

CSCI 414 / 553: Networking III

Unix Network Programming

Spring 2008



Compiling, Linking & Libraries



Today's Agenda

- First a bit more about version control
 - Check subversion task from Thursday
- Compilers, Linking & Libraries
- Debuggers
- Discuss Lab 2



Today's Agenda

- Before we begin, or after class to try on your own:

```
$ cd
```

```
$ mkdir compilers
```

```
$ cd compilers
```

```
$ tar xvfz /home/csci553/classfiles/compilers.tgz
```



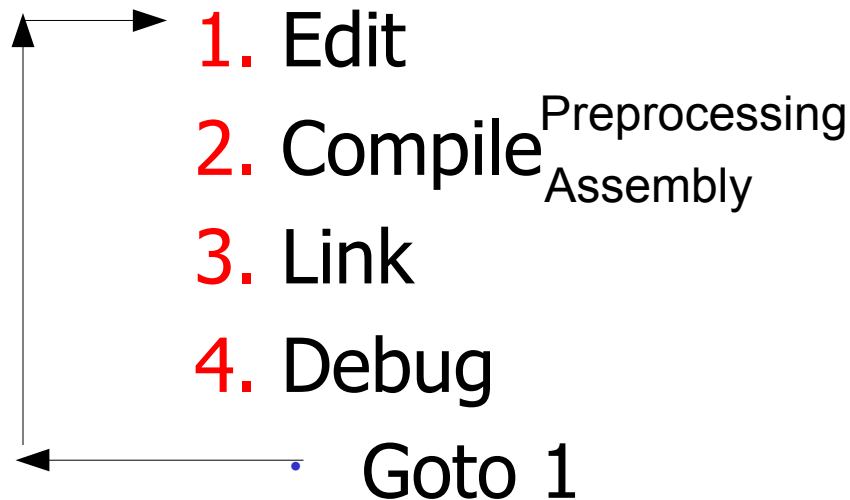
Introduction

- C is a powerful systems level programming language
 - It is the fundamental language of Unix
 - It is a source for many of the paradigms of programming that have found their way into modern languages
- So a basic familiarity with C concepts is fundamental to being a good programmer
- Linking and Libraries are parts of good modular programming



Execution Cycle

- C is an example of a sturdy language (SWC)
- The full cycle:





C Compiler

- Free implementation of c compiler, GNU c (gcc), is ubiquitously available
 - cc command in most Linux distributions is simply a symbolic link to gcc
- gcc can do all 4 steps in 1 invocation:
preprocessing, compiling, assembling, linking
 - Or can be stopped at any stage



Compiling a C Program

- Single-Module (Self-contained) program
 - Single source file

```
$ vi reverse.c
```

```
... editing session
```

```
$ cc reverse.c
```

```
$ ls -l
```

```
total 12
```

```
-rwxrwxr-x 1 dharter dharter 5047 2008-01-24 15:14 a.out
```

```
-rw-rw-r-- 1 dharter dharter 504 2008-01-24 15:13 reverse.c
```



Running a C Program

- Or any executable program, for that matter

```
$ a.out
```

```
bash: a.out: command not found
```

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

```
reverse ("cat") = tac
```

```
reverse ("noon") = noon
```

- Solution:

- 1) Add . or directory where executable is to PATH
- 2) give a correct relative or absolute path name to executable



Running a C Program

Besides finding the executable, the executable script/program needs to be, well, executable

```
$ chmod ugo-x a.out
```

```
$ ls -l
```

```
total 12
```

```
-rw-rw-r-- 1 dharter dharter 5047 2008-01-24 15:14 a.out
```

```
-rw-rw-r-- 1 dharter dharter 504 2008-01-24 15:13 reverse.c
```

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

```
bash: ./a.out: Permission denied
```



Options for cc

- cc on many systems now a-days is a symbolic link to the gnu gcc compiler
- man gcc for options
- Override the default executable name

```
$ gcc reverse.c -o reverse
```

```
$ ls -l
```

```
total 20
```

```
-rwxrwxr-x 1 dharter dharter 5047 2008-01-24 15:24 reverse
```

```
-rw-rw-r-- 1 dharter dharter 504 2008-01-24 15:13 reverse.c
```

```
$ ./reverse
```

```
reverse ("cat") = tac
```

```
reverse ("noon") = noon
```



Multimodule Programs

- Real world software needs to be modular
 - Break into functions, modules, packages, etc.
- Breaking related functions / functionality into separate files enhances reusability
 - In vanilla c world, link into standard system libraries
 - Similar concept to packages in Java, Python

Compiling Separate Files/Modules



- Default gcc behavior
 - given a bunch of source files,
 - attempt to compile them all individually
 - and link together

```
$ gcc reverse.c main.c
```

```
$ ls -l
```

```
total 20
```

```
-rwxrwxr-x 1 dharter dharter 5130 2008-01-24 15:35 a.out
```

```
-rw-rw-r-- 1 dharter dharter 265 2008-01-24 15:34 main.c
```

```
-rw-rw-r-- 1 dharter dharter 241 2008-01-24 15:32 reverse.c
```

```
-rw-rw-r-- 1 dharter dharter 114 2008-01-24 15:33 reverse.h
```

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

```
reverse ("cat") = tac
```

```
reverse ("noon") = noon
```

Compiling and Linking Separately



- gcc options allow you to stop the process at any step, preprocessing, assembling the object files, linking, etc.
- compile source files, and stop at object compilation:

```
$ gcc -c main.c
```

```
$ gcc -c reverse.c
```

```
$ ls -l *.o
```

```
-rw-rw-r-- 1 dharter dharter 1060 2008-01-24 15:51 main.o
```

```
-rw-rw-r-- 1 dharter dharter 783 2008-01-24 15:51 reverse.o
```



Use gcc to Link object files

- gcc can take object files and link them into an executable for you

```
$ gcc reverse.o main.o -o reverse
```

```
$ ./reverse
```

```
reverse ("cat") = tac
```

```
reverse ("noon") = noon
```

The Stand-Alone Linker/Loader



- When gcc is used to link object files, it transparently invokes ld
- Often never need to directly invoke ld
 - But it is wise to know a little bit about it
 - Especially if you want to create linkable libraries

The Stand-Alone Linker/Loader

```
$ ld --eh-frame-hdr -m elf_i386 --hash-style=gnu -dynamic-linker  
/lib/ld-linux.so.2 /usr/lib/crt1.o /usr/lib/crti.o  
/usr/lib/gcc/i386-redhat-linux/4.1.2/crtbegin.o  
-L/usr/lib/gcc/i386-redhat-linux/4.1.2 -L/usr/lib  
reverse.o main.o  
-lgcc --as-needed -lgcc_s --no-as-needed -lc  
/usr/lib/gcc/i386-redhat-linux/4.1.2/crtend.o /usr/lib/crtn.o  
-o reverse
```

Creating Stand Alone Libraries (Archives)



- Archiver tool ar create stand along libraries
 - static libraries (.a)
 - dynamic link shared object libraries (.so)



Creating a Static Library

- Compile object files

```
$ gcc -c palindrome.c reverse.c
```

- Use ar to create library libreverse.a

```
$ ar -crv libpalindrome.a reverse.o palindrome.o
```

```
a - reverse.o
```

```
a - palindrome.o
```

- Link an executable using a library

- -L directory where to find library

- -I directory where to find include file (header)

```
$ gcc -c main.c
```

```
$ gcc -o palindrome main.o -L . -lpalindrome
```

```
$ ./palindrome
```

```
cat palindrome? = 0
```

```
cattac palindrome? = 1
```



Library Naming Conventions

- Libraries are named with prefix "lib"
- The following command

```
$ gcc src-file.c -lm -lpthread
```

 - /usr/lib/libm.a
 - /usr/lib/libpthread.a
- Standard system library locations
 - /lib
 - /usr/lib



Using an Archive/Library

- Many standard libraries are already available:
 - `/usr/lib/libmath.a` “Standard c math functions”

```
$ gcc -c math.c
```

```
$ gcc -o math math.o -lm
```



gcc and ar options

| Command | Option | Purpose |
|------------|-------------|---|
| gcc | | |
| | -c | Stop at compilation phase, e.g. do not link executable |
| | -o file | Place output in file. Default is file.o if only compiling object file, a.out if linking executable. |
| | -I dir | Search dir for include (header) files |
| | -L dir | Search dir for library/archive files to link against |
| | -lname | Link executable with library named /usr/lib/libname.a |
| | -g -ggdb | Produce debugging information in the object file. The second form produces extra information useful for gdb debugger. |
| ar | | |
| | -c | Create a new archive |
| | -r | Insert files into archive with replacement |
| | -v | Be verbose, give information about files being placed in archive. |



Summary

- c language concepts pervade modern programming systems and languages
- plain c is modular
- Unix/Linux use library/archive concepts to share modular code libraries