Overview and Tools

Advanced Programming in the UNIX Environment

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Outline

Prepare your UNIX environment

A Brief Introduction to the UNIX environment

Fundamental UNIX programming practices

Tools

Prepare Your UNIX Environment

Use Ubuntu Linux (Debian-based) as examples

Recommended minimum set of Ubuntu packages

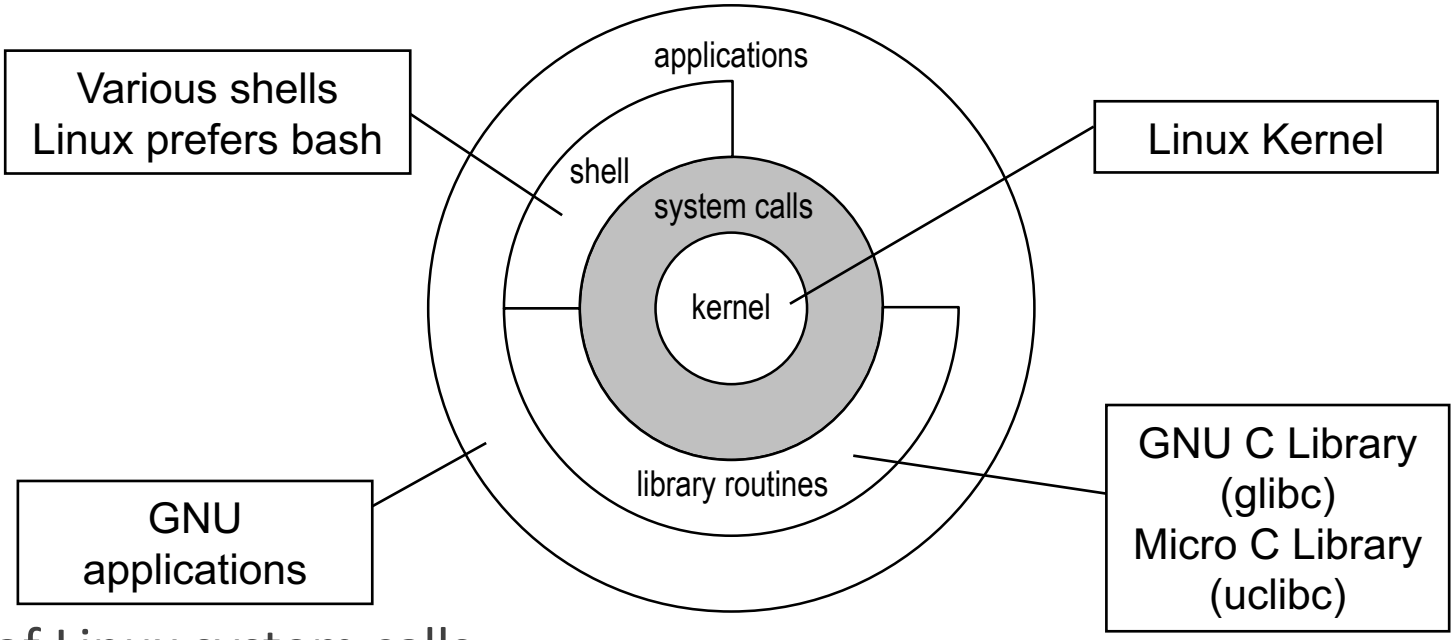
- gcc, g++, gdb, make
- manpages-dev, manpages-posix, manpages-posix-dev
- `$ sudo apt-get install gcc g++ gdb make manpages-dev manpages-posix manpages-posix-dev`
- https://help.ubuntu.com/lts/serverguide/apt.html.en (Ubuntu Linux)
- https://wiki.archlinux.org/index.php/pacman (Arch Linux)

Virtual machine settings

- Virtualbox
- Dual network interfaces
  - Primary: NAT (for Internet access)
  - Secondary: Host-Only (for host-to-host communication, e.g., ssh connection from local to VM)

A Brief Introduction to the UNIX Environment

UNIX Architecture



List of Linux system calls

- http://man7.org/linux/man-pages/man2/syscalls.2.html
- (x86_64) https://github.com/torvalds/linux/blob/master/arch/x86/entry/syscalls/syscall_64.tbl
- (x86) https://syscalls.kernelgrok.com/
- (x86_64) http://www.cs.utexas.edu/~bismith/test/syscalls/syscalls64_orig.html
- (multiple) https://w3challs.com/syscalls/

UNIX Architecture (Cont'd)

An Android Example

Booting Process

OS loader (e.g., grub)

- Loads kernel and an (optional) initial RAM disk into the memory

Kernel initializes system hardware components

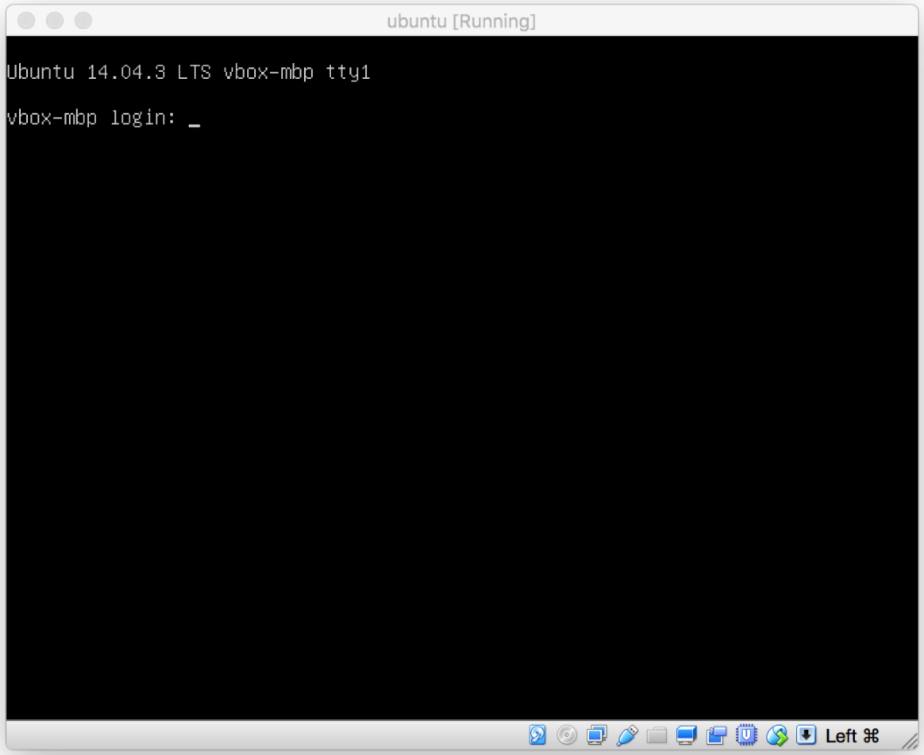
Launch the first process

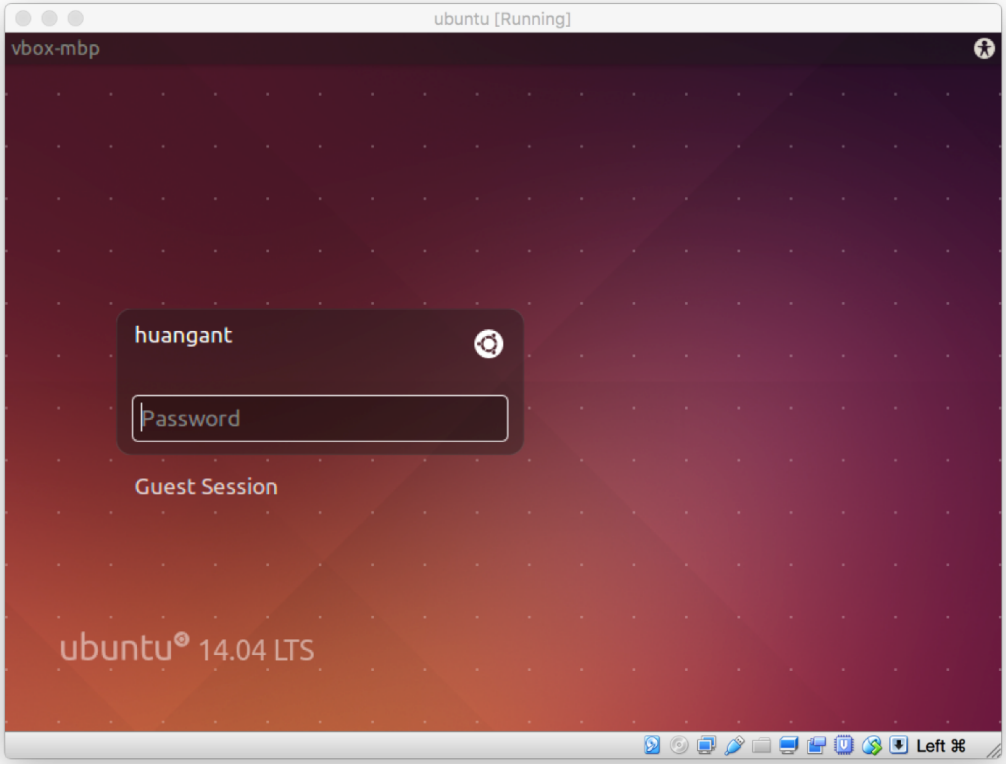
- /sbin/init, /etc/init, /bin/init, and finally /bin/sh
- Modern Linux systems have replaced init with systemd

The init process brings up the rest of everything

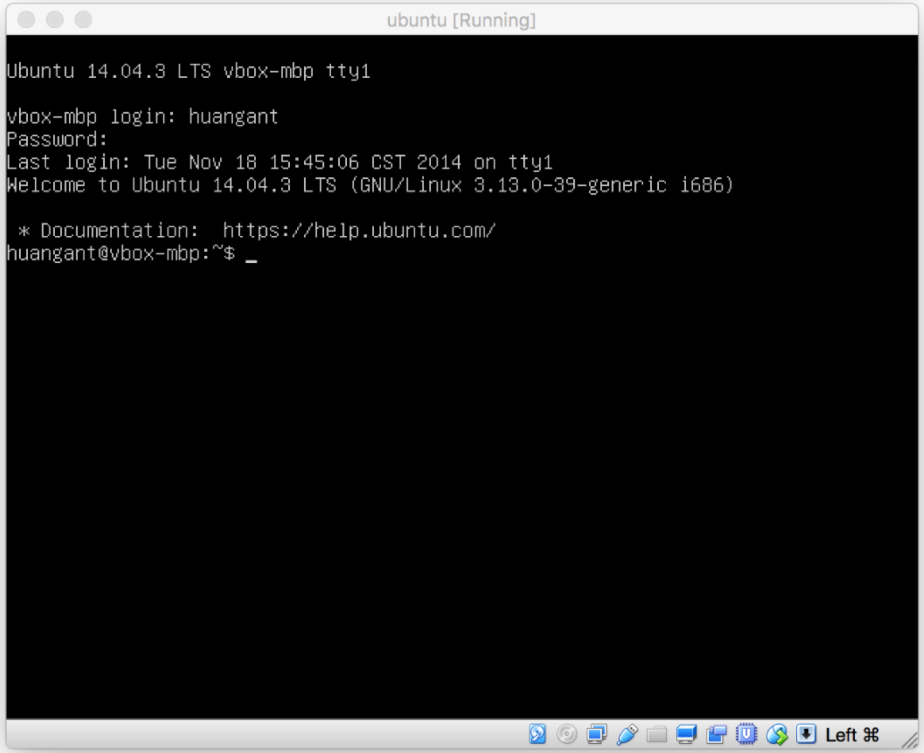
- Mount file systems
- Setup networks
- Launch services
- Provide the login interface

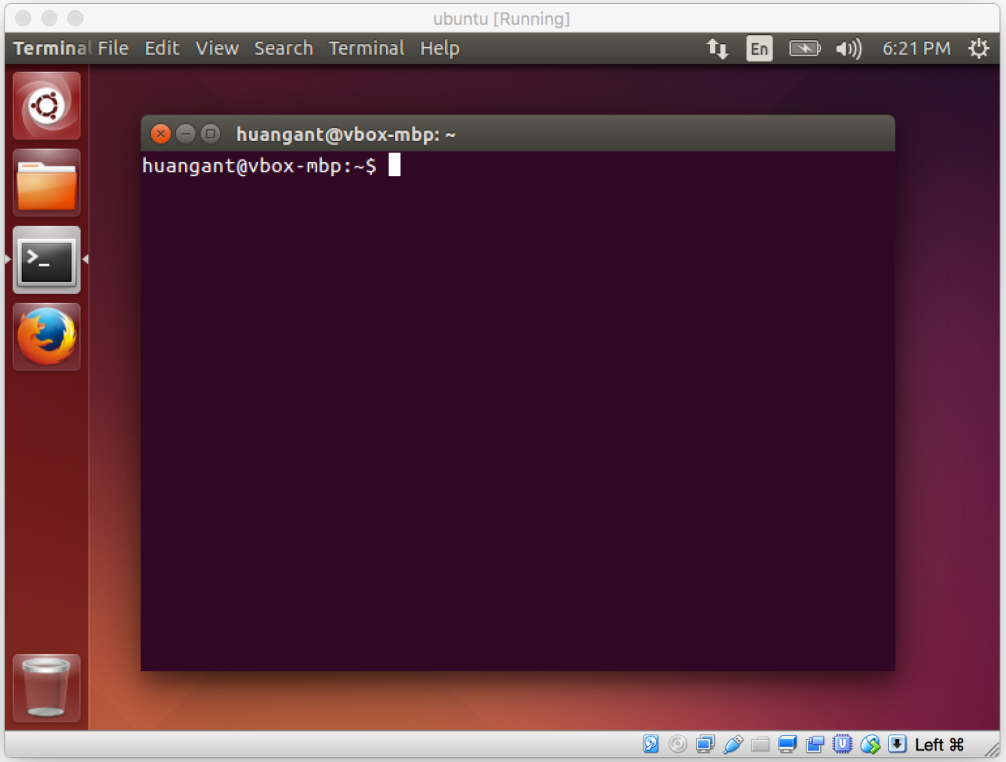
Your First Impression





Your Second Impression





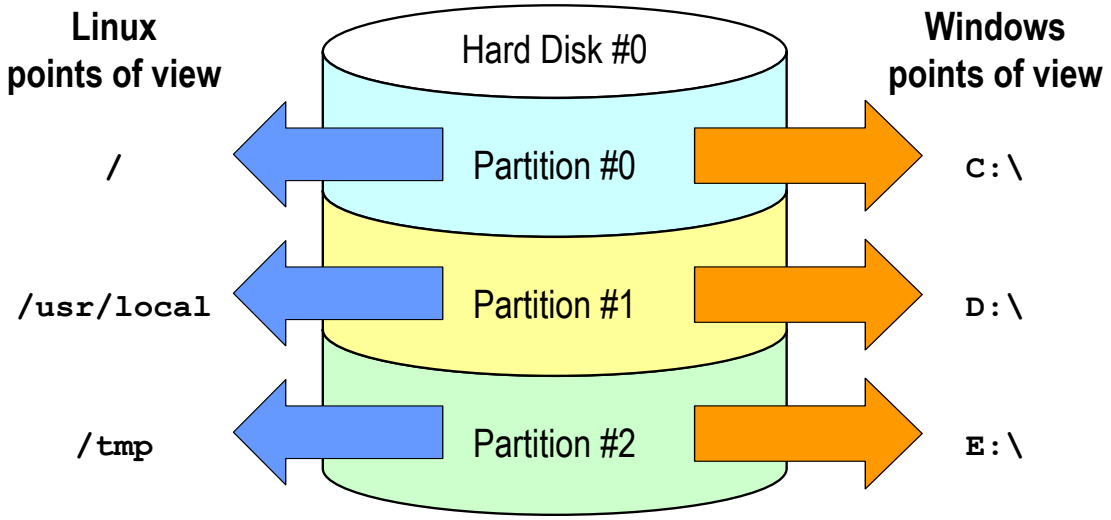
File System Architecture

Hierarchical arrangement of directories and files

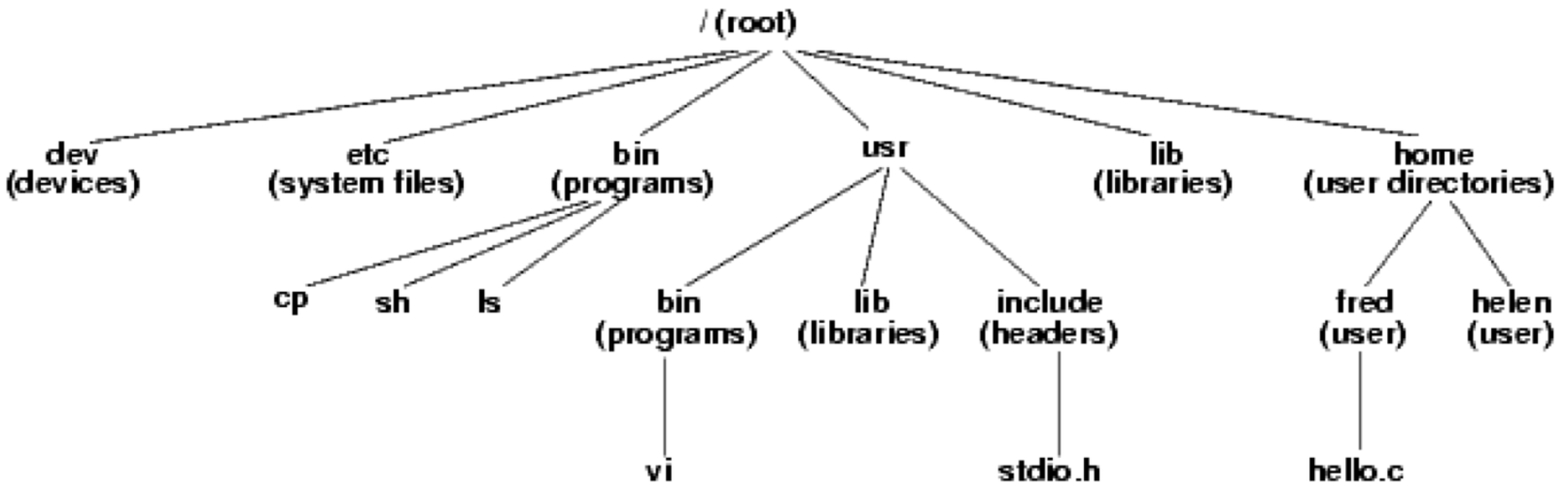
Everything starts from the "root directory" (/)

The "`mount`" program

Filenames (and commands) are usually case-sensitive
- Mac OS X's default file system (HFS) is an exception



File System Architecture (Cont'd)



Working with UNIX Commands

Simple commands

- ls: list files
- mkdir: make directory
- cd: change directory
- pwd: print working directory
- rmdir: remove directory
- cp: copy
- mv: move
- rm: remove
- cat: concatenate and print
- less (or more): page splitter
- echo: print a string
- date: print or set the date and time
- env: print out all environment vars
- touch: change file time
- tar: archive tool

Working with UNIX Commands (Cont'd)

There are **a lot of** UNIX commands, and it is impossible to cover all of them in this course!!!

Built-in commands: Provided by the login shell

Other commands: Binaries installed by the system administrators

- Often placed in standard locations
- For examples: /bin, /sbin, /usr/bin, /usr/sbin, /usr/local/bin, /usr/local/sbin
- Binaries are searched according the directories listed in the PATH environment

The Linux standard base (LSB)

- What tools and libraries are mandatory for a Linux operating system
- Official: http://www.linuxfoundation.org/collaborate/workgroups/lsb

The (Linux) filesystem hierarchy standard (FHS), is one part of the LSB

- Recommended locations to placed your files
- Official: http://www.linuxfoundation.org/collaborate/workgroups/lsb/fhs

Common Notations in UNIX Documents

Run command as a regular user

- % *command* … (sometimes we use $ instead of %)

Run command as a privileged user (super user, or root)

- # command … (don't be confused with comments)

Special symbols for command arguments

- Square brackets [ ]: optional part, e.g., cat [filename]
- Dots …: Multiple arguments are allowed, e.g., cat [file …]
- Dash - or --: Usually options for a command, e.g.,
  - Part of options for the ls command: -a, --all, --color, -F, …
  - Single dash options may be aggregated: -aF

Redirection and Pipe

Redirection

- Outputs of a command can be stored in a file
  - % echo Hello, World! > a
  - % echo Hello, World! >> a
- File content can be used as inputs to a command
  - % cat < a

Pipe

- Outputs of a command can be inputs of another command
  - % echo Hello, World! | cat
  - % cat hello.c | less
- Pipe can be chained
  - % echo Hello, World! | tr a-z A-Z | cat

Read the Manual Pages

The man(1) command

- The command you must know in the UNIX world!

Manual pages for commands, system calls, library functions, kernel routines, …

Basic usage

- `$ man [section] page`
- `$ man -k regexp`

A common notation – `page(section)`

- Examples:
  `ls(1)`,`man(1)`, `read(2)`, `crypt(3)`,`tty(4)`,`shadow(5)`,
  `printf(1)`,`printf(3)`,…

Read the Manual Pages (Cont'd)

Manual page sections

1. User commands
2. System calls
3. C library functions
4. Devices and special files
5. File formats and conventions
6. Games et al.
7. Miscellaneous
8. System administration tools and daemons

Course Sample Codes

Available from the course web site

UNIX Programming

- Course web site -> Downloads -> Sample code download
- Instructor's version: modified version with a Makefile
- Text-book's version: unmodified from the text-book authors

Password protected

Sample commands to download, extract, and build the sample codes

```
$ wget --user unix1XX --password PASSWORD
   http://people.cs.nctu.edu.tw/~chuang/courses/unixprog/resources/inclass-20180508.tar.gz
$ wget --user unix1XX --password PASSWORD
   http://people.cs.nctu.edu.tw/~chuang/courses/unixprog/resources/textbook-20180326.tar.gz
$ tar xzf inclass-20180508.tar.gz
$ tar xzf textbook-20180326.tar.gz
$ cd unix_prog
$ make
```

Fundamental UNIX Programming Practices

The "Hello, World." Sample

```
#include <stdio.h>

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

Compile and run "Hello, World." in the UNIX environment

- `$ gcc hello.c` `// this generates a.out`
- `$ ./a.out`
- `$ gcc hello.c -o hello` `// this generates hello`
- `$ ./hello`

Return from the main() Function

Return value of the main() function

- It is actually a one byte value
- Return zero: the value indicates 'True', or no problem
- Return non-zero values: the values indicate 'False', or error
- Can be used to determine program execution status … the 'bash -e' option!

Read return values from your program

- Run '`echo $?`' immediately right after your program execution

Some examples (see return.c and testret.sh)

- return 0;
- return 10;
- return -10;

Return from the main() Function (Cont'd)

Shell's short cut branch

- Break an evaluation when the final result is known

Boolean OR (||) – Stop evaluation when a condition is true

- `$ ./return 0 || echo 'A'`
- `$ ./return 1 || echo 'B'`
- `$ true || echo 'A'`
- `$ false || echo 'B'`

Boolean AND (&&) – Stop evaluation when a condition is false

- `$ ./return 0 && echo 'C'`
- `$ ./return 1 && echo 'D'`
- `$ true && echo 'C'`
- `$ false && echo 'D'`

Handle Program Options

```
int main(int argc, char *argv[]) {
        int i;
        for(i = 0; i < argc; i++)
                printf("'%s' ", argv[i]);
        printf("\n");
        return 0;
}
```

What will be the outputs?

- `$ ./args`
- `$ ./args a b c d`
- `$ ./args "a b c d"`
- `$ ./args 'a b c d'`
- `$ ./args "home = $HOME"`
- `$ ./args 'home = $HOME'`

Handle Program Options (Cont'd)

The getopt(3) and getopt_long(3) style options

Built-in standard option handling routines in many UNIX platforms

getopt(3) reads dash plus single character options (short options)

- Options can be aggregated
- For example, -a -b is equivalent to -ab

getopt_long(3) also reads double-dash plus key word options (long options)

- For example, --all, --color

```
$ ping
Usage: ping [-aAbBdDfhLnOqrRUvV] [-c count] [-i interval] [-I interface]
            [-m mark] [-M pmtudisc_option] [-l preload] [-p pattern] [-Q tos]
            [-s packetsize] [-S sndbuf] [-t ttl] [-T timestamp_option]
            [-w deadline] [-W timeout] [hop1 ...] destination
```

getopt(3)

```
int getopt(int argc, char * const argv[], const char *optstring);
```

- argc: the argc parameter received by the main function
- argv: the argv parameter received by the main function
- optstring: list of valid option characters (usually colons and alphabets)
- Add a colon (:) right after an option character indicates that the option requires an additional argument
- Common return value of getopt(3)
  - -1: No more options
  - Colon (:) or question mark (?): Invalid option encountered
- Global variables
  - optind: An integer stores the number of arguments consumed by getopt(3)
  - optarg: A string points to the additional argument of the current option (if : is given)
- Examples: see getopt.c

UNIX Time Representations

Wall clock time: `time_t`, in second unit

- Number of seconds elapsed from 00:00:00, January 1st, 1970 UTC (the "epoch")
- It is often a 32-bit signed integer
- Will be overflowed after 03:14:07 January 19th, 2038 – The year 2038 problem!

High precision time: `struct timeval`, in microsecond unit

- Basically `time_t` plus a microsecond precision timestamp

CPU time: `clock_t`, in CPU-ticks unit

- The CLOCKS_PER_SEC constant
- POSIX requires CLOCKS_PER_SEC to be 1,000,000 independent of the actual clock resolution

From `select(2)`:

```
struct timeval {
    long tv_sec;  // seconds
    long tv_usec; // microseconds
};
```

UNIX Time Representations (Cont'd)

time(3) function: Get time in time_t format

```
time_t time(time_t *t);
```

gettimeofday(2) function: Get time in struct timeval format

- The use of tz is obsoleted, it should be NULL

```
int gettimeofday(struct timeval *tv, struct timezone *tz);
```

clock(3) function: Get time in clock_t format

```
clock_t clock(void);
```

Measure Program Performance

A simple metric: Program running time

A simple example: the time command

```
$ time sleep 10
real    0m10.003s
user    0m0.000s
sys     0m0.003s
```

Real time, user time, and sys time

How to get these numbers?

- gettimeofday(3): get wall clock time in microsecond precision (in timeval format)
- clock(3): get CPU ticks (user + sys)
- getrusage(3): get CPU time (in timeval format)

Measure Program Performance (Cont'd)

Basic idea

```
t0 = get_the_current_timestamp();

// The codes we want to measure ...
Do something ...

t1 = get_the_current_timestamp();

Compute and output (t1 – t0)
```

See examples: testtime.c and rusage.c

Error Handling

Check function return values

- (Integer) Zero or positive values: return without errors
- (Integer) Negative values (usually -1): return with errors
- (Pointer) Non-NULL: return without errors
- (Pointer) NULL: return with errors
- This is applicable for most of the C library functions

What kinds of error?

- Determine using the `errno` variable.
- A global variable built in C library
  - It is not thread-safe! (in the past)
  - But not a problem if your system supports thread local storage (TLS)
- Check it right after receiving an error return value

List of error codes

- See `errno(3)` manual pages

Display Errors

Required headers and declarations

```
#include <stdio.h>   // for perror
#include <string.h>  // for strerror
#include <errno.h>   // errno variable, and definitions for error codes
```

Convert an error number to a human-readable string

- `strerror`
- `perror`

```
printf("error = %s\n", strerror(errno));
perror("some prefix");
```

Error Recovery

Fatal errors

- No way to recovery
- Show error messages, log, and then exit

Non-fatal errors

- May be temporary errors
- Delay for a short time and then retry
- Examples
  - EAGAIN, ENFILE, ENOBUFS, EWOULDBLOCK, …

Tools

The Compiler

gcc – GNU C Compiler

g++ – GNU C++ Compiler

Frequently used options

- `-S`: do not compile, generate assembly only (output to .s)
- `-E`: do not compile, perform preprocessing only (output to stdout)
- `-c`: compile only, do not link
- `-g`: embed debugging information
- `-Wall`: turn on all warnings
- `-I`: add include path, e.g., `-I/usr/local/include`
- `-l`: link with a library, e.g., `-lxxx` will link with a library named `libxxx.a`
- `-L`: add library path, e.g., `-L/usr/local/lib`

Compile a Single Source Code

Compile and generate the executable binary

- % g++ hello.cpp (the output will be a.out)
- % g++ hello.cpp -o hello (the output will be hello)

Execute the executable

- % ./a.out (or ./hello)
- Do not miss the ./ prefix

Try -E and -S options

Compile Multiple Source Code Files

Suppose you have s1.cpp, s2.cpp, and s3.cpp

Strategy #1

- g++ s1.cpp s2.cpp s3.cpp -o output (generates output)

Strategy #2

- g++ -c s1.cpp (generates s1.o)
- g++ -c s2.cpp (generates s2.o)
- g++ -c s3.cpp (generates s3.o)
- g++ s1.o s2.o s3.o -o output (generates output)

Which one would be better?

Linking C and C++ Files (1/3)

Suppose we have two source code files, a.c and b.cpp

a.c:

```
int b();
int main() {
        return b();
}
```

b.cpp:

```
int b() {
        return -1;
}
```

We then compile and link the two files:

- gcc -c a.c (generates a.o)
- g++ -c b.cpp (generates b.o)
- g++ -o test a.o b.o (does it work?)

Linking C and C++ Files (2/3)

Let's check what we have in the object codes

We can use the nm tool to dump symbols

```
$ nm a.o
                 U b
0000000000000000 T main
```

```
$ nm b.o
0000000000000000 T _Z1bv
```

Why?

Linking C and C++ Files (3/3)

We have to modify b.cpp if a function will be called from a C program

b.cpp:

```
#ifdef __cplusplus          (only needs for a C++ compiler)
extern "C" {                (declare that everything within the scope)
int b();                    (should be handled as C symbols, not C++ )
}
#endif

int b(int n) {
        return n;
}

int b() {
        return b(-1);
}
```

```
$ nm b.o
000000000000000c T b
0000000000000000 T _Z1bi
```

Make and Makefile

Outline

Why make and Makefile?

The make command

The Makefile

Examples

Why make and Makefile

Project management

- Simplify build process
- Manage project dependencies

A common scenario

- Build a program with multiple source files

Steps

- Write rules in a file named *Makefile*
- Run the *make* command
  - By default, make run *the first* rule in the makefile

The make Command

Simply type ‘make’ in the command prompt

- `$ make`
- Or alternatively, specify a target rule: `$ make clean`

Common options

- `-C {dir}`: switch to the given directory and run the make command
- `-f {makefile}`: use a non-default makefile
- `-I {dir}`: specify include directory search path
- `-j {n}`: allow simultaneously jobs (commands)
- For the details, see the man page!

The Makefile

Rule definitions

Variable definitions

Automatic variables

Special rules

Pattern rules

Rule Definitions

General format

- rulename: dependencies (or prerequisites)
  (tab) rules

Rulename – the target to be built

Dependencies

- Prerequisites required to build the target
- Separated by spaces

Rules

- Commands to build the target

Rule Definitions (Cont'd)

Comments: start with a pond sign (#)

Split a single line into multiple lines: back slash (\)

- See (external) examples

An Example

```
test: test1.c test2.c              # comment
      gcc -c test1.c
      gcc -c test2.c
      gcc -o test test1.o test2.o
```

This is *not* a good example

Both the test1.c and the test2.c files are compiled if either one of them is modified – refine it later …

Variable definitions

Common usage

- Set: VARNAME=value
- Use: $(VARNAME)

Create variables

- `CC   = gcc`
- `CXX  = g++`
- `CFLAGS      = -I. -Wall`

Use the variables

- `$(CC) -c test.c $(CFLAGS)`
- `Note that a nonexistence variable produces an empty string`

Automatic Variables

$@: The target file name

$<: The name of the first prerequisite

$?: The name of all prerequisites that are *newer* than the target

$^: The name of all prerequisites. *Duplicated entries will be removed*

$+: Like $^, but duplicated entries will *not* be removed

A Refined Example

```
CC      = gcc
CFLAGS = -g –Wall

.c.o:           # old-fashioned!
        $(CC) –c $< $(CFLAGS)

test: test1.o test2.o
        $(CC) -o test $^
```

This one is better!

Only modified objects will be re-built

Special Rules

.SUFFIXES (old fashioned!)

- Add non-default suffixes (filename extensions)
- Example

```
.SUFFIXES:                              # (remove all)
.SUFFIXES: .asm .inc
```

.PHONY

- Don’t check if a target is an existing file
- Example

```
.PHONY: all clean
```

Pattern Rules – The % Symbol

Definition of “stem”: the text between the prefix and the suffix

Remember the old-fashioned “.c.o:” rule?

It is equivalent to

```
%.o: %.c
```

The new style provides much more flexibilities

External Examples

Sample codes

- sample codes/Makefile
- sample codes/Make.rules
- sample codes/lib/Makefile

A complete reference to make and Makefile

- The make manual page
- http://www.gnu.org/software/make/manual/

Debug with GDB

GDB – Quick Introduction

A command line based (interactive) debugger

All source codes must be compiled with the -g option!

Example #1

- $ gcc -g test.c

Example #2

- Makefile
- See CFLAGS

```
GCC     = gcc
CFLAGS = -g –Wall

.c.o:           # old-fashioned!
        $(GCC) –c $< $(CFLAGS)

test: test1.o test2.o
        $(GCC) -o test $^
```

The First Impression

$ gdb a.out *# a.out is the program executable*

```
GNU gdb (GDB) 7.10.1
Copyright (C) 2015 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.  Type "show copying"
and "show warranty" for details.
This GDB was configured as "x86_64-unknown-linux-gnu".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
<http://www.gnu.org/software/gdb/documentation/>.
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from a.out...done.
(gdb) _
```

Compiled without -g Option

$ gdb a.out *# a.out is the program executable*

```
GNU gdb (GDB) 7.10.1
Copyright (C) 2015 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.  Type "show copying"
and "show warranty" for details.
This GDB was configured as "x86_64-unknown-linux-gnu".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
<http://www.gnu.org/software/gdb/documentation/>.
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from a.out...(no debugging symbols found)...done.
(gdb) _
```

Basic Commands

Show source codes

- list [line # | function | file:line # | file:function]

Start to debug a program

- run [arguments …]

Run the next command

- next (will *not* enter a function)
- step (will enter a function)

Display

- print

Breakpoints

Set breakpoints

- break [line # | function | file:line # | file:function]

Delete breakpoints

- clear [line # | function | file:line # | file:function]

Show breakpoints

- info breakpoints

Run until a breakpoint is reached

- continue

Sample Source Code

Source code: hello.c

```
 1: #include <stdio.h>
 2:
 3: int
 4: main() {
 5:         int i;
 6:         char hello[] = "Hello, World!\n";
 7:         char *ph = hello;
 8:         for(i = 0; ph[i]!='\0'; i++) {
 9:                 putchar(ph[i]);
10:         }
11:         return 0;
12: }
```

Compile, Load, and Run

```
$ gcc -g bug.c -o bug
$ gdb bug
(gdb) run
Starting program: /raid/home/chuang/tmp/bug
Hello, World!

Program exited normally.
(gdb)
```

List Source Codes

```
(gdb) list 1
1       #include <stdio.h>
2
3       int
4       main() {
5               int i;
6               char hello[] = "Hello, World!\n";
7               char *ph = hello;
8               for(i = 0; ph[i]!='\0'; i++) {
9                       putchar(ph[i]);
10              }
(gdb)
```

Set Breakpoints and Run

```
(gdb) b 8
Breakpoint 1 at 0x8048485: file bug.c, line 8.
(gdb) run
Starting program: /raid/home/chuang/tmp/bug

Breakpoint 1, main () at hello.c:8
8               for(i = 0; ph[i]!='\0'; i++) {
(gdb) n
9                       putchar(ph[i]);
(gdb) print i
$1 = 0                   # print a variable
(gdb) print ph[i]
$2 = 72 'H'              # print another variable
(gdb) print putchar(ph[i])
$3 = 72                  # run a function, may also consider 'call'
(gdb) print printf("%c\n", ph[i])
HH                       # note that we are using bufferred I/O
$4 = 2
(gdb)
```

Debug a Crashed Program

Given another buggy program …

```
 1 #include <stdio.h>
 2 #include <stdlib.h>
 3 #include <time.h>
 4
 5 void walk(int depth) {
 6         int *p = 0;
 7         printf("%d\n", depth);
 8         if(rand()%5==0) *p = depth;
 9         else            walk(depth+1);
10         return;
11 }
12
13 int main() {
14         srand(time(0));
15         walk(0);
16         return 0;
17 }
```

Debug a Crashed Program

Run the program

```
$ gcc –g bug2.c –o bug2
$ ./bug2
0
1
2
3
4
Segmentation fault (core dumped)
$ ls –la bug core
-rwxr-xr-x 1 chuang chuang   8577 2015-02-28 15:58 bug2
-rw------- 1 chuang chuang 155648 2015-02-28 15:58 core
```

Debug a Crashed Program

Load the core and show call stack

```
$ gdb bug2 core
...
Reading symbols from /raid/home/chuang/tmp/bug2...done.
[New Thread 31638]

warning: Can't read pathname for load map: Input/output error.
Reading symbols from /lib/tls/i686/cmov/libc.so.6...(no debugging symbols found)...done.
Loaded symbols for /lib/tls/i686/cmov/libc.so.6
Reading symbols from /lib/ld-linux.so.2...(no debugging symbols found)...done.
Loaded symbols for /lib/ld-linux.so.2
Core was generated by `./bug2'.
Program terminated with signal 11, Segmentation fault.
#0  0x080484c3 in walk (depth=4) at bug.c:8
8               if(rand()%5==0) *p = depth;
(gdb) bt
#0  0x080484c3 in walk (depth=4) at bug2.c:8
#1  0x080484d5 in walk (depth=3) at bug2.c:9
#2  0x080484d5 in walk (depth=2) at bug2.c:9
#3  0x080484d5 in walk (depth=1) at bug2.c:9
#4  0x080484d5 in walk (depth=0) at bug2.c:9
#5  0x08048500 in main () at bug2.c:15
(gdb)
```

No coredump File Generated?

You may have to modify your system configuration

You will need root permission

Take Ubuntu Linux as an example: /etc/security/limits.conf

```
# /etc/security/limits.conf
#
#Each line describes a limit for a user in the form:
#
#<domain>        <type>  <item>  <value>
#
...
#*               soft    core            0
*                soft    core            1000000
#root            hard    core            100000
#*               hard    rss             10000
...
```

GDB: Debug w/ Library Symbols (1/3)

You will need

- Library source codes
- Library files with debugger symbols

Usually you have to add **-g** option and re-compile the library

It is easier to do that on Ubuntu, because

- It has separated debugger symbol packages for some libraries
- For example, C library: the `libc6-dbg` package
- Look at our course Docker file

GDB: Debug w/ Library Symbols (2/3)

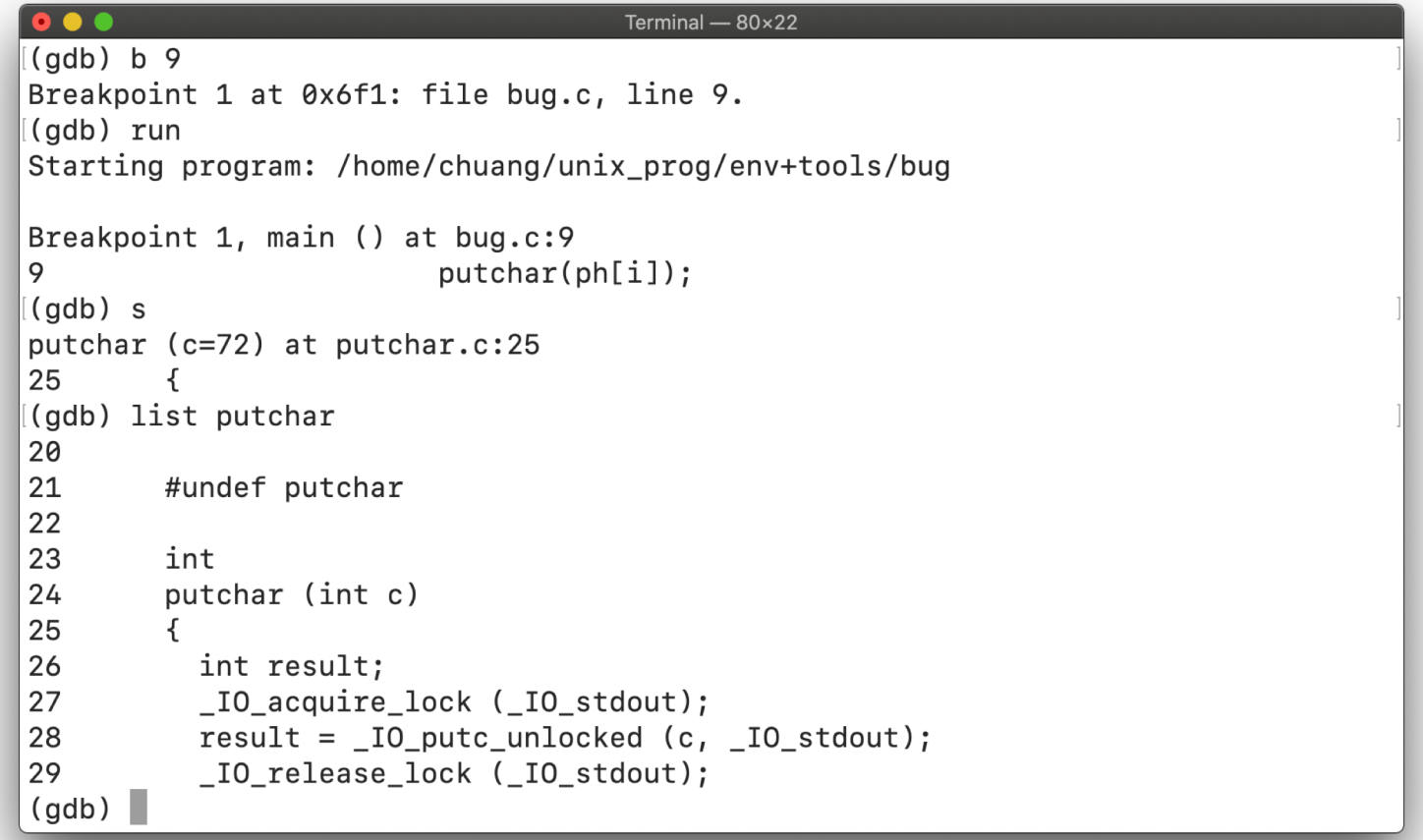
Add directories to look for source codes

- The `directory` keyword, for example
- `directory /glibc-2.27/stdio-common`
- `directory /glibc-2.27/libio`

The putchar() function in bug.c sample program

- See the next slide and demo

GDB: Debug w/ Library Symbols (3/3)



GDB: Debug w/o (Debug) Symbols

Scenario #1: We have symbols in the binary, but we don't have debugger symbols

- "info functions" to list symbols
- Set breakpoints based on symbol names
- "layout asm" to see codes (^X A to on/off; ^X O to switch focus)
- "set disassembly-flavor intel" to use Intel syntax

Scenario #2: The executable is stripped

- Suppose the executable is a dynamically linked binary
- "set stop-on-solib-events 1" to stop when a so is loaded/unloaded
- When libc.so is loaded … break on __libc_start_main
- Looking for ptr call, e.g., "call rax"

GDB v5 reference card

SOURCE: GDB-7.2 SOURCE CODE

TYPE 'HELP' TO SEE HELPS IN THE GDB INTERFACE

AVAILABLE ON THE COURSE WEBSITE: HTTP://SNSL.CS.NTOU.EDU.TW/COURSES/LINUXPROG/DAT/REF/GDB72.PDF

GDB QUICK REFERENCE GDB Version 5

Essential Commands

`gdb` *program* [*core*]	debug *program* [using coredump *core*]
`b` [*file*`:`]*function*	set breakpoint at *function* [in *file*]
`run` [*arglist*]	start your program [with *arglist*]
`bt`	backtrace: display program stack
`p` *expr*	display the value of an expression
`c`	continue running your program
`n`	next line, stepping over function calls
`s`	next line, stepping into function calls

Starting GDB

`gdb`	start GDB, with no debugging files
`gdb` *program*	begin debugging *program*
`gdb` *program core*	debug coredump *core* produced by *program*
`gdb --help`	describe command line options

Stopping GDB

`quit`	exit GDB; also `q` or `EOF` (eg `C-d`)
`INTERRUPT`	(eg `C-c`) terminate current command, or send to running process

Getting Help

`help`	list classes of commands
`help` *class*	one-line descriptions for commands in *class*
`help` *command*	describe *command*

Executing your Program

`run` *arglist*	start your program with *arglist*
`run`	start your program with current argument list
`run ... <`*inf* `>`*outf*	start your program with input, output redirected
`kill`	kill running program
`tty` *dev*	use *dev* as stdin and stdout for next `run`
`set args` *arglist*	specify *arglist* for next `run`
`set args`	specify empty argument list
`show args`	display argument list
`show env`	show all environment variables
`show env` *var*	show value of environment variable *var*
`set env` *var string*	set environment variable *var*
`unset env` *var*	remove *var* from environment

Shell Commands

`cd` *dir*	change working directory to *dir*
`pwd`	Print working directory
`make ...`	call "`make`"
`shell` *cmd*	execute arbitrary shell command string

[ ] surround optional arguments ... show one or more arguments

Breakpoints and Watchpoints

`break` [*file*`:`]*line* `b` [*file*`:`]*line*	set breakpoint at *line* number [in *file*] eg: `break main.c:37`
`break` [*file*`:`]*func*	set breakpoint at *func* [in *file*]
`break +`*offset*	set break at *offset* lines from current stop
`break -`*offset*	
`break *`*addr*	set breakpoint at address *addr*
`break`	set breakpoint at next instruction
`break ... if` *expr*	break conditionally on nonzero *expr*
`cond` *n* [*expr*]	new conditional expression on breakpoint *n*; make unconditional if no *expr*
`tbreak ...`	temporary break; disable when reached
`rbreak` [*file*`:`]*regex*	break on all functions matching *regex* [in *file*]
`watch` *expr*	set a watchpoint for expression *expr*
`catch` *event*	break at *event*, which may be `catch`, `throw`, `exec`, `fork`, `vfork`, `load`, or `unload`.
`info break`	show defined breakpoints
`info watch`	show defined watchpoints
`clear`	delete breakpoints at next instruction
`clear` [*file*`:`]*fun*	delete breakpoints at entry to *fun*()
`clear` [*file*`:`]*line*	delete breakpoints on source line
`delete` [*n*]	delete breakpoints [or breakpoint *n*]
`disable` [*n*]	disable breakpoints [or breakpoint *n*]
`enable` [*n*]	enable breakpoints [or breakpoint *n*]
`enable once` [*n*]	enable breakpoints [or breakpoint *n*]; disable again when reached
`enable del` [*n*]	enable breakpoints [or breakpoint *n*]; delete when reached
`ignore` *n count*	ignore breakpoint *n*, *count* times
`commands` *n* [`silent`] *command-list*	execute GDB *command-list* every time breakpoint *n* is reached. [`silent` suppresses default display]
`end`	end of *command-list*

Program Stack

`backtrace` [*n*] `bt` [*n*]	print trace of all frames in stack; or of *n* frames—innermost if *n*>0, outermost if *n*<0
`frame` [*n*]	select frame number *n* or frame at address *n*; if no *n*, display current frame
`up` *n*	select frame *n* frames up
`down` *n*	select frame *n* frames down
`info frame` [*addr*]	describe selected frame, or frame at *addr*
`info args`	arguments of selected frame
`info locals`	local variables of selected frame
`info reg` [*rn*]...	register values [for regs *rn*] in selected frame; `all-reg` includes floating point
`info all-reg` [*rn*]	

Execution Control

`continue` [*count*] `c` [*count*]	continue running; if *count* specified, ignore this breakpoint next *count* times
`step` [*count*] `s` [*count*]	execute until another line reached; repeat *count* times if specified
`stepi` [*count*] `si` [*count*]	step by machine instructions rather than source lines
`next` [*count*] `n` [*count*]	execute next line, including any function calls
`nexti` [*count*] `ni` [*count*]	next machine instruction rather than source line
`until` [*location*]	run until next instruction (or *location*)
`finish`	run until selected stack frame returns
`return` [*expr*]	pop selected stack frame without executing [setting return value]
`signal` *num*	resume execution with signal *s* (none if 0)
`jump` *line*	resume execution at specified *line* number or *address*
`jump *`*address*	
`set var=`*expr*	evaluate *expr* without displaying it; use for altering program variables

Display

`print` [*/f*] [*expr*] `p` [*/f*] [*expr*]	show value of *expr* [or last value `$`] according to format *f*:
`x`	hexadecimal
`d`	signed decimal
`u`	unsigned decimal
`o`	octal
`t`	binary
`a`	address, absolute and relative
`c`	character
`f`	floating point
`call` [*/f*] *expr*	like `print` but does not display `void`
`x` [*/Nuf*] *expr*	examine memory at address *expr*; optional format spec follows slash
N	count of how many units to display
u	unit size; one of `b` individual bytes `h` halfwords (two bytes) `w` words (four bytes) `g` giant words (eight bytes)
f	printing format. Any `print` format, or `s` null-terminated string `i` machine instructions
`disassem` [*addr*]	display memory as machine instructions

Automatic Display

`display` [*/f*] *expr*	show value of *expr* each time program stops [according to format *f*]
`display`	display all enabled expressions on list
`undisplay` *n*	remove number(s) *n* from list of automatically displayed expressions
`disable disp` *n*	disable display for expression(s) number *n*
`enable disp` *n*	enable display for expression(s) number *n*
`info display`	numbered list of display expressions

Expressions

expr	an expression in C, C++, or Modula-2 (including function calls), or:
addr`@`*len*	an array of *len* elements beginning at *addr*
file`::`*nm*	a variable or function *nm* defined in *file*
{*type*}*addr*	read memory at *addr* as specified *type*
`$`	most recent displayed value
`$`*n*	*n*th displayed value
`$$`	displayed value previous to $
`$$`*n*	*n*th displayed value back from $
`$_`	last address examined with `x`
`$__`	value at address $_
`$`*var*	convenience variable; assign any value
`show values` [*n*]	show last 10 values [or surrounding $*n*]
`show conv`	display all convenience variables

Symbol Table

`info address` *s*	show where symbol *s* is stored
`info func` [*regex*]	show names, types of defined functions (all, or matching *regex*)
`info var` [*regex*]	show names, types of global variables (all, or matching *regex*)
`whatis` [*expr*]	show data type of *expr* [or `$`] without evaluating; `ptype` gives more detail
`ptype` [*expr*]	
`ptype` *type*	describe type, struct, union, or enum

GDB Scripts

`source` *script*	read, execute GDB commands from file *script*
`define` *cmd* *command-list*	create new GDB command *cmd*; execute script defined by *command-list*
`end`	end of *command-list*
`document` *cmd* *help-text*	create online documentation for new GDB command *cmd*
`end`	end of *help-text*

Signals

`handle` *signal act*	specify GDB actions for *signal*:
`print`	announce signal
`noprint`	be silent for signal
`stop`	halt execution on signal
`nostop`	do not halt execution
`pass`	allow your program to handle signal
`nopass`	do not allow your program to see signal
`info signals`	show table of signals, GDB action for each

Debugging Targets

`target` *type param*	connect to target machine, process, or file
`help target`	display available targets
`attach` *param*	connect to another process
`detach`	release target from GDB control

Controlling GDB

`set` *param value*	set one of GDB's internal parameters
`show` *param*	display current setting of parameter

Parameters understood by `set` and `show`:

`complaint` *limit*	number of messages on unusual symbols
`confirm` *on/off*	enable or disable cautionary queries
`editing` *on/off*	control `readline` command-line editing
`height` *lpp*	number of lines before pause in display
`language` *lang*	Language for GDB expressions (`auto`, `c` or `modula-2`)
`listsize` *n*	number of lines shown by `list`
`prompt` *str*	use *str* as GDB prompt
`radix` *base*	octal, decimal, or hex number representation
`verbose` *on/off*	control messages when loading symbols
`width` *cpl*	number of characters before line folded
`write` *on/off*	Allow or forbid patching binary, core files (when reopened with `exec` or `core`)
`history` ...	groups with the following options:
`h` ...	
`h exp` *off/on*	disable/enable `readline` history expansion
`h file` *filename*	file for recording GDB command history
`h size` *size*	number of commands kept in history list
`h save` *off/on*	control use of external file for command history
`print` ...	groups with the following options:
`p` ...	
`p address` *on/off*	print memory addresses in stacks, values
`p array` *off/on*	compact or attractive format for arrays
`p demangl` *on/off*	source (demangled) or internal form for C++ symbols
`p asm-dem` *on/off*	demangle C++ symbols in machine-instruction output
`p elements` *limit*	number of array elements to display
`p object` *on/off*	print C++ derived types for objects
`p pretty` *off/on*	struct display: compact or indented
`p union` *on/off*	display of union members
`p vtbl` *off/on*	display of C++ virtual function tables

`show commands`	show last 10 commands
`show commands` *n*	show 10 commands around number *n*
`show commands +`	show next 10 commands

Working Files

`file` [*file*]	use *file* for both symbols and executable; with no arg, discard both
`core` [*file*]	read *file* as coredump; or discard
`exec` [*file*]	use *file* as executable only; or discard
`symbol` [*file*]	use symbol table from *file*; or discard
`load` *file*	dynamically link *file* and add its symbols
`add-sym` *file addr*	read additional symbols from *file*, dynamically loaded at *addr*
`info files`	display working files and targets in use
`path` *dirs*	add *dirs* to front of path searched for executable and symbol files
`show path`	display executable and symbol file path
`info share`	list names of shared libraries currently loaded

Source Files

`dir` *names*	add directory *names* to front of source path
`dir`	clear source path
`show dir`	show current source path
`list`	show next ten lines of source
`list -`	show previous ten lines
`list` *lines*	display source surrounding *lines*, specified as:
[*file*:]*num*	line number [in named file]
[*file*:]*function*	beginning of function [in named file]
`+`*off*	*off* lines after last printed
`-`*off*	*off* lines previous to last printed
`*`*address*	line containing *address*
`list` *f*`,`*l*	from line *f* to line *l*
`info line` *num*	show starting, ending addresses of compiled code for source line *num*
`info source`	show name of current source file
`info sources`	list all source files in use
`forw` *regex*	search following source lines for *regex*
`rev` *regex*	search preceding source lines for *regex*

GDB under GNU Emacs

`M-x gdb`	run GDB under Emacs
`C-h m`	describe GDB mode
`M-s`	step one line (`step`)
`M-n`	next line (`next`)
`M-i`	step one instruction (`stepi`)
`C-c C-f`	finish current stack frame (`finish`)
`M-c`	continue (`cont`)
`M-u`	up *arg* frames (`up`)
`M-d`	down *arg* frames (`down`)
`C-x &`	copy number from point, insert at end
`C-x SPC`	(in source file) set break at point

GDB License

`show copying`	Display GNU General Public License
`show warranty`	There is NO WARRANTY for GDB. Display full no-warranty statement.

Q & A