

CSE 351: The Hardware/Software Interface

Section 1

Intro, C programming, C tools

Introduction

- * I am a fifth-year Masters student in CSE
- * Graduated last quarter with a degree in Computer Engineering
- * Interests include embedded software and systems engineering
 - * Third time being a TA for CSE 351
- * My office hours will be on Monday from 12:30-1:20 in the 002 lab, but you can always schedule an appointment with me
- * Contact: discussion board or by email (madman2@cs)

Course Tools

- * Use whatever works best for you: [the CSE home VM](#), attu, the instructional Linux machines, or your own Linux installation (we won't provide support if you go this route, though)
- * From pretty much any machine, you can use [PuTTY](#) (Windows) or an SSH client (OS X, Linux, iOS, Android, etc.) to access attu
 - * Via SSH: `ssh [username]@attu.cs.washington.edu`

Course Tools

- * We'll be using the GNU C Compiler (gcc) for compiling C code in this course, which is available on pretty much every platform except Windows (unless through Cygwin)
- * For an editor, use whatever makes you comfortable; Emacs, Vim, gedit, and Eclipse are good choices

Unix Commands

- * We're going to assume that you know some basic Unix commands; there are many guides online if you need additional help [such as this one](#)
- * `cd`: change directory
 - * Example: `cd path/to/directory`
- * `pwd`: print working directory
 - * Example: From my home directory on attu, `pwd` prints out `/homes/iws/snowden`
- * `ls`: list directory contents
 - * Example: `ls ..` (list the directory one above this one)
- * `chmod`: change mode (permissions)
 - * Example: `chmod +x file` (make file executable)

Compiling C Code

- * There are two steps to get from a C source file to an executable file: compiling and linking
- * To compile a source file with GCC, use the `-c` option:
`gcc -c example.c`
 - * This will produce a corresponding `example.o` file, which contains the machine code for the `example.c` source file
- * To link object files into an executable with GCC, list them as arguments: `gcc -o example example.o [...]`
 - * Here the `-o` option specifies what to name the output; it will be an executable file called “example”

Compiling C Code

- * It's also possible to combine the two steps: `gcc -o example example.c`
 - * This will accomplish both the compilation and the linking at once
 - * Why might it be a good idea to separate these two steps?
- * GCC takes a number of flags, which you will see/have seen with lab 0
 - * `-g` to include debugging symbols
 - * `-Wall` to warn about all recognized problems
 - * `-std=gnu99` to use the C99 standard instead of the C89 standard, which is just a couple years out of date
 - * **Example:** `gcc -g -Wall -std=gnu99 -o example example.c`

A Basic C Program

*The Hello World of C:

```
#include <stdio.h>
int main(int argc, char* argv[]){
    printf("Hello World\n");
    return 0;
}
```

A Basic C Program

```
#include <stdio.h>
int main(int argc, char* argv[]){
    printf("Hello World\n");
    return 0;
}
```

- * The first line is a *header* inclusion
- * Headers provide declarations (but not normally definitions) of other code
 - * `stdio.h` contains the declaration of the `printf` function, which is used for printing to the console

A Basic C Program

```
#include <stdio.h>
int main(int argc, char* argv[]){
    printf("Hello World\n");
    return 0;
}
```

- * On Linux, you can look under /usr/include to see the contents of these header files
- * To refer to headers that aren't part of "special" directories, put the path to them in quotes
 - * As an example, `#include "path/to/header.h"`

A Basic C Program

```
#include <stdio.h>
int main(int argc, char* argv[]){
    printf("Hello World\n");
    return 0;
}
```

* The next part of the file is the declaration of the entry point for the program: `main()`

* `main()` takes two parameters, the first of which is the number of strings contained in the second parameter. `argv` is an array of the arguments to the program

A Basic C Program

```
#include <stdio.h>
int main(int argc, char* argv[]){
    printf("Hello World\n");
    return 0;
}
```

*The `printf()` function prints to the console.

It is equivalent to Java's `System.out.printf()` and requires that you insert a newline explicitly

A Basic C Program

```
#include <stdio.h>
int main(int argc, char* argv[]){
    printf("Hello World\n");
    return 0;
}
```

- * Finally, `return 0` indicates the status code of the program when it exits
- * A status code of 0 indicates success, whereas other numbers have a different meaning
 - * `errno.h` includes the names of many status codes, which are documented in “`man errno`”

A Basic C Program

```
#include <stdio.h>
int main(int argc, char* argv[]){
    printf("Hello World\n");
    return 0;
}
```

* Let's compile and run the program

Formatting Output

- * In C, there is no easy way to concatenate strings as there is in Java. Instead, `printf()` supports a number of format codes
- * **Example:** `int val = 10; printf("%d\n", val);`
 - * `%d` is the format code for ints, so the above code will print “10” with a newline
- * Other format codes: `%f` for floats and doubles, `%s` for strings, `%x` for hexadecimal values, `%p` for pointers. See the [cplusplus site](#) for more info

Formatting Output

* A few different scenarios:

```
printf("There are %d students enrolled "  
      "in the class\n", 88);  
printf("The course number for this "  
      "class is %s\n", "CSE 351");  
printf("If you want a %f in %s, you'll "  
      "need to work for it\n", 4.0,  
      "CSE 351");
```

Man Pages

- * Much of the functionality of Linux is documented in *man pages*. Man pages are manuals describing how a variety of commands, functions, and so forth work
- * As an example, take a look at `man ssh`. This describes how the `ssh` command works
- * For C functions, look in section 3; that is, use `man 3 [topic]`, **SO** `man 3 printf` for the `printf()` **function**

Debugging

- * The best way of debugging C programs is to use GDB (not printf statements!)
- * GDB is the GNU debugger, and it does a variety of amazing things. To use it, compile your program using the `-g` option (to include debugging symbols) and then run in under GDB with `gdb ./example`
- * Let's run the hello world program from before under GDB

Debugging

- * Use the “p” (print) command within GDB to print out values of variables and their addresses
- * Use the “b” (breakpoint) command to set a breakpoint at a particular line/file/function, e.g. “b 79” to break execution at line 79 in the current file
- * Use the “c” (continue) command to resume execution after hitting a breakpoint
- * Use the “d” (delete breakpoint) command to remove breakpoints, e.g. “d 1” to delete breakpoint 1
- * Use the “list” command to output the code with line numbers in the current file. “list [line-#]” will list code from the given line; press Enter to see more code

Debugging

- * Use the “x” (examine) command within GDB to examine memory at a certain address (more useful in later labs)
- * Use the “r” (run) command to execute the program
- * Use the “s” (step) command within GDB to execute one C statement
- * Use the “n” (next) command to execute one C statement, skipping over function calls

Debugging

- * Use the “bt” (backtrace) command within GDB to print out the current call stack
- * Use the “frame” command jump to the indicated stack frame, e.g. “frame 3” for stack frame 3. Use this in combination with the “bt” command
- * When setting breakpoints, you can specify a condition so that the debugger only breaks if the condition is met, e.g. “b example.c:83 if x == 10” will set a breakpoint at line 83 of example.c that will activate only when x is 10

Your Turn

- * Working in pairs/groups, download the two .c files for this section from the course website and use GDB to debug and fix the problems using the techniques given in the source files
 - * Work first on conditional.c, then on backtrace.c
 - * Alternatively, if you haven't completed lab 0, now would be a good time to do it
- * Be sure to ask for help if needed!
- * GDB Cheat Sheet:
 - * <http://csapp.cs.cmu.edu/public/docs/gdbnotes-x86-64.pdf>