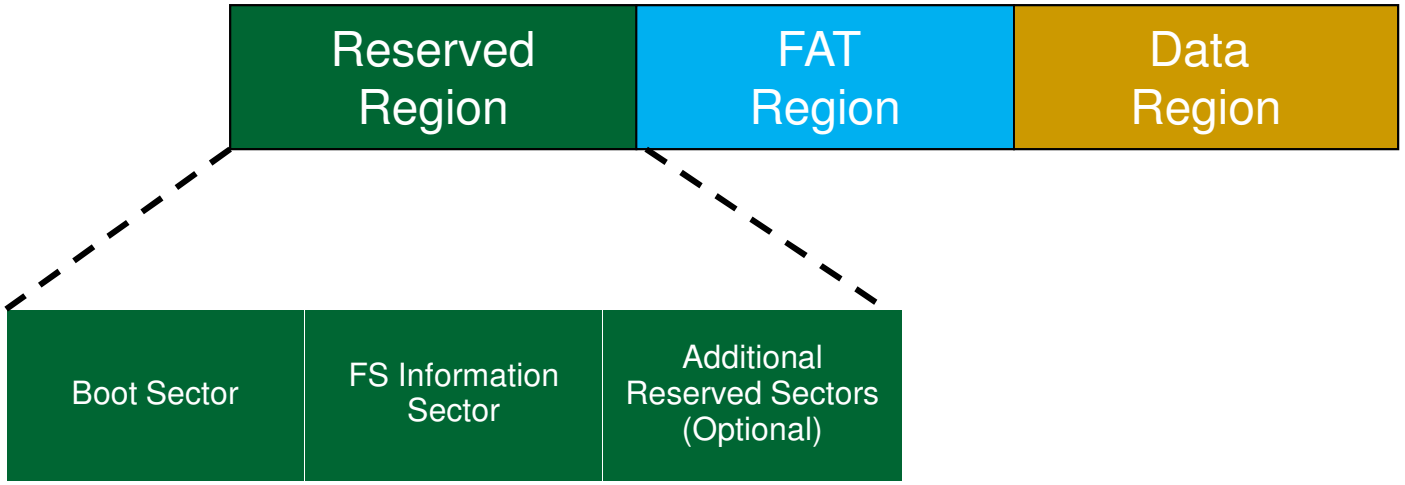
FAT32 Disk Layout

- 3 main regions…



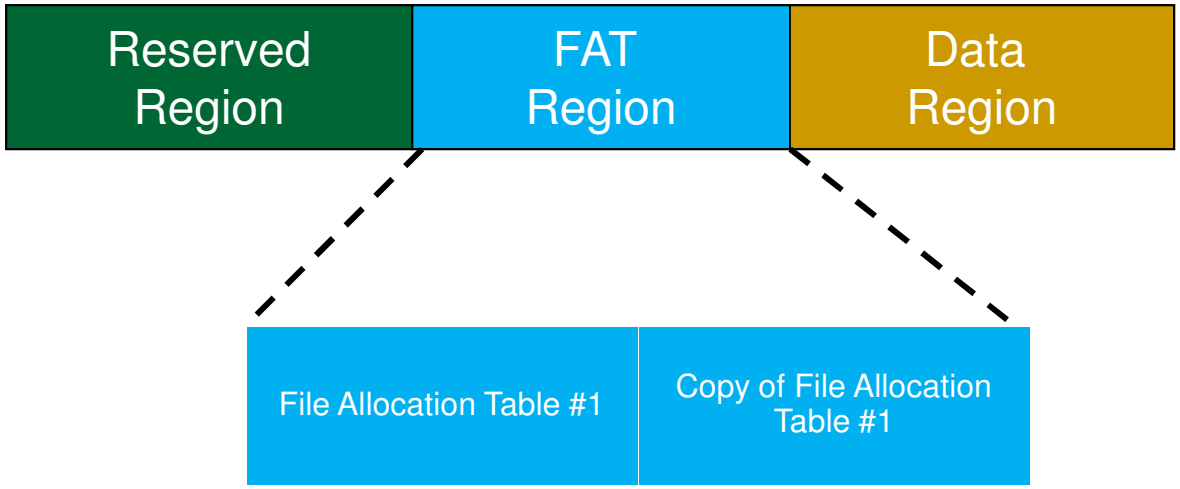
Reserved Region

- **Reserved Region** – Includes the boot sector, the extended boot sector, the file system information sector, and a few other reserved sectors



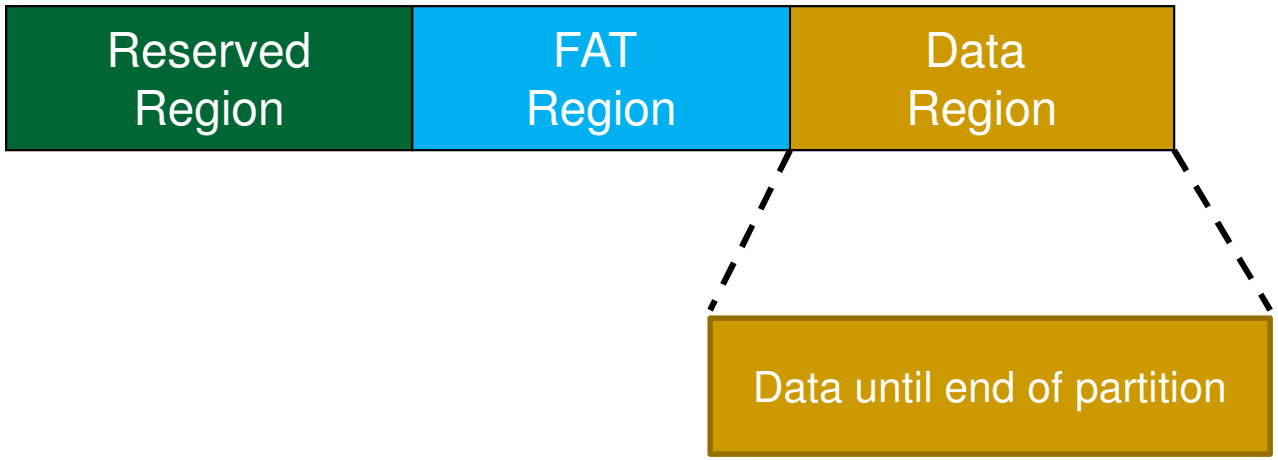
FAT Region

- **FAT Region** – A map used to traverse the data region. Contains mappings from cluster locations to cluster locations



Data Region

- **Data Region** – Using the addresses from the FAT region, contains actual file/directory data



Endian

Big or little?

Machine Endianness

- The endianness of a given machine determines in what order a group of bytes are handled (ints, shorts, long longs)
  - Big-endian – most significant byte first
  - Little-endian – least significant byte first
- This is important to understand for this project, since FAT32 is always formatted as little-endian

FAT32 Endianness

- The following are a few cases where endianness matters in your project:
  - Reading in integral values from the FAT32 image
  - Reading in shorts from a FAT32 image
  - Combining multiple shorts to form a single integer from the FAT32 image
  - Interpreting directory entry attributes

Endian Example (English Version)

- Imagine you can only communicate three letters at a time, and your word is “RAPID”
- Big-endian
  - 1. RAP
  - 2. ID
  - Word = RAPID
- Little-endian
  - 1. PID
  - 2. RA
  - Word = PIDRA (come again?)

Endian Example (data version)

- short value = 15; /* 0x000F */
- char bytes[2];
- memcpy(bytes, &value, sizeof(short));
- In little-endian:
  - bytes[0] = 0x0F
  - bytes[1] = 0x00
- In big-endian:
  - bytes[0] = 0x00
  - bytes[1] = 0x0F

Endian Example (data version 2)

- int value = 13371337; /* 0x00CC07C9 */
- char bytes[4];
- memcpy(bytes, &value, sizeof(int));
- In little-endian:
  - bytes[0] = 0xC9
  - bytes[1] = 0x07
  - bytes[2] = 0xCC
  - bytes[3] = 0x00
- In big-endian:
  - bytes[0] = 0x00
  - bytes[1] = 0xCC
  - bytes[2] = 0x07
  - bytes[3] = 0x09

Visualizing Example 2
Value = 13371337 (0x00CC07C9)

index	0	1	2	3
little endian	0xC9	0x07	0xCC	0x00
big endian	0x00	0xCC	0x07	0xC9

Additional Project 3 Information

- Like other projects, may work in teams or alone
- Project deadline is December 3rd, 2010 at 11:59:59pm (Friday before finals week)
  - No extensions
  - Can use remainder of slack days
  - Cannot be more than 3 days late
    - Monday, December 6th is absolute last day to turn in

Project 3 Partners

- Raise your hand if you are looking for a partner…
- Also use the discussion board

Until Next Time

- Set up your environment
- Download the image file
- Practice mounting the image file with the OS FAT32 drivers
  - Make sure you can cd into /mnt and read/write to the files
- Read over the FAT32 Specification