CSO-Recitation 02

CSCI-UA 0201-007

R02: GCC & Makefiles & Test

Today’s Topics

- Compiling with gcc
- Makefiles
- Testing code

Reminder

- Your first weekly mini-quiz
  - Gradescope
  - Due Friday 9pm EST

Compiling

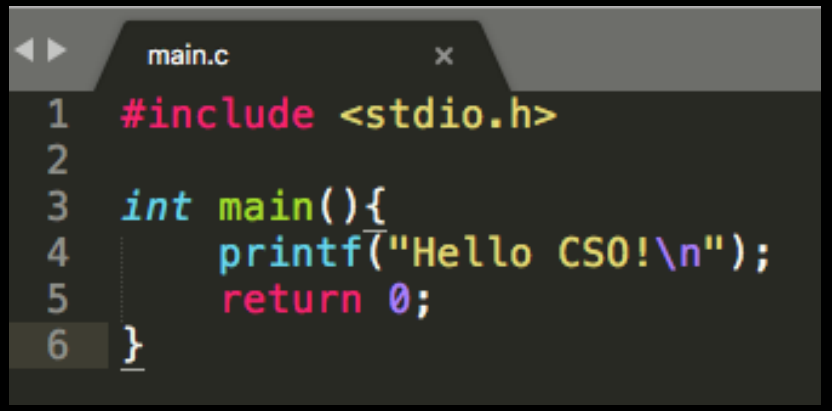
The basics of GCC

GCC

- GCC (upper case) refers to the GNU Compiler Collection
  - This is an open source compiler suite which include compilers for C, C++, Objective C, Fortran, Ada, Go and Java
- gcc (lower case) is the C compiler in the GNU Compiler Collection

What is a compiler?

- C code is for people, not computers
  - In fact, high level languages in general are for people
  - Computer processors only “understand” binary instructions



Source code

Machine code
(binary instructions)

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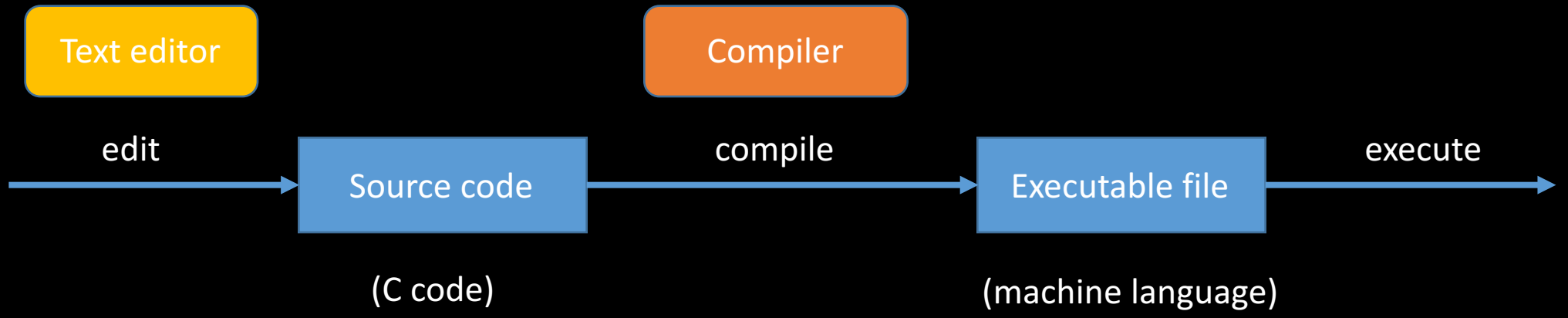
  - Computer processors only “understand” binary instructions
- A compiler translates code between languages
  - In our cases, it translates from C (the source language) to machine code (the target language)



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- A compiler translates code between languages
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- An alternative way to do things is to have a program read the code and execute commands
  - Such a program is called an interpreter
  - Python is an example of a language that uses an interpreter

How do you use a compiler?

- Consider a simple C program:

main.c

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

- To run this program, we must first compile it
  - Can use gcc: gcc main.c will produce a file called a.out
  - We can run a.out by issuing ./a.out
  - You can choose the name of executable with -o, as in gcc main.c -o myprogram

How do you use a compiler?

- You can also compile more than one file

main.c

```c
#include <stdio.h>
void helper();
int main(){
    helper();
    return 0;
}
```

util.c

```c
#include <stdio.h>
void helper(){
    printf("Hello CSO!\n");
}
```

- To compile this, we can simply specify both files
  - gcc main.c util.c -o myprogram

A Problem

- For large projects, recompiling everything can be slow
- To avoid this, we can compile files separately
  - Must compile without linking using the -c flag
  - Ordinarily, the compiler compiles each source file into object code, and then links them and deletes the intermediate object code
- gcc -c main.c util.c
  - Will create main.o and util.o
  - Then we can add to main.c and util.c and not have to recompile the other
  - We can later do link by running gcc main.o util.o -o myprogram

Compilation and linking

- Compiling isn’t quite the same as creating an executable file!
- Instead, creating an executable is a multistage process divided into two components: compilation and linking
- Compilation:
  - Refers to the processing of source code files and the creation of an ‘object’ file
  - Merely products the machine language instructions
- Linking:
  - Refers to the creation of a single executable file from multiple object files

Compiling

- .c is the source code
- .o extension is for object files
  - is a binary file generated by compilation unit
- executable files should have no extension
  - By default a.out, which has the .out extension

A new problem

- Now we need to keep track of when we have to recompile.

Make

A helpful build automation tool

Why do we need Make?

- Even a small project is unbearable to compile with gcc alone
- But in the real world, things are much worse!
  - The Linux kernel has over 45,000 files of C code!
    - So it uses Makefiles… almost 2700 of them
- Make will also know when we need to recompile different sources

What does Make do?

- Make builds projects for us, keeping track of when it needs to recompile or not
  - When make recompiles, each changed C source file must be recompiled
  - If any source file has been recompiled, all the object files must be linked together to produce the new executable file
- We tell make about the dependencies in our code using a Makefile
- Then, by issuing the command make we can build our project, and Make will only compile what it has to

What is a Makefile?

- Makefile consists of a number of ‘rules’:

  target ... : *dependencies* ...

  command

  …

- Rules specify:
  - A target, which is usually the name of a file that is generated by a program
    - Targets include main.o or myprogram
  - Dependencies, which are files that are used as input to create the target
    - main.o needs main.c
    - myprogram needs main.o and util.o
  - Commands, which are actions that make carries out
    - gcc -c main.c -o main.o

What is a Makefile?

- Rules look like this:

```
myprogram: main.o util.o
        gcc main.o util.o -o myprogram
```

- There must be no space before the target, and there must be a tab before every command for that rule
- Running the *make* command builds the first target by default
- However, the rule that specifies commands for the target need not have dependencies, for example “clean”
  - make clean

What is a Makefile?

- Rules look like this:

```
myprogram: main.o util.o
        gcc main.o util.o -o myprogram
```

- A bad Makefile for this little project is:

```
myprogram: main.c util.c
        gcc main.c util.c -o myprogram
```

- Why is that bad?

A better Makefile

```
myprogram: main.o util.o
	gcc main.o util.o -o myprogram
main.o: main.c
	gcc -c main.c -o main.o
util.o: util.c
	gcc -c util.c -o util.o
clean:
	rm -f main.o util.o myprogram
```

That still seems bad for the 45,000 linux files..

- That's right, and there are better ways of using Makefiles - this is just what you absolutely positively need to know
- Make also supports pattern matching with the percent sign %
  - %.c means all .c files
- Make has "automatic variables"
  - Variables whose meaning within a rule depends on context
  - $@ is the name of the rule
  - $^ is the list of dependencies
- Example:

```
%.o: %.c
        gcc -c $^ -o $@
```

An exercise

#TODO: Create a makefile for this project

#The name of the executable must be test

#The source code files involved are main.c and util.c

#*make clean* should remove test and any .o files

Testing

Making sure your code does what you think it does

Why test code?

- You need to know that your code works
- You need to know when you broke your own code by changing something
- Many projects actually have more test code than production code
  - An extreme example is SQLite, a popular database program
    - 138,900 lines of C code for production
    - 91,946,200 lines of test code

How do you test code?

- A common way is to write tests for individual units of code, such as functions
- There are many frameworks written to help developers write test cases
  - Wikipedia lists more than 50 for the C programming language
  - You don't need a framework, though
- You can write your own tests
  - Think of edge cases that might make your code failed
  - Write a program that calls your code with different inputs and checks that the output is what you'd expect
    - You can use assert to have your program die if something goes wrong
    - assert(1+1==2) will crash if 1+1 is not 2, but be fine otherwise