Debugging with GDB

Humayun Kabir

Professor, CS, Vancouver Island University, BC, Canada

GDB

- GDB is the GNU Project debugger
- GDB provides some helpful functionality
  - Run programs
  - Make the program stops on specified places or on specified conditions
  - Give information about current variables' values, the memory and the stack
  - Let you examine the program execution step by step - *stepping*
  - Let you examine the change of program variables' values - *tracing*
- GDB is a command-line program

GDB

- To be able to debug your program, you must compile it with the **-g** option (creates the symbol table) !
  - `g++ -Wall -g -o my_prog my_prog.c`
  - `g++ -Wall -ggdb -o my_prog my_prog.c`
- To start gdb with your program type:
  - `>gdb my_prog`
- You can also start GDB without your program and then load it later using gdb file command
  - >**gdb**
  - (gdb) **file** *my_prog*
- You can quit from GDB using its quit command
  - (gdb) **quit**

GDB

- When gdb starts, your program is not actually running.
- You have to use the **run** command to start execution.
- Before you do that, you should place some **break points**.
- Once you hit a break point, you can examine any variable.

GDB – Running Programs

Running a program:

`run` (or `r`)

-- creates an inferior process that runs your program.

- if there are no execution errors the program will finish and results will be displayed
- in case of error, the GDB will show:

  - the line the program has stopped on and
  - a short description of what it believes has caused the error

There is a certain information that affects the execution of a program:

- program's arguments
- program's environment
- program's working directory
- the standard input and output

GDB – Program's arguments

Specifying arguments for your program:

- As arguments to `run`: **`run`** *`arg1 arg2`* …
- With `set args` command: **`set args`** *`arg1 arg2`* …

! `run` without arguments uses the same arguments used by the previous `run`.

! `set args` without arguments – removes all arguments.

! `show args` command shows the arguments your program has been started with.

GDB – Program's environment

Changing the PATH environment variable:

`path` *`dir`*

– add the directory *`dir`* at the beginning of the PATH variable. You may specify several directory names separated by '**:**' or white space.

`show paths` – displays the search paths for executables.

Changing the working directory:

`cd` *`dir`*

– to change the working directory

Redirecting output:

`run >` *`outfile`* direct the output to the file *`outfile`*.

Debugging an already-running process

From inside GDB:

`attach` *`process-id`*

// You need to know the process ID of the program

// To get the process ID use the UNIX command `ps`

`detach` **–** detaches the currently attached process from the GDB control. A detached process continues its own execution.

GDB – Breakpoints and watchpoints

Breakpoints and watchpoints allow you to specify the places or the conditions where you want your program to stop.

`break` *`arg`* – stops when the execution reaches the specified line

`arg` `– file: line number, line number, function-name, +/- offset`

`watch` *`expr`* – stops whenever the value of the expression changes

`clear` `[`*`arg`*`]`

Without arguments deletes any breakpoint at the next instruction to be executed in the current stack frame

`delete` `[`*`bnum`*`]`

Without arguments deletes all breakpoints.

GDB – Examining variables

! Global variables can be examined from every point in the source file.

! Local variables – can be examined only in their scope or using:

`file::variable` or *`function::variable`*

The variable type: **`ptype`** *`var`*

Current value: **`print`** *`var`*

Automatic display: **`display`** *`var`*

– adds *`var`* to the *automatic display list.*

`undisplay` *`dnum`*

Specifying the output format (`x`, `o`, `d`, `u`, `t`, `a`, `f`, and `c`) :

`print /t` *`var`* - prints the value of *`var`* in binary format

GDB – Value history

The ***value history*** keeps the values printed by the `print` command.

Previously printed values can be accessed by typing `$` followed by their history number.

`$` - refers to the most recent value and

`$$n` - refers to the *n-th* value from the end.

```
show values [n|+]
```

Without argument – the last 10 values.

n – 10 values centered around *n*

+ – 10 values after the last printed

Stepping through the program

`step` `[`*`count`*`]` – program execution continue to next source line going into function calls.

`next` `[`*`count`*`]` – program execution continue to the next source line omitting function calls.

`continue` – resume program execution

`until` – continue until the next source line in the current stack frame is reached. /useful to exit from loops/

GDB – Altering execution

Returning from a function

finish – forced return

return [*ret_value*] – pops the current stack frame

Continuing at different address

jump *line_num*|**address*

Altering the value of a variable

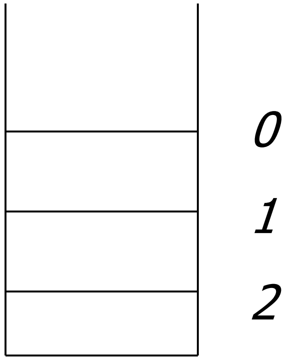
set *i=256*

Proceeding to a specified point:

until [*line_num*|**address* |*function_name*]

GDB – The stack frame

Stack frames are identified by their addresses, which are kept in the *frame pointer* register.



- ***Selecting a frame:***

  `frame` *`n|addr`*

  `up` *`n`*

  `down` *`n`*

- ***Information about the current frame***

  `frame` – *brief description*

  `info args` – *shows function arguments*

  `info locals` – *shows local variables*

GDB – Convenience variables

- Convenience variables are used to store values that you may want to refer later. Any string preceded by `$` is regarded as a convenience variable.

  Ex.: **`$table`** `=` *`*table_ptr`*

- There are several automatically created convenience variables:

`$pc` – program counter

`$sp` – stack pointer

`$fp` – frame pointer

`$ps` – processor status

`$_` – contains the last examined address

`$__` – the value in the last examined address

`$_exitcode` – the exit code of the debugged program

GDB – Examining memory

The `x` command (for "examine"):

- `x/nfu addr` – specify the number of units (*n*), the display format (*f*) and the unit size (*u*) of the memory you want to examine, starting from the address *addr*. Unit size can be – `b`, `h` (half), `w` and `g` (giant).
- `x addr` – start printing from the address *addr*, others default
- `x` – all default

Registers

Registers names are different for each machine. Use `info registers` to see the names used on your machine.

GDB has four "standard" registers names that are available on most machines: program counter, stack pointer, frame pointer and processor status.

GDB – Additional process information

`info proc` – summarize available information about the current process.

`info proc mappings` – address range accessible in the program.

`info proc times` – starting time, user CPU time and system CPU time for your program and its children.

`help info` !

`info signals` – information about the system signals and how GDB handles them.

GDB Quick Reference Guide

run	-- run the program
run args	-- run program with command line args.
break function	-- set breakpoint at function entry
break linenum	-- set breakpoint at line
break *addr	-- set breakpoint at address
break … if cond	-- set breakpoint; break if condition
clear funct	-- remove breakpoint at function entry
delete bnum	-- delete breakpoint bnum
disable bnum	-- disable breakpoint bnum
enable bnum	-- enable breakpoint bnum
condition bnum	-- set conditions for breakpoint bnum
commands bnum	-- set commands for breakpoint bnum
cont	-- continue execution to next break point
next	-- step next source level statement or function
next**i**	-- step next machine instruction or function
step	-- step next source level statement
step**i**	-- step next machine instruction
print expr	-- print value of expression including $n for machine registers
print/f expr	-- print value of expression according to format specified by f: x hexadecimal, d decimal, u unsigned decimal, o octal, a address, c character, f single precision floating point.
x/sf addr	-- Examine memory of size s bytes in format f: s = b one byte, s = h halfword, s = w word, s = g double word; x hexadecimal, d decimal, u unsigned decimal, o octal, a address, c character, f single precision floating point, s ascii string, I machine instruction

GDB Quick Reference Guide

display/f expr	-- p/sf, print every gdb command
display/sf expr	-- x/sf, examine every gdb command
undisplay n	-- remove item n from display list.
jump *addr	-- execute next instruction at address addr.
printf string, expr	-- formatted output, similar to printf in C but without the parentheses surrounding the arguments.
info data	-- information about break, display, registers, functions, variables
list	-- list ten source lines
where	-- show call stack
q	-- exit gdb
disassemble	-- dump the assembly code
display	-- done at each prompt
commands	-- done at specific breakpoint
backtrace [<n>]	-- prints a backtrace <n> levels deep

Note: pressing Enter repeats the last command.

GDB Example

```
/* REVERSE.C */

#include <stdio.h>
#include <string.h>

/* Function Prototype */
void reverse (char*, char*);


int main ()

{
	char str [100]; /* Buffer to hold reversed string */

	reverse ("cat", str); /* Reverse the string "cat" */
	printf ("reverse (\"cat\") = %s\n", str); /*    Display */
	reverse ("noon", str); /* Reverse the string "noon" */
	printf ("reverse (\"noon\") = %s\n", str); /* Display */
	return 0;
}
```

GDB Example

```
/* REVERSE.C */

………………….
void reverse (char* before, char* after)

{
        int i;
        int j;
        int len;

        len = strlen (before);

        for (j = len - 1, i = 0; j >= 0; j--, i++) /* Reverse loop */
                after[i] = before[j];

        after[len] = 0; /* NULL terminate reversed string */
}
```

GDB Example

```
$ gdb reverse1
GNU gdb (GDB) 8.1
Copyright (C) 2018 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 "i686-w64-mingw32".
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 reverse1...done.
```

GDB Example

```
(gdb) list
3       #include <stdio.h>
4       #include <string.h>
5
6
7       /* Function Prototype */
8       void reverse (char*, char*);
9
10
/**********************************************************************/
11
12        int main ()
```

GDB Example

```
(gdb) list
13
14      {
15        char str [100]; /* Buffer to hold reversed string */
16
17        reverse ("cat", str); /* Reverse the string "cat" */
18        printf ("reverse (\"cat\") = %s\n", str); /*        Display */
19        reverse ("noon", str); /* Reverse the string "noon" */
20        printf ("reverse (\"noon\") = %s\n", str); /* Display */
21        return 0;
22      }
(gdb)
```

GDB Example

```
(gdb) break main
Breakpoint 1 at 0x4015ce: file reverse1.c, line 17.
(gdb) break reverse
Breakpoint 2 at 0x40162b: file reverse1.c, line 36.
(gdb) break 18
Breakpoint 3 at 0x4015e2: file reverse1.c, line 18.
(gdb) info break
Num     Type           Disp Enb Address    What
1       breakpoint     keep y   0x004015ce in main at reverse1.c:17
2       breakpoint     keep y   0x0040162b in reverse at reverse1.c:36
3       breakpoint     keep y   0x004015e2 in main at reverse1.c:18
(gdb) run
Starting program: C:\Users\Tanha\vs_code_projects\gdb_tutorial\reverse1.exe
[New Thread 18128.0x4bb4]
[New Thread 18128.0x4e98]

Thread 1 hit Breakpoint 1, main () at reverse1.c:17
17          reverse ("cat", str); /* Reverse the string "cat" */
(gdb)
```

GDB Example

```
Starting program: C:\Users\Tanha\vs_code_projects\gdb_tutorial\reverse1.exe
[New Thread 18128.0x4bb4]
[New Thread 18128.0x4e98]

Thread 1 hit Breakpoint 1, main () at reverse1.c:17
17          reverse ("cat", str); /* Reverse the string "cat" */
(gdb) continue
Continuing.

Thread 1 hit Breakpoint 2, reverse (before=0x404044 "cat", after=0x61fe6c "~Dí-¼,j") at
reverse1.c:36
36          len = strlen (before);
(gdb) backtrace
#0  reverse (before=0x404044 "cat", after=0x61fe6c "~Dí-¼,j") at reverse1.c:36
#1  0x004015e2 in main () at reverse1.c:17
(gdb) next
38          for (j = len - 1, i = 0; j >= 0; j--, i++) /* Reverse loop */
(gdb)
```

GDB Example

```
(gdb) next
39            after[i] = before[j];
(gdb) print after[i]
$1 = 126 '~'
(gdb) print before[j]
$2 = 116 't'
(gdb)
$3 = 116 't'
(gdb) next
38          for (j = len - 1, i = 0; j >= 0; j--, i++) /* Reverse loop */
(gdb) print after
$4 = 0x61fe6c "tDí-¼,j"
(gdb) print before
$5 = 0x404044 "cat"
(gdb) continue
Continuing.

Thread 1 hit Breakpoint 3, main () at reverse1.c:18
18          printf ("reverse (\"cat\") = %s\n", str); /*         Display */
(gdb)
```

GDB Example

```
(gdb) next
[New Thread 18128.0x56a8]
reverse ("cat") = tac
19          reverse ("noon", str); /* Reverse the string "noon" */
(gdb) step

Thread 1 hit Breakpoint 2, reverse (before=0x40405e "noon", after=0x61fe6c "tac") at reverse1.c:36
36          len = strlen (before);
(gdb) return 0
Make reverse return now? (y or n) y
#0  main () at reverse1.c:20
20          printf ("reverse (\"noon\") = %s\n", str); /* Display */
```

GDB Example

```
(gdb) print str
$6 =
"tac\000¼,j\000:\000\000\000\000\000\000\000\200\026@\000lþa\000`\000\000
@Ìÿa\000pÝ)uÞ\036¢âþÿÿÿ\032\200)uÏ\024@\000\200\026@\000>\037ëv\000\000
\000\000\001\000\000\000:\000\000\000¼,j\000hÿa\000ë\026@\000\200\026@\0
00\000\000\000\000:\000\000\000¼,j"
(gdb) next
reverse ("noon") = tac
21          return 0;
(gdb) quit
A debugging session is active.

        Inferior 1 [process 18128] will be killed.

Quit anyway? (y or n) y
```

GDB Example: Challenge

```
/* REVERSE2.C */

#include <stdio.h>
#include <string.h>

/* Function Prototype */
int reverse (char*);

int main()
{
        char str[1024];
        printf("Give me a word to reverse: ");
        gets(str);
        reverse(str);
        printf("REVERSED: %s\n", str);
        return 0;
}
```

GDB Example: Challenge

```
/* REVERSE2.C */

int reverse (char* str)
{
    int i;
    int len;
    char c;
    len = strlen (str);
    for (i = 0; i < len; i++) /* Reverse loop */
    {
        c = *(str+i);
        *(str+i) = *(str+len-i-1);
        *(str+len-i-1) = c;
    }
    return 0;
}
```