COMP1917: Computing 1

12. Debugging

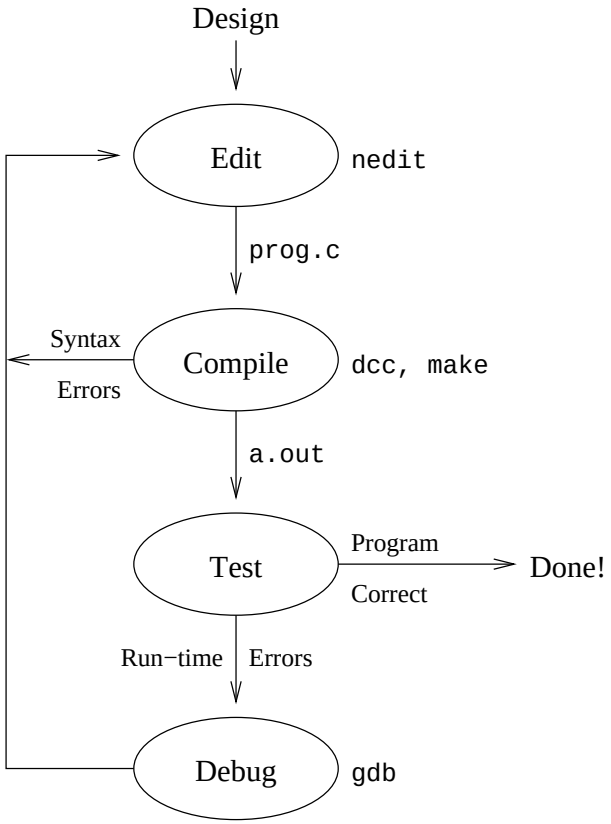
Overview

- Programming cycle
- Do-it-yourself debugging
- Debugging with `gdb`
- Nastier bugs
- Memory leaks

Developing Programs

1. Understand the problem
2. Design data structures and algorithms
3. Implement design as a C program
4. Execute the program on test data
5. Check whether it gives correct results
6. **Repeat** above steps until it works ok

The Programming Cycle



Compiler Errors

The C compiler will pick up superficial errors, and give warnings when it thinks a program “looks wrong”:

- mis-spelling of function or variable names
- forgetting to include a header file
- missing brackets, semicolons, etc.

Linker Errors

The compiler produces object code for each module independently.

It assumes that all references to external names will be resolved later.

If you refer to an undefined name:

```
Undefined                       first referenced
 symbol                             in file

_print                              program.o

ld fatal: Symbol referencing errors.
       No output written to a.out
```

Often caused by misspelling function names, or forgetting to include an external declaration or function prototype in your header file.

Program Debugging

Debugging: process of locating and fixing bugs.

Bug: piece of program that does not do what you intended.

Consequences of bugs:

- run-time error (if you're lucky)
- incorrect results (if you're unlucky)

To perform debugging, you need to know:

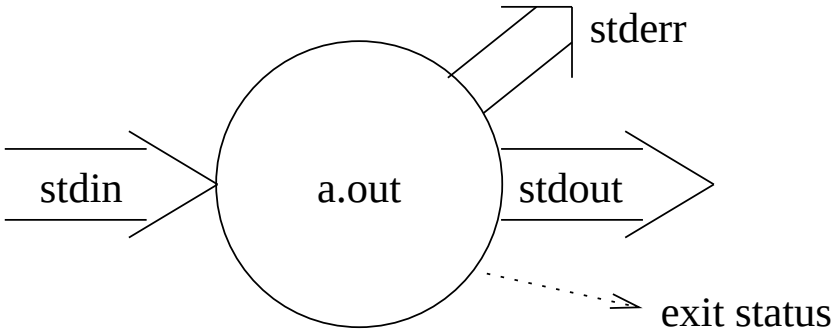
- in detail, what the code should do
- in detail, what it actually does

A debugger (e.g. `gdb`) can assist with the latter.

Program Execution

Under Unix, a program executes either:

- to completion, producing results (correct?)
- until it detects an error and `exits`
- until a run-time error halts it
  (e.g. `Segmentation violation - core dumped`)



Do-it-yourself Debugging

place `printf()`'s in your code to print intermediate values of variables

The `assert()` function can also be used to check assumptions about what should be true at certain points in your code.

```
#include <assert.h>
    ...
    assert( expression );
```

if the asserted expression evaluates to `0` (False) the program will print a diagnostic message and halt.

Making your own `DEBUG` mode

You must remember to remove debugging `printf()` statements from the final version of your program. `assert()` statements should also be removed, because they may slow down execution of the code.

Pre-processor directives can be used to switch debugging on and off:

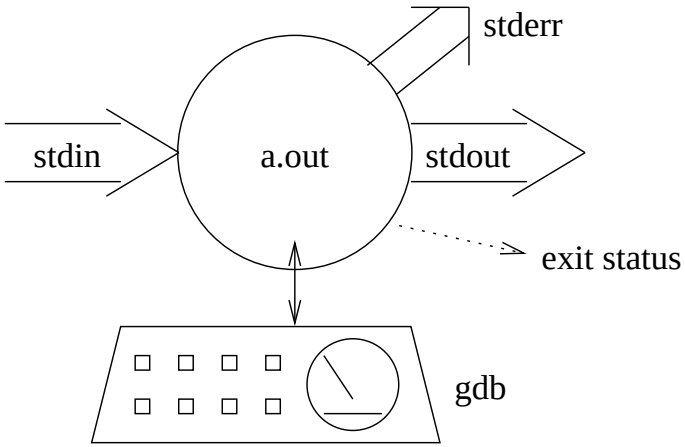
```
#define DEBUG  1
    ...
#ifdef DEBUG
    printf(" x = %d, y = %d\n", x, y );
#endif
```

When you think the bugs are all fixed, comment out the top line and all the debugging code will be suppressed.

Debuggers

A debugger gives you control of program execution:

- normal execution (`run`, `cont`)
- stop at a certain point (`break`)
- one statement at a time (`step`, `next`)
- examine program state (`print`)



The `gdb` debugger

`gdb` – a line-based interactive debugger.

`ddd` – an X-windows-based interface for `gdb`.

To use programs with `gdb` (or `ddd`), they must be compiled with the `gcc` compiler.

`gdb` (`ddd`) takes two arguments:

```
% gdb executable core
```

E.g.

```
% gdb a.out core
% gdb myprog
```

(The `core` argument is used when the program has already crashed.)

gdb sessions

A session with gdb is a sequence of commands to control and observe the executable.

Command = sequence of words on single line.

```
% gcc -Wall -g -o prog prog.c
% gdb prog
GNU gdb 6.8-debian
Copyright (C) 2008 Free Software Foundation, Inc.
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.
(gdb) break f
Breakpoint 1 at 0x1082c: file prog.c, line 32.
(gdb) run
```

gdb sessions

```
Starting program: ..../prog
Enter a b c: 1 2 3
Breakpoint 1, f (i=1, j=2) at prog.c:32
32              a = i + j;
(gdb) next
33              b = i*i + j*j;
(gdb) next
34              return a*b;
(gdb) print a
$1 = 3
(gdb) print b
$2 = 5
(gdb) cont
...
```

Basic `gdb` commands

- `quit` – quits from `gdb`
- `help [CMD]` – on-line help

Gives information about `CMD` command.

- `run ARGS` – run the program

`ARGS` are whatever you normally use, e.g.

```
% ./prog < data
```

is achieved by:

```
(gdb) run < data
```

`gdb` status commands

- `where` – stack trace

Find which function the program was executing when it crashed.

Stack may also have references to system error-handling functions.

- `up [N]` – move "up" the stack

Allows you to skip to "scope" of a particular function in stack.

- `list [LINE]` — show code

Displays five lines either side of current statement.

- `print EXPR` – display expression values

`EXPR` may use (current values of) variables.

Special expression `aat1` shows all of the array `a`.

`gdb` execution commands

- `break [PROC|LINE]` - set break-point

On entry to function `PROC` (or reaching line `LINE`), stop execution and return control to `gdb`.

- `next` - single step (over functions)

Execute next statement; if statement is a function call, execute entire function body.

- `step` - single step (into functions)

Execute next statement; if statement is a function call, go to first statement in function body.

For more details see `gdb`'s on-line help.

Nastier Bugs

When a program really makes a mess of things, the debugger may get confused due to corruption of system memory.

There are other compilers like `dcc`, which are similar to `gcc` but do more checking. If the program crashes, or an array is overrun, etc., the compiler will (hopefully) give you some useful information:

```
*******
mudflap violation 47 (check/write): time=1161558399.248071
ptr=0xbfbf1aa8 size=4
pc=0xb7ee6347 location=‘overrun.c:10 (main)’
Segmentation fault
```

`dcc` error messages

```
*******
mudflap violation 1 (check/write): time=1161558716.559908
ptr=0xbf84fb0c size=4
pc=0xb7e44347 location=‘overrun.c:10 (main)’
      /usr/lib/libmudflap.so.0(__mf_check+0x37) [0xb7e44347]
      ./a.out(main+0x79) [0x8048761]
      /usr/lib/libmudflap.so.0(__wrap_main+0x176) [0xb7e44f66]
Nearby object 1: checked region begins 1B after and ends 4B after
mudflap object 0x80cb318: name=‘overrun.c:6 (main) a’
bounds=[0xbf84fae4,0xbf84fb0b] size=40 area=stack check=0r/10w
liveness=10
alloc time=1161558716.559778 pc=0xb7e44d97
number of nearby objects: 1
```

Memory Leaks and `valgrind`

Sometimes a program eventually crashes due to a "memory leak" – a slow accumulation of memory blocks which are `malloc`'ed but never `free`'d.

Tools like `valgrind` can help you to track these memory leaks.

```
% gcc -g -o xyz xyz.c
% valgrind xyz
```

When the program terminates, `valgrind` will give you a summary of memory usage and report any memory blocks which have not been `free`'d.

Warning: `valgrind` makes the program run very slowly because it does so much checking.

valgrind messages

```
==31180== ERROR SUMMARY: 0 errors from 0 contexts (suppressed: 11 from 1)
==31180== malloc/free: in use at exit: 64 bytes in 8 blocks.
==31180== malloc/free: 8 allocs, 0 frees, 64 bytes allocated.
==31180== For counts of detected errors, rerun with: -v
==31180== searching for pointers to 8 not-freed blocks.
==31180== checked 59,376 bytes.
==31180==
==31180== LEAK SUMMARY:
==31180==    definitely lost: 64 bytes in 8 blocks.
==31180==      possibly lost: 0 bytes in 0 blocks.
==31180==    still reachable: 0 bytes in 0 blocks.
==31180==         suppressed: 0 bytes in 0 blocks.
==31180== Use --leak-check=full to see details of leaked memory.
```