C Primer Continued … (Makefiles, debugging, and more)

Hello Word!

~/ctest/

Continue: How do I learn C?

In addition to syntax you need to learn:

- the Tools
- the Libraries.
- And the Documentation.

Last Time: A Simple(st) C Program 1-hello-world.c

```
/* header files go up here -- specifies headers needed for routines */
/* note that C comments are enclosed within a slash
and a star, and may wrap over lines */
// but if you use the latest gcc, two slashes will work too, like C++
#include <stdio.h>  /* prototypes processed by cpp */


// a comment about comments single dine doesn't always work
/*    and multiline comment
*/


/* main returns an integer */
int main( int argc, char *argv[] )
{
printf( "hello, world\n" );
return(0);   /* returns 0 by conventions indicates all went well */
}
```

declarations

functions()

main()

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/* note that C comments are enclosed within a slash
and a star, and may wrap over lines */
// but if you use the latest gcc, two slashes will work too, like C++
#include <stdio.h>  /* prototypes processed by cpp */

/* main returns an integer */
int main( int argc, char *argv[] )
{
/* printf is our output function; by default it writes to standard out */
/* printf returns an integer, but we ignore it here */
/*1 [stout]   >& redirect stout and stderr */
/* >& /dev/null - suppress all output */ /*(cat f1 > myout) >& myerror */


printf( "hello, world\n" );
return(0);   /* returns 0 by conventions indicates all went well */
}
```

declarations

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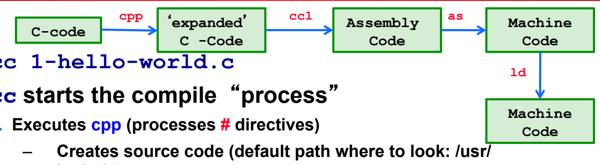
*.c File Name

- Naming the program (e.g., 1-hello-world.c, main.c , marialSawesome.c)
  - » Arbitrary – Not Like in Java where file name is connected with file content (class name).
  - » Constraint: Need to end with a *.c'

Compiling and Running a C-program: 1-hello-world.c



- `gcc 1-hello-world.c`
- gcc starts the compile "process"
  1. Executes cpp (processes # directives)
     – Creates source code (default path where to look: /usr/include)
  2. Compilation (cc1)
     – Transforms C code to assembly code
  3. Assembler (as) runs
     – Transforms assembly code to machine code
  4. Linker (ld) runs
     – Links code together to create the final executable
- `./a.out`
  - » `int main( int argc, char *argv[] )`

1

argv[1]=NULL (end)

Compile Command line & 'flags'

- `prompt> gcc -o first first.c # -o lets you specify the executable name`
- `prompt> gcc -Wall first.c # -Wall gives much better warnings`
- `prompt> gcc -g first.c # use -g to enable debugging with gdb`
- `prompt> gcc -O first.c # use -O to turn on optimization`

Linking Libraries

- Example: `fork()` requires a library, namely the C-library. The C library is *automatically* linked, so all we need then is :
  - » The 'including' the right `#include` file "<>", -i, -I to to find the prototype of the function (return type, date types of parameters).
  - » How to find out:
    - – `man fork`
  - » CAVEAT: the controversial and dreaded `LD_LIBRARY_PATH`
  - » http://www.cs.uga.edu/~maria/classes/1730-Spring-2006/gcc-getstarted.txt
    - – May fix (e.g., readline) problems

Lets say that again….

- fork() requires the C-library (`clib`). The C library is *automatically* linked in, so all we need then is … :
  - » How do you know what to include?
  - » `man fork`
  - » BUT – Wait a minute why a library - fork is a system call! [a request of 'service' by the OS from the application]
    - – `C library provides C –wrappers for all system calls – which simply traps into the OS`
    - – The 'real' system call in Linux e.g., is `sys_fork()`

Other Libraries: The Math Library (m)

- gcc [flag ...] file ... -lm [link library math...]
- #include <math.h>
  - » In /usr/lib
  - » Statically linked .a (compile time)
    - – Combines code (copies) directly into executable
  - » Dynamically linked shared library .so (run time)
    - – Smaller code base (can be shared by multiple processes)
    - – A reference and only links when needed, smaller code base (some work), hooks in code triggers the run time system to load in the library, only when needed
  - » /usr/libm.a & /usr/libm.so
  - » Link editor searches for library in a certain order.
  - » -lm directory path include) and –L(directory path)

Multiple Files (`hw.c, helper.c Makefile2`)

```
prompt> gcc –o hw hw.c helper.c -lm
```

Problem: Remake everything (2 programs here) every time, even if the change is only in hw.c

Approach: Separate 2 step compilation process that only re-compiles source files that have been modified

- Create object files then link *.o files
- Then link these files into an executable

Separate Compilation

```
# note that we are using -Wall for
  warnings and -O for optimization
prompt> gcc -Wall -O -c hw.c
prompt> gcc -Wall -O -c helper.c
prompt> gcc -o hw hw.o helper.o -lm
```

- -c flag produces an object file
  - Machine level code (not executable)
  - Need to link to make an executable

```
prompt> gcc -o hw hw.c helper.c -lm
```

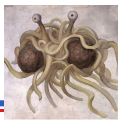
Make & Makefiles
make target
make –f Makefile2 target

- Make make things easier to handle the compilation process.

```
target: prerequisite1 prerequisite2
  command1
  command2
```

- Set of Rules
  - First Line: Target followed by dependencies
    - Target usually the name of executable of (1) the object file or (2) the action (like clean)
  - Below that a tab \t followed by the action or command

Make – Makefiles (be aware of the dreaded white space phenomena)



```
hw: hw.o helper.o
      gcc -o hw hw.o helper.o -lm
hw.o: hw.c
      gcc -O -Wall -c hw.c
helper.o: helper.c
      gcc -O -Wall -c helper.c
clean:
      rm -f hw.o helper.o hw
```

- Vi – see white spaces by (escape then) :list or :set list

OK what is going on here?

```
hw: hw.o helper.o
    gcc -o hw hw.o helper.o -lm
hw.o: hw.c
  gcc -O -Wall -c hw.c
helper.o: helper.c
  gcc -O -Wall -c helper.c
clean:
  rm -f hw.o helper.o hw
```

- Goes to target hw (first target) need the prerequisites
- Check them in turn (according to date) and see if they need to be re-made

Make macros

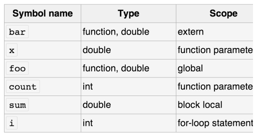
- Also you can create macros:
  - » CC = gcc
  - » OBJECTS = data.o main.o
  - » Project1: $(OBJECTS)
- Examples of Special macros
  - » CC, CFLAGS (compiler, and compiler flags)
  - » $@ short cut for full name of current target

```
%.o : %.c
      $(CC) –c –o $@ $(CFLAGS)
```

Advice Getting Started with Makefile

- Start by using a working Makefile (template), then edit the file how you like it.
- Posted on class list
- Be aware of white spaces

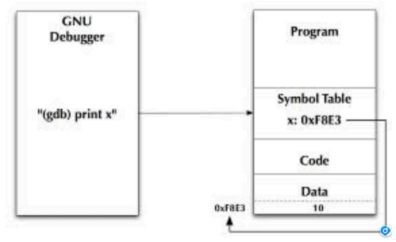
Debugger



Symbol name	Type	Scope
`bar`	function, double	extern
`x`	double	function paramete
`foo`	function, double	global
`count`	int	function paramete
`sum`	double	block local
`i`	int	for-loop statement

- The debugger: it is a program
- Gnu Debugger (GDB)
- `gcc -g -o program program.c`
  - » `-g "make the executable debuggable"`
- `-g'ing gcc.`
  - » `Symbol Table`
    - `– List of "names" of identifier is accessible to the debugger`
      - `type, scope, and location of identifiers (e.g., variables and functions)`
  - » `Prevent the compiler from re-arranging (optimizing) the code`

Debugger



- Visualization

Examining Object Files

- nm – list symbols from object file
  - » http://linux.about.com/library/cmd/blcmdl1_nm.htm
- Objdump - more detailed information
- readelf

Debugging

```
#include <stdio.h>
struct Data {
int x;
};
int main( int argc, char *argv[] )
{
struct Data *p = NULL;
printf("%d\n", p->x);
}
```

Debugging

- `gcc -g -o 3-buggy 3-buggy.c`
- `{nike:maria:428} 3-buggy`
- `Segmentation Fault(coredump)`
- `gdb 3-buggy`
  - `run`
  - `print p`
  - `break main`

GDB

- `(gdb) help`
- `Help running`
- `Help files`
- `Help breakpoints`

A Note : Integrated Development Environments (IDE)

- Debugger, Editor, Compilation
- Eclipse - http://www.eclipse.org/callisto/c-dev.php
- Microsoft Visual Studios

Documentation: Oh Man

- **man XXX**
- **man -k**

The *Ultimate* C Reference Guides

- ***"The C book" or the "K & R Book":***
  - » ***The C Programming Language, by Brian Kernighan and Dennis Ritchie (thin, concise and all you really need…)***
- ***The GDB Booklet***
  - » ***Debugging with GDB: The GNU Source-Level Debugger, by Richard M. Stallman, Roland H. Pesch***
    - – ***http://sourceware.org/gdb/current/onlinedocs/gdb.html***
- ***The Unix System Programming Book***
  - » ***Advanced Programming in the UNIX Environment, by W. Richard Stevens***

A note on your shell

Quiz 1 : Reading

```
Get a piece of notebook paper and pen, or pencil.  Close books,
laptops, notebooks, and put away phones and other electronics.
Then: Write your name, and todays date on top of paper, and answer
questions below. When done please turn in paper to instructor. Good
Luck.
```

1. **What is the UNIX Kernel?**
2. **What is a UNIX Shell? (what does it do?, and give example of a shell)**
3. **What is a process?**
4. **What is a System Call?**
5. **How do processes communicate? (give at least 3 methods of communication of processes).**