CS35L – Spring 2019

Slide set:	4.3
Slide topics:	GDB, Debugging
Assignment:	4

Debugging Process

- Reproduce the bug
- Simplify program input
- Use a debugger to track down the origin of the problem
- Fix the problem

Debugger

A program that is used to run and debug other (target) programs

Advantages:

Programmer can:

- step through source code line by line
  - each line is executed on demand
- interact with and inspect program at run-time
- If program crashes, the debugger outputs where and why it crashed

GDB – GNU Debugger

Debugger for several languages

- C, C++, Java, Objective-C… more

Allows you to inspect what the program is doing at a certain point during execution

Logical errors and segmentation faults are easier to find with the help of gdb

Using GDB

1. **Compile Program**
   - Normally: $ gcc [flags] <source files> -o <output file>
   - Debugging: $ gcc [other flags] **–g** <source files> -o <output file>
     - enables built-in debugging support

2. **Specify Program to Debug**
   - $ gdb <executable>

     or

   - $ gdb
   - (gdb) file <executable>

Using GDB

3. Run Program

- `(gdb) run` or
- `(gdb) run [arguments]`

4. In GDB Interactive Shell

- Tab to Autocomplete, up-down arrows to recall history
- `help [command]` to get more info about a command

5. Exit the gdb Debugger

- `(gdb) quit`

Run-Time Errors

Segmentation fault

- Program received signal SIGSEGV, Segmentation fault. 0x0000000000400524 in *function* (arr=0x7fffc902a270, r1=2, c1=5, r2=4, c2=6) at *file.c*:12
  - Line number where it crashed and parameters to the function that caused the error

Logic Error

- Program will run and exit successfully

How do we find bugs?

Setting Breakpoints

Breakpoints

- used to stop the running program at a specific point
- If the program reaches that location when running, it will pause and prompt you for another command

Example:

- (gdb) break file1.c:6
  - Program will pause when it reaches line 6 of file1.c
- (gdb) break my_function
  - Program will pause at the first line of my_function every time it is called
- (gdb) break [*position*] if *expression*
  - Program will pause at specified position only when the expression evaluates to true

Breakpoints

Setting a breakpoint and running the program will stop program where you tell it to

You can set as many breakpoints as you want

- (gdb) info breakpoints/break/br/b shows a list of all breakpoints

Deleting, Disabling and Ignoring BPs

(gdb) delete [bp_number / range]

- Deletes the specified breakpoint or range of breakpoints

(gdb) disable [*bp_number* / *range*]

- Temporarily deactivates a breakpoint or a range of breakpoints

(gdb) enable [*bp_number* / *range*]

- Restores disabled breakpoints

If no arguments are provided to the above commands, all breakpoints are affected!!

(gdb) ignore *bp_number iterations*

- Instructs GDB to pass over a breakpoint without stopping a certain number of times.
  - bp_number: the number of a breakpoint
  - Iterations: the number of times you want it to be passed over

Displaying Data

Why would we want to interrupt execution?

- to see data of interest at run-time:
- (gdb) print [/format] *expression*
  - Prints the value of the specified expression in the specified format
- Formats:
  - d: Decimal notation (default format for integers)
  - x: Hexadecimal notation
  - o: Octal notation
  - t: Binary notation

Resuming Execution After a Break

When a program stops at a breakpoint

- 4 possible kinds of gdb operations:
  - **c or continue**: debugger will continue executing until next breakpoint
  - **s or step**: debugger will continue to next source line
  - **n or next**: debugger will continue to next source line in the current (innermost) stack frame
  - **f or finish**: debugger will resume execution until the current function returns. Execution stops immediately after the program flow returns to the function's caller
    - the function's return value and the line containing the next statement are displayed

Watchpoints

Watch/observe changes to variables

- (gdb) watch my_var
  - sets a watchpoint on my_var
  - the debugger will stop the program when the value of *my_var* changes
  - old and new values will be printed
- (gdb) rwatch *expression*
  - The debugger stops the program whenever the program reads the value of any object involved in the evaluation of *expression*

Process Memory Layout

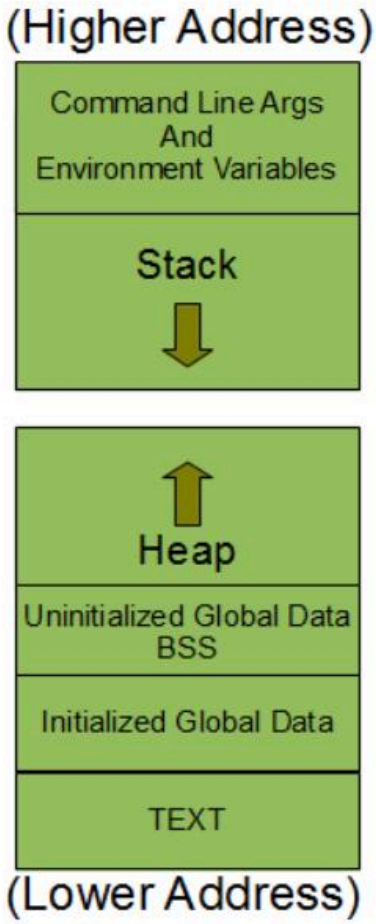

Image source : thegeekstuff.com

- TEXT segment
  - Contains machine instructions to be executed
- Global Variables
  - Initialized
  - Uninitialized
- Heap segment
  - Dynamic memory allocation
  - malloc, free
- Stack segment
  - Push frame: Function invoked
  - Pop frame: Function returned
  - Stores
    - Local variables
    - Return address, registers, etc
- Command Line arguments and Environment Variables

Stack Info

A program is made up of one or more functions which interact by calling each other

Every time a function is called, an area of memory is set aside for it. This area of memory is called a **stack frame** and holds the following crucial info:

- storage space for all the local variables
- the memory address to return to when the called function returns
- the arguments, or parameters, of the called function

Each function call gets its own stack frame. Collectively, all the stack frames make up the **call stack**

Stack Frames and the Stack

```
1   #include <stdio.h>
2   void first_function(void);
3   void second_function(int);
4
5   int main(void)
6   {
7      printf("hello world\n");
8      first_function();
9      printf("goodbye goodbye\n");
10
11     return 0;
12  }
13
14
15  void first_function(void)
16  {
17     int imidate = 3;
18     char broiled = 'c';
19     void *where_prohibited = NULL;
20
21     second_function(imidate);
22     imidate = 10;
23  }
24
25
26  void second_function(int a)
27  {
28     int b = a;
29  }
```

Stack Frames and the Stack

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21     second_function(imidate);
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```

One stack frame belonging to main():
Uninteresting since main() has no automatic variables, no parameters, and no function to return to

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15  void first_function(void)
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19     void *where_prohibited = NULL;
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21     second_function(imidate);
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```

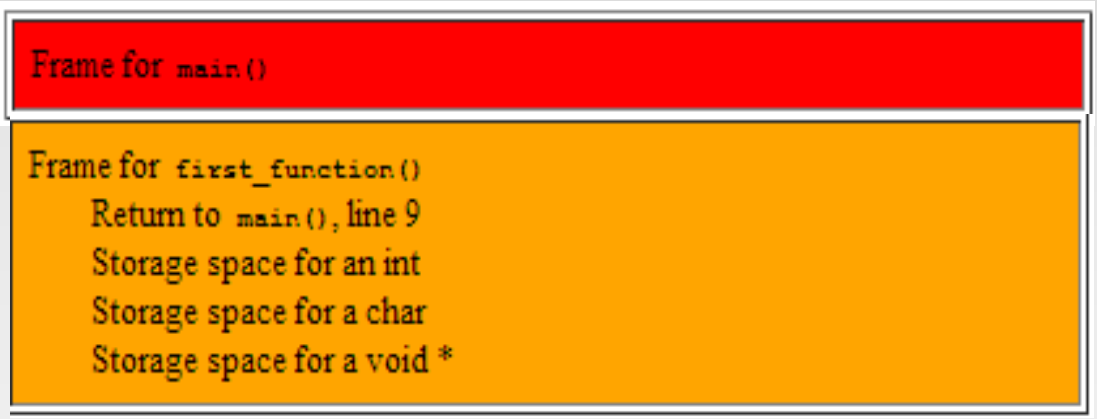

Call to first_function() is made, unused stack memory is used to create a frame for first_function(). It holds four things: storage space for an int, a char, and a void *, and the line to return to within main()

Stack Frames and the Stack

```
1   #include <stdio.h>
2   void first_function(void);
3   void second_function(int);
4
5   int main(void)
6   {
7      printf("hello world\n");
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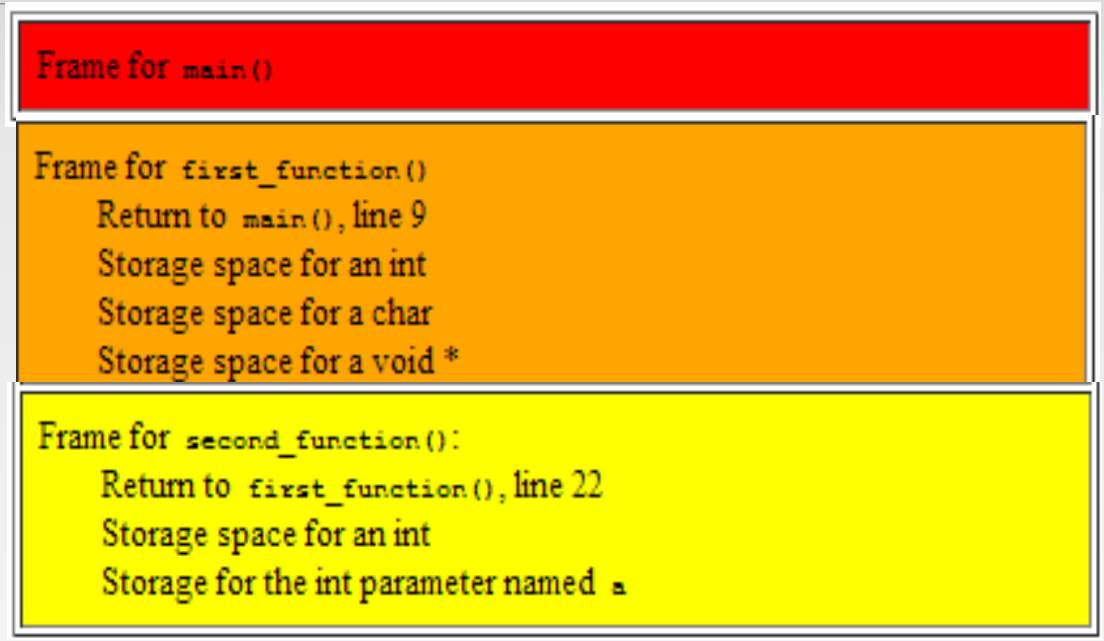

Call to second_function() is made, unused stack memory is used to create a stack frame for second_function(). The frame holds 3 things: storage space for an int and the current address of execution within second_function()

Stack Frames and the Stack

```
1   #include <stdio.h>
2   void first_function(void);
3   void second_function(int);
4
5   int main(void)
6   {
7      printf("hello world\n");
8      first_function();
9      printf("goodbye goodbye\n");
10
11     return 0;
12  }
13
14
15  void first_function(void)
16  {
17     int imidate = 3;
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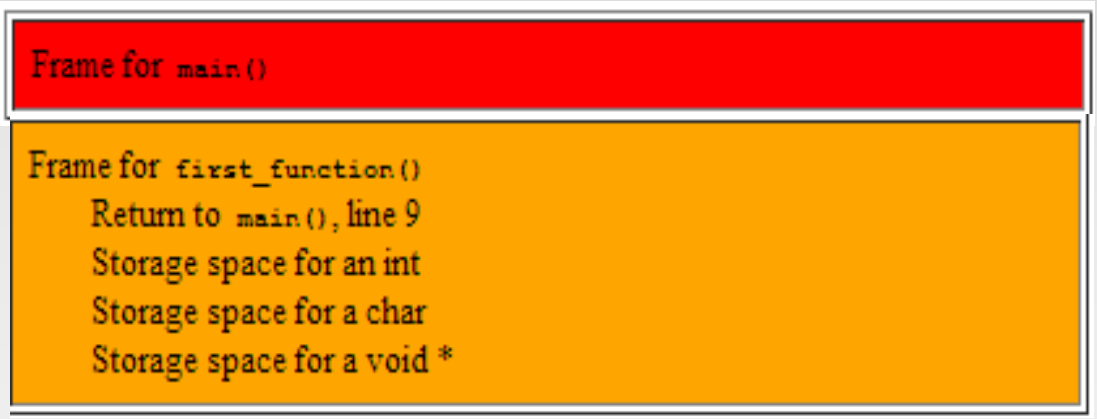

When second_function() returns, its frame is used to determine where to return to (line 22 of first_function()), then deallocated and returned to stack.

Stack Frames and the Stack

```
1   #include <stdio.h>
2   void first_function(void);
3   void second_function(int);
4
5   int main(void)
6   {
7      printf("hello world\n");
8      first_function();
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11     return 0;
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23  }
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28     int b = a;
29  }
```

When first_function() returns, its frame is used to determine where to return to (line 9 of main()), then deallocated and returned to the stack

Analyzing the Stack in GDB

(gdb) backtrace|bt

- Shows the call trace (the call stack)
- Without function calls:
  - #0 main () at program.c:10
  - one frame on the stack, numbered 0, and it belongs to main()
- After call to function display()
  - #0 display (z=5, zptr=0xbffffb34) at program.c:15

    #1 0x08048455 in main () at program.c:10
  - Two stack frames: frame 1 belonging to main() and frame 0 belonging to display().
  - Each frame listing gives
    - the arguments to that function
    - the line number that's currently being executed within that frame

Analyzing the Stack

(gdb) info frame

- Displays information about the current stack frame, including its return address and saved register values

(gdb) info locals

- Lists the local variables of the function corresponding to the stack frame, with their current values

(gdb) info args

- List the argument values of the corresponding function call

Other Useful Commands

(gdb) info functions

- Lists all functions in the program

(gdb) list

- Lists source code lines around the current line