OS Agenda

Agenda OS420 Operating Systems CSC 420

README

This file contains the agenda overview (what I had planned), the objectives (what we managed to do) and (much of the) content of each taught session of the course. I want to avoid splitting the content up over many files - so that you have to navigate as little as possible (like a book)!

The companion file to this file, less structured and with the captain's log, is the notes.org file.

Welcome to the course - w1s1 (11-Jan)

- Aspiration and ambition (Lyon Data Science program)
- Introduction to the course & the lecturer
- Homework assignments: **GitHub**, DataCamp, Emacs
- What's next?

Aspirations and ambitions (DS program 2021-2023)

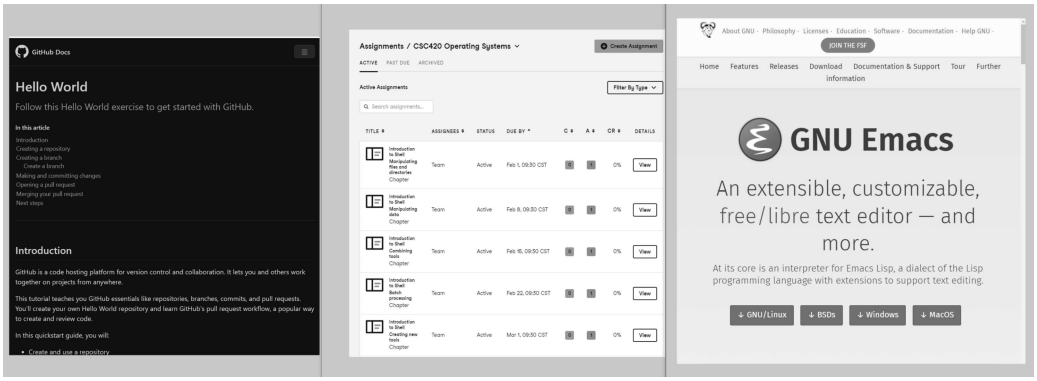
CLASS	CODE	TERM	Topics
Data Science Tools and Methods	DSC 101	Fall 2021	R, Basic EDA, Base R
Introduction to Advanced Data Science	DSC 205	Spring 2022	R, Advanced EDA, Tidyverse
Database Theory and Applications	CSC 330	Spring 2022	SQL, SQLite
Operating Systems	CSC 420	Spring 2022	Bash, awk, sed, regular expressions
Applied Math for Data Science	DSC 482/MTH 360	Fall 2022	Probability, Statistics + R
Data Visualization	DSC 302	Fall 2022	D3, Processing, Javascript, Bokeh
Machine Learning	DSC 305	Spring 2023	Predictive algorithms, neural nets
Digital Humanities	CSC 105	Spring 2023	Data science applications

Introduction to the course & the lecturer

Figure 2: DESY APE research group, Hamburg/Rome, 1994

- Why me?
- Syllabus for this course (Schoology)

Homework assignments week 1 (11-Jan/13-Jan-2022)



- GitHub Hello World Exercise (Info: FAQ)
- DataCamp platform registration (Link: Schoology)
- GNU Emacs installation (Info: FAQ)

GitHub

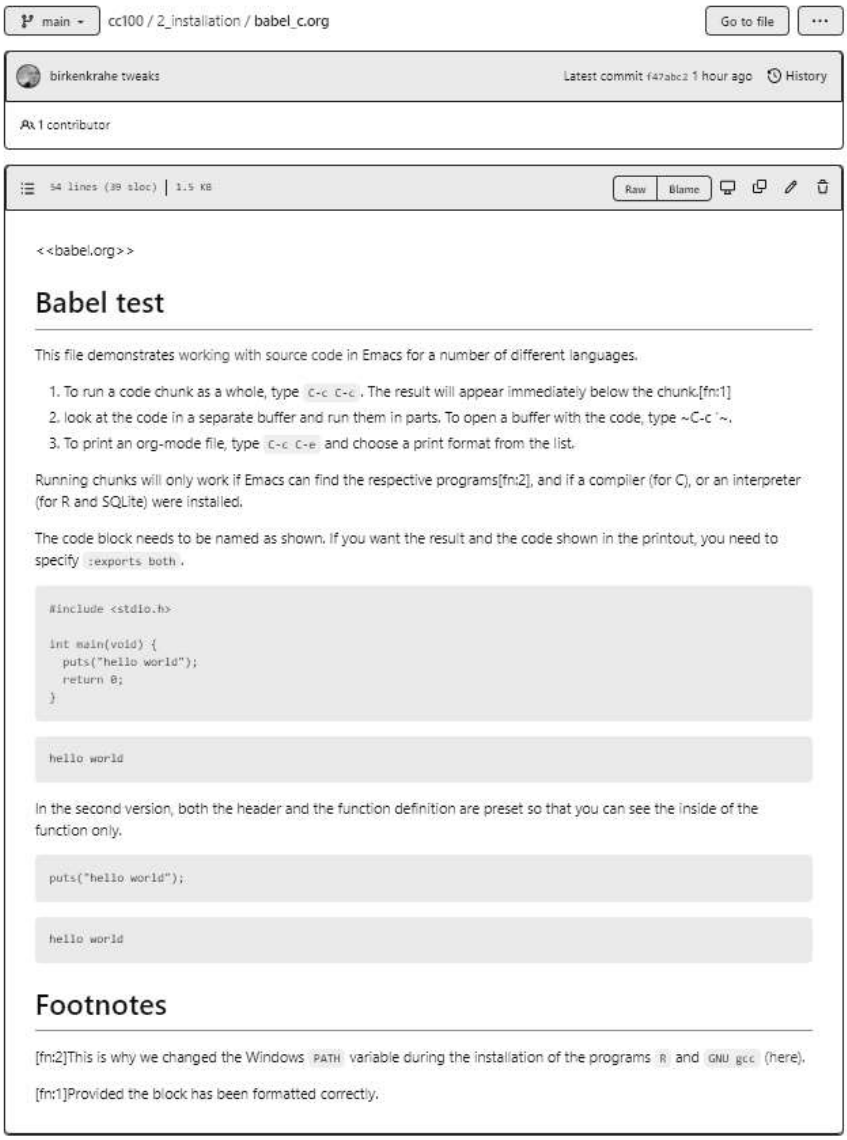
- What is it?
  - Software development platform
  - Built around Git by Linus Torvalds
  - Bought by Microsoft in 2018
  - AI support (e.g. GitHub Copilot)

  Watch: "What is GitHub?" (GitHub, 2016)

Gif: "So long binder of requirements" Source: GitHub

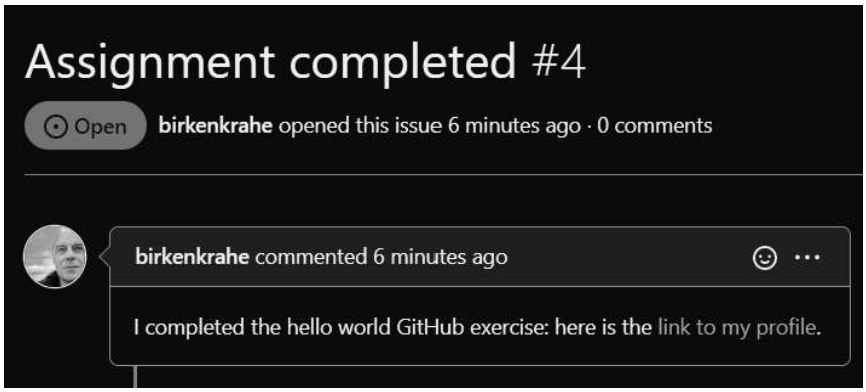
- Why are we using it?

  Image: Org-mode file in GitHub



  - It's free
  - To host course materials
  - Upload assignments (esp. Emacs Org-files)
  - Discussion
  - Wiki for collaboration
  - Complements Schoology
- What will you have to do?
  - Sign up with GitHub - use Lyon Email
  - Pick an available username **using your own first and last name**, e.g. `MarcusBirkenkrahe`, or `DonaldTrump`
  - Complete GitHub Hello World exercise (see FAQ)
  - Give me your GitHub username so that I can add you as a collaborator to my private `os420` repository
  - Create an issue from the `os420` repository like in the example below (except from your account instead of mine).

Image: Issue "Assignment completed"



If you do have a GitHub account already, do the exercise anyway using your existing account (it takes 10 min)! Make sure you let me know what your user name is so that I can add you to my repo.

- What else can you do?
  - You can fork the `os420` repository
  - You can watch the `os420` repository - and set `Notifications` to `Participating and @mentions` so that you see my comments (see image below).

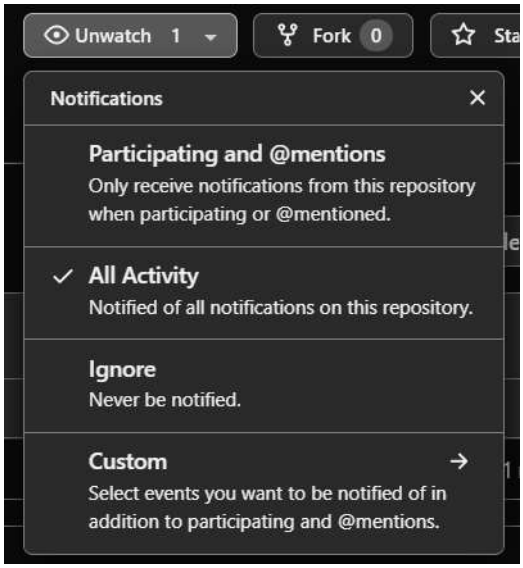
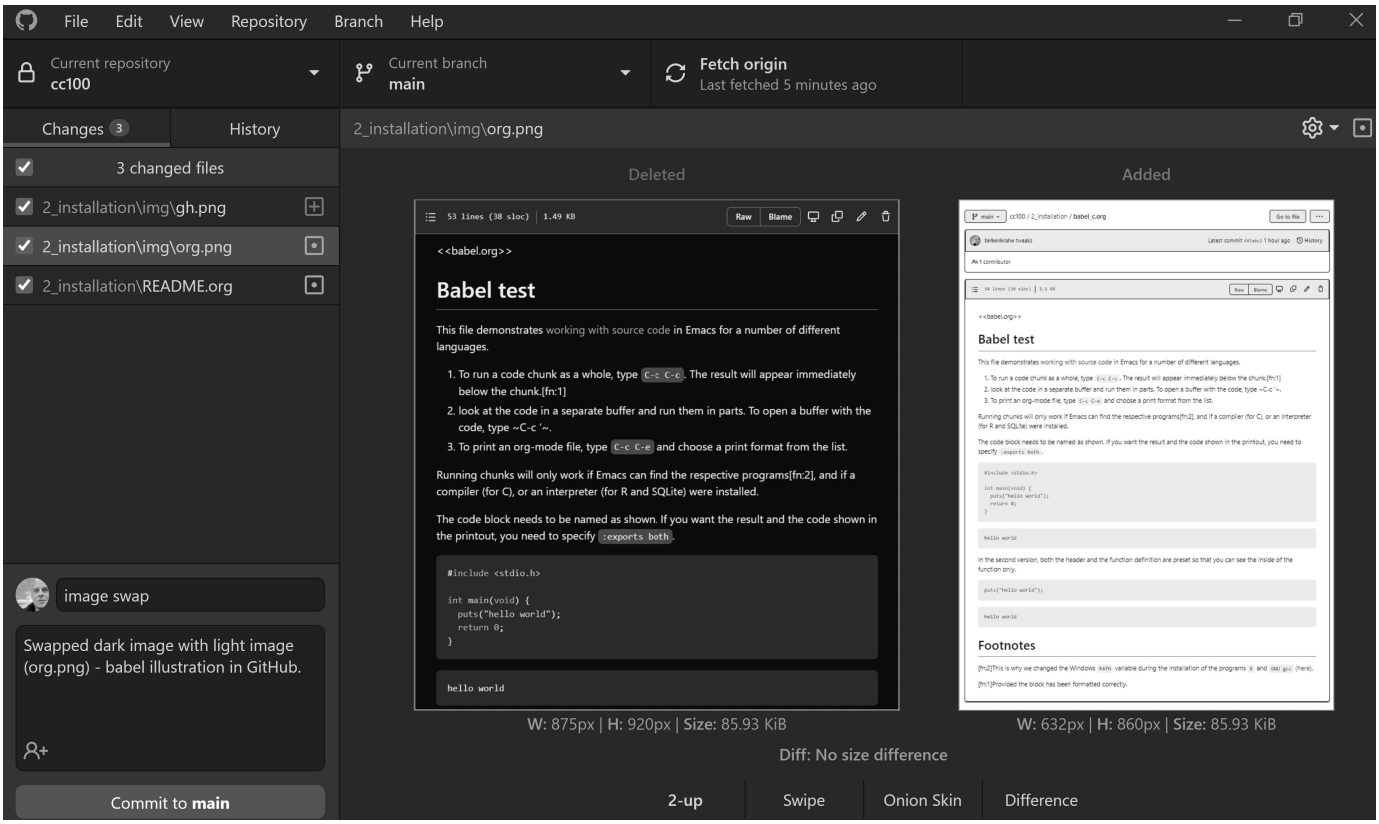


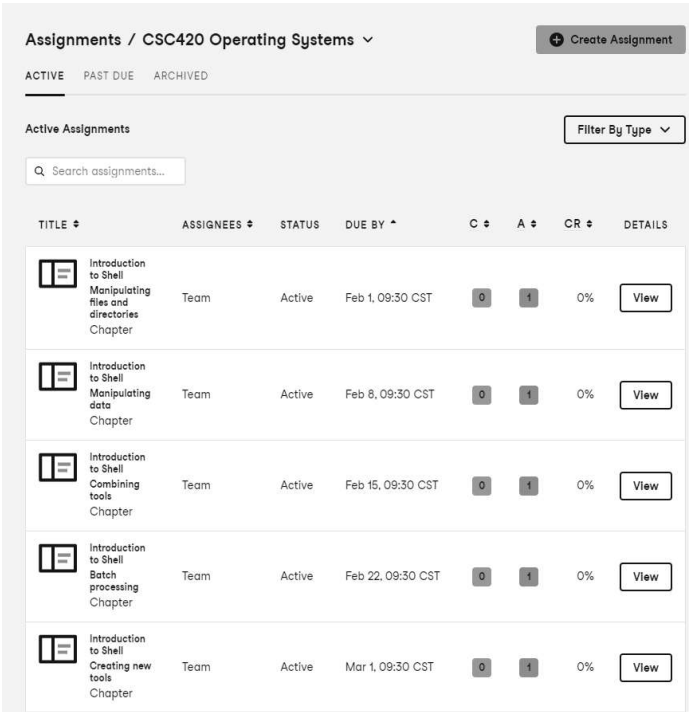
Image: Notifications settings when watching a repository

  - You can submit issues from the repository (e.g. if you notice mistakes or if you want extra information, or to share a link)
  - You can participate in discussions (sometimes I will make you)
  - You can add to the wiki (e.g. comments and links to interesting resources)
  - You can install the mobile app on your smartphone
  - You can use it as a platform for projects or coding
  - You can download the desktop client to manage repos on your PC (see image below).

Image: GitHub desktop client commit



DataCamp



- Why are we using it?
- How are we using it?

- What will you have to do?

GNU Emacs

- Why are we using it?
- How are we using it?
- What will you have to do?

What's next?

- See schedule (GitHub)
- Watch online lecture on "Systems" (to be published)
- Everything else => followup notes (GitHub)
- ~~See you (hopefully) Thursday in class! (Lyon 104)~~

GitHub, GNU Emacs installation - w1s2 (13-Jan)

Overview

HOW	WHAT
Review	GitHub Hello World exercise (FAQ)
Lecture	What operating systems do
Practice	Install GNU Emacs (FAQ)
Demo	Emacs guided tour
Self	Work through the Emacs onboard tutorial (18p)

Objectives

- [X] Understand the basics of Git
- [X] Describe the general organization of a computer system

- [x] Install the GNU Emacs editor on your OS
- [ ] Understand how GNU Emacs works
- [ ] Make GNU Emacs work for you

Interrupts, basic I/O - w2s3 (18-Jan)

Overview

HOW	WHAT
Review (S)	Quiz: course, OS foundations / GNU Emacs
Resource (S)	Fundamentals of Operating Systems YouTube playlist
Lecture (S)	Interrupts / I/O operations example / bootstrapping
Demo	Emacs guided tour
Self	Work through the Emacs onboard tutorial (18p)

Nachtrag: watch History of Databases and The Computer Chronicles

Objectives

- [x] Review / retention: complete Schoology Quiz 1 (15 min)
- [x] Understand bootstrapping, and interrupts management
- [x] Understand how basic I/O processes work
- [ ] Understand how GNU Emacs works
- [ ] Make GNU Emacs work for you

What's next?

- GNU Emacs practice exercises (class)
- Computer system architecture
- Getting started with Pi

OS tasks, virtualization, GNU Emacs - w2s4 (20-Jan)

Overview

HOW	WHAT
Lecture	Storage structure & OS management tasks
Practice	Emacs guided tour (tour)(tutorial)

Objectives

- [x] Storage structure, User vs kernel mode, multiprogramming
- [x] Management tasks of the Operating System
- [x] Virtualization and open source vs commercial system
- [x] Understand how GNU Emacs works
- [ ] Make GNU Emacs work for you

What's next?

- Operating system services & design principles
- Emacs practice & assignment
- Getting started with Pi: bootloading Raspbian Linux
- Complete quiz 2 online **before class**
- Will do 5 min review in class together

OS foundations, Eshell - w3s5 (25-Jan)

Overview

HOW	WHAT
Summary	Foundations of Operating Systems (10 tenets)
Preview	DataCamp course "Introduction to Shell"
Practice	Open three shells inside Emacs
Assignment	Create `hello world` shell program in Emacs

Objectives

- [X] Summarize foundations of operating systems
- [X] Understand how GNU Emacs shells work
- [X] Understand the first DataCamp assignment (Intro to Shell)
- [ ] Create an bash(1) hello world program in the shell
- [ ] Run shell program inside Emacs

Summary: foundations of operating systems

10 tenets

1. An operating system is software that manages the computer hardware, as well as providing an environment for application programs to run.
2. Interrupts are a key way in which hardware interacts with the operating system. A hardware device triggers an interrupt by sending a signal to alert the CPU, whose interrupt handler manages the interrupt.
3. For a computer to do its job, programs must be loaded in main memory (RAM), which is the only memory area that the CPU can access directly.
4. To best utilize the CPU, the OS can handle several jobs in memory at the same time so that there's always one job to execute. True multitasking, however, is an illusion.
5. To prevent user programs from interfering, the system hardware has two modes: user mode and kernel ("sudo") mode.
6. Privileged instructions that can only be executed in kernel mode include: switching to kernel mode; I/O control; time management; interrupt management.
7. Process management includes creating and deleting processes, and providing process communication and synchronization. Processes are active, programs are passive.
8. Memory management means that the OS keeps track of what parts of memory are being used and by whom, and dynamically freeing and allocating memory.
9. Storage space is managed by the OS through file systems (files, directories) and managing space on mass-storage devices.
10. Virtualization involves abstracting a computer's hardware into several different execution environments.

Short definition

> The Operating System takes physical resources (CPU, memory, disk), and **virtualizes** them. It handles **concurrent** processes, and it stores files **persistently** to make them safe in the long term.

OS attributes

- **Performance** / overhead reduction
- **Protection** between applications, and between OS and apps
- **Isolation** of processes from one another
- **Reliability** of operations
- **Security** against malicious attacks
- **Mobility** across, and towards smaller, and embedded devices

OS Timeline

Early era	OS are just libraries with (human) batch operators
Mainframe era	Protection through the system handler
Minicomputer era	Interrupt-based memory management
PC era	DOS attacks and infinite MacOS loops
Modern era	Linux and the return to sanity

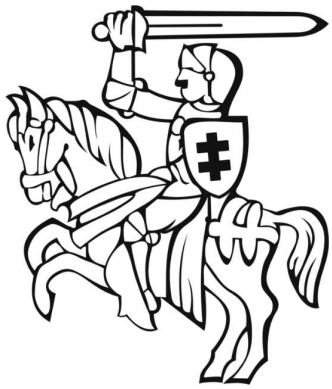


Figure 9: Unix the white knight of Operating Systems

DataCamp course: Introduction to Shell

> This chapter is a brief introduction to the Unix shell. You'll learn why it is still in use after almost 50 years, how it compares to the graphical tools you may be more familiar with, how to move around in the shell, and how to create, modify, and delete files and folders.

Three shells inside Emacs!

- Works really well only under Linux or MacOS

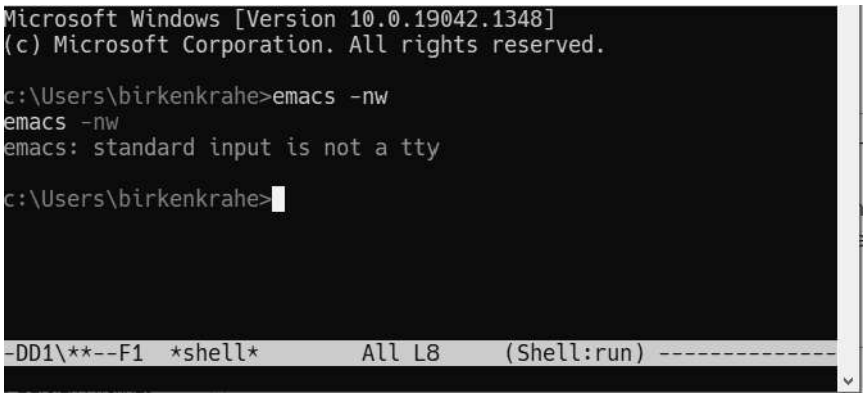
SHELL COMMAND	CHARACTERISTICS	MODELINE
`M-x shell`	Windows shell `CMD.exe`	`*shell*`
`M-x eshell`	Lisp simulated shell	`*eshell*`
`M-x term`	Terminal emulator	`*terminal*`

Cp. the variable `shell-file-name`.

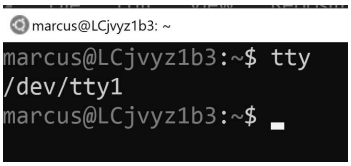
- Start Emacs from the terminal: `emacs -nw -q`
- Start all three shells in Emacs

- Start Emacs with `emacs -nw inside an Emacs ~*shell*`

> You should get the error message `emacs: standard input is not a tty`. TTY stands for "TeleTYpewriter". The (Unix) `tty` command is used to check if the output is a terminal or not (see Wikipedia).



On Linux (Ubuntu App in Windows 10):



Assignment: hello world!

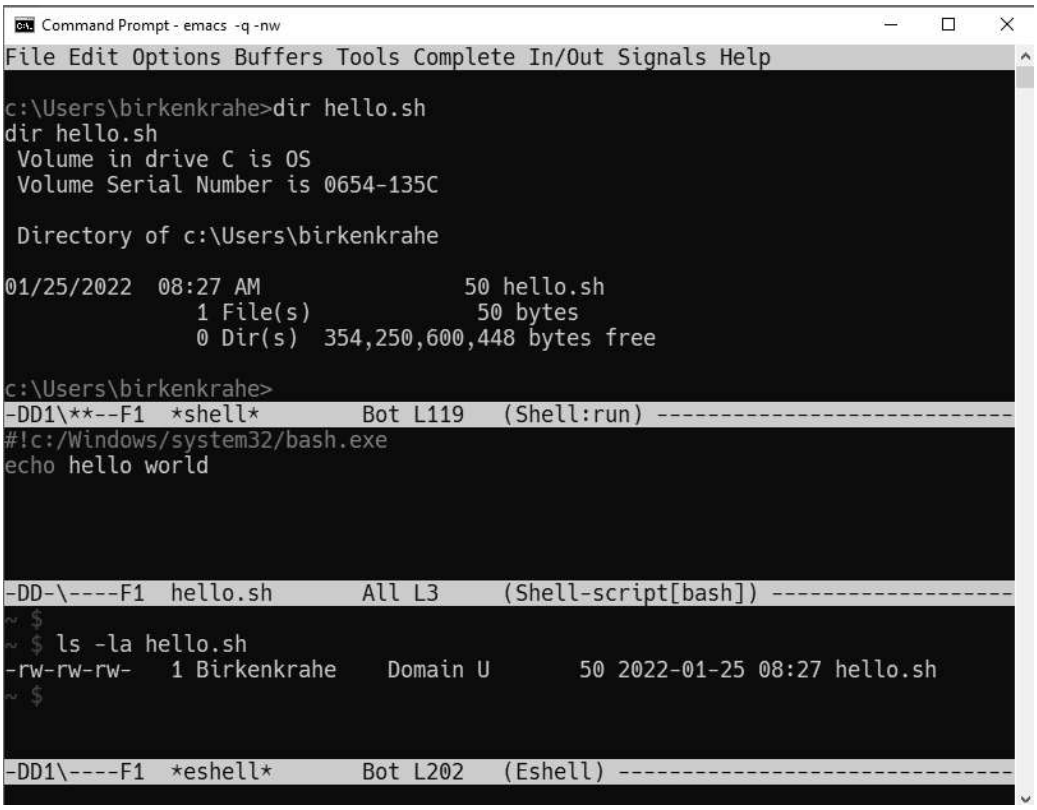


Figure 12: Windows CMD shell in Emacs and hello world pgm

Next @Pi: eshell demo `cpu.c`

- Start several processes using `cpu.exe`
- Show process list with `jobs`
- Kill processes in list with `d`
- Start same processes in Ubuntu
- Kill processes with `kill`

What's next?

- Review 'hello world' shell exercise
- Fix `.emacs` issue on desktop computers
- Getting started with Pi: bootloading Raspbian Linux

Shell scripts, Raspberry Pi setup - w3s6 (27-Jan)

Overview

HOW	WHAT
Review	`hello.sh` assignment
Fix	`.emacs` issue (https://tinyurl.com/lyonemacs)
	Find the file on the lab desktop
	Put it into the `$HOME` directory
	Restart Emacs
Practice	Getting started with Raspberry Pi: installation

Objectives

- `[X]` Review `hello.sh` exercise
- `[X]` Install Raspberry Pi OS (Raspbian Linux) via NOOBS
- `[X]` Complete basic Pi setup with `sudo raspi-config`

Review assignment

- Start Emacs without init file

```
> emacs -nw -q
```

- Known `Class not registered` error on Windows 10 (fix). See notes for a quick solution (installing CygWin).

Set up Raspberry Pi

1. Open the box in front of you
2. Take out the Pi and connect it to the KVM switch
3. Connect the Ethernet cable to the Pi
4. Plug in the power cord and then plug it into the Pi
5. Install using NOOBS
6. Get the password from me!
7. Open a terminal app on the Pi
8. In terminal, enter `sudo raspi-config`
9. In the configurator, change boot options > Desktop/GUI to `Console autologin`, then <TAB> to <Finish>
10. Reboot the Pi (`sudo reboot`)
11. Login as user `pi` with password
12. Check network connection with `ifconfig`
13. Update OS with `sudo apt update`

14. Upgrade OS with `sudo apt upgrade -y`
15. Install Emacs with `sudo apt install emacs`
16. Start emacs, check it and exit again
17. Finish session with `sudo shutdown now`
18. Unplug the power chord, then the KVM connections
19. Return Pi to box
20. Cross yourself and close the box.

What's next

- Review first DataCamp assignment
- Explore Linux on the command line

Linux shell, UNIX man pages - w4s7 (1-Feb)

Overview

HOW	WHAT
Review	Quiz 3: file and folders / Installing Raspbian
Lecture	Raspberry Pi - the hardware & the history
FAQ	Should you upgrade your Operating System?
Pi Practice	Understanding the shell and Unix man pages

Objectives

- `[X]` Review Introduction to the shell - Files and folders (Quiz 3)
- `[X]` Getting OS release information
- `[X]` Understand the shell(s) - Unix man pages
- `[ ]` Understand the Linux file tree

Setting up the Linux boxes (almost every session)

This is something you can do as soon as you arrive:

- Take out the [Raspberry] Pi
- Connect the HDMI from the KVM switch to the Pi
- Connect the USB from the KVM switch to the Pi (any USB port)
- Plug in the power charger under the desk
- Connect the mini-USB of the power charger to the Pi
- Press the button on the KVM switch (color changes to green)
- The system should boot straight to console with autologin as user `pi`

The Ethernet cable is not usually needed except for installations and for updates and upgrades.

For the Pi400, the setup is slightly different because the Pi4 has a mini-HDMI connector.

Understanding the shell

> "Typing commands instead of clicking and dragging may seem clumsy at first, but as you will see, once you start spelling out what you want the computer to do, you can **combine** old commands to create new ones and **automate** repetitive operations with just a few keystrokes." (Shotts, 2019)

- The shell is just another program to pass keyboard commands to the OS
- On the desktop GUI, the shell is emulated (an X Windows program connects to it and interpretes key strokes, just like `eshell` on Emacs)
- The original shell is the Bourne Shell (`/bin/shell`).
- Linux uses an enhanced Bourne Shell, the Bourne-Again SHell `bash`.

- [X] Look up the man page for `bash` with the command `man bash` [1].
- [X] To get out, press `q`
- There are many other shells, including: `ksh` (Korn shell), `csh` (C shell), `zsh` (MacOS shell).
- Different shells differ in editing styles (command line editing), scripting abilities (e.g. closer to C), and process management functions (what you can do with CPU processes).
- Emacs commands are Unix commands: `C-a`, `C-e` etc. all work
- Some other shell commands to try now:
  - [X] `history` keeps the last 1000 commands or so. Commands are numbered. How can you repeat a command?
  - [X] `date` and `cal` time functions
  - [X] `df` and `df -H` (for humans) show the free disk space
  - [X] `free` and `free -h` (for humans) show the free memory
  - [X]

    `echo` repeats back what you type - except when you use variables as arguments:

    ```
    $ echo $PS1 # prompt path name
    $ echo $PS2 # prompt for inner shell (like SQLite or R)
    $ marcus = "me" # defining a variable
    $ echo marcus # this just returns the string "marcus"
    $ echo $marcus # returns "me"
    ```

- A terminal shell session is ended with the `exit` command.
- [X] End your terminal session!

Unix manual pages

- Man pages are split into eight numbered sections:

Section	Description
1	General commands
2	System calls
3	Library functions, covering in particular the C standard library
4	Special files (usually devices, those found in /dev) and drivers
5	File formats and conventions
6	Games and screensavers
7	Miscellaneous
8	System administration commands and daemons

Example: look for the man page of `sshd`, the OpenSSH daemon. What does it do? (Source)

Unplugging the Pi (almost every session)

- Shut down the Pi with `sudo shutdown now` on the console
- Unplug the power mini-USB
- Unplug the other cables
- Press the button on the KVM switch to return to Windows
- Sign out of Windows if necessary

Shell commands, Linux file tree - w5s8 (8-Feb)

Overview

HOW	WHAT
Test info	Test on Thursday, Feb 10 at 10.00-10.45 AM

HOW	WHAT
Setup	USB/HDMI > power > switch > `startx`
Review	Shell warm-up exercise (15 min)
Poll (vote)	Should you update your operating system?
Practice	`sudo apt update -y` [update OS]
	`sudo apt upgrade -y` [upgrade OS]
	`sudo apt autoremove -y` [remove old OS]
Lecture	The Linux File System ("Everything is a file")
Practice	Navigating the file system (DataCamp)
	Manipulate files and folders (DataCamp)
	Start an interactive notebook `bash.org`
Shutdown	`sudo shutdown now` > USB/HDMI > Power > switch

Objectives

1. [X] Poll/Discussion: should you upgrade your OS?
2. [X] Understand Thursday test rules and content
3. [X] Review shell command structure
4. [X] Understand the Linux file system structure and content
5. [X] Understand navigation and the Linux file tree
6. [ ] Start an interactive Org-mode notebook
7. [ ] Understand how to manipulate data using the shell

Test info

- Online in Schoology
- Quiz 1-3 are not visible during the test
- The 10 hardest questions of quiz 1-3 (< 50%)
- 10 brand new questions
- Maximum time = 45 min

Review: shell command structure

- The structure of all shell commands: [cmd] -[options] [arguments]
- There must be > 1 space between all elements
- There must not be a space between the option and the dash
- Many commands have an `-v` option that provides you with information at run-time

- There are short options (e.g. `-l`) and long options (e.g. `--reverse`)

```
pi@raspberrypi:~/GitHub/os420$ ls -lt *.org
-rw-r--r-- 1 pi pi 31073 Feb  6 10:45 agenda.org
-rw-r--r-- 1 pi pi 20720 Feb  6 09:38 notes.org
-rw-r--r-- 1 pi pi  3064 Feb  5 08:56 FAQ.org
-rw-r--r-- 1 pi pi 11641 Feb  4 08:07 schedule.org
-rw-r--r-- 1 pi pi 21862 Feb  4 08:07 syllabus.org
-rw-r--r-- 1 pi pi  1157 Feb  4 08:07 bookmarks.org
-rw-r--r-- 1 pi pi  1828 Feb  4 08:07 diary.org
-rw-r--r-- 1 pi pi  1389 Feb  4 08:07 README.org


pi@raspberrypi:~/GitHub/os420$ ls -lt --reverse *.org
-rw-r--r-- 1 pi pi  1389 Feb  4 08:07 README.org
-rw-r--r-- 1 pi pi  1828 Feb  4 08:07 diary.org
-rw-r--r-- 1 pi pi  1157 Feb  4 08:07 bookmarks.org
-rw-r--r-- 1 pi pi 21862 Feb  4 08:07 syllabus.org
-rw-r--r-- 1 pi pi 11641 Feb  4 08:07 schedule.org
-rw-r--r-- 1 pi pi  3064 Feb  5 08:56 FAQ.org
-rw-r--r-- 1 pi pi 20720 Feb  6 09:38 notes.org
-rw-r--r-- 1 pi pi 31073 Feb  6 10:45 agenda.org
pi@raspberrypi:~/GitHub/os420$
```

Figure 13: long time listing of Org-files (and reversion)

- Another useful long option for the `emacs` command that starts GNU Emacs is `--chdir=[dirname]` where `[dirname]` is the name of the folder where you want Emacs to "wake up"

Shell warm-up exercise

Complete the exercise on the command line (15 min):

Go to your `$home` directory, `/home/pi`

Use `wget` to get `sample.txt` from `os420` in GitHub[2]

Display first line of `sample.txt`

Make a sub directory titled `practice` in `$home`

Change directory to `/home/pi/practice`

Verify that you are where you want to be

Move `sample.txt` to your current directory as `sample_1.txt`

Make a copy of `sample_1.txt` and name it `sample_2.txt`

Ascertain that the files are indeed identical by using `diff`

View both files together using `less`

Inside `less`, move between the two files

Leave `less`

- Solution in the interactive notebook
- Will make a solution screencast, too

THE LINUX FILE SYSTEM ("EVERYTHING IS A FILE")

- Open a terminal and look at the file system

```
ls -lF /
```

DIRECTORY	CONTENT
/	Root directory where everything begins
/bin	Executable binaries for the OS to boot and run
/boot	Linux kernel, initial RAM disk image to boot
/dev	List for kernel with all known devices
/etc	System configuration files (e.g. /etc/passwd)
/home	Directory for user directories (e.g. /home/pi)
/lib	Shared library files (like Windows DLLs)
/lost+found	Panic room for each formatted disk partition
/media	Mount points for removable media (e.g. USB stick)
/mnt	Mount points for manually mounted removable media
/opt	Optional commercial software
/proc	Virtual FS for the kernel (e.g. /proc/cpuinfo)
/root	$HOME directory of the root super-user
/sbin	System binaries for system tasks (sudo shutdown)
/tmp	Holding bay for temp files, emptied at reboot
/usr	Programs and support files for regular users
/usr/bin	Executable programs of the distro[3] (e.g. cat)
/usr/lib	Shared libraries for /usr/bin programs
/usr/local	Programs not included in your distro
/usr/sbin	More system administration programs
/usr/share	Shared data for /usr/bin programs (e.g. sound files)
/usr/share/doc	Man pages and other package documentation
/var	Databases, spool files, user mail (volatile files)
/var/log	Records of system activity (e.g. /var/log/syslog)

What's next

- Test 1, Thursday 10 February 2022, 10:00-10:45
- Raspberry Pi history & hardware
- Manipulating files and data
- New DataCamp assignment due Feb 15 ("Combining tools"))

Raspberry Pi history and hardware - w5s9 (10-Feb)

Overview

HOW	WHAT

HOW	WHAT
Lecture/demo	Raspberry Pi - the hardware & the history 1
Test 1	10:00-10:45 AM

Objectives

- [x] Know Raspberry Pi: history & hardware (part 1)
- [x] Complete test 1 (online)

Raspberry Pi - hardware & history: hardware

- Raspberry Pi history
- Which other devices have an Arm processor?

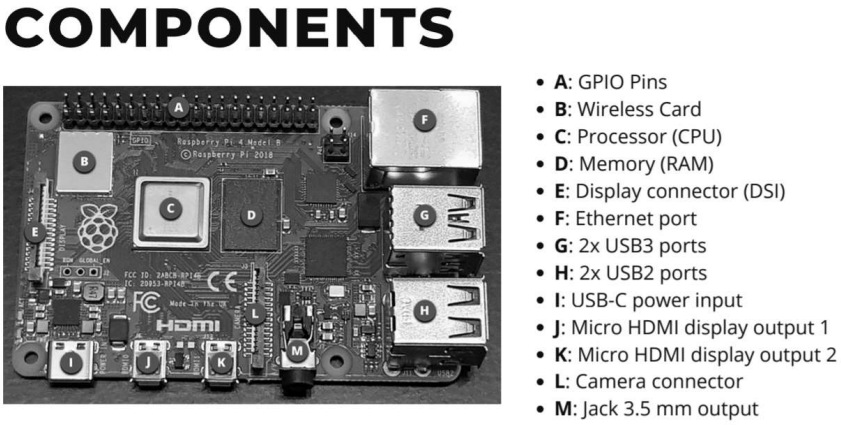


Figure 14: Raspberry Pi 4 Board (Source: raspberryptips.com)

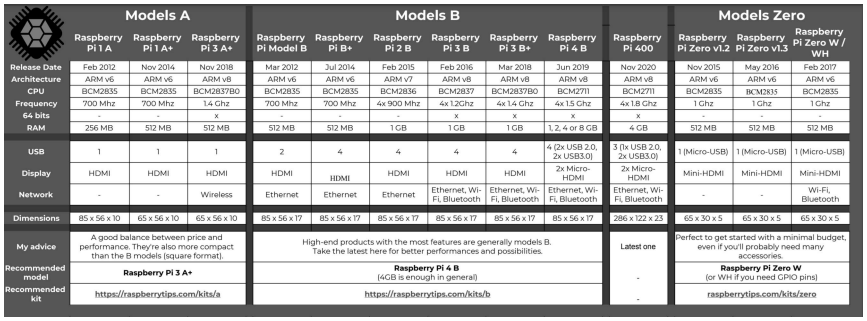


Figure 15: Raspberry Pi 4 Board (Source: raspberryptips.com)

- Identify your model of Raspberry Pi+ (`cat /proc/cpuinfo`)
- Introduction to GPIO pins (gh) - my fifth Pi project

Review of test 1 - w6s10 (15-Feb)

News

- **Eliminated** some DataCamp assignments (bash scripting) because otherwise we'll get too far out of step with the course content

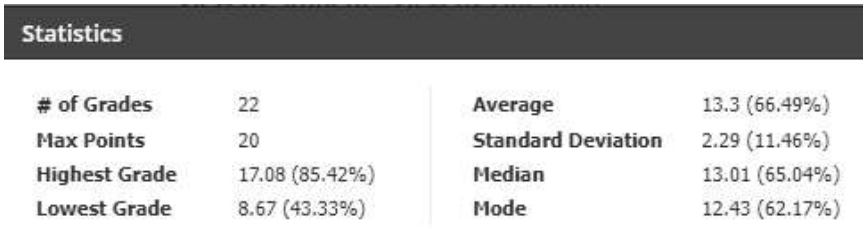
- **Join us** for a talk by Matthew Stewart, Stone Ward (Fri 18 Feb 3-3.50 PM) via Google Meet

Objectives

- [X] Understand test results
- [X] Know what to do different next time
- [X] Discuss all questions and answers
- [X] Share your views & suggestions

Test results - stats and plots

- The results are nothing to write home about - though > 50% means that the class passed (on average).



Statistics			
# of Grades	22	Average	13.3 (66.49%)
Max Points	20	Standard Deviation	2.29 (11.46%)
Highest Grade	17.08 (85.42%)	Median	13.01 (65.04%)
Lowest Grade	8.67 (43.33%)	Mode	12.43 (62.17%)

Figure 16: Test 1 results (Schoology)

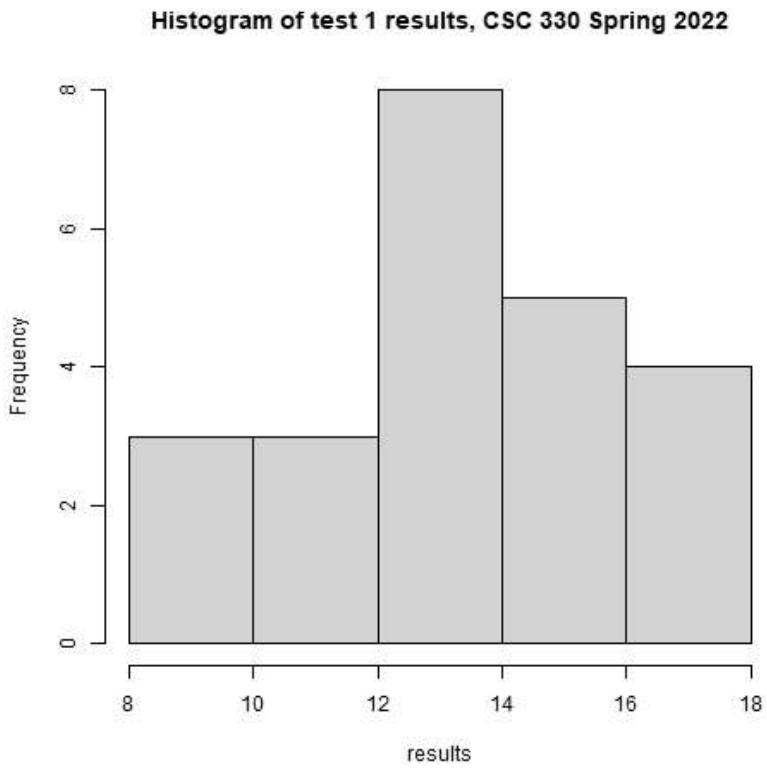
- I am an obsessive fact-checker. When checking the stats with R, I find slightly different results:

```
results <- c(11.88,13.92,12.43,13.6,9.93,8.67,14.87,
             14.87,13.02,10.58,17.08,9.72,12.77,15.42,16.5,
             17.02,13,16.13,14.03,12.93,12.43,14.73,11.9)
length(results)
sd(results)
summary(results)
```

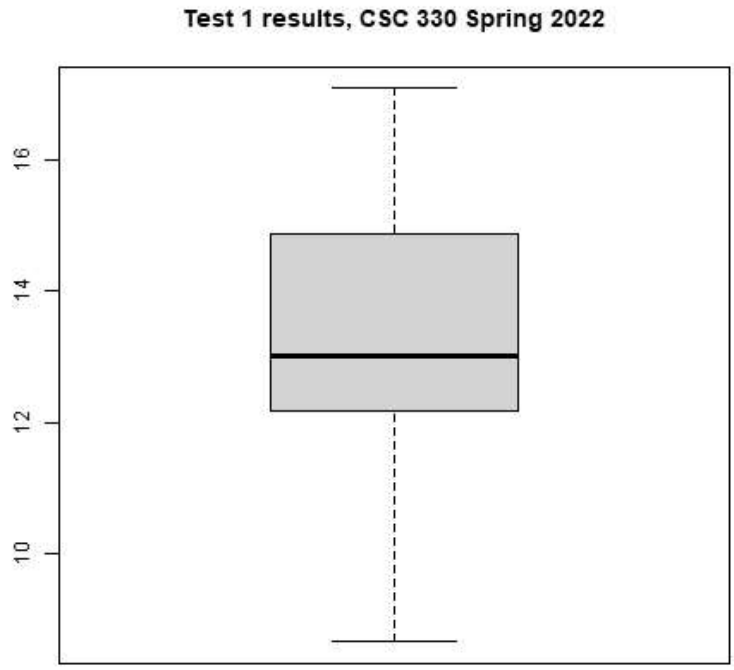
```
[1] 23
[1] 2.314336
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
   8.67   12.16   13.02   13.37   14.87   17.08
```

- Let's make some plots: histogram, boxplot and density plot. I'd like the histogram and the density plot (a smoothened histogram) to peak more to the right, and for the boxplot to be smaller and higher up.

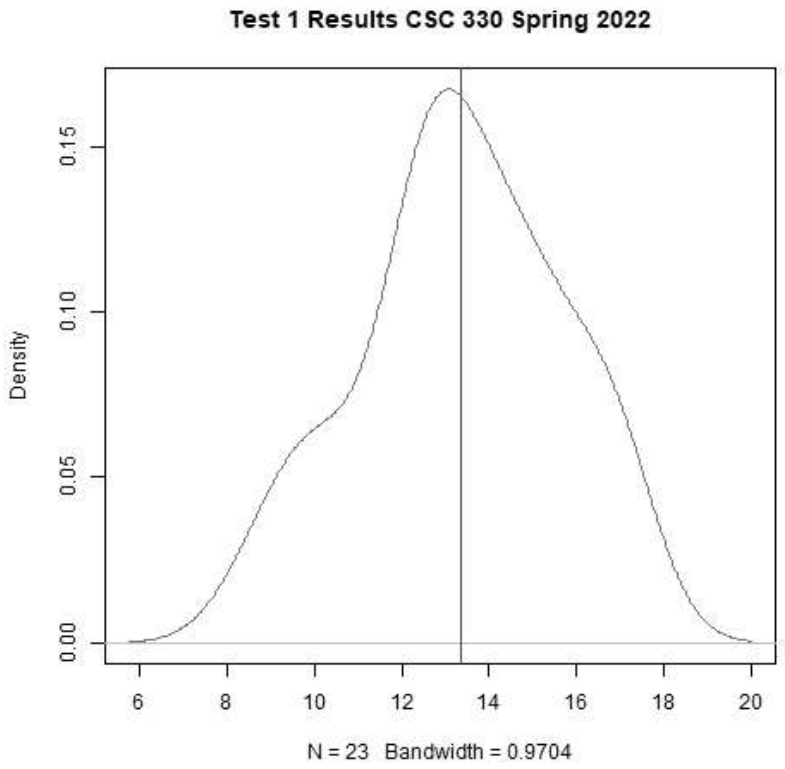
```
hist(results, main="Histogram of test 1 results, CSC 330 Spring 2022")
```




```
boxplot(results, main="Test 1 results, CSC 330 Spring 2022")
```



```
ave <- mean(results)
d <- density(results)
plot(d, col="steelblue",main="Test 1 Results CSC 330 Spring 2022")
abline(v=ave,col="red")
```



Analysis - feedback and action points

- Test 1 can now be played an unlimited number of times. I will add feedback to all new questions today.
- What surprised me most was that many of you did not use the available time. However, I have not (yet) been able to correlate test time and test success.
- See also: "I can teach it to you but I cannot learn it for you"
- Questions:
  - How did you study for this test?
  - If you didn't perform well, what will you change?
  - What can I do to help you help yourself?
- Changes to be applied in future quizzes/tests:
  - Fewer multiple choices (max. 4)
  - Announce if a question has > 1 answer (and/or how many)
  - Try and schedule tests for different classes on different days

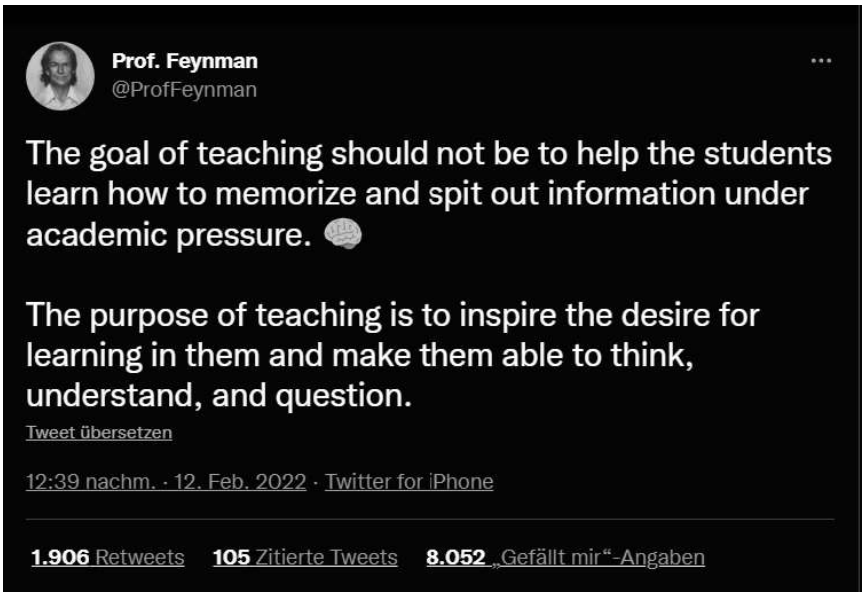


Figure 20: Feynman (via Twitter)

Test questions and answers

- We go through all questions together
- Everybody can contribute an answer
- Write down questions and ask them now!

Feedback for some individual questions

- "What is Booting?" - The kernel program must be in memory before the BIOS (Basic IO System), which is part of the kernel, can run. Then, when I/O is established, information can flow between memory (RAM), non-volatile memory (disk/card) and CPU. The system daemon oversees these processes.
- "Sort the OS timeline" - this is a question answered in the agenda file. 1) The whole thing started with OS as libraries without supporting programs - the support (e.g. for switching jobs) was done by humans. 2) Mainframe OS are for large computers - decades before the PC - and the introduction of a system handler program replaced the human operators. 3) Minicomputers are dedicated to specific jobs - e.g. visualization, and graph generation, or number crunching. These computers (which look like large PCs - workstations) already have the modern interrupt-based OS architecture. 4) PCs came up in the 1980s - Microsoft and Apple introduced OS (DOS/Windows and AppleOS/MacOS) that sacrificed security and relability (compared to UNIX) to convenience and usability. 5) Since the mid 1990s, we are slowly returning to the pre-PC world - the reintroduction of UNIX via Linux, but also in Windows and MacOS itself. Of course, if you can, go Linux all the way, why compromise?
- "Command line prompt" analyzed:
    1. `pi` is the standard user on the Raspberry Pi, belongs to the `gpio` group and can assume `root` rights with `sudo`.
    2. `@` is the at-sign separating the user from the hostname.
    3. `raspberrypi` is the hostname (you can get it with the command `hostname` or `hostname -I` for the internet address), or the name of the host = your computer.
    4. `/ is the current directory. In this case ~$HOME.`
    5. `$` is the prompt sign for regular users, after which you enter commands on the command line. For the `root` user, this prompt changes to `#`.
    6. Operating system definition:

        > The Operating System takes PHYSICAL resources (CPU, memory, disk), and VIRTUALIZES them. It handles CONCURRENT processes, and it stores files PERSISTENTLY to make them SAFE in the long term.

        Focuses on the three core characteristics of a modern OS: VIRTUALIZATION (i.e. the user does not see what's happening, everything seems to be in one place), CONCURRENCY (the user thinks processes run simultaneously,

while actually the CPU runs one job at a time), and PERSISTENT storage (referring to mass-storage management).

This week

- Test review
- Raspberry Pi Hardware - GPIO pins

GPIO pins - w6s11 (17-Feb)

Overview

HOW	WHAT
Setup	USB/HDMI > Power > Switch > `startx`
Lecture/demo	Raspberry Pi - the hardware & the history 2
Review/Practice	Manipulating data / Combining shell tools (DataCamp)
Shutdown	`sudo shutdown now` > USB/HDMI > Power > switch

Objectives

- [X] Know Raspberry Pi: hardware and history part 2
- [X] Understand GPIOs and how to see and control them

What's next

- Catching up with DataCamp: back to the Linux command line tools

Wildcards and Links - w7s12 (22-Feb)

Objectives

- [X] Review shell commands in DataCamp so far
- [X] Understand wildcards
- [X] Understand file links
- [X] Practice file and data manipulation

Warmup exercise: what's wrong with these commands?

Situation:

- `agenda.org` is this file
- the directory `testdir` exists in this directory (`./`)
- `test3` contains the file listing of this directory

Complication: none of these commands will run! Why?

```
head n 3 agenda.org # print top three lines to stdout
rm ./testdir/   # remove test
grep -count "org" ./test3  # search test3 for "org"
cat ./testdir/  # view testdir
ls-la  # list long info of all files
```

Manipulating files and directories

- Files are organized in a hierarchical directory structure[4]
- Imagine you stand somewhere inside an upside down tree:

- the `pwd` command tells you were you are
- above you (towards the root) are *parent directories*
- below you (away from the root) are *child directories*

- At the top is the *root directory*

Figure 21: upside down tree

- `[X]`

  To see the tree visualized, install the package as super user:

```
$ sudo apt install tree
$ tree
```

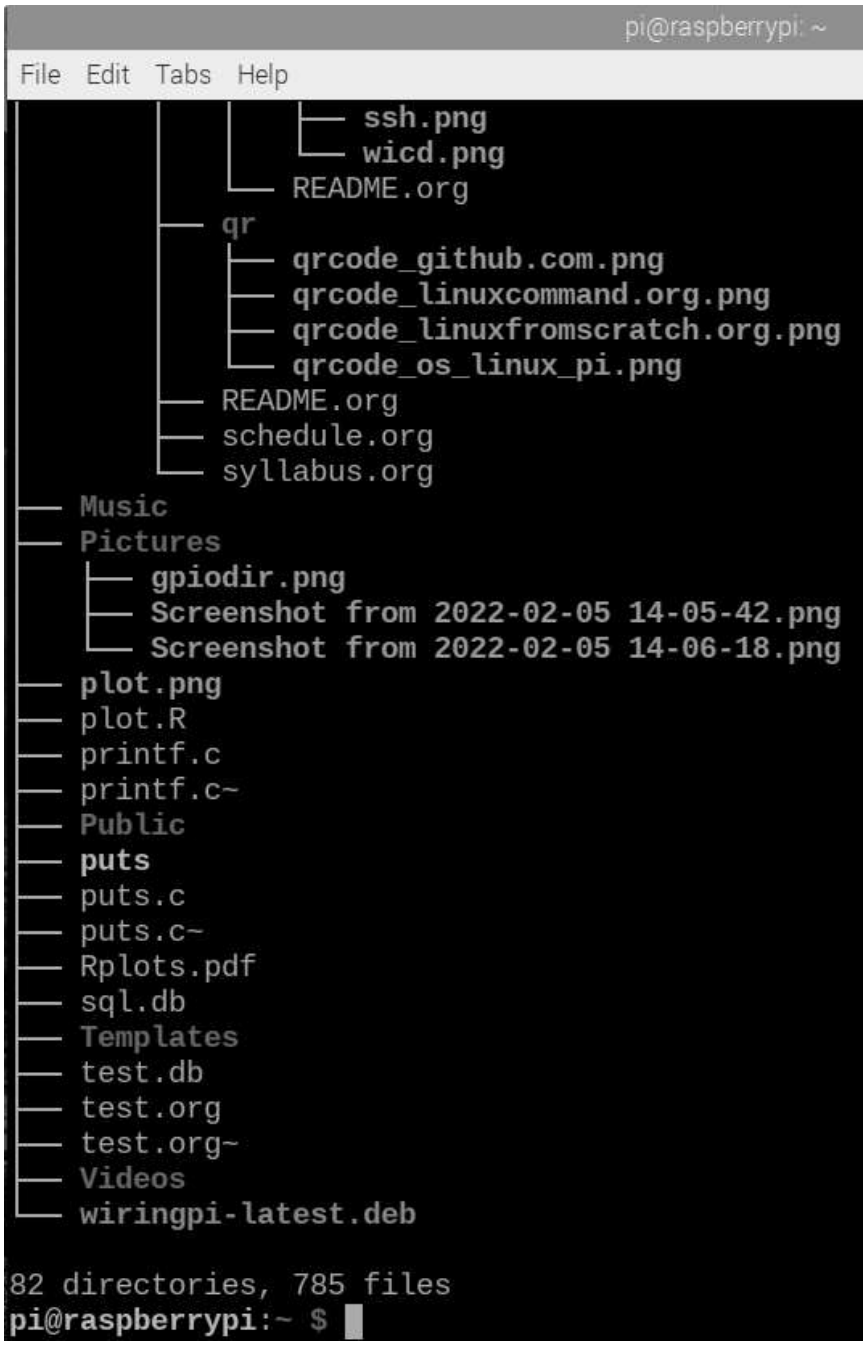


Figure 22: Linux tree command (screenshot)

- To list files, use `ls`. It has many useful options. I usually use `ls -la` to get a long, complete listing. This is also the standard `Dired` setting in Emacs.
- `[X]` Compare `ls`, `ls -l`, `ls -la`, `ls -lF`, and `ls -laF`
- `[X]` Which command would show the top directories of the OS?[5]
- To create an empty file, use `touch`
- `[X]` Create a file from the command line with `touch`.
- Filenames are character-sensitive.
- Don't embed spaces in file names, replace them by _
- Linux has no concept of file extensions - though many applications do (like Emacs, to identify a major mode like Org-mode)
- Hidden files (often for configuration like `.emacs`) remain hidden unless you invoke the `-a` option of `ls`

Shell commands so far (DataCamp course)

COMMAND	FUNCTION	OPTIONS
cp	copy file	-iruv
mv	move file	-iuv
mkdir	make directory	
rm	remove files or directories	-irfv
rmdir	remove directory	
ln	link	-s
head	show N first lines	-n N
tail	show M last lines	-n M
less	view file pagewise	
more	view file pagewise	
cat	view file	
cut	print COLS separated by SEP	-d SEP -f COLS
paste	merge lines of files	-d SEP
grep	search pattern	-chilnv
wc	word count	-cwl
sort	sort row data	-nrbf
uniq	remove adjacent duplicates	-c
history	last commands entered (!)	
man	Unix man page (sect. 1-8)	

Wildcards ("globbing")

- `bash(1)` does not recognize regular expressions - there are utilities like `sed` and `awk` that interpret them
- The commands below can be tested with the `echo` command or with `ls`
- Wildcards use character sets and classes, like `:digit:` for numerals, or `:upper~/`:lower:~ for uppercase/lowercase letters

WILDCARD	MEANING	Example
`*`	Matches any characters	`*.org`
`?`	Matches any single character	`?????.org`
`[char]`	Match any character in [char]	`[ba]*.*`
		`ls FILE[0-9][0-9][0-9]`
`[!char]`	Match any character not in [char]	`[!ba]*.*`
`[[:class:]]`	Match any character in class	`[[:upper:]]*.org`
		`[[:!digit:]]*`

- Wildcards can be used with any commands that accepts file name arguments
- Powerful in connection with pattern search cmds like `grep`
- Many wildcards have found their way into graphical user interfaces, too[6]
- The SQL injection hack is based on wildcards - the openess of Linux can be detrimental if system administrators are too lax

Links

- The `ln` command creates hard or symbolic (soft) links (symlinks)

```
ln file link  # create hard link from file
ln -s item link # create soft link from item
```

Hard links and `inode`

- A hard link creates an additional directory entry for a file
- A hard link cannot leave its (physical) file system
- A hard link is indistinguishable from the file itself

- A file is made up of a **name** part and of a **content** part: when creating hard links, the system assigns a chain of disk blocks to an `inode`, a unique number in the file system that you can see with the listing command `ls -i`

```
ls -i *.org
```

```
388132 agenda.org
389984 bash.org
388137 bookmarks.org
388142 diary.org
388130 FAQ.org
388201 notes.org
388131 README.org
388219 schedule.org
388220 syllabus.org
```

Soft (sym) links

- A symlink contains a text pointer to the reference file or directory
- Operates like a Windows OS shortcut
- If you write to the symbolic link of a file, the file is written to
- When you delete the link, the file is untouched
- If the file is deleted first, the link is said to be broken

Practice

You can get the Org-mode file for practice `manipulate.org` from GitHub.

Next topics

- Redirection
- Permissions
- Processes

Standard streams, Notebook tutorial - w8s13 (1-Mar)

Objectives

- [x] Review: quiz 4-5 (comment/complain/challenge)
- [x] Review: warming up exercise "N'est pas une pipe"
- [x] Lecture: standard streams
- [x] Practice: getting started with interactive notebooks
- [ ] Practice file and data manipulation 2
- [ ] Getting (more) help

Always first

- Update your system

```
sudo apt update -y
sudo apt upgrade -y
```

Warming up - "N'est pas une pipe"

Figure 23: Magritte's "The Treachery of Images" (1928)

After completing the last DataCamp assignment, I got my wires crossed somehow. Can you define these terms and give examples?

TERM	MEANING
grep -v [expr]	inverse pattern search
:digits:	numerical wildcard class
pipeline operator	connects stdout to stdin
redirection operator >	directs stdout to file
???	wildcard for any 3 characters
wc -l	count number of lines

Standard streams

- Every Unix tool does only one thing really well
- E.g. `grep` filters, `sort` sorts, `wc` counts lines
- Power = OS manages tool communication streams
- There are three such streams: `stdin`, `stdout`, `stderr`

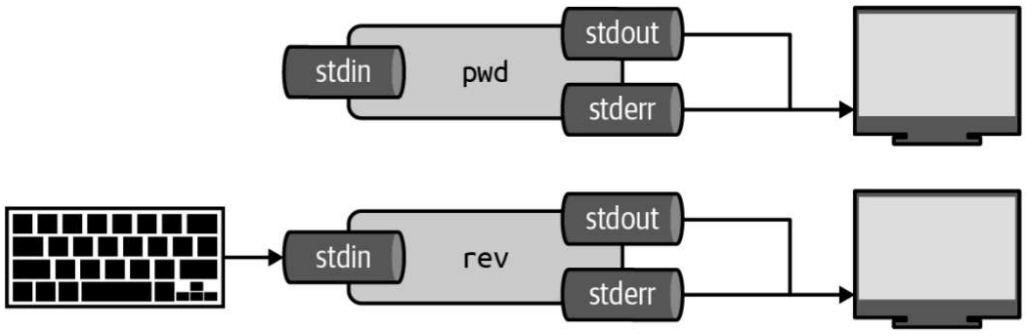


Figure 24: stdin, stdout, stderr streams (Source: Janssens)

- `stdout` and `stderr` are by default redirected to terminal
- E.g. `rev` will wait until it gets `stdin` (end with `C-c C-c`

```
Birkenkrahe@LCjvyz1b3 ~
$ rev
newline
enilwen
I don't know what this command does
seod dnammoc siht tahw wonk t'nod I
```

Figure 25: rev reverses stdin to stdout characters

- One command's `stdout` can become another command's `stdin`

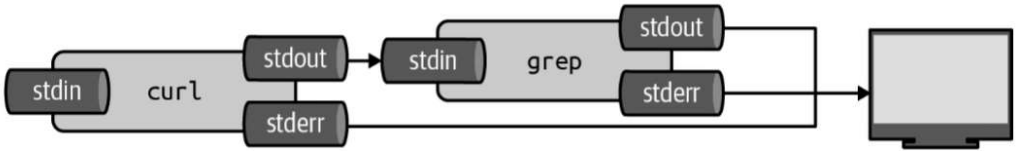


Figure 26: pipe with curl and grep (Source: Janssens)

- E.g. download the book "Alice's Adventures in Wonderland" by Lewis Carroll and pipe it to `grep` for a pattern search:

```
curl -s "https://www.gutenberg.org/files/11/11-0.txt" | grep " CHAPTER"
```

```
Birkenkrahe@LCjvyz1b3 ~
$ curl -s "https://www.gutenberg.org/files/11/11-0.txt" |grep " CHAPTER"
 CHAPTER I.     Down the Rabbit-Hole
 CHAPTER II.    The Pool of Tears
 CHAPTER III.   A Caucus-Race and a Long Tale
 CHAPTER IV.    The Rabbit Sends in a Little Bill
 CHAPTER V.     Advice from a Caterpillar
 CHAPTER VI.    Pig and Pepper
 CHAPTER VII.   A Mad Tea-Party
 CHAPTER VIII.  The Queen’s Croquet-Ground
 CHAPTER IX.    The Mock Turtle’s Story
 CHAPTER X.     The Lobster Quadrille
 CHAPTER XI.    Who Stole the Tarts?
 CHAPTER XII.   Alice’s Evidence
```

Figure 27: piping example with curl and grep

- And if we want to know how many chapters there are, apply `wc -l`
- Output redirection works with the `>` operator[7]: you can e.g. pipe the chapter list into a file.

```
chap > chapterlist
```

- This presumes that you defined an alias `alias chap='[cmd]'`. Try it!
- You can also append output to a file with >>

- If you want to pass a file through a command without running an additional process, use <. These two commands do the same thing:

```
cat sample.txt | wc -w
< sample.txt wc -w
```

- We'll deal with more complicated examples in another session!
- This section is based on Janssen's "Data Science at the Command Line (2nd ed)" (2021), which you can read for free online.

Getting started with interactive notebooks

- Get the files from the GDrive repository
- Work through the Notebook Tutorial (`start_nb.org`)

Next

- Redirection
- Permissions
- Processes

Mid-term speech, REPLit, redirection stdout- w8s14 (3-Mar)

Objectives

- [X] Notebooks stuff moved to GDrive
- [X] Mid-term grades improvement
- [X] REPL in the cloud - scripting and shell
- [X] Understand redirection better 1

Notebooks stuff moved to GDrive

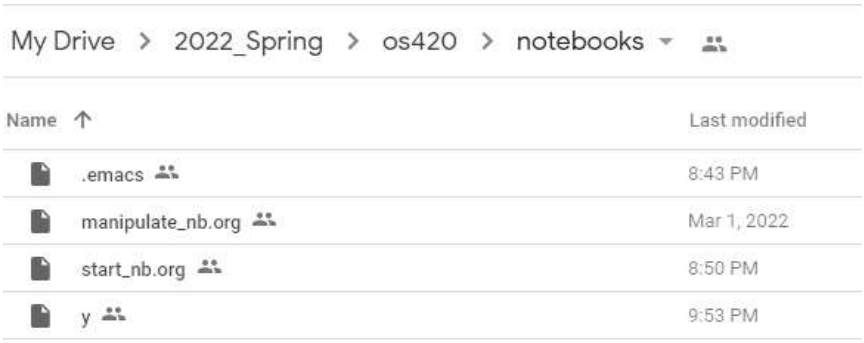


Figure 28: Replit.com startup screen

Mid-term grades improvement

- You can ask me personally and specifically, what to do to get your grades up
- There is no reason not to have at good grade in my class:
    1. You can usually submit in-class assignments late
    2. The deadlines of the DataCamp assignments are well known
    3. The quizzes contain ample instructions and can be repeated

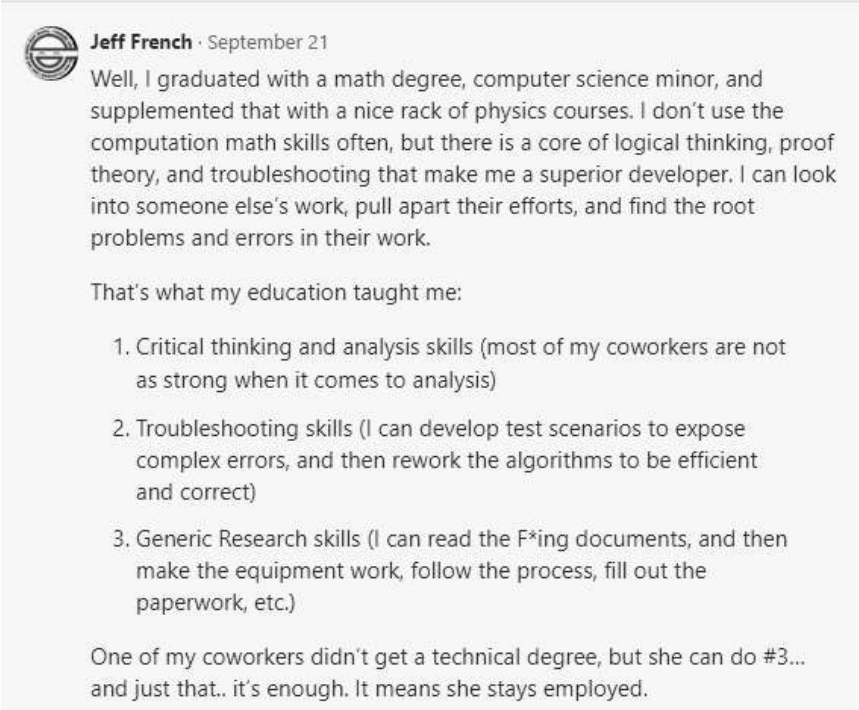
4. Class attendance + Whiteboard screenshots + GitHub info
5. You can always talk to me for personal support

- Hence, to improve your grade, do:
  - Submit in-class assignments if you could not attend class
  - Complete DataCamp assignments on time
  - Play the quizzes until you have 100% and read the feedback
  - Attend class + look at screenshots + files afterwards
  - Practice your skills whenever you can
  - When you are attending in person, really attend
  - Ask me in or outside of class if anything is unclear
- These skills are related to successful studying, which in turn is related to success in life through traditional values: **discipline**, **duty**, and **diligence**. This doesn't have anything to do with computer science.

- What I'm going for in my classes is what I think computer scientists need more than anything else:

1. Critical thinking and analysis skills
2. Troubleshooting skills
3. Research skills

This is nicely mirrored in this comment to the question "Why are computer science degrees so math intensive when the field doesn't seem to use much math at all?" on Quora.



Jeff French · September 21

Well, I graduated with a math degree, computer science minor, and supplemented that with a nice rack of physics courses. I don't use the computation math skills often, but there is a core of logical thinking, proof theory, and troubleshooting that make me a superior developer. I can look into someone else's work, pull apart their efforts, and find the root problems and errors in their work.

That's what my education taught me:

1. Critical thinking and analysis skills (most of my coworkers are not as strong when it comes to analysis)
2. Troubleshooting skills (I can develop test scenarios to expose complex errors, and then rework the algorithms to be efficient and correct)
3. Generic Research skills (I can read the F*ing documents, and then make the equipment work, follow the process, fill out the paperwork, etc.)

One of my coworkers didn't get a technical degree, but she can do #3... and just that.. it's enough. It means she stays employed.

Figure 29: What's math got do to with computer science?

`bash` Read-Eval-Printing-Loop in the cloud

- In a perfect world, we'd all be working on Linux boxes so that you can do `bash` scripting at home
- In the real world, you can also use a cloud REPL to learn and practice scripting with bash
- replit.com uses a Nix Docker container to emulate the shell (this is another way to get hold of Linux tools…do you remember the others?[8])
- Login to your Google or GitHub account (the latter is more useful)

- Register with Replit.com

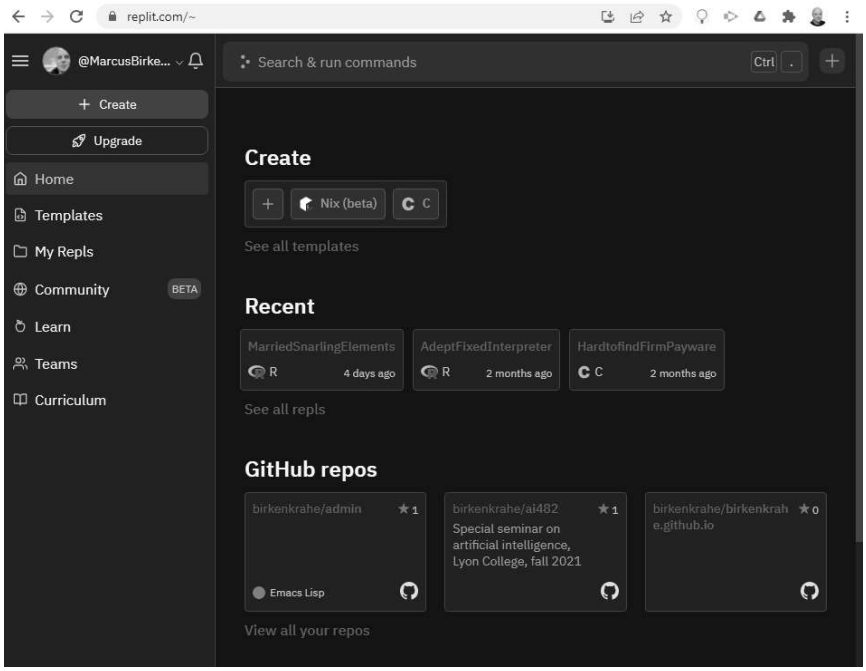


Figure 30: Replit.com startup screen

- Once registered, you can pick among many language templates
- You can create as many REPLs as you like on a free account

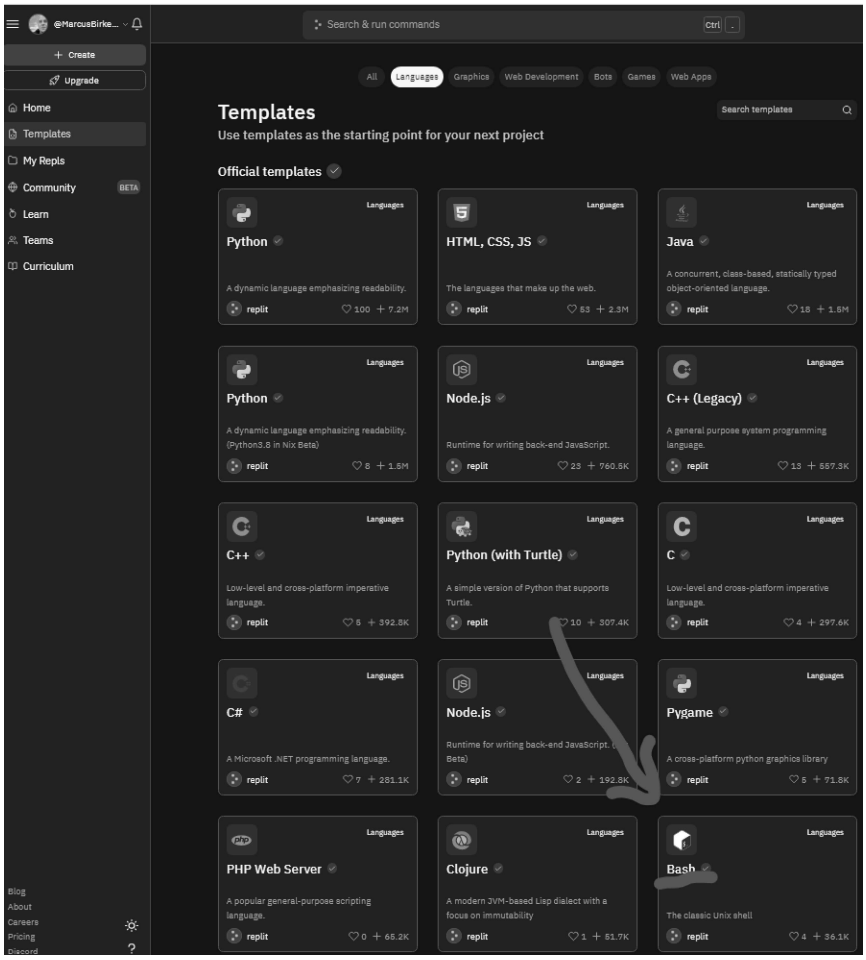


Figure 31: Replit.com language templates

- Pick Bash! Your REPLs are automatically public and shareable.
- For example, to join the bash REPL shown below, use this link.

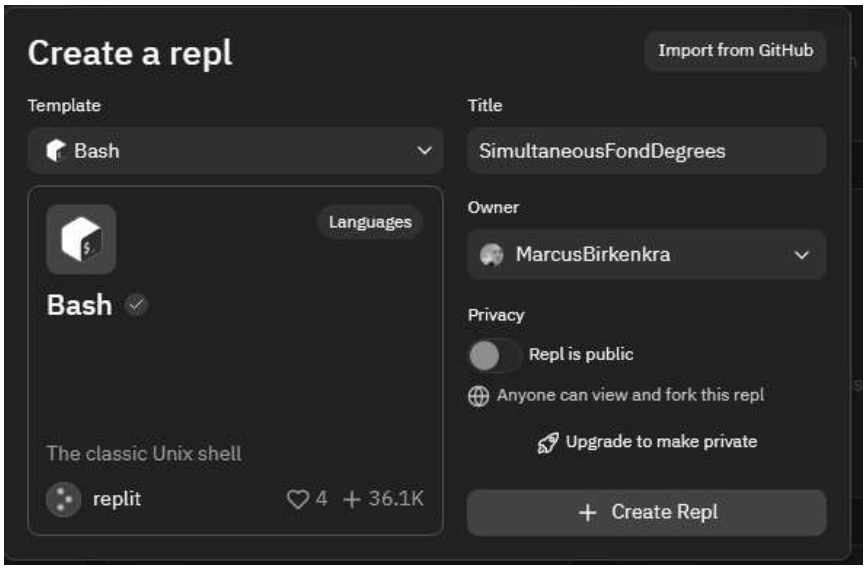


Figure 32: Create a titled, shareable repl

- You can now run any (?) bash script in the REPL

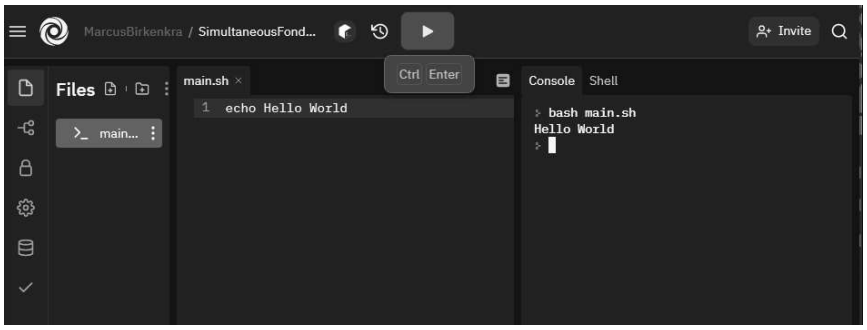


Figure 33: Run bash script in the REPL

- It gets better: you also have access to a shell REPL
- Open the `Shell` tab. Looks like this:

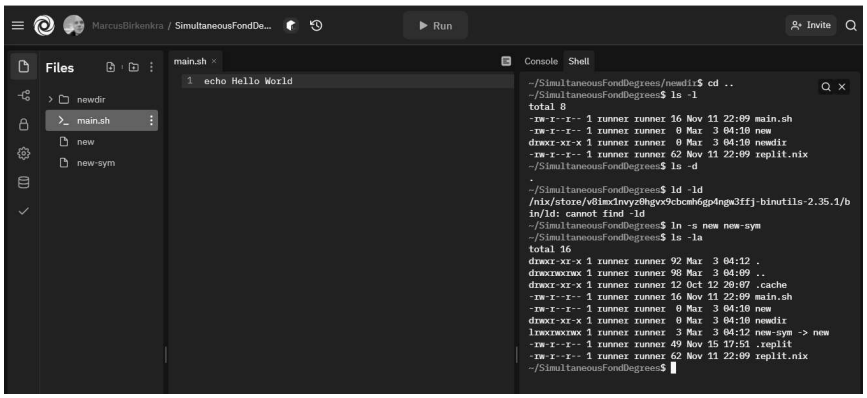


Figure 34: Use the shell in REPL mode

- Perform a little shell gymnastics:
  1. Check where you are
  2. Check if you can get to the root
  3. Check the operating system
  4. What timezone is the server linked to?
  5. Check your shell program
  6. Go to your home directory
  7. Make another directory and go there
  8. Create an empty file called `file`
  9. Create a symbolic link called `file-sym`
  10. Store the symlink creation command in an alias 'symlink'
  11. Test the alias on another file
  12. Unalias the alias
  13. Go back to your home directory and clean up
  14. Bookmark your REPL before closing the application

Redirection revisited

- I/O redirection is the coolest command line feature
- Important commands include:
  - `cat` to concatenate files

    - `sort` to sort lines of text
    - `uniq` to report or omit repeated lines
    - `grep` to print lines matching a pattern
    - `wc` to print file newline, word, and byte counts
    - `head` to output the first part of a file
    - `tail` to output the last part of a file
    - `tee` to read from `stdin` and write to `stdout` and files
- `stdin`, `stdout` and `stderr` are special files
- `[X]` Execute the following commands in your REPL of choice.

Redirecting standard output

- `[X]`

  It's often useful to store results in a file. What does the command in 1 do?

  ```
  ls -l /usr/bin > ls-output.txt
  ```

- `[X]`

  Let's look at the file from the outside first.

  ```
  ls -l ls-output.txt
  ```

- `[X]`

  Let's look at the first and the last part of the file

  ```
  head ls-output.txt
  tail ls-output.txt
  ```

- `[X]`

  We redirect again, this time using a directory that does not exist. This results in an error - but why is it not sent to the file instead of `stdout`?

  ```
  ls -l /bin/usr > ls-output.txt
  ```

- `[X]`

  What happened to the output file?

  ```
  ls -l ls-output.txt
  ```

- `[X]`

  If you ever want to create a new empty file (without `touch`), you can use this trick:

  ```
  > ls-output.txt
  ```

- `[X]`

  To append redirected output to a file instead of overwriting it from the beginning, use >>. Let's test this:

  ```
  ls -l /usr/bin >> ls-output.txt
  ls -l /usr/bin >> ls-output.txt
  ls -l /usr/bin >> ls-output.txt
  ls -l ls-output.txt
  ```

Redirection: stderr, stdin - w9s15 (8-Mar)

Agenda

- [X] Waking up in `AppData/Roaming`? Change your Emacs HOME now.
- [X] How to Create Symlinks in Windows 10 (it's not impossible!)
- [X] Improve your grade with a project (see FAQ)
- [X] Preparations for test 2 (Tue 15-Mar)
- [X] Review Docker/container technology (notes)
- [X] Complete Manipulate Files notebook on your own!
- [ ] Review DataCamp ("Batch Processing")

Preparations for test 2 (Tue 15-Mar)

- Test 2 will only cover questions from quiz 4-6 + new questions.
- You can find quiz 4-6 with solutions + feedback as PDF (in /quiz)
- I will create an update of content Org files (in pdf/)

Creating symlinks in Windows 10

- I changed my Emacs HOME directory and needed to symlink the `.emacs` file from there to the old location
- You can do this with the GUI or on the CMD line. Confusingly, the argument order is the reverse from UNIX: `mklink [link] [origin]` instead of `ln -s [origin] [link]`.

```
mklink C:\Users\birkenkrahe\.emacs C:\Users\birkenkrahe\Documents\GitHub\.emacs
```

```
C:\Users\birkenkrahe>dir *emacs*
 Volume in drive C is OS
 Volume Serial Number is 0654-135C

 Directory of C:\Users\birkenkrahe

03/06/2022  03:09 PM    <SYMLINK>      .emacs [C:\Users\birkenkrahe\Documents\GitHub\.emacs]
03/05/2022  08:18 PM    <DIR>          .emacs.d
01/31/2022  10:00 AM             1,089 .lyonemacs
10/09/2021  01:30 PM               125 emacs.org
01/28/2022  10:21 AM               106 emacs.sh
               4 File(s)          1,320 bytes
               1 Dir(s)  345,446,686,720 bytes free
```

Figure 35: symlink example in Windows 10

Improve your grade with a project (FAQ)

If you want to improve your grade, you can talk to me about doing a small, independent research project leading to a writeup in the form of a notebook, or a short (10-15 min) presentation. The topic must be related to the topic of this course. (See FAQ.)

Redirection revisited: stderr and stdout

- Download `redirection.org` from the `practice` directory in GDrive (Link in Schoology), or from GitHub.
- Code along while working on the file in GNU Emacs.

Redirection: pipeline commands - w9s16 (10-Mar)

Agenda

- [ ] Complete `redirection.org` workbook
- [ ] Review quiz questions quiz 4-6

References

- element14 (n.d.). Identifying Your MOdel of Raspberry Pi [blog]. URL: community.element14.com.
- Janssens (2021. Data Science at the Command Line (2e). O'Reilly. URL: datascienceatthecommandline.com.
- Shotts (2019). The Linux Command Line (2e). NoStarch Press.
- Vaughan-Nichols (9 Feb 2022). Best desktop Linux for pros 2022: Our top 5 choices [blog]. URL: www.zdnet.com.
- Wikipedia (25 Dec 2021). The Treachery of Images [website]. URL: wikipedia.org.

Footnotes:

[1] Unix manual pages are formatted with `troff`, the Unix "typsetter roff", a document processing system. "roff" stands for "I'll run off a document".

[2] An alternative (that takes much longer, because many files have to be downloaded, and the Pi 3B+ isn't the strongest networker) is to clone the entire `os420` repository with the command:

```
$ git clone https://github.com/birkenkrahe/os420
```

[3] A "distro" is a Linux distribution, like Ubuntu or Raspbian, or Kali. Distro design and distro news bind a lot of fanboy energy, see e.g. "Best desktop Linux for pros 2022" (Vaughan-Nichols, 2022).

[4] Windows likes to call directories 'folders' - another unnecessary dumbing down. A folder is just a container, but a directory (like the "telephone directory") has a data structure, an index, labels, and serves to search and find. Don't say "folder".

[5] Answer: `ls /` lists the root directory, because `/` is root's home. The particular ordering and naming of these directories is up to the Linux OS file administrator, but there are certain style rules that are usually obeyed by every professional.

[6] I have not tried this but I would have thought that the Google search bar permits use of wildcards.

[7] In the language R, both of these are combined as `|>` because they really are the same thing:

```
mtcars |> head(1)
```

```
          mpg cyl disp  hp drat   wt  qsec vs am gear carb
Mazda RX4  21   6  160 110  3.9 2.62 16.46  0  1    4    4
```

Output:

```
:           mpg cyl disp  hp drat   wt  qsec vs am gear carb
: Mazda RX4  21   6  160 110  3.9 2.62 16.46  0  1    4    4
```

[8] (1) Virtualbox with a Linux image; (2) Cygwin utility tool bundle; (3) dual boot with Linux e.g. from a USB Stick or an SD-card; (4) Installing the Ubuntu app from the Microsoft store. (5) eshell (emulated Lisp shell in Emacs), (6) replit.com (online cloud Linux), (7) download and install a Docker image/container. If you're serious about learning OS, you should give all of these a try just for fun (Research + analysis skills)! Also, any of these will enable you to practice many of the commands you learn in this course. And when a command does not work, you'll learn why (troubleshooting skill!).

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