

# Introduction to C

CSC101 Introduction to programming in C/C++ SUMMER 2022

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## 1 What will you learn?

- What is C?
- What is its origin?
- What is its importance?
- What's the difference to C++?
- Why are we not just learning C++?
- What are C's strengths and weaknesses?
- Why are you learning C from me?
- What's next in the course?

Source:

- Textbook King (2008) ch.1<sup>1</sup>
- See also [slides \(GDrive\)](#)

## 2 What is C?

- C is a programming language created in the early 1970s.
- It grew out of the development of the UNIX operating system
- In turn, UNIX grew out of a space travel game (Brock, 2019).

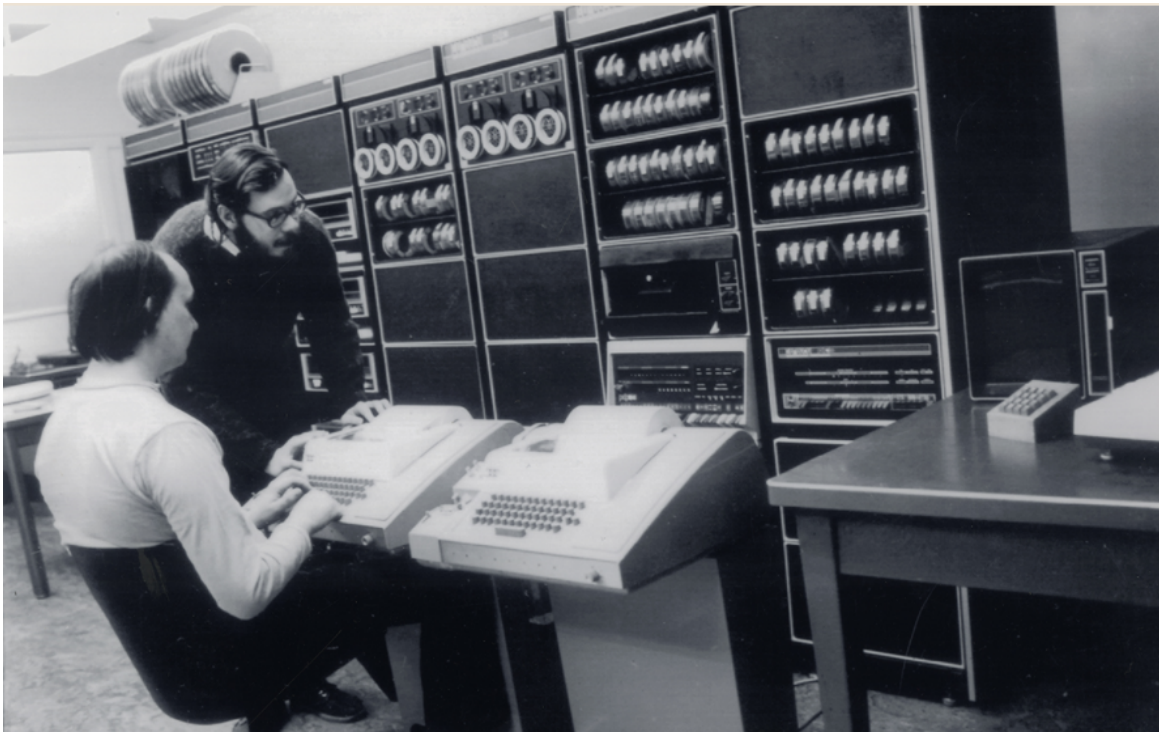


Figure 1: Thompson & Ritchie & DEC PDP-11, 1970. (Brock, 2019)

### 3 How popular is C?

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C consistently ranks among the top 3 programming languages

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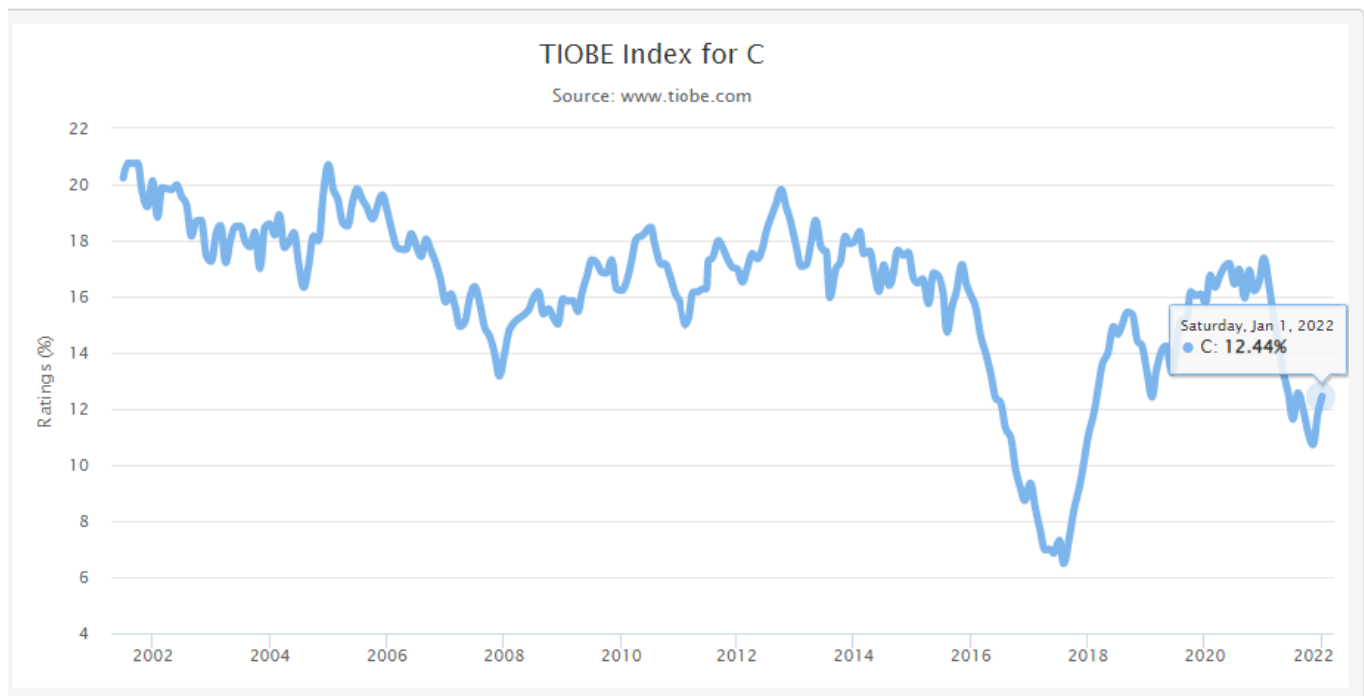


Figure 2: TIOBE Index for C, 2002-2022 (Source: TIOBE)

Popularity contest: cp. [TIOBE Index](#)<sup>2</sup>





Rank	Language	Type	Score
1	Python	  	100.0
2	Java	  	96.3
3	C	  	94.4
4	C++	  	87.5
5	R		81.5
6	JavaScript		79.4
7	C#	   	74.5
8	Matlab		70.6
9	Swift	 	69.1
10	Go	 	68.0

Figure 3: IEEE index (Source: Cass, 2019)

## 4 How important is C?



Figure 4: Real world applications of C (Source: DataFlair)

Some well-known programs written in C:

- The Linux kernel (and therefore, Android)
- UNIX operating system (core of MacOS)
- Windows 1.0 to Windows XP
- Doom (early video game)
- Wolfenstein 3D
- Git version control system
- Clang and MinGW compilers
- ...Any software that crosses platforms easily...

See also: "[Why C programming is awesome](#)" (Hawkes, 2016).

## 5 What is a programming language?

"A programming language is a *formal language* comprising of a set of *strings* that produce various kinds of *machine code* output. Programming languages are one kind of computer language, and are used in computer programming to implement algorithms." (Source: [Wikipedia](#))

- **Formal** language?
- Set of **strings**?
- **Machine** code?
- **Algorithm**?

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Fortunately, computer (and data) science isn't really a science at all!

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(Right, it's more of a craft like mining, knitting, or pottering.)

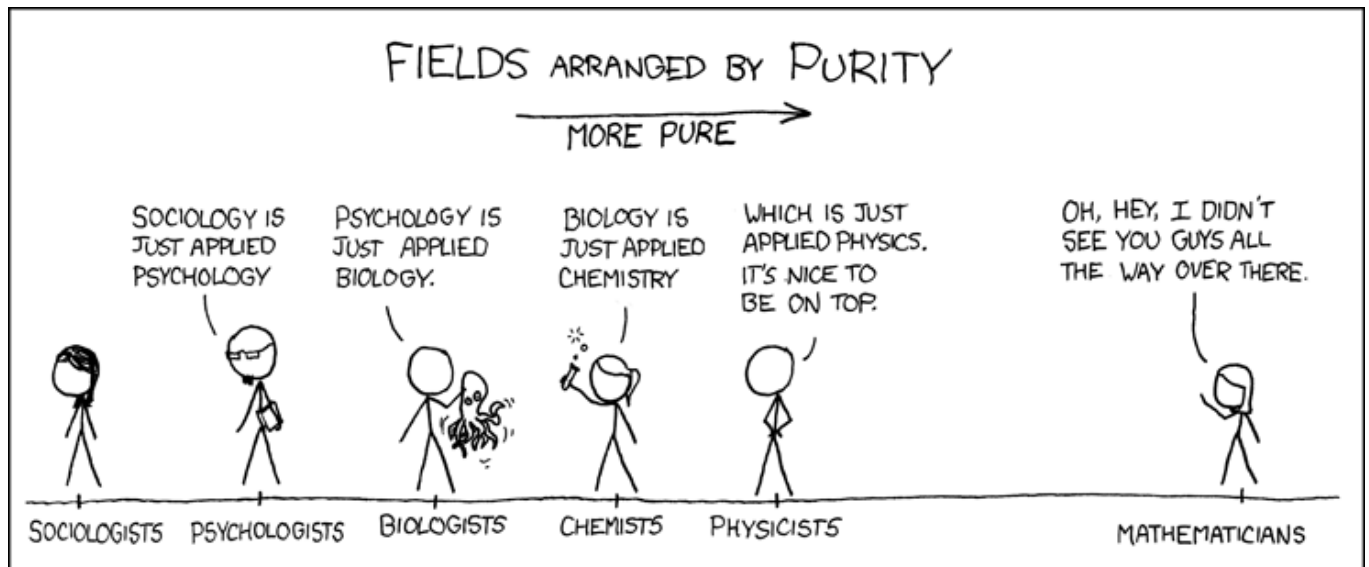


Figure 5: Scientific fields arranged by "purity" (xkcd)

## 6 Where does C come from?

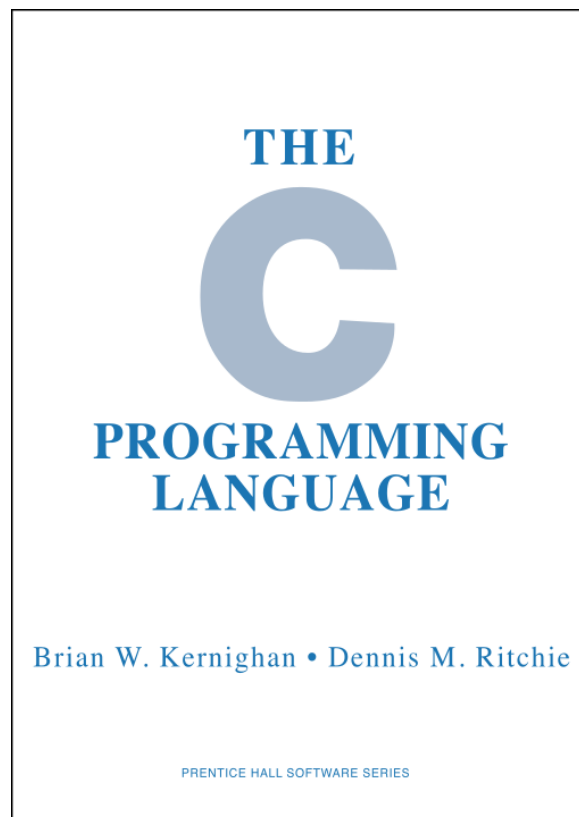


Figure 6: "K&R" (Kernighan/Ritchie, 1978)

- By-product of the UNIX operating system 1969 <sup>3</sup>
- Developed on DEC PDP-7 (computer with 8K words of main memory)
- Written originally in assembly language
- UNIX rewritten in C by 1973 for [DEC PDP-11](#)
- Standardization of C, 1973-2018

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Challenge: what does "8K words of main memory" mean? <sup>4</sup>

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## 7 Standardization



Figure 7: How standards proliferate (Source: xkcd)

Details: see [ANSI](#) (American National Standards Institute)

## 8 How computers work

Well, at least this is one way of looking at it.

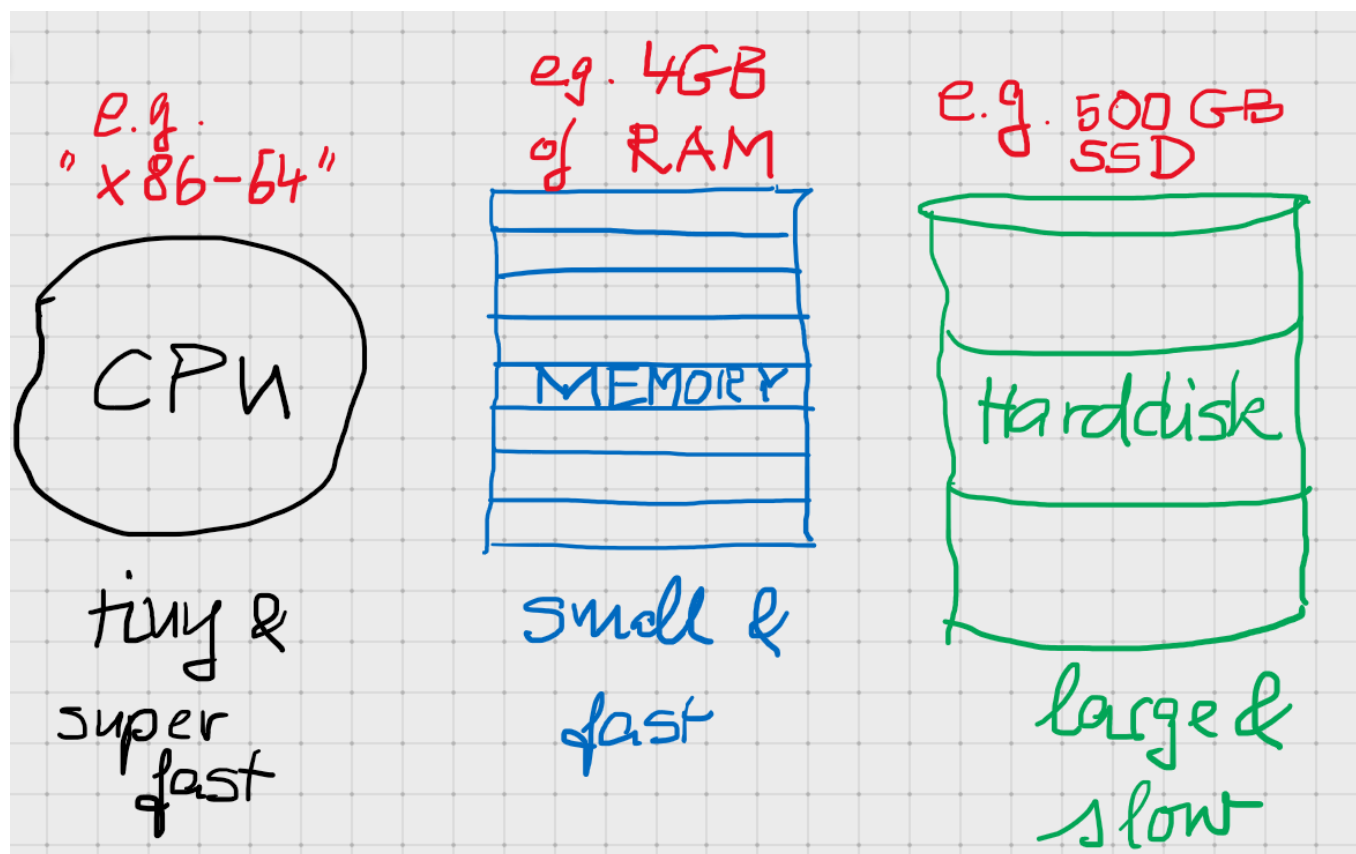


Figure 8: Computer architecture (simplified)

The "hard disk" can also be a Solid State Drive (SSD) or some other form of Non-Volatile Memory (NVM) - i.e. it doesn't disappear when the power goes out.

## 9 How programs are processed

### 9.1 Simplified process

1. **WRITE** source code in an editor (NVM)
2. **COMPILE** source code to machine code (RAM)
3. **RUN** program (CPU)
4. **DISPLAY** results (RAM)
5. **SAVE** result (NVM)

### 9.2 Complete process

Specifically for C and our compiler GCC, this process looks technically like this:



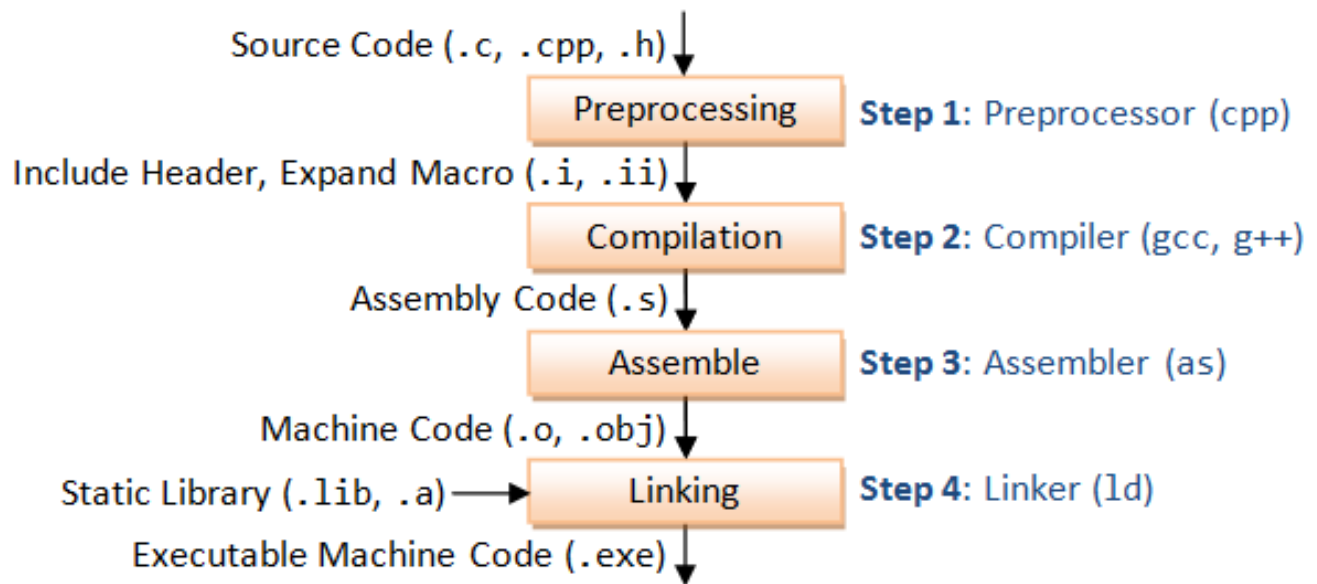


Figure 9: GCC compilation process (Source: Hock-Chuan, 2018).

## 10 Looks matter

She's a beauty.



Figure 10: PDP-11/70

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Challenge: was C the first programming language? [5](#)

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## 11 The Latin of programming languages

The following languages are C-based:

- C++ (OOP extension of C, games)
- Java (OOP, VM-portable, and no pointers)
- C# (Microsoft, games)
- Perl (scripting, text mining)

"C is to programming languages what Latin is to Western natural languages." (Anonymous)

## 12 C is lightning fast and terribly tiny

"C is fast because it's the speed of light, and relativity?"<sup>6</sup> ([Stackoverflow](#))

Language	Time, s	Memory, MiB	Energy, J
C++/g++	11.561 $\pm$ 0.257	2.53 $\pm$ 00.89 + 1.37 $\pm$ 00.86	198.02 $\pm$ 10.79
C/gcc	12.638 $\pm$ 0.191	0.63 $\pm$ 00.00 + 1.00 $\pm$ 00.04	271.04 $\pm$ 04.12
Rust	13.468 $\pm$ 0.603	1.99 $\pm$ 00.07 + 0.31 $\pm$ 00.03	260.96 $\pm$ 26.40
C/clang	14.006 $\pm$ 0.558	0.69 $\pm$ 00.00 + 0.95 $\pm$ 00.03	277.62 $\pm$ 28.40

...

Python/pypy	65.668 $\pm$ 2.354	63.37 $\pm$ 00.05 + 47.76 $\pm$ 00.05	1333.51 $\pm$ 81.90
Julia	75.405 $\pm$ 1.755	200.84 $\pm$ 00.22 + 0.61 $\pm$ 00.00	1569.12 $\pm$ 122.00
Ruby/truffleruby (- -jvm)	120.743 $\pm$ 5.839	581.66 $\pm$ 04.97 + 539.81 $\pm$ 13.64	2466.87 $\pm$ 108.51
Ruby/truffleruby	131.313 $\pm$ 4.944	445.97 $\pm$ 01.32 + 574.91 $\pm$ 13.29	2693.24 $\pm$ 211.06
Haskell	220.958 $\pm$ 4.270	3.81 $\pm$ 00.02 + 26.13 $\pm$ 00.00	4785.77 $\pm$ 295.26

Image source: [Kostya](#)

[benchmark, GitHub, Nov 2021](#)

- Excerpts for parsing and printing a *Mandelbrot* set
- *Benchmarks* depend on algorithm implementation
- C always wins the size battle (*memory allocation*)
- Some very *specialized* languages are even faster

## 13 Strengths and weaknesses of C

STRENGTH	WEAKNESS
Efficiency	Permissiveness (Error-prone)
Portability	Terseness and Understanding
Power	Large program maintenance
Flexibility	
Standard library	
Integration with UNIX	

## 14 What is the difference between C and C++?

C++ is a superset of C.



Figure 12: C/C++ logos

WHAT	C	C++
TIME	Thompson/Ritchie 1970s	Stroustrup 1980s
TYPE	Imperative procedural	Object-oriented
GOOD	System programming	Games and graphics
USED	Internet of Things	Flight Software

Source: Lemonaki, 2021.

# 15 Why are we not just learning C++?

- Object-orientation is a difficult paradigm (C++)
- System programming is pure power (C)
- C is simpler, smaller, and faster

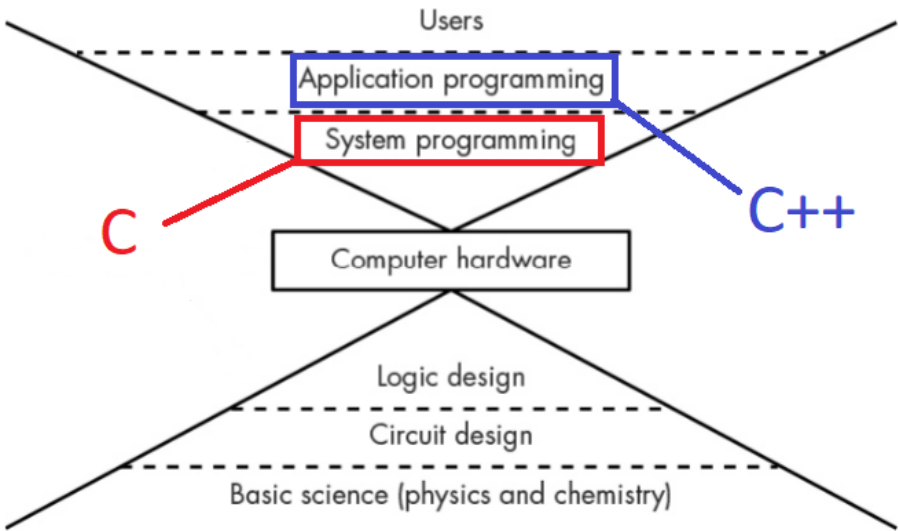


Figure 13: Computer Landscape. (Modified from: Steinhart, 2019)

- Bjarne Stroustrup (2011): "[C is obsolete](#)"<sup>7</sup>
- Linus Torvalds (2007): "[C++ is a horrible language](#)"<sup>8</sup>.

Also, there's this:

"Languages are tools. Memorizing them no more makes you a computer scientist than studying hammers makes you a carpenter." -[Neilsen](#)

- It's easy to pick up additional languages
- Data structures and algorithms are key to understanding
- First language could be anything<sup>9</sup>

## 16 Why am I teaching C/C++?

It's personal.

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### The C++ Virtual Library

[Recent Changes](#) -- Mail additions to this list to <lilje@desy.de>

You can also [search for a keyword on this server](#).

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[The HTML formatted version](#) on the draft C++ standard.

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#### [Getting Start\(l\)ed](#)

Documents and sources on [C++](#) and [OOP](#). The draft C++ standard is now generally available.

Please read the [informal announcement](#).

#### [Editing](#)

Customizable environment for Emacs editors

#### [Learning C++](#)

Virtual courses and tutorials.

#### [Newsgroups](#)

Internet groups for discussions and questions on C++

#### [Free Packages](#)

Freely available C++ packages from various application areas.

#### [Conferences](#)

List of OOP and Computing conferences

#### FreeHEP

[software information](#) and [reviews](#) from [freeHEP](#) [\[FAQ\]](#)

#### [OOLP](#)

Discussion on Object-Oriented Literate Programming

#### Tools & Products

The [C++ Products List and Description](#). See also: the [Darmstadt archive](#)

#### [General OO](#)

Object-Oriented programming resources.

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**To report errors, use this form to contact [Lutz](#), please.**

Last updated October 25th, 1995

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**Big thanks to Marcus for starting up all this!**

[Info about Marcus Speh](#)

<marcus@x4u.desy.de>


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Figure 14: The C++ Virtual Library, 1993-1995 (DESY)

I used C++ during my PhD studies at DESY, Germany, to write a library of multigrid functions (numerical method for lattice gauge theory simulations in theoretical particle physics).<sup>[10](#)</sup>

- What will happen to C/C++ in the next 20 years?

Whatever happens, good new for learning C.


**Wouter Van Ooijen**  
 Head Lecturer Computer Engineering · Updated 11mo

### What will happen to C/C++ in the next 20 years?

Note: there is no such thing as C/C++! Stop using that term!

If the recent past is any guide:

- the C language will remain mostly stable and unchanged
- The C++ language will adopt many new things, in 20 years it will probably be from 2 to 10 times as complex as it is now
- Some alternative programming languages will rise for the domain that is now dominated by C and C++, but they will not get much traction. The successful ideas from these languages will be incorporated in C++ (and a few unsuccessful ones too), but will be ignored by C.

C will remain dominant in Electrical Engineering curricula and careers (and in the Linux kernel). C++ will become dominant in low-level/high-performance/resource-constrained programming that is not intimately tied to electronics.

Hardware will continue to evolve, hence things that are now done in C and C++ will be done in other, more programmer-friendly but less performant (less CPU-friendly) languages. New application areas will arise that require performant languages to get the most out of the hardware, these things (gadgets? wearables? intelligent dust? who knows) will be programmed in C or (I hope!) C++.

This is my somewhat tongue-in-cheek but reasonably probable answer. For a better answer, please direct me to the nearest crystal ball repair shop.

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 737
 
 17
  81
 


Figure 15: One expert's opinion (Source: Quora)

I increasingly see propaganda for [replacing C++ by Rust](#) (Kirsh, 2021), another relatively new language with OOP support and better security properties.

## 17 Summary

- The C programming language was created 50 years ago

- C is small, simple, very fast, and close to the computer
- Linux (and Android) are largely written in C
- The object-oriented programming (OOP) language C++ contains C
- System programming is a powerful skill set

## 18 Glossary

CONCEPT/TOPIC	DEFINITION
DEC PDP-11	1970s mainframe computer
UNIX	Operating system (ca. 1969)
ANSI	American National Standard Institute
String	A data type representing text
Assembler	Machine code (hard to write/read)
Algorithm	Fixed process or set of rules
Linux	Operating system (ca. 1991)
C	Imperative, procedural programming language
compiler	Software to translate source into machine code
C++	Object-oriented (OO) superset of C
Clang	C/C++ compiler
gcc	GNU compiler bundle (incl. C/C++)
Java,C#	OO programming language
Perl	Scripting language
Git	Software version control system
GitHub	Developer's platform (owned by Microsoft)
Library	Bundle of useful functions and routines
Portability	Ability of software to run on different hardwares
Efficiency	Software speed of execution and memory requirements
Permissiveness	Degree to which a language tolerates ambiguities
Object-orientation	Ability to define abstractions
System programming	Programming close to the machine
Application programming	Programming close to the user

## 19 What's next?

- Getting started: Infrastructure (Lab)
- MinGW (compiler) + Emacs (editor) + GitHub (collaboration)
- First program: "hello world" (Lecture + Lab)



## 20 References

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- xkcd(n.d.) Purity [cartoon]. [URL:xkcd.com/](https://xkcd.com/).

## Footnotes:

<sup>1</sup> All sources are referenced at the end of the script, followed by the footnotes, which do unfortunately not render as links [on GitHub](#). The book by King (2008) does not cover a few recent updates to the ANSI standard for C, like C11, and the current standard C17. The next major C standard revision (C23) is expected for 2023. Gustedt (2019) is a good (but quite difficult) book on "modern C".



- <sup>2</sup> Since 2000, C has consistently ranked among the top two languages in the TIOBE index (based on searches).
- <sup>3</sup> The motivation to create Unix, according to [Wikipedia](#), was to port Thompson's space travel video game to the PDP-7 mainframe computer. So in a way we owe modern computing to gaming.
- <sup>4</sup> How many bits can be stored in memory of 8K words depends on the bit length of a word (or byte). One byte holds  $8 = 2^3$  bits (binary digits, or memory locations capable of storing 2 states). 8K byte correspond to  $8 * 2^{10} = 8 * 1,024 = 8,192$  bits. By comparison, the main memory of my laptop is  $16\text{GB} = 16 * 2^{30} = 3.2\text{E}+31$  bits. It follows from these memory restrictions that UNIX (and C) had to be designed to be very small, or space effective.
- <sup>5</sup> Answer: no. By 1966, there were already ca. 700 programming languages (Chatley et al, 2019), today there are almost 9,000. C descends from ALGOL60, other important languages are Lisp (functional language), SIMULA (first OOP language), and PROLOG (logic language).
- <sup>6</sup> This is a joke based on someone mixing up *c* (speed of light constant) and C (the programming language).
- <sup>7</sup> However, he is biased, since he is the creator of C++. The title of the video is misleading: Stroustrup believes that every C program should rather be a proper C++ program. However, he also concedes that C++ is still too complex for many ("We have to clean it up").
- <sup>8</sup> Torvalds (who wrote the Linux kernel in C) argues here in favor of writing his hugely successful version control program *git* in C instead of C++. He highlights some of the strengths of C: efficient, system-level, portable code.
- <sup>9</sup> My first real programming language was FORTRAN (specialized on scientific computing), then C++. Recently, I picked up R (for data science). In between I've sampled (not mastered) many others, including: Python, Lisp, PROLOG, C, PHP, SQL, SQLite etc.
- <sup>10</sup> I changed my name from 'Speh' to 'Birkenkrahe' when I got married.

Author: Marcus Birkenkrahe

Created: 2022-05-19 Thu 12:21