Introduction to C

CSE 220: Systems Programming

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Welcome to CSE 220

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or by appointment

The syllabus is on the course web page\(^1\) and UBlearns.

So are these — and all other — slides!

\(^1\)https://www.cse.buffalo.edu/~eblanton/course/cse220/
Systems Programming

This course is concerned with systems programming.

You will learn:

- More about the structure and properties of computer systems
- How architecture affects programs
- How to effectively write efficient and correct programs
- The C programming language and POSIX API
Programming in Context

Programming doesn’t occur in a vacuum.

Computer systems have greatly influenced our:
- Programming languages
- Development tools
- Preferred algorithms

This course will help you understand that context.

This may be one of the hardest classes you take at UB.
Today’s Assignments

Immediately:
- Read the Syllabus.
- Watch the intro videos on Panopto.

By Beginning of lab this week:
- Create a GitHub account if you don’t already have one.
- Download and install the course VM (Spring 2021!).
- Watch the lab video, read the handout, and take the quiz.

By next Friday:
- Complete the AI quiz and Course Format quiz.
Lab

We have labs this week!
Why C?

There are dozens of programming languages. Why C?

C is “high level” — but not very.

- C provides functions, structured programming, complex data types, and many other powerful abstractions
- …yet it also exposes many architectural details

Most operating system kernels are written in C.

Many runtimes and virtual machines are written in C.

C influences many other languages.
Effective C programming requires that you master the machine. You must be aware of its architecture and details of operation.

We will be using C in Linux on x86-64. The dialect of C we will use is C99.\(^2\)

The compiler we will use is gcc.

\(^2\)K&R describes ANSI C (C89), but we will discuss the differences when important.
CSE 220 and C

That said, CSE 220 is not (only) about learning C.

CSE 220 teaches you systems concepts, and you will implement them in C.

We will not cover all details of C syntax.

We will cover key ideas and particularly important syntax.

You should consult:
- The C Programming Language (K&R)
- Unix man pages
- Given code
On Precision

In this course I will attempt to be precise, but must simplify some things.

Usually this is because the details:

- are unnecessarily confusing, or
- require knowledge you are not expected to have.

If something here conflicts with the standard or the compiler, the standard or compiler wins.

I will try to mark imprecise statements with a pilcrow: ¶.
The Processor and Memory

The C language exposes a particular machine model.

Data is stored in memory at accessible addresses.

The CPU manipulates data stored in memory.

Program code is executed as a series of instructions:
- Also stored in memory
- Though possibly not accessible
A Dedicated Computer

Most modern, multi-tasking OSes (including Unix) provide a particular model.

That model is that each process has its own dedicated machine.

Each process appears to have:
- A dedicated CPU
- Private, dedicated memory
- Private input and output facilities

That isn’t strictly true, but it is approximated by the OS.

The OS provides mechanisms to share resources in this model.
Programs as Instructions

C programs$^3$ are translated into machine instructions.

The computer executes these instructions in order.

Instructions are things like:
- Add two numbers together
- Compare a number to zero
- Store a number to a location in memory

As we will see, it’s all numbers.

$^3$Indeed, all programs!
main()

Every C program starts with the function `main()`. ¶

```c
int main() {
    return 0;
}
```

Every C function:

- takes zero or more parameters
- returns a single value

All arguments are pass-by-value, which means they are copies of whatever is passed to them.

C program statements end with a semicolon (;).
Program Arguments

The `main()` function is given two parameters:

```
int main(int argc, char *argv[])
```

Return value

Parameter list
Program Arguments

The `main()` function is given two parameters:

```c
int main(int argc, char *argv[])
```

- **First parameter**

The first is an `integer` containing the number of arguments passed to the program on the command line.
Program Arguments

The `main()` function is given two parameters:

```c
int main(int argc, char *argv[])
```

The first is an `integer` containing the number of arguments passed to the program on the command line.

The second is the program arguments as an `array of strings`. (We will discuss strings and arrays more later.)
Program Arguments

The \texttt{main()} function is given two parameters:

\begin{verbatim}
int main(int argc, char *argv[])
\end{verbatim}

The first is an \texttt{integer} containing the number of arguments passed to the program \texttt{on the command line}.

The second is the program arguments as an \texttt{array of strings}. (We will discuss strings and arrays more later.)

Each parameter has a \texttt{type} and a \texttt{name}. 
Aside on Slide Syntax

$ gcc program.c -o program

The $ indicates the terminal prompt.

- Please do not type this — you will get an error!
- You should type everything that follows the $

This is a good time to brush up on your Unix basics:

- Quick tutorial:
  https://www.digitalocean.com/community/tutorials/an-introduction-to-linux-basics

- Comprehensive tutorial
  https://ryanstutorials.net/linuxtutorial/
Compiling the Example

Assume that this code is in trivial.c:

```c
int main () {
    return 0;
}
```

We can compile it into an executable as follows:\(^4\)

```
$ gcc trivial.c
```

This will produce the file a.out, which is a native binary.

You can run the binary as follows:

```
$ ./a.out
```

\(^4\)K&R uses cc, which will also work.
Developing Hello World

“Hello World” is a classic first program when learning a language.

We will develop a Hello World together.
Summary

- C is a high level language used in systems programming.
- Architectural details are important in C.
- The C/POSIX model is:
  - A dedicated machine for each program
  - Sequential execution of program instructions
  - Data is stored in accessible, addressed memory
- We explored some trivial C programs.

*Remember your required readings!*
Next Time …

- More about types
- Variable declaration and usage
- C Strings
- Looping
References I

Required Readings

[1] *Course Syllabus.*
https://www.cse.buffalo.edu/~eblanton/course/cse220-2021-0s/materials/syllabus.pdf.

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