

COMP201

Computer Systems & Programming

Lecture #01 – Introduction



KOÇ
UNIVERSITY

Aykut Erdem // Koç University // Spring 2022

A little about me...

Koç University
Associate Professor
2020-now



Hacettepe University
Associate Professor
2010-2020



Università Ca' Foscari di Venezia
Post-doctoral Researcher
2008-2010



Middle East Technical University
1997-2008
Ph.D., 2008
M.Sc., 2003
B.Sc., 2001



MIT
Fall 2007
Visiting Student



VirginiaTech
Visiting Research Scholar
Summer 2006



- I explore better ways to understand, interpret and manipulate visual data.

- My research interests span a diverse set of topics, ranging from image editing to visual saliency estimation, and to multimodal learning for integrated vision and language.



<https://aykuterdem.github.io>

Plan For Today

- Course Introduction
- COMP201 Course Policies
- Unix and the Command Line
- Getting Started With C

Disclaimer: Slides for this lecture were borrowed from
—Nick Troccoli's Stanford CS107 class

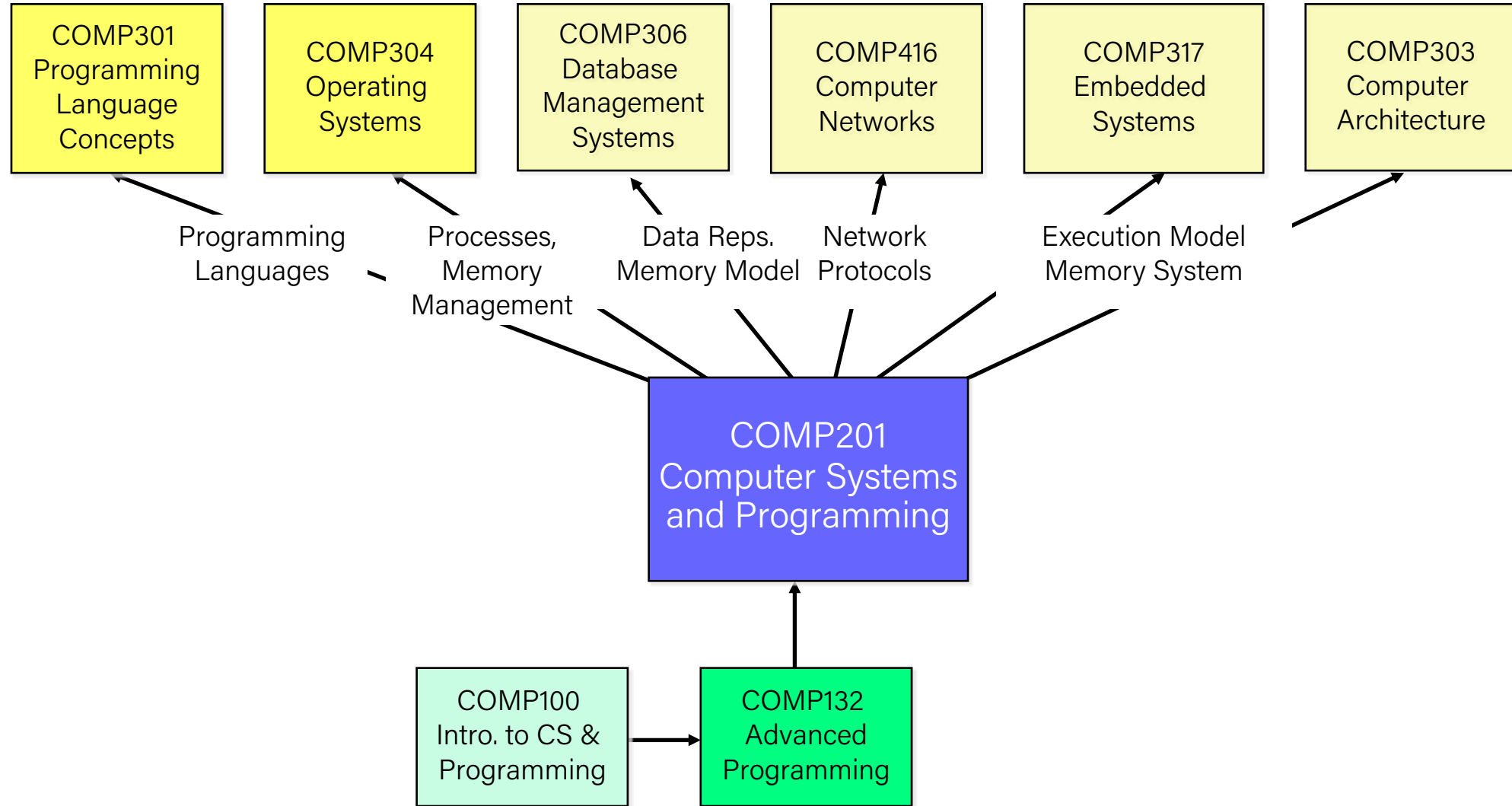
Lecture Plan

- Course Introduction
- COMP201 Course Policies
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- Getting Started With C

What is COMP201?

- A new addition to the COMP curriculum, designed from ground-up.
- The third course in the line of COMP's introductory programming courses (COMP100, COMP132, and COMP201)
 - COMP100 teaches you the notion of computational thinking and how to solve problems as a programmer (using Python)
 - COMP132 introduces you object-oriented programming paradigm (using Java)
- COMP201 takes you **behind the scenes**:
 - Not quite down to hardware or physics/electromagnetism (that's for later...)
 - It's how things work **inside C++/Python/Java**, and how your programs map onto the components of computer systems
 - Not only does it just feel good to know how these work, it can also inform projects you work on in the future.

Role within COMP Curriculum



What is COMP201?



Computer Systems and Programming

- How languages like C++ and Java **represent data** under the hood
- How programming structures are encoded in **bits and bytes**
- How to efficiently **manipulate and manage memory**
- How computers **compile** programs
- How **cache memories work** and **how to exploit them** to improve the performance of your programs
- Uses the **C** programming language
- Programming **style** and software development practices

COMP201 Learning Goals

The goals for COMP201 are for students to gain **mastery** of

- writing C programs with complex use of memory and pointers
- an accurate model of the address space and compile/runtime behavior of C programs

to achieve **competence** in

- translating C to/from assembly
- writing programs that respect the limitations of computer arithmetic
- finding bottlenecks and improving runtime performance
- working effectively in a Unix development environment

and have **exposure** to

- a working understanding of the basics of cache memories

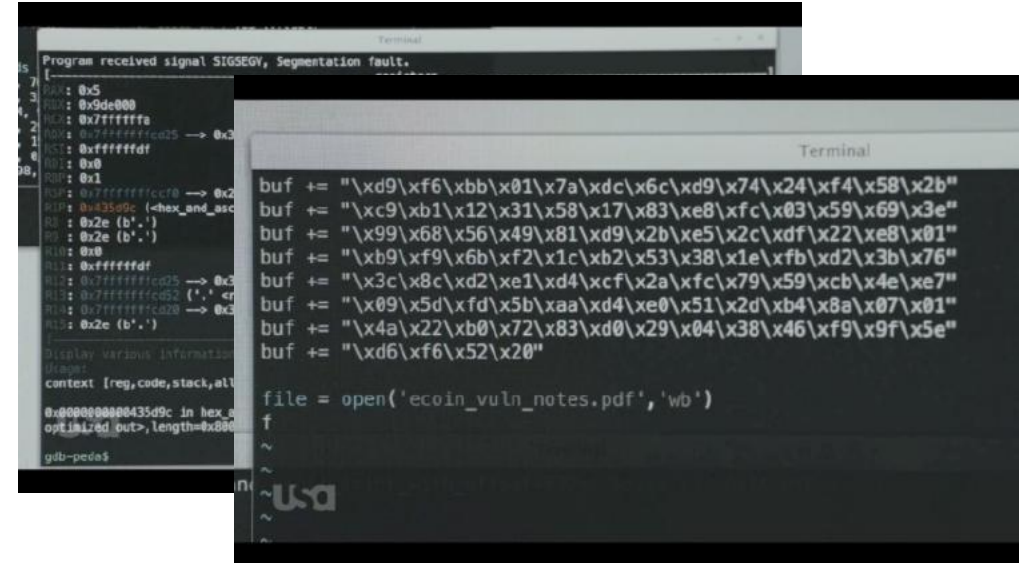


COMP201 Learning Goals

(also learn to identify legitimate programmer scenes in Hollywood movies)



Jeff Goldblum's character saving the
world by uploading a virus to
the alien mothership
Independence Day, 1996



Elliot creating a malicious PDF file, which contains some sort of shellcode that will allow him to take over any Linux computer that opens that file in Evince.

Mr. Robot, S3, Ep9 - eps3.8_stage3.torrent (2017)

Course Overview

1. **Bits and Bytes** - *How can a computer represent integer numbers?*
2. **Chars and C-Strings** - *How can a computer represent and manipulate more complex data like text?*
3. **Pointers, Stack and Heap** – *How can we effectively manage all types of memory in our programs?*
4. **Generics** - *How can we use our knowledge of memory and data representation to write code that works with any data type?*
5. **Assembly** - *How does a computer interpret and execute C programs?*
6. **The Memory Hierarchy** - *How does the memory system is organized as a hierarchy of different storage devices with unique capacities*
7. **The Heap Allocators** - *How do core memory-allocation operations like malloc and free work?*

COMP201 - The Hybrid Edition

- This semester, we will try our best to make your COMP201 experience as close as the face-to-face teaching version.
- **We are working to emphasize community and connection.**
- We understand that the pandemic poses unique challenges for each and every one of us involved.
- We will constantly evaluate and listen to ensure the class is going as smoothly as possible for everyone.
- Please don't hesitate to reach out if you want our support. We are always here for you.

Teaching Team



Aykut Erdem



Samet Demir



Mert Çökelek



Nafiseh Jabbari
Tofighi



Pınar Erbil



Doğa Ege
İnhanlı



Irem Karaca



Omer
Faruk Tal



Ahmet Uyar

Course Website

<https://aykuterdem.github.io/classes/comp201/>

*lecture videos on Panopto – can be accessed through Blackboard or from the course webpage

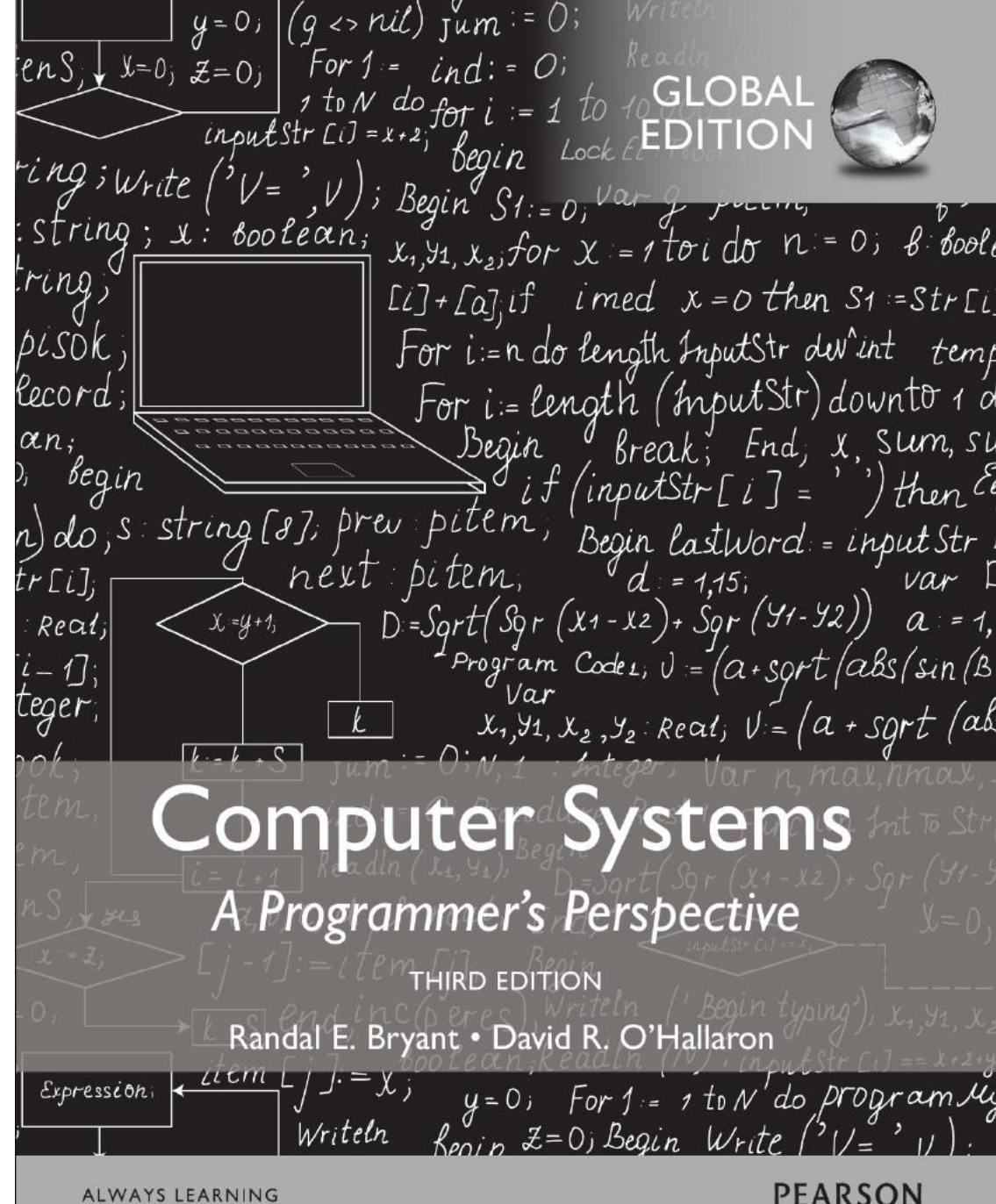
Question Break!

Lecture Plan

- Introduction
- **COMP201 Course Policies**
- Unix and the Command Line
- Getting Started With C

Textbooks

- *Computer Systems: A Programmer's Perspective* by Bryant & O'Hallaron, 3rd Edition
 - 3rd edition matters – important updates to course materials
- A C programming reference of your choice
 - *The C Programming Language* by Kernighan and Ritchie
 - Other C programming books, websites, or reference sheets



Course Structure

- **Lectures:** understand concepts, see demos
- **Labs:** learn tools, study code, discuss with peers (fully online)
- **Assignments:** build programming skills, synthesize lecture/lab content

Monday	Wednesday	Friday
Lecture	Lecture	Lab-A-B

- **assg0:** out later on Wednesday, due Feb 24
- **C bootcamp:** this week (details will be announced soon)

Grading

33%	6 Programming assignments
24%	10 Labs
21%	Midterm exam
22%	Final exam

Grading

33% Programming assignments

24% Labs

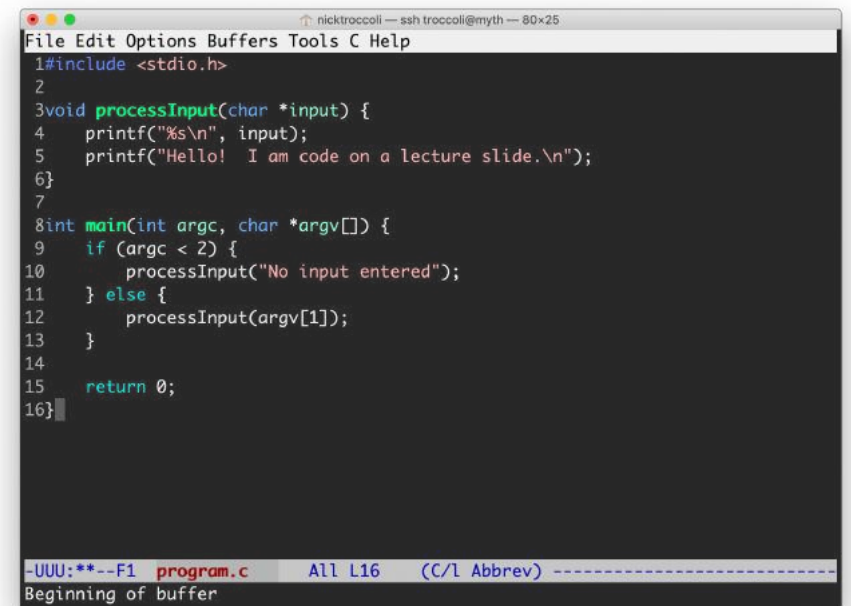
21% Midterm exam

22% Final exam

Assignments

- 6 programming assignments completed individually using **Unix command line tools**
 - Free software, pre-installed on linuxpool cluster dedicated to COMP students
 - GitHub Classroom
 - We will give out starter projects for each assignment
- Graded on **functionality** (*behavior*) and **style** (*elegance*)
 - Functionality graded using *automated tools*, given as point score
 - Style graded via *automated tests* and TA code review,
 - Grades returned via Blackboard

GitHub Classroom



```
nicktroccoli — ssh.troccoli@myth — 80x25
File Edit Options Buffers Tools C Help
1#include <stdio.h>
2
3void processInput(char *input) {
4    printf("%s\n", input);
5    printf("Hello! I am code on a lecture slide.\n");
6}
7
8int main(int argc, char *argv[]) {
9    if (argc < 2) {
10        processInput("No input entered");
11    } else {
12        processInput(argv[1]);
13    }
14
15    return 0;
16}
-UUU:**--F1 program.c All L16 (C/l Abbrev) -----
Beginning of buffer
```


Late Policy

- **Start out with 7 *grace days*:** each late day allows you to submit an assignment without penalty if you have free grace days left.
- **Hard deadline:** No submissions will be accepted **48 hours** after the original due date of an assignment
- Penalty per day after grace days are exhausted
 - 1 day: 20% off
 - 2 days: 40% off
- Submissions made on Blackboard at 00:01am after the deadline counts as late and are considered as using 1 grace day

Grading

33%	Programming assignments
24%	Labs
21%	Midterm exam
22%	Final exam

Lab Sections

- Weekly 100-minute labs led by a TA, starting *next* week, offered online on Fridays.
- Hands-on practice with lecture material and course topics.

GitHub Classroom + `linuxpool.ku.edu.tr`

- Graded on attendance + participation (*verified by submitting lab work*)
 - Two graded part:
 - In-class practice problem (40%)
 - After-class problem (60%)
 - Your lowest 2 scores will be dropped, hence there will be no make-up

Grading

33%	Programming assignments
24%	Labs
21%	Midterm exam
22%	Final exam

Midterm and Final Exams

- Face-to-face exams
 - Midterm: At week 10, exact date and time will be announced later
 - Final: Date and time will be announced later

Grading

33%	Programming assignments
24%	Labs
21%	Midterm exam
22%	Final exam

Question Break!

Getting Help

- Post on the **Discussion Forum at Blackboard**
 - Online discussion forum for students; post questions, answer other students' questions
 - Best for general assignment questions (DON'T POST ASSIGNMENT CODE!)
- Visit **Online Office Hours**
 - More info to come soon!
- **Email the Course Staff**
 - Best for **private matters** (e.g. grading questions).

Koç University Honor Code

- For assignments students should be required to digitally add and approve a version of the agreement below.

I hereby declare that I have completed this examination individually, without support from anyone else.

I hereby accept that only the below listed sources are approved to be used during this open-source examination:

(i) Coursebook,

(ii) All material that is made available to students via Blackboard for this course, and

(iii) Notes taken by me during lectures.

I have not used, accessed or taken any unpermitted information from any other source. Hence, all effort belongs to me.

Honor Code and COMP201

- Please help us ensure academic integrity:
 - Indicate any assistance received on HW (books, friends, etc.).
 - Do not look at other people's solution code or answers
 - Do not give your solutions to others or post them on the web or to the forum.
 - Report any inappropriate activity you see performed by others.
- Assignments are checked regularly for similarity with help of automated software tools.
- If you realize that you have made a mistake, you may retract your submission to any assignment at any time, no questions asked. Come to use before we come for you.
- If you need help, please contact us and we will help you.
 - We do not want you to feel any pressure to violate the Honor Code in order to succeed in this course.

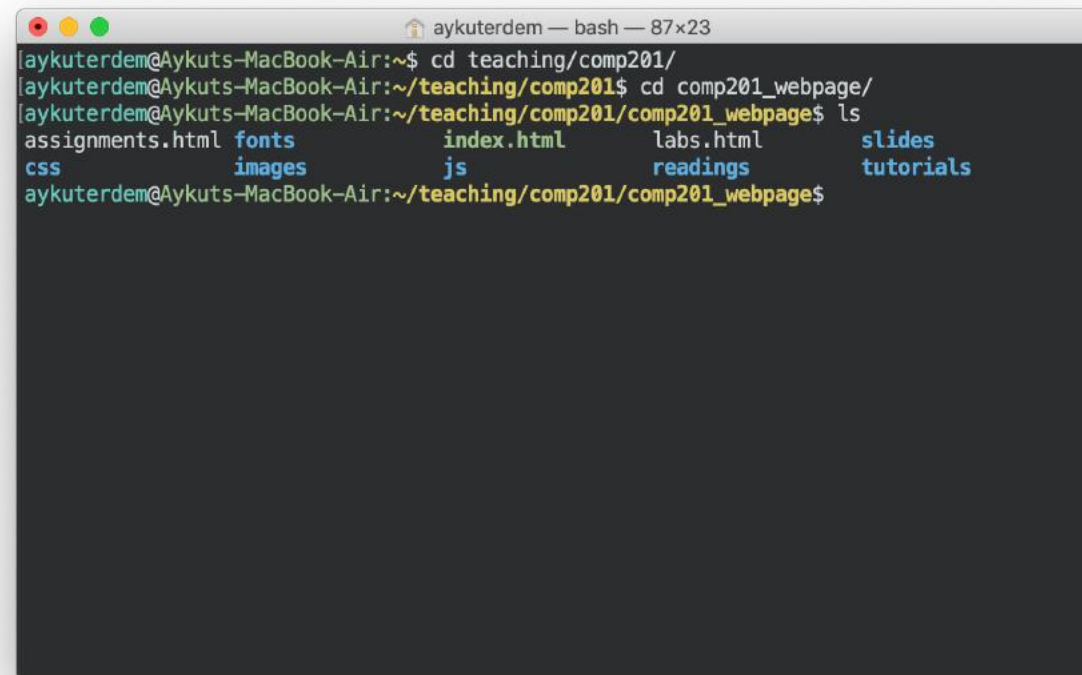
Poll Time

Lecture Plan

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What is Unix?

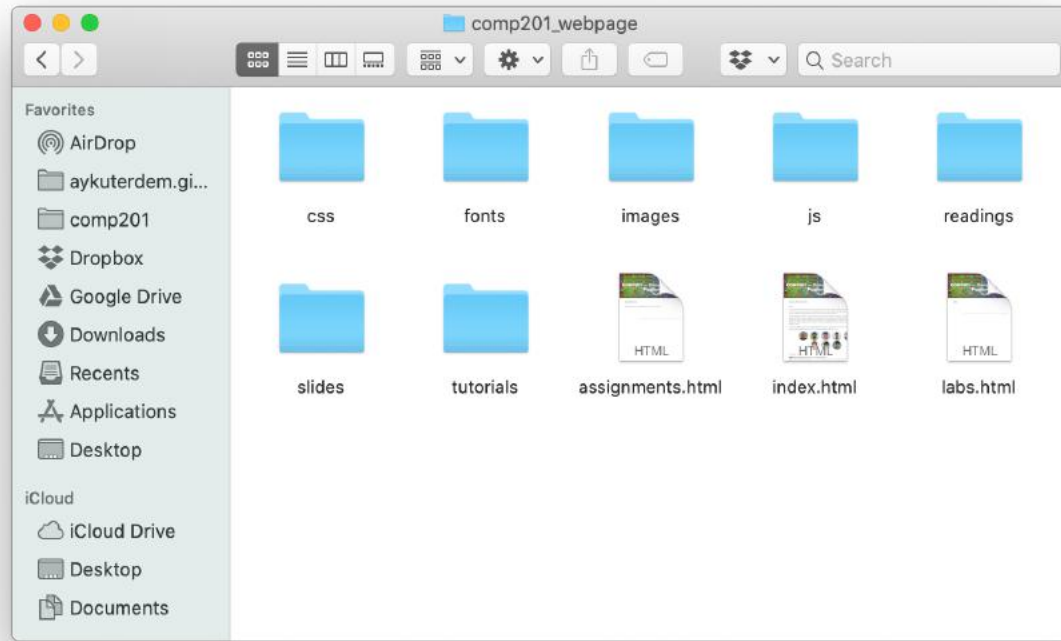
- **Unix**: a set of standards and tools commonly used in software development.
 - **macOS** and **Linux** are operating systems built on top of Unix
- You can navigate a Unix system using the **command line** ("terminal")
- Every Unix system works with the same tools and commands



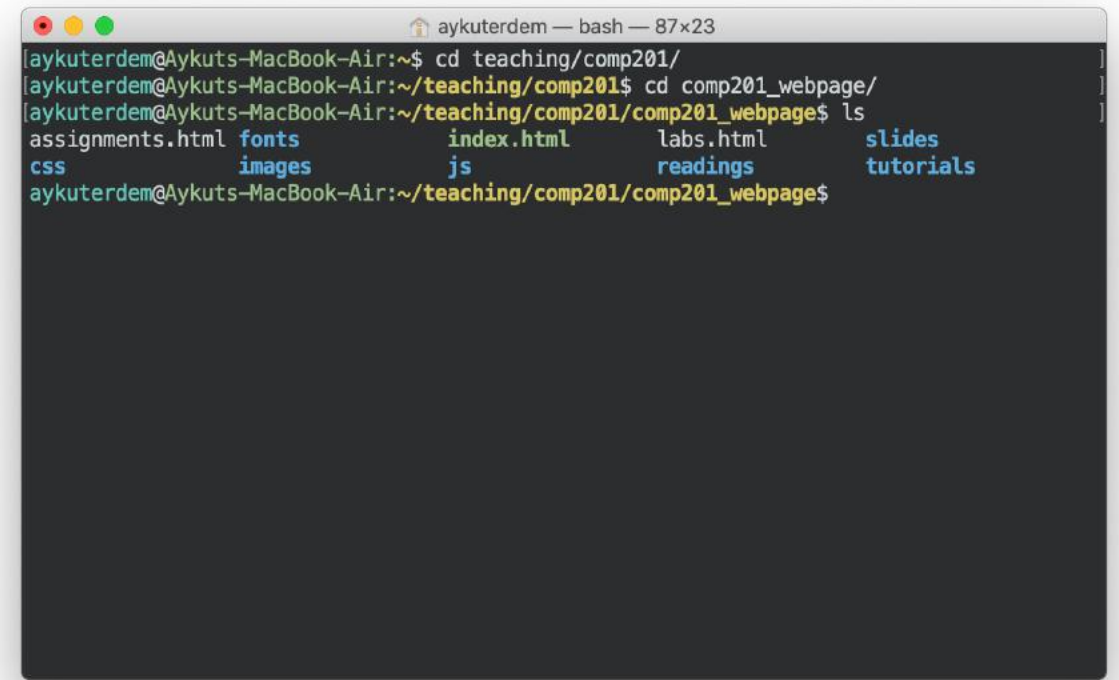
```
aykuterdem — bash — 87x23
aykuterdem@Aykuts-MacBook-Air:~$ cd teaching/comp201/
aykuterdem@Aykuts-MacBook-Air:~/teaching/comp201$ cd comp201_webpage/
aykuterdem@Aykuts-MacBook-Air:~/teaching/comp201/comp201_webpage$ ls
assignments.html  fonts          index.html     labs.html     slides
css               images         js             readings      tutorials
aykuterdem@Aykuts-MacBook-Air:~/teaching/comp201/comp201_webpage$
```

What is the Command Line?

- The **command-line** is a text-based interface (i.e., **terminal** interface) to navigate a computer, instead of a Graphical User Interface (GUI).



Graphical User Interface

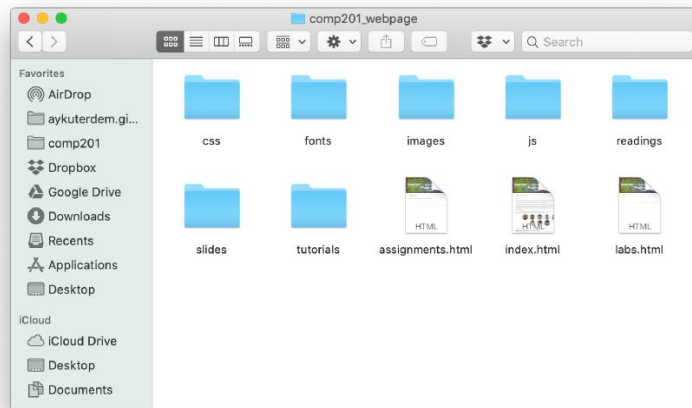


Text-based interface

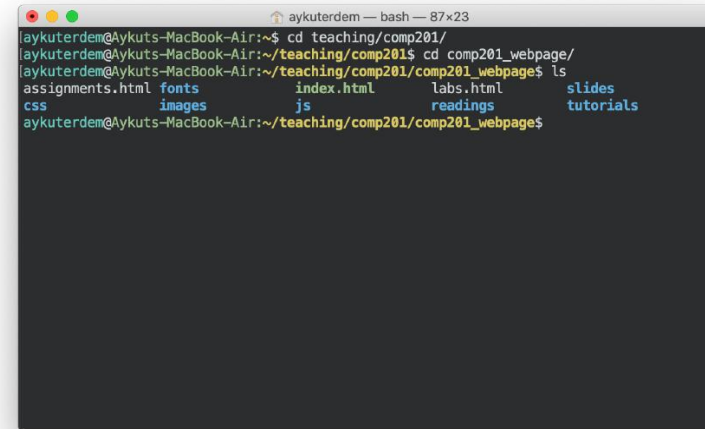
Command Line vs. GUI

Just like a GUI file explorer interface, a terminal interface:

- shows you a **specific place** on your computer at any given time.
- lets you go **into folders** and **out of folders**.
- lets you **create new files** and **edit files**.
- lets you **execute programs**.



Graphical User Interface



Command-line interface

Why Use Unix / the Command Line?

- You can navigate almost any device using the same tools and commands:
 - Servers
 - Laptops and desktops
 - Embedded devices (Raspberry Pi, etc.)
 - Mobile Devices (Android, etc.)
- Used frequently by software engineers:
 - **Web development:** running servers and web tools on servers
 - **Machine learning:** processing data on servers, running algorithms
 - **Systems:** writing operating systems, networking code and embedded software
 - **Mobile Development:** running tools, managing libraries
 - And more...
- We'll use Unix and the command line to implement and execute our programs.

Demo: Using Unix and the Command Line



Unix Commands Recap

- **cd** – change directories (..)
- **ls** – list directory contents
- **mkdir** – make directory
- **emacs** – open text editor
- **vi** – open text editor
- **rm** – remove file or folder
- **man** – view manual pages



Lab 1:
The Linux Shell
(*next week*)

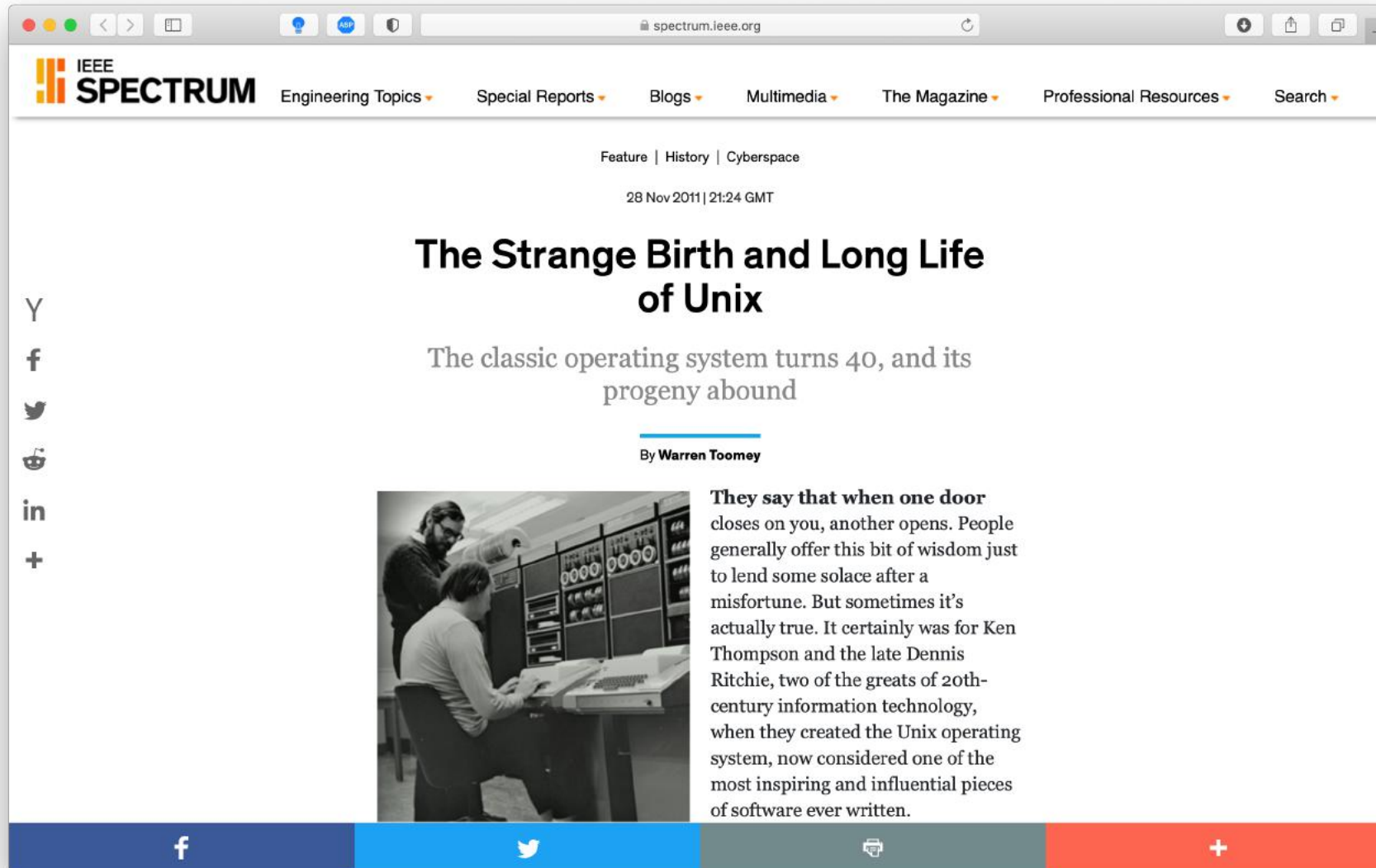
See the Resources page of the course website for more commands, and a complete reference.

Learning Unix and the Command Line

- Using Unix and the command line can be intimidating at first:
 - It looks retro!
 - How do I know what to type?
- It's like learning a new language:
 - At first, you may have to constantly look things up (**Resources** page on course website!)
 - It's important to spend as much time as possible (during labs and assignments) building muscle memory with the tools

Question Break!

Additional Reading



<https://spectrum.ieee.org/tech-history/cyberspace/the-strange-birth-and-long-life-of-unix>

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The C Language

C was created around 1970 to make writing Unix and Unix tools easier.

- Part of the C/C++/Java family of languages (C++ and Java were created later)
- Design principles:
 - Small, simple abstractions of hardware
 - Minimalist aesthetic
 - Prioritizes efficiency and minimalism over safety and high-level abstractions

C vs. C++ and Java

They all share:

- Syntax
- Basic data types
- Arithmetic, relational, and logical operators

C doesn't have:

- More advanced features like operator overloading, default arguments, pass by reference, classes and objects, ADTs, etc.
- Extensive libraries (no graphics, networking, etc.) – this means not much to learn C!
- many compiler and runtime checks (this may cause security vulnerabilities!)

Programming Language Philosophies

- **C is procedural:** you write functions, rather than define new variable types with classes and call methods on objects. C is small, fast and efficient.
- **C++ is procedural, with objects:** you write functions, and define new variable types with classes, and call methods on objects.
- **Python is also procedural, but dynamically typed:** you still write functions and call methods on objects, but the development process is very different.
- **Java is object-oriented:** virtually everything is an object, and everything you write needs to conform to the object-oriented design pattern.

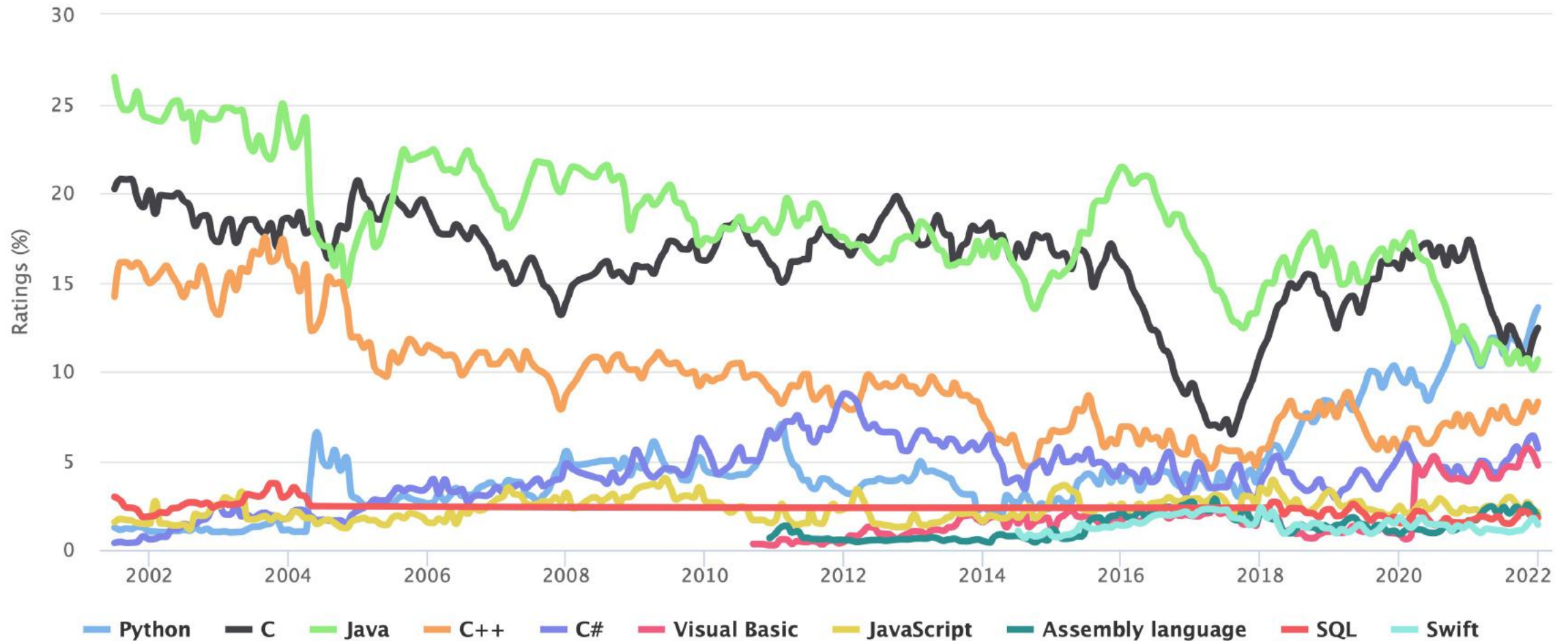
Why C?

- Many tools (and even other languages, like Python!) are built with C.
- C is the language of choice for fast, highly efficient programs.
- C is popular for systems programming (operating systems, networking, etc.)
- C lets you work at a lower level to manipulate and understand the underlying system.

Programming Language Popularity




TIOBE Programming Community Index

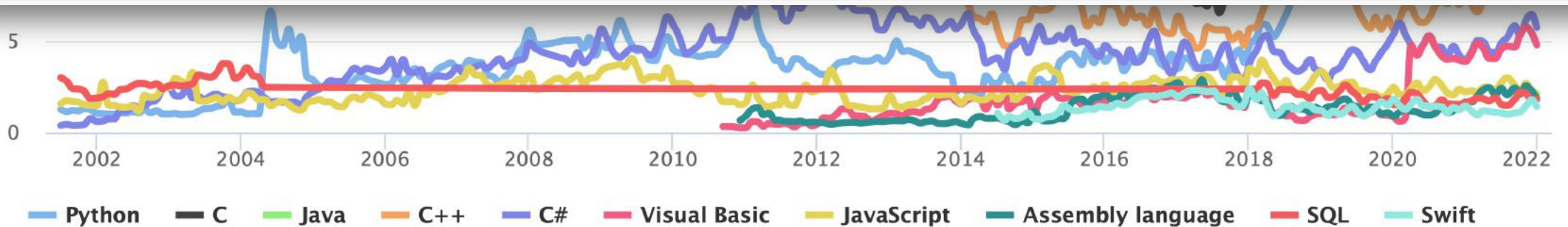
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Programming Language Popularity

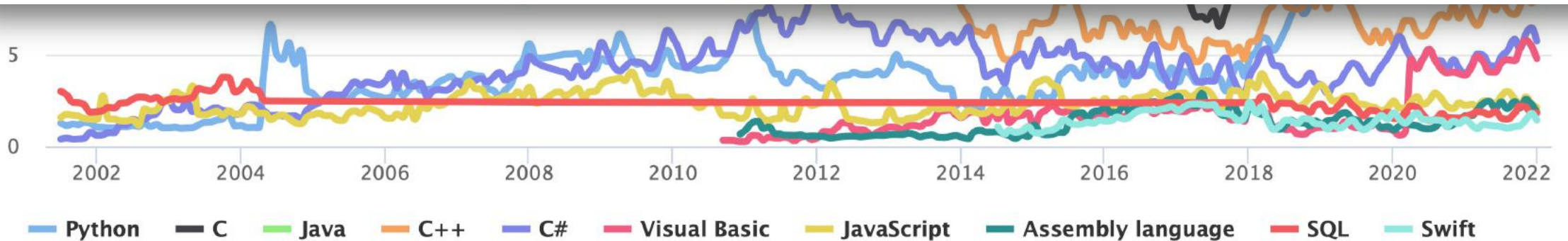
Sep 2021	Sep 2020	Change	Programming Language	Ratings	Change
1	1		 C	11.83%	-4.12%
2	3		 Python	11.67%	+1.20%
3	2		 Java	11.12%	-2.37%
4	4		 C++	7.13%	+0.01%
5	5		 C#	5.78%	+1.20%



<https://www.tiobe.com/tiobe-index/>

Programming Language Popularity

Jan 2022	Jan 2021	Change	Programming Language	Ratings	Change
1	3	▲	 Python	13.58%	+1.86%
2	1	▼	 C	12.44%	-4.94%
3	2	▼	 Java	10.66%	-1.30%
4	4		 C++	8.29%	+0.73%
5	5		 C#	5.68%	+1.73%



<https://www.tiobe.com/tiobe-index/>

Our First C Program

```
/*  
 * hello.c  
 * This program prints a welcome message  
 * to the user.  
 */  
#include <stdio.h>    // for printf  
  
int main(int argc, char *argv[]) {  
    printf("Hello, world!\n");  
    return 0;  
}
```


Our First C Program

```
/*  
 * hello.c  
 * This program prints a welcome message  
 * to the user.  
 */
```

```
#include <stdio.h> // for printf
```

```
int main(int argc, char *argv[]) {  
    printf("Hello, world!\n");  
    return 0;  
}
```

Program comments

You can write block or inline comments.

Our First C Program

```
/*  
 * hello.c  
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#include <stdio.h> // for printf  
  
int main(int argc, char *argv[]) {  
    printf("Hello, world!\n");  
    return 0;  
}
```

Import statements

C libraries are written with angle brackets.
Local libraries have quotes:

```
#include "lib.h"
```

Our First C Program

```
/*  
 * hello.c  
 * This program prints a welcome message  
 * to the user.  
 */  
#include <stdio.h>    // for printf
```

```
int main(int argc, char *argv[]) {  
    printf("Hello, world!\n");  
    return 0;  
}
```

main function – entry point for the program
Should always return an integer (0 = success)

Our First C Program

```
/*  
 * hello.c  
 * This program prints a welcome message  
 * to the user.  
 */  
#include <stdio.h>    // for printf  
  
int main(int argc, char *argv[]) {  
    printf("Hello, world!\n");  
    return 0;  
}
```

Main parameters – main takes two parameters, both relating to the command line arguments used to execute the program.

argc is the number of arguments in argv
argv is an array of arguments (char * is C string)

Our First C Program

```
/*  
 * hello.c  
 * This program prints a welcome message  
 * to the user.  
 */  
#include <stdio.h>    // for printf  
  
int main(int argc, char *argv[]) {  
    printf("Hello, world!\n");  
    return 0;  
}
```

printf – prints output to the screen

Familiar Syntax

```
int x = 42 + 7 * -5;           // variables, types
double pi = 3.14159;
char c = 'Q';                  /* two comment styles */

for (int i = 0; i < 10; i++) {  // for loops
    if (i % 2 == 0) {           // if statements
        x += i;
    }
}

while (x > 0 && c == 'Q' || b) { // while loops, logic
    x = x / 2;
    if (x == 42) { return 0; }
}

binky(x, 17, c);               // function call
```

Boolean Variables

To declare Booleans, (e.g. **bool b = _____**), you must include **stdbool.h**:

```
#include <stdio.h>    // for printf
#include <stdbool.h>   // for bool

int main(int argc, char *argv[]) {
    bool x = 5 > 2 && binky(argc) > 0;
    if (x) {
        printf("Hello, world!\n");
    } else {
        printf("Howdy, world!\n");
    }
    return 0;
}
```

Boolean Expressions

C treats a nonzero value as true, and a zero value as false:

```
#include <stdio.h>

int main(int argc, char *argv[]) {
    int x = 5;
    if (x) {    // true
        printf("Hello, world!\n");
    } else {
        printf("Howdy, world!\n");
    }
    return 0;
}
```


Console Output: printf

```
printf(text, arg1, arg2, arg3);
```

```
// Example
```

```
char *classPrefix = "COMP";
```

```
int classNumber = 201;
```

```
printf("You are in %s%d", classPrefix, classNumber);    // You are in COMP201
```

`printf` makes it easy to print out the values of variables or expressions.

If you include *placeholders* in your printed text, `printf` will replace each placeholder *in order* with the values of the parameters passed after the text.

`%s` (string)

`%d` (integer)

`%f` (double)

Question Break!

Writing, Debugging and Compiling

We will use:

- the **vi/emacs** text editor to write our C programs
- the **make** tool to compile our C programs
- the **gdb** debugger to debug our programs
- the **valgrind** tools to debug memory errors and measure program efficiency

Demo: Compiling And Running A C Program



Working On C Programs Recap

- **ssh** – remotely log in to `linuxpool` computers (*later*)
- **Vi/Emacs** – text editor to write and edit C programs
 - Use the mouse to position cursor, scroll, and highlight text
 - `:w` / `Ctl-x Ctl-s` to save, `:q` / `Ctl-x Ctl-c` to quit
- **make** – compile program using provided Makefile
- **./myprogram** – run executable program (optionally with arguments)
- **make clean** – remove executables and other compiler files
- Lecture codes are accessible at Blackboard

Recap

- COMP201 is a programming class, which uses C to teach you about what goes on under the hood of programming languages and software.
- We'll use Unix and command line tools to write, debug and run our programs.
- Please regularly visit the course website, <https://aykuterdem.github.io/classes/comp201> and follow the announcements on Blackboard.
- **We're looking forward to an exciting semester!**
- **Next time:** *How a computer represents integer numbers? What are the limitations?*

