

ECE 471 – Embedded Systems

Lecture 6

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Announcements

- HW#2 was posted, how's it going?
Sorry posted code late
- People doing OK getting Pis setup?
Can turn into almost a sysadmin task rather than embedded systems
- NSF CSSI Meeting report
Future of government grants seems to be all AI all the time

Human-Computer Interfaces (HCI)

- This is a whole course of study on how to efficiently use computers
These days it has gotten worse, including dark patterns
- You might be most used to phone/touchscreen
- Also graphical user interface (GUI) or windows/icons/menus/pointer (WIMP)
- In ancient times, maybe punch-cards, switches+lights, teletypes, glass terminals
- A remnant of ancient times is the command line

Using the Linux Command-Line

- You can interact fully with Linux at a text-based command line (a shell prompt)
- Even in a GUI you can bring up a terminal emulator to do this
- The way we did things in the old days.
Some of us still prefer the command line.
- Good to know as in some situations (server, sysadmin, HPC, **embedded systems**) you might only get command line access to a machine

Files

- On Linux/UNIX “everything is a file”
- A file is a collection of bytes that you can randomly access by name
- They are usually stored in a filesystem

Filesystems

- Gives a name and directory (folder) hierarchy so you can easily find the files (rather than having to remember the block offset on disk where it lives)
- Various types of filesystems available
- Yet another Operating System abstraction

Do people even use filesystems anymore?

- There's worry that on modern interfaces (like phones) files are just magically on the cloud and you find them by search, essentially magic
- At least currently the files still actually live on a filesystem somewhere (unless they're in a database which is another story for another time)

Aside on Linux Filenames

- Case sensitive, so Hello and hello are different files (this is unlike Windows and MacOS)
- Extensions (like .exe) are allowed but they aren't needed
- Filenames can be anything but NUL and /
- All of the above can lead to various computer security issues and so there have been calls to be a bit stricter about things

The Linux Shell

- The command prompt is just a program called a “shell”
- Default is bash, the “Bourne Again Shell” (more computer person humor).
- There are various shells available (bash, sh, zsh, csh, tcsh, ksh)
- You can select via `chfn`
- It's just another program in C, started by `login`
- When you run a program it runs as a separate process, but when done it returns to the shell

Root Filesystem Layout

- Executables in `/bin`, `/usr/bin`
Describe the on-going merge of `/usr/bin` with `/bin`
- System executables under `/sbin`, `/usr/sbin`
- Device nodes under `/dev`
- Config files under `/etc`
- Home directories under `/home`, also `/root`
- Temp Files under `/tmp`. Often wiped at reboot.
- Magic dirs under `/proc`, `/sys`
- Libraries under `/lib`, `/usr/lib`, sometimes `lib64` too
- Boot files under `/boot`

Root Filesystem Layout Continued

- `/usr` historically was where user files lived (now that's `/home`). A long time ago when low on disk space sysadmins put extra stuff in `/usr` and it stuck.
- `/opt` often commercial software installed there
- `/srv`, `/run`, `/var` these are where server programs store data
- `/media`, `/mnt` places to mount external disks like memory keys and CD roms
- `/lost+found` where the disk checker may store lost files it finds when fixing a disk after unclean shutdown

Interesting Config Files in /etc

- /etc/fstab – the filesystems to mount at boot time
- /etc/passwd – list of all users, world readable
- /etc/shadow – passwords stored here for security reasons
- /etc/hostname – name of the machine
- /etc/hosts – list of local machines, usually searched before resorting to DNS lookup over network
- /etc/resolv.conf – where your nameserver address is put
- /etc/sudoers – list of users allowed to use “sudo”

Running things on Boot

- Useful for 471 projects
- Official solution is to write a systemd service/unit file
- In the old days you just stuck a shell script in `/etc/rc*`
- You can still do that with `rc.local` but not sure if that will keep working

Devices

Block vs Char devices

- `/dev/sd*` – SCSI (hard disks)
- `/dev/mmc*` – SD cards
- `/dev/tty*` – tty (teletype, logins, serial ports)
- `/dev/zero`
- `/dev/full`
- `/dev/random` , `/dev/urandom`
- `/dev/loop`

Network devices are an exception.

Interesting /proc Files

These files are not on disk, but “virtual” and created on-the-fly by the operating system when you request them.

- /proc/cpuinfo – info on cpu
- /proc/meminfo – memory info
- Each process (running program) has its own directory that has info about it

Processes

- Each program assigned its own number, a process id, often called a “pid”
- Can list processes with `ps -efa`
- Also can get real-time view of what's going on in a system with `top`
- `htop` is a more advanced `top`
- `btcp` is also a fun one

Common Commands – ls

- `ls` : list files

`ls -la` : list long output, show all (hidden) files. on Linux any file starting with `.` is hidden

`ls -la /etc` : list all in `/etc` directory

`ls *.gz` : show all ending in `gz`. `*` and `?` are wildcards and can be used as regular expressions.

Common Commands – cd

- cd DIR : change directories (folders)
 - cd .. : go to parent directory
 - cd . : go to current directory
 - cd / : go to root directory
 - cd ~ : go to home directory

Viewing Files

- `cat FILE` – dump file to screen (originally used to conCATenate files together but more commonly used to list files)
- `more / less` – list contents of file but lets you scroll through them. `less` more advanced version of `more`
- `hexdump` – list contents of file in hexadecimal. Why?

Disk Usage

- `df` – show disk free
 `df -h` pretty-prints it
- `du` – show disk used
 `du -h` pretty-prints it

Documentation

- `man command` – show documentation (manual) for a command. For example `man ls`

File Manipulation

- `rm` remove file. CAREFUL! Especially famous `rm -rf`. In general on Linux you cannot undo a remove.
- `cp` copy file. CAREFUL! By default will overwrite the destination without prompting you.
- `mv` move file. CAREFUL! Can overwrite!
`mv -i` will prompt before overwrite

Logging Out

- `exit` / `logout` / `control-D` – log out of the machine
- `shutdown` – shutdown / reboot machine

Compressing Files

- `tar` create archive file `tar cvf output.tar dir`
`tar xzvf output.tar.gz` uncompresses a `.tar.gz` file
- `gzip` / `gunzip` / `bzip2` / `bunzip2`
compress/uncompress a file. `gzip` and `bzip2` are two common formats, many more exist
- `xz` (`xz` / `unxz`)

Compiler / Devel Commands

- `make` – build a file based on list of dependencies in Makefile
- `gcc` – C compiler. Simplest something like this: `gcc -O2 -Wall -o hello hello.c`
- `g++` C++ `gfortran` Fortran
- `as`, `ld` – assembler and linker
- `gdb` – debugger
- `strace` – list system calls
- `git` – source code management

Text Editor / nano

Linux and UNIX have many, many editors available. Most famous are vi and emacs. On our board using nano might be easiest.

- nano – a simple text editor.

`nano FILENAME` – edit a filename

It shows the commands you can do at the bottom. `^O` means press control-O

control-O : writes

control-X : exits

control-W : searches

control-\: search and replace

control-C : prints line number

Other Fun Commands Part1

- `su / sudo` – switch to root, run command as root
- `uptime` – how long machine has been up
- `date` – show the date
as root you can use `date -s` to set the date
- `whoami` – who are you
- `wall` – send message to all logged in users
- `w / who` – see who is logged in

Other Commands Part2

- `wc` – count words/bytes/lines in a file
- `dmesg` – print system and boot messages (might need `sudo`)
- `ln` – link files together, sort of like a shortcut
`ln -s goodbye.c hello.c` – symbolic link. also hard links
- `dd` – move disk blocks around, often used for creating disk images
- `mount` / `umount` – mount or unmount filesystems
- `mkfs.ext3` – make new filesystem
- `e2fsck` – filesystem check

Other Commands Part3

- `ifconfig / route` – show and setup network config being replaced by `ip` tool
- `dpkg / apt-get update/upgrade/install` – Debian only package management
- `ssh / scp` – log into other machines, copy files remotely
- `lynx` – text-based web browser
- `reset` – clear the screen and reset settings (useful if you accidentally `cat` a binary file and end up with a screenful of garbage). `Control-L` also refreshes the screen

Other Fun Commands (Deprecated)

- These are traditional commands that were around for years but recently have been removed (or made optional so you have to manually install them yourself if you want them)
- `last` – list last people to log in
- `cal` – show a calendar
- `write` / `talk` – chat with other users logged into the system
- `finger` – get info on other users

Novelty Commands

- `linux_logo` – my program
Try `linux_logo -L 9 | less`
- `cowsay`
- `nyancat`

Redirection and Pipes

- redirect to a file : `ls > output`
- redirect from a file : `wc < output`
- pipe from one command to another : `ls | wc, dmesg | less`
- re-direct stderr : `strace 2> output`

Suspend/Resume

- Press control-C to kill a job
- Press control-Z to suspend a job
- Type `bg` to continue it in the background
- Type `fg` to resume it (bring to foreground)
- Run with `&` to put in background to start with. (ie, `mpg123 music.mp3 &`).

Permissions

- user, group – use chgrp
- read/write/execute – use chmod

Shell Scripts

- Create a list of files in a dir
- Start with the shell, `#!/bin/sh` (or perl, etc)
- Make executable `chmod +x myfile`

Command Line History

- Can press “tab” to auto-complete a command
- Can press “up arrow” to re-use previous commands
- Can use “control-R” to search for previous commands

Environment Variables

- `env`
- Varies from shell to shell.
- `export TERM=vt102`
- `PATH`, and why `“.”` isn't in it. This is why you have to run self-compiled binaries as `./blah`

IOCCC Examples

- endoh1
- my submissions, 2005, 2025

Some Commands to Explore

- Login
- Use `pwd` to print current working directory
- Use `mkdir` to create a directory for 471 files
- Use `cd` to enter the new directory
- Use `ls` to list files
- Use `wget` to download assignment file
- Use `tar` to decompress/unpack assignment
- Use `cd` again to enter directory
- Edit the file using an editor `nano` or similar

Commands to Explore (continued)

- Run `make` to build assignment
Aside: look at contents of Makefile
- Run `./hello_world` to test what we built
Aside: why do you need the `./`?
As with lots of weird things, for security reasons
- Run `env` to look at the environment variables
- Run `shutdown` to shut down when done
Does it require `sudo` privileges?