C Basics - Hello world program

CSC100 Introduction to programming in C/C++ Spring 2024

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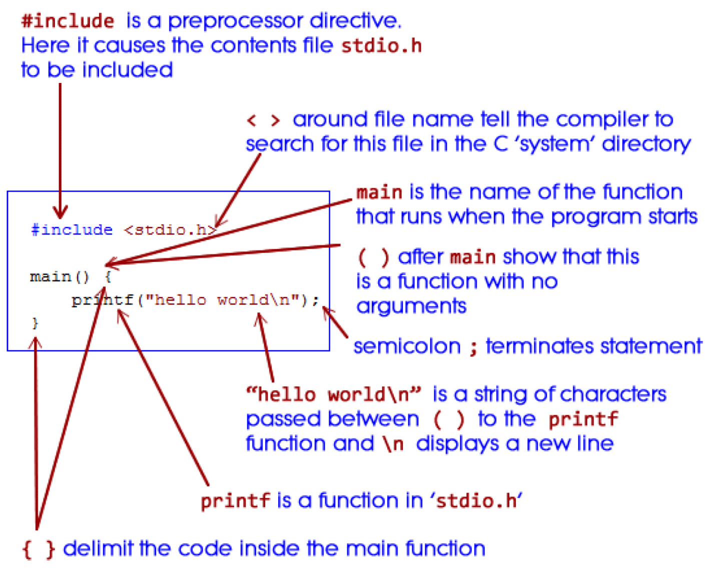
Contents

1 README

- This script summarizes and adds to the treatment by King (2008), chapter 2, C Fundamentals - see also slides (GDrive).
- There is an Org-mode file available for practice. Download `3_hello_practice.org` as a raw file from GitHub (tinyurl.com/y32yd3ax)
- Open a command line terminal and change (`cd`) to the Downloads directory
- Open the file in Emacs with `emacs -nw --file 3_hello_practice.org`
- When you leave class without having completed the file, save a copy to GDrive as a backup and/or to work on it from home
- When you've completed the file, upload it to Canvas where you'll find a "Class practice" assignment named `3_hello_practice.org`.



```
#include <stdio.h>

main() {
    printf("hello world\n");
}
```

#include is a preprocessor directive. Here it causes the contents file stdio.h to be included
< > around file name tell the compiler to search for this file in the C 'system' directory
main is the name of the function that runs when the program starts
( ) after main show that this is a function with no arguments
semicolon ; terminates statement
"hello world\n" is a string of characters passed between ( ) to the printf function and \n displays a new line
printf is a function in 'stdio.h'
{ } delimit the code inside the main function

Figure 1: main function structure (Collingbourne, 2017)

2 Program structure

- All C program statements must be included in a `main` function
- The `main` function has a body delimited by `{...}`
- There can be *pre-processor directives* - `#include` or `#define`.
- `main()` is similar to `f(x)` in mathematics - () means "no argument"
- `printf()` prints its argument: `"hello world"` which is a 'string'
- `\n` means "go to the next line" - 'escape character'
- `;` ends every command - the computer waits for the next one!
- The computer (aka compiler) ignores "white space"

3 "What a Tangled Web We Weave..."

"Oh, what a tangled web we weave, when first we practice to deceive!" (Sir Walter Scott, 1808)

In this section, we're once again running code blocks from within Org-mode - with a few new *literate programming* features:

- To distinguish (and reference) code blocks, we will name them (`#+NAME:`). The name can can then be referenced anywhere
- To turn the code block into a source code C file (`.c`), we will add a `:tangle FILENAME` statement to the header
- To create the tangled (source code) file from a block, use the keys `C-c C-v t` (`org-babel-tangle`) [1]
- To create the tangled (source code) from a file (all blocks), use the keys `C-c C-v f` (`org-babel-tangle-file`)
- Since source code files should have comments, we add the header argument `:comments both`: now, the most recent org block is used as a comment
- The workflow of "tangling" and "weaving"[2] looks like this:

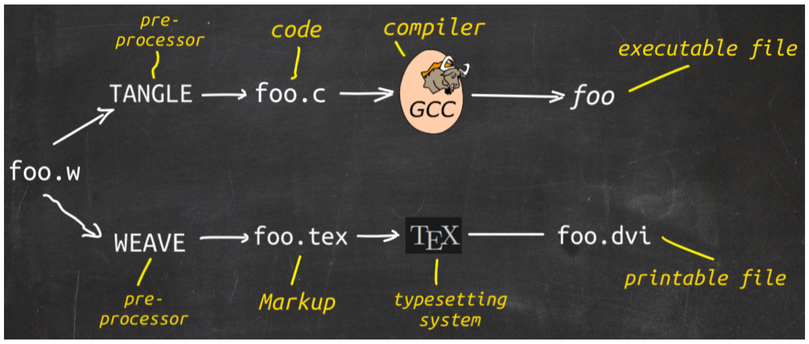


Figure 2: A file is woven into a document or tangled into a source file

Learn more about extracting source code from Org files.

[1]To tangle only the currently selected block, use `org-babel-tangle` with a prefix argument: `C-u C-c C-v t` or `C-u M-x org-bable-tangle`.

[2]In our case, instead of weaving TEX files (`.tex`) to print, we weave Markdown files (`.md`), or WORD (`*.odt`) files, or we dispense with the weaving altogether because Org-mode files (equivalent of the `*.w` or "web" files) look fine on GitHub. GitHub.

4 Hello World Version 1 (medium)

```
#include <stdio.h>
int main(void)
{
  printf("Hello world\n");
  return 0;
}
```

```
Hello world
```

What happens in this code block:

- A *header* file (`stdio.h`) is included for input/output
- A *function* (`main`) without arguments (`void`) is defined
- The function returns *integer* data (`int`)
- A *string* (`"..."`) is printed out
- A *new-line* is added at the end (`\n`)
- If successful, the program *returns* the value `0`

5 Hello World Version 2 (short)

The program could also have been written much simpler:

- In this code block, the function `main` is missing the `void` argument, and the `int` (indicating the type of variable returned - an integer).

  ```
  #include <stdio.h>
  main()
  {
    printf("Hello world\n");
  }
  ```

  ```
  Hello world
  ```

- It is the job of the *compiler*, `gcc`, which acts behind the scenes as it were, to resolve issues like "missing `int`" or "missing `return`"

- If you *tangle* the code block and compile the source file `hello2.c` in a shell, you get a warning:

  ```
  $ gcc hello2.c
    hello2.c:2:1: warning: return type defaults to 'int' [-Wimplicit-int]
    main()
    ^~~~
  ```

6 Hello World Version 3 (long)

The program could also have been written more complicated:

- `int argc` is an integer, or single number - the number of arguments that were passed to `main`
- `char **argv` (or `char *argv[]`) is a *pointer* that refers to an *array* of characters - a more complicated data structure

```
#include <stdio.h>

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

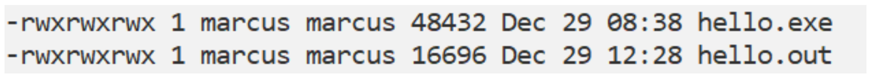
```
hello world
```

7 Compiler workflow

The machine cannot process a C source file like `hello.c` without help. It must:

Preprocess	The preprocessor acts on lines beginning with `#`
Compile	The compiler translates instructions into object code
Link	The linker combines object code and functions like `printf()`
Run	The final `*.exe` program is a binary (machine) program
Debug	The debugger controls rule violations along the way

I compiled the `hello.c` program on a Linux box - the executable is called `hello.out`. The other binary is `hello.exe` compiled on Windows. Compare the two executables - what do you notice?



```
-rwxrwxrwx 1 marcus marcus 48432 Dec 29 08:38 hello.exe
-rwxrwxrwx 1 marcus marcus 16696 Dec 29 12:28 hello.out
```

Question: are these executables portable?[3]

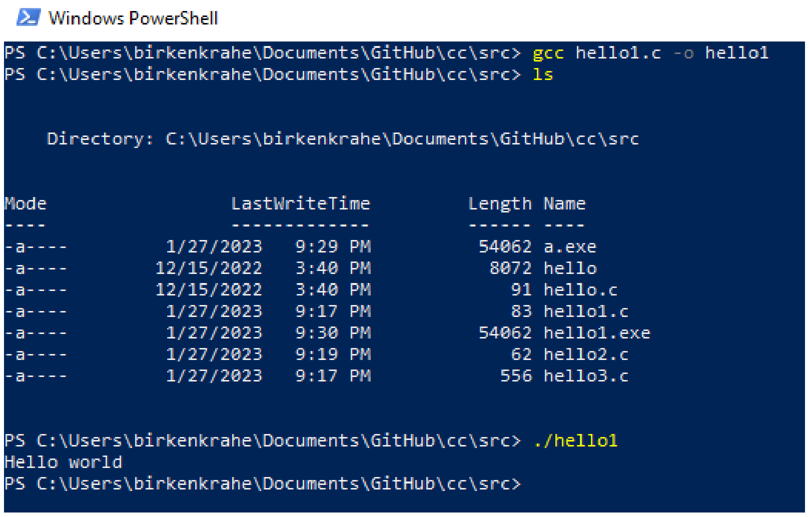
8 Shell execution

- You can also save the code in a C source code file `hello.c`
- Instead of Emacs, you could use `notepad` on Windows or `nano` on Linux
- You can compile the source files on the command line terminal or in the Emacs shell. Here is the workflow:

COMMAND	ACTION
`C-x C-f hello.c`	Create C file `hello.c`
	Copy block or write code anew in `hello.c`
`C-x C-s`	Save `hello.c`
`M-x eshell`	start a Linux shell in an Emacs buffer
`gcc hello.c -o hello`	compile program and create executable
`ls -l hello*`	list files - you should see `hello`, `hello.c`
`./hello`	execute program

- The *eshell* is an Emacs Lisp simulation of a Linux shell (`bash`)
- On Windows, `PowerShell` works as well as the CMD shell:

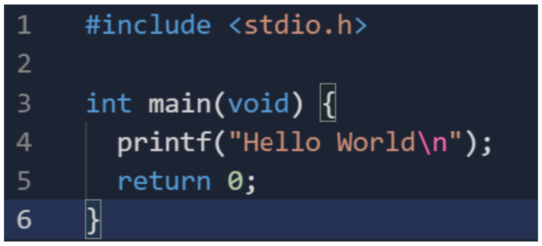
[3]Executables are the result of compilation for a specific computer architecture and OS. The `.exe` program was compiled for Windows, the `.out` program was compiled for Linux. They will only run on these OS.



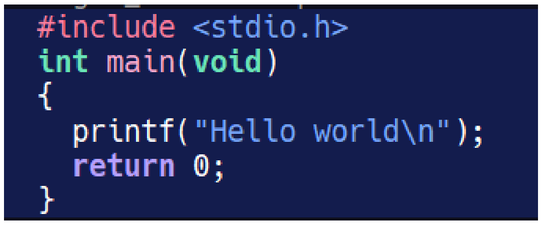
```
Windows PowerShell
PS C:\Users\birkenkrahe\Documents\GitHub\cc\src> gcc hello1.c -o hello1
PS C:\Users\birkenkrahe\Documents\GitHub\cc\src> ls


    Directory: C:\Users\birkenkrahe\Documents\GitHub\cc\src


Mode                 LastWriteTime         Length Name
----                 -------------         ------ ----
-a----         1/27/2023   9:29 PM          54062 a.exe
-a----        12/15/2022   3:40 PM           8072 hello
-a----        12/15/2022   3:40 PM             91 hello.c
-a----         1/27/2023   9:17 PM             83 hello1.c
-a----         1/27/2023   9:30 PM          54062 hello1.exe
-a----         1/27/2023   9:19 PM             62 hello2.c
-a----         1/27/2023   9:17 PM            556 hello3.c


PS C:\Users\birkenkrahe\Documents\GitHub\cc\src> ./hello1
Hello world
PS C:\Users\birkenkrahe\Documents\GitHub\cc\src>
```

9 Syntax highlighting in Emacs

- Notice the slight syntax highlighting difference to an online REPL `repl.it` [4]:



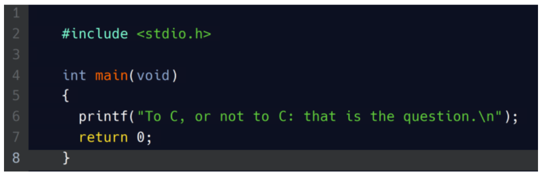
```c
#include <stdio.h>

int main(void) {
  printf("Hello World\n");
  return 0;
}
```



```c
#include <stdio.h>
int main(void)
{
  printf("Hello world\n");
  return 0;
}
```

[4]replit.com is an online Read-Eval-Print-Loop (REPL) that looks like a Linux installation (in fact, it is a so-called Docker container, an emulated, customized Linux installation). When registering (for free) you can use many different programming languages - here is a link to my container.

- There is no highlighting standard - you should experiment with different themes[5].
- Display line numbers with `display-line-numbers-mode`, and highlight lines with `hl-line-mode` - you can toggle these, and you can go through the minibuffer history with `M-x M-p` and `M-n`:



```

#include <stdio.h>

int main(void)
{
  printf("To C, or not to C: that is the question.\n");
  return 0;
}
```

10 Comments

Forgetting to terminate a *comment* may cause the compiler to ignore part of your program - but both syntax highlighting and auto-indent in the editor will tip you off:

```
printf("My "); /* forgot to close this comment ...
                  printf("cat ");
                  printf("has ");  /* so it ends here */
printf("fleas");
```

```
My fleas
```

Let's fix this:

```
printf("My "); /* forgot to close this comment */
printf("cat ");
printf("has no ");  /* so it ends here */
printf("fleas");
```

```
My cat has no fleas
```

[5]You can find different themes for GNU Emacs here, and install them using `M-x package-list-packages`. To see the differences, enter `M-x custom-themes` and pick another theme now. You can save it automatically for future sessions.

11 Let's practice!

Save the practice file as `1_hello_practice.org` and complete it:

1. understand and change syntax highlighting
2. understanding and using comments in C

   `../img/3_practice1.gif`

12 Summary

- C programs must be compiled and linked
- Programs consist of directives, functions, and statements
- C directives begin with a hash mark (`#`)
- C statements end with a semicolon (`;`)
- C functions begin and end with parentheses `{` and `}`
- C programs should be readable
- Input and output has to be formatted correctly

13 Code summary

CODE	EXPLANATION
`#include`	directive to include other programs
`stdio.h`	standard input/output header file
`main(int argc, char **argv)`	main function with two arguments
`return`	statement (successful completion)
`void`	empty argument - no value
`printf`	printing function
`\n`	escape character (new-line)
`/* ... */ //...`	comments
`main(void)`	main function without argument

14 Glossary

CONCEPT	EXPLANATION
Compiler	translates source code to object code
Linker	translates object code to machine code
Syntax	language rules
Debugger	checks syntax
Directive	starts with `#`, one line only, no delimiter
Preprocessor	processes directives
Statement	command to be executed, e.g. `return`
Delimiter	ends a statement (in C: semicolon - `;`)
Function	a rule to compute something with arguments

15 References

- Collingbourne (2019). The Little Book of C (Rev. 1.2). Dark Neon.
- King (2008). C Programming - A Modern Approach. Norton. Online: knking.com.