Debugging

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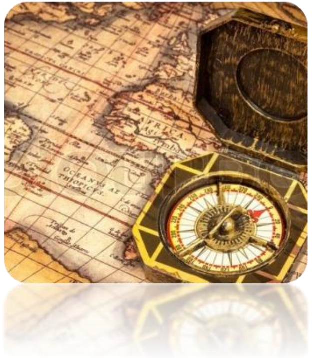
Outline

Profiling

Debugging

Profiling outline



Mapping

Profiling Tools

Profiling Behaviour

Profiling Efficiency

Map the workflow

A call tree (more precisely, a **call graph**) is a control flow graph that exhibits the calling relationships among routines in a program.
A *node* in the graph represent a routine, while an *edge* represents a calling relationship.

We'll concentrate on ***dynamic* call graphs** – i.e. the **records of program executions**.

The most complete graph is context-sensitive, which means that every call stack of a procedure is recorded as a separate node (the resulting graph is called *calling context tree* instead of *call tree*).

However, that requires a larger amount of memory for large program, it is useful in case of code reuse (the same code being executed at different points by differentcall paths).

Basic profiling concepts

INSTRUMENTATION

Inserts extra code at compile time wrapping function calls to count how many times it calls / is called and how much time it takes to execute.

SAMPLING

The profiler ask for interrupts $N_{\mathtt{samples}}$ per sec + interrupts at function calls + interrupts at selected events, and records on a histogram the number of occurrences in every part of the program. The call graph is inferred from these data.

DEBUGGING

The profiler ask for interrupts at every line code and function call (more correct: enters the by-step execution mode)

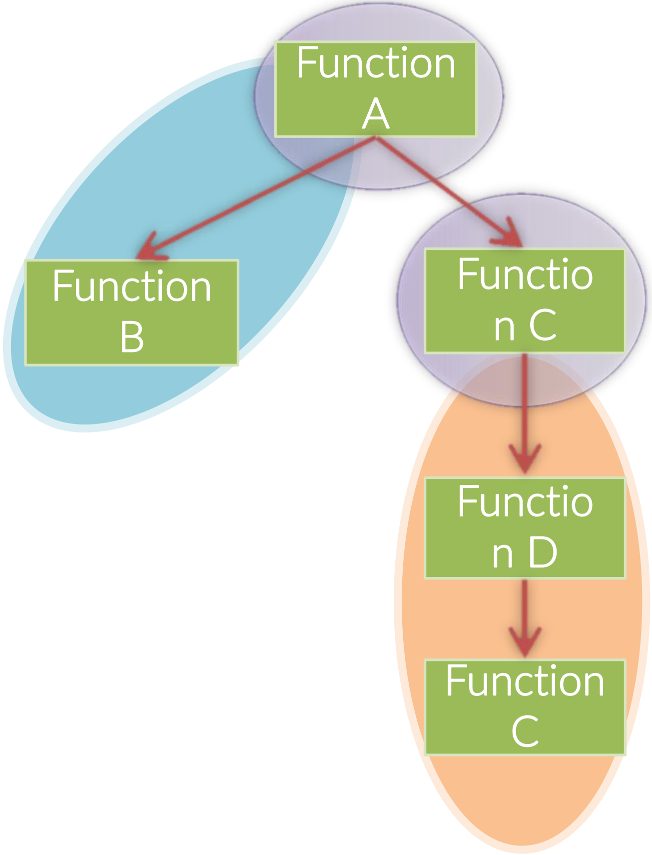
Basic profiling concepts

Collect **program events**

- Hardware interrupts
- Code instrumentation
- Instruction set simulation
- tracing

Periodic sampling

- Top of the stack (exclusive)
- All stack (children inclusive)



How to obtain the call tree

There are several way to obtain a dynamic call tree.
The main open source alternatives are:

1. Using gcc and **gprof**
2. Using linux **google perftools**
3. Using **valgrind**
4. Using **perf**
5. Some others, mostly non-free (among significant free: CodeXL by AMD

Many IDE uses the aforementioned tools or their own plug-ins (eclipse, netbeans, code::block, codelite, …)

The call-tree

Using **gcc + gprof**

Just compile your source using **–pg** option.
You should also profile turning on the optimizations you're interested in.

```
gcc –[my.optimizations] -pg -o myprogram.x myprogram.c
```

Note: don't use the option –p. It provides less information than –pg.

After that, run your program normally. Profiling infos will be written in the file `gmon.out`.

▶ You can read (options and details in the man page) the informations by

```
gprof myprogram.x
```

▶ You can visualize the call graph by (read the man pages...)

```
gprof myprogram.x | gprof2dot.py | dot -T png -o callgraph.png
```

The call-tree

Well, now that you just met, say goodbye to the glorious **`gprof`**

He’s a dinosaur from the past decades..

- lacks real multithread support
- lacks real line-by-line capability
- does not profile shared libraries
- need recompilation
- may lie easier than other tools (see later..)

You may still consider it for some call counts business

How to induce you profiler to lie

`gprof` (`gcc -pg`) does not record the call stack

```c
#include <stdlib.h>
void loop(int n)
{
  int volatile i; // does not optimize out
  i = 0;
  while(i++ < n);
}

void light(int n) { loop(n); }void heavy(int n)
{ loop(n); }

int main(void)
{
  light(100000);
  heavy(100000000);
return 0;
}
```

How to induce you profiler to lie

```
Flat profile:

Each sample counts as 0.01 seconds.
  %   cumulative   self              self     total
 time   seconds   seconds    calls  ms/call  ms/call  name
101.30      0.20     0.20        2   101.30   101.30  loop
  0.00      0.20     0.00        1     0.00   101.30  heavy
  0.00      0.20     0.00        1     0.00   101.30  light
```

How to induce you profiler to lie

How could it happen?
The man page is clear:

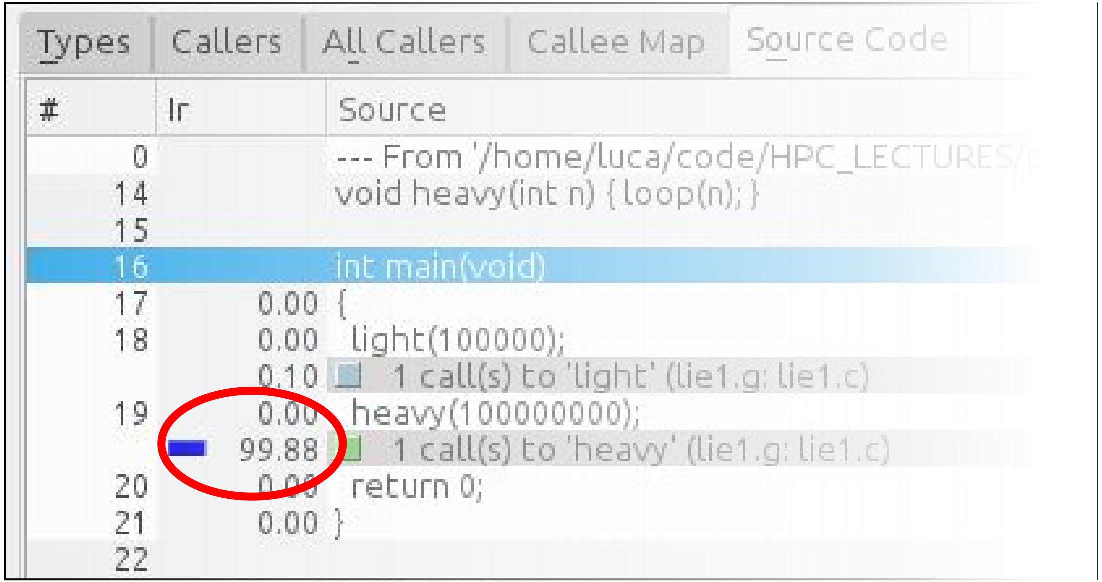
We assume that the time for each execution of a function can be expressed by the total time for the function divided by the number of times the function is called.

Thus the time propagated along the call graph arcs to the function's parents is directly proportional to the number of times that arc is traversed.

How to induce you profiler to lie

VALGRIND seems to better understand the situation, because it doesn't record only the number of calls to a function but also the time spent in a function given a call path (which, at odds, gprof infers backwardly).
That's way the valgrind measure of time spent in a function plus its callees is reliable.

However, it may as well end up to a misleading picture if we stick in and additional layer of complexity, *unless* you explicit tells it to track separately different call stacks with the command-line option -`-separate-callers = N`



The call-tree

Using **google perftools**

That is the CPU profiler used at Google's. It provides a **thread-caching malloc**, a **heap-checker**, **heap-profiler**, **CPU profiler**.

As for the latter, basically there are 3 phases:

1. linking the library to the executable
2. running the executable
3. analyzing results

[1] LINKING
There are two options:

- Link `-lprofiler` at the executable
- Adding the profiler at run time `LD_PRELOAD="/usr/lib/libprofiler.so" /path/to/exec`

This does not start the CPU profiling, though.

The call-tree

Using **google perftools**

[2] RUNNING

- Define
  `env CPUPROFILE= exec.prof /path/to/exec`

  You may define a signal, too
  ```
  env CPUPROFILE= exec.prof /path/to/exec \
  CPUPROFILESIGNAL= XX exec.prof &
  ```

  so that to be able to trigger the start and stop of the profiling by
  `killall -XX exec`

- In the code, include `<gperftools/profiler.h>` and encompass the code segment to be profiled within
  ```
  ProfilerStart("name_of_profile_file")
  …
  ProfilerStop()
  ```

`CPUPROFILE_FREQUENCY=x` modifies the sampling frequency

The call-tree

Using **google perftools**

[3] ANALYZING RESULTS

`pprof exec exec.prof`	"interactive mode"
`pprof --text exec exec.prof`	output one line per procedure
`pprof --gv exec exec.prof`	**annotated call graph via 'gv'**
`pprof --gv --focus = some_func …`	restrict to code paths including "*some_func*"
`pprof --list = some_func …`	per-line annotated list of some_func
`pprof --disasm= some_func …`	annotated disassembly of some_func
`pprof –callgrind exec exec.prof`	**output call infos in callgrind format**

The call-tree

Using **perf**

[1] COMPILING

```
gcc -g -fno-omit-frame-pointer my_prog.c -o my_prog
```

[2] RUNNING

```
perf record -F ffff -call-graph <fp|lbr|dwarf> \
my_prog.c <args>
```

[3] ANALYZING

```
perf report --call-graph=graph < --stdio >
```

The call-tree

Using **valgrind**

[1] COMPILING

```
gcc -g –fno-omit-frame-pointer my_prog.c –o my_prog
```

[2] RUNNING

```
Valgrind –tool=callgrind –callgrind-out-file= $CALLGRIND_OUT –dump-
instr=yes –coolect-jumps=yes –cache-sim=yes –branch-sim=yes < --I1=… >
< --D1=…>  my_prog <args>
```

[3] ANALYZING

```
kcachegrind $CALLGRIND_OUT
```

Tools

- BASIC / SYSTEM tools
  - gprof / gdb / perf / gperftools
  - Valgrind – cachegrind, callgrind, ..
- HARDWARE COUNTER / PMU interface
  - perf
  - PAPI
  - Intel PMI
  - Likwid
  - …
- HPC Tools
  - HPCtoolkit
  - OpenISpeedShop
  - TAU
  - SCOREP +
- VENDOR tools
  - ARM-Allinea
  - CodeXL (AMD)
  - Intel tools
  - …

Tools : valgrind

An instrumentation framework for building dynamic analysis tools.
Valgrind basically runs your code in a virtual “sandobx” where a synthetic CPU (the same you have) is simulated and executes an instrumented code.

There are various Valgrind based tools for debugging and profiling purposes.

- Memcheck is a memory error detector → correctness
- Cachegrind is a cache and branch-prediction profiler → velocity
- Callgrind is a call-graph generating cache profiler. It has some overlap with Cachegrind
- Helgrind is a thread error detector → correctness
- DRD is also a thread error detector.
  Different analysis technique than Helgrind
- Massif is a heap profiler → memory efficiency using less memory
- DHAT is a different kind of heap profiler → memory layout inefficiencies
- SGcheck (experimental tool) that can detect overruns of stack and global arrays

KCacheGrind is a very useful GUI

Tools : valgrind

Memcheck : highlighting memory errors

- Unvalid memory access: overrunning/underrunning of heap blocks or top of stack, addressing freed blocks, …
- Use of variables with undefined values
- Incorrect freeing of heap memory
- Errors in moving memory (unwanted src/dst overlaps, …)
- Memory leaks

Cachegrind: simulating the cache

It can report how many hits (L1, L2 and L3, I- and D-) and how many misses.
It can analyze CPU's branch prediction.

`Ir, I1mr, LLmr, Dr, D1mr, DLmr, Bc, Bcm, Bi, Bim, …`

Callgrind: profiling the CPU

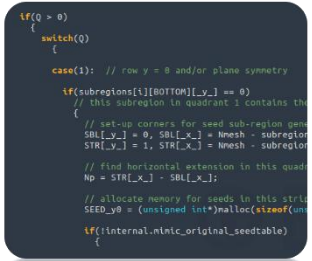
It collects the number of instructions executed, links them to source lines, records the caller/callee relationship between functions, and the numbers of such calls. It can collect data on cache simulation and/or branches.

Outline

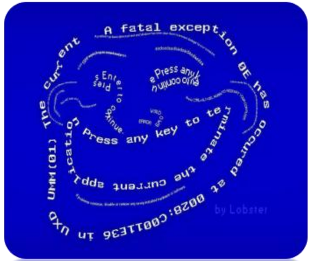
Debugging

Debugging outline

Introduction



Debugging a code



Inspecting a code crash

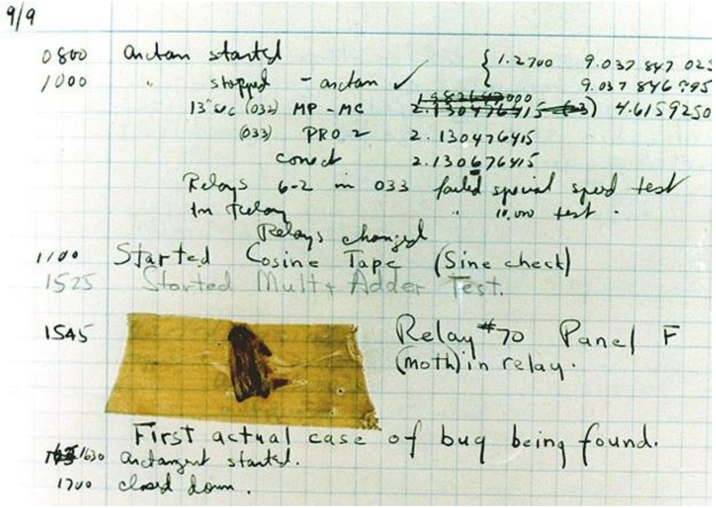
Debugging running process(es)

Introducing debugging

Smithsonian

It has long been recognized and documented that insects are the most diverse group of organisms, meaning that the numbers of species of insects are more than any other group. In the world, some 900 thousand different kinds of living insects are known. This representation approximates 80 percent of the world's species. The true figure of living species of insects can only be estimated from present and past studies. Most authorities agree that there are more insect species that have not been described (named by science) than there are insect species that have been previously named. Conservative estimates suggest that this figure is 2 million, but estimates extend to 30 million. In the last decade, much attention has been given to the entomofauna that exists in the canopies of tropical forests of the world. From studies conducted by Terry Erwin of the Smithsonian Institution's Department of Entomology in Latin American forest canopies, the number of living species of insects has been estimated to be 30 million. Insects also probably have the largest biomass of the terrestrial animals. At any time, it is estimated that there are some 10 quintillion (10,000,000,000,000,000,000) individual insects alive.

Introducing debugging



The usage of ***bug*** and, hence, of ***de-bugging*** referred to programming is a long-standing tradition, whose origin is difficult to trace back.

An often-told story is about Mark-II calculator located at Harvard: On Sept. 9th, 1945, a technician found a moth in a relay that caused a flaw in a "program" execution.

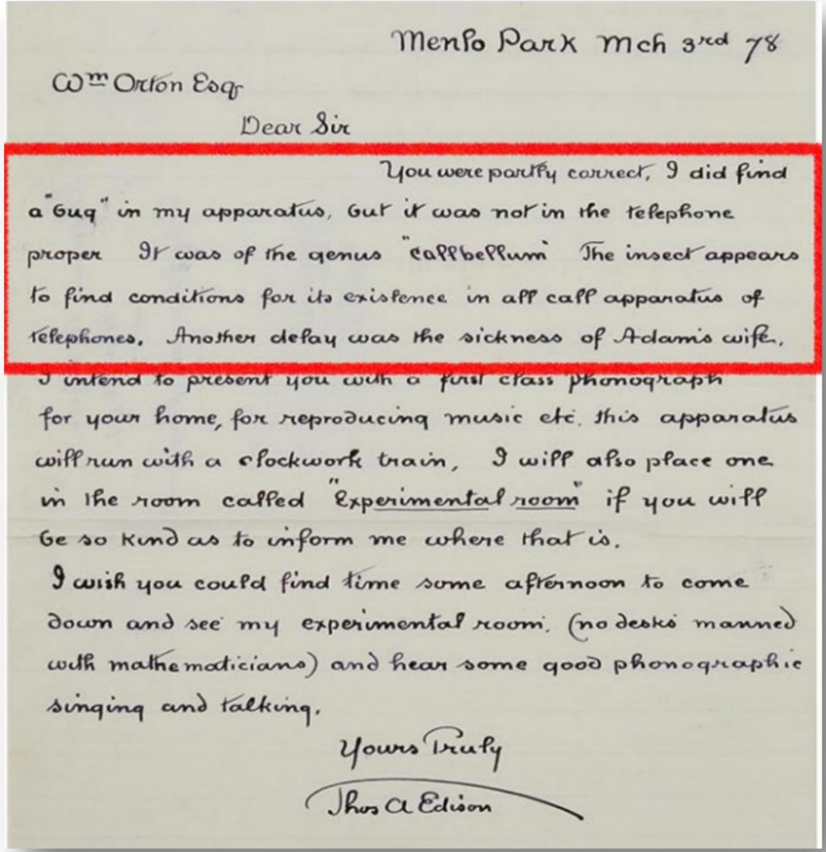
Adm. Grace Hopper is reported to have written in its diary about that as "first *actual* case of bug being found"

Introducing debugging

However, **Thomas Edison** found another *actual* bug in one of his phones, as he reports in a letter to an associate.

He later writes:

"It has been just so in all of my inventions. The first step is an intuition and comes with a burst, then difficulties arise—this thing gives out and [it is] then that "bugs"—as such little faults and difficulties are called—show themselves and months of intense watching, study and labor are requisite before commercial success or failure is certainly reached."



Menlo Park Mch 3rd 78

Wm Orton Esqr

Dear Sir

You were partly correct, I did find a "bug" in my apparatus, but it was not in the telephone proper. It was of the genus "callbellum" The insect appears to find conditions for its existence in all call apparatus of telephones. Another delay was the sickness of Adam's wife. I intend to present you with a first class phonograph for your home, for reproducing music etc. this apparatus will run with a clockwork train, I will also place one in the room called "Experimental room" if you will be so kind as to inform me where that is.

I wish you could find time some afternoon to come down and see my experimental room, (no desks manned with mathematicians) and hear some good phonographic singing and talking.

Yours Truly

Thos A Edison

Introducing debugging

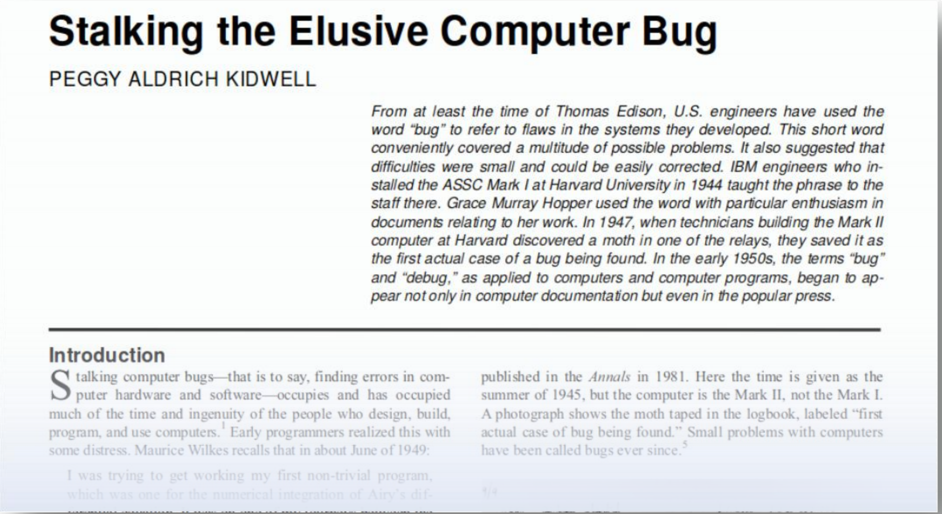
It is difficult to trace back how this term has been poured into computer programming jargon. However, already in the early 60s it was appearing in technical papers without need of explanation.

The immortal I. Asimov used it in a 1944 short robot story “Catch that rabbit”, and his incredible influence contributed much to make the term popular.

More funny infos:

IEEE Annals of the History of Computing
(Volume: 20 , Issue: 4 , Oct-Dec 1998)

ask for the PDF if you’re interested and do not have access



Stalking the Elusive Computer Bug

PEGGY ALDRICH KIDWELL

From at least the time of Thomas Edison, U.S. engineers have used the word “bug” to refer to flaws in the systems they developed. This short word conveniently covered a multitude of possible problems. It also suggested that difficulties were small and could be easily corrected. IBM engineers who installed the ASSC Mark I at Harvard University in 1944 taught the phrase to the staff there. Grace Murray Hopper used the word with particular enthusiasm in documents relating to her work. In 1947, when technicians building the Mark II computer at Harvard discovered a moth in one of the relays, they saved it as the first actual case of a bug being found. In the early 1950s, the terms “bug” and “debug,” as applied to computers and computer programs, began to appear not only in computer documentation but even in the popular press.

Introduction

Stalking computer bugs—that is to say, finding errors in computer hardware and software—occupies and has occupied much of the time and ingenuity of the people who design, build, program, and use computers.[1] Early programmers realized this with some distress. Maurice Wilkes recalls that in about June of 1949:

I was trying to get working my first non-trivial program, which was one for the numerical integration of Airy’s dif-

published in the *Annals* in 1981. Here the time is given as the summer of 1945, but the computer is the Mark II, not the Mark I. A photograph shows the moth taped in the logbook, labeled “first actual case of bug being found.” Small problems with computers have been called bugs ever since.[5]

Introducing debugging

That maybe is too dramatic and emphatic, but the point to get from Edison is that the *de-bugging activity* is an inherent and intrinsic one in software development

*"It has been just so in all of my inventions. The **first step** is an intuition and comes with a burst, **then difficulties arise**—this thing gives out and [it is] then that "**bugs**"—as such little faults and difficulties are called—show themselves and **months of intense watching, study and labor are requisite** before commercial success or failure is certainly reached."*

T. Edison

Introducing debugging

Provided that

- you'll have close encounters with bugs in your life;
- de-bugging is a fundamental and unavoidable part of your work;

what is the best way to proceed ?

Introducing debugging

1. Do not insert bugs

Highly encouraged, but rarely works

Introducing debugging

1. Do not insert bugs
   Highly encouraged, but rarely works

2. Add **`printf`** statements everywhere
   Highly discouraged, but sometimes works.
   In case of memory problems – tipically due to pointers chaos – you may see that the problem "disappear", or changes its appearance, when you insert a new `printf`

Introducing debugging

1. Do not insert bugs

   Highly encouraged, but rarely works

2. Add `printf` statements everywhere

   Highly discouraged, but sometimes works.

   In case of memory problems – tipically due toaos

3. Use a DEBUGGER

   That is definitely the best choice and, fortunately, the subject of this lecture.

Introducing debugging

gdb is almost certainly the best free, extremely feature-rich command-line debugger ubiquitously available on *niX systems.

There are 3 basic usages(*) of GDB:

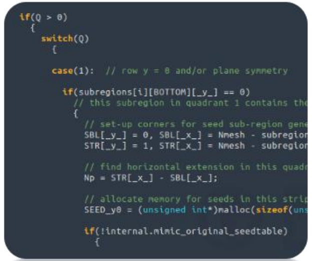
1. Debugging a code
   best if it has been compiled with −g

2. Inspecting a code crash through a core file

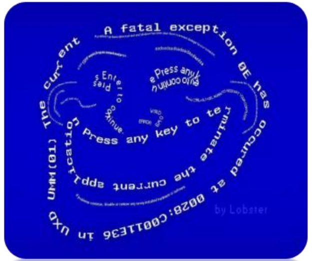
3. Debugging / inspecting a running code

(*) Higly advised: learn keyboard commands. Although many gui exist (we'll see some later), keyboard is still the best productivity tool.

Debugging outline



Debugging a code



Inspecting a code crash

Debugging a running process(es)

Compiling with dbg infos

In order to include debugging information in your code, you need to compile it with –g family options (read the gcc manual for complete info):

-g	produce dbg info in O.S. native format
-ggdb	produce gdb specific extended info, as much as possible
-g*level*	default level is 2. 0 amounts to no info, 1 is minimal, 3 includes extra information (for instance, macros expansion) – this allows macro expansion; add **-gdwarf-*n*** in case, where possibile, where *n* is the maximum allowed (4)
-ggdb*level*	you can combine the two to maximize the amount of useful info generated
	remember: **-fno-omit-frame-pointer**, especially if you are using –Ox

Debugging: start

▶ live demo with **gdb_try_args.c**

You just start your code under `gdb` control:

```
%> gdb program
```

You can define the arguments needed by your program already at invocation:

```
%> gdb --args program arg1 arg2 … argN
```

Or you can define the arguments from within the gdb session:

```
%> gdb program
Reading symbols from program...done.
(gdb) set args arg1 arg2 … argN
(gdb) run
```

Debugging: run & stop

You may just want the code to run, for instance to reach the point of a seg fault:

```
%> (gdb) run
```

Or, you may want to stop it from the beginning to have full control of each step:

```
%> (gdb) break main
%> (gdb) run
```

Or you may already know what is the problematic point to stop at:

```
%> (gdb) break location
%> (gdb) run
```

Debugging: run & stop

Breakpoints are a key concept in debugging. They are stopping point at which the execution interrupts and the control is given back to you, so that you can inspect the memory contents (variables values, registers values, …) or follow the subsequent execution step by step.

You can define a breakpoint in several way

`(gdb) break`	insert a break at the current pos
`(gdb) break ± offset`	insert a break *offset* lines after/before the current line
`(gdb) break filename:linenum`	insert a break at *linenum* of file *filename*
`(gdb) break functionname`	insert a break at the entry point of function *functionname*

`There are more options, just check the manual`

Debugging: run & stop

A breakpoint may be defined as dependent on a given condition:

```
(gdb) break my_function if (arg1 > 3 )
```

This sets a breakpoint at function *my_function* : the condition will be evaluated each time the point is reached, and the execution is stopped only if it is true.

Condition can be any valid expression.

```
(gdb) info break
```

gives you informations on active breakpoints.

```
(gdb) delete [n]
      clear [location]
      <disable | enable>   see the manual
```

Debugging: run & stop

You can define a list of commands to be executed when a given breakpoint is reached:

```
(gdb) break my_function if (arg1 > 3 )
Breakpoint 1 at 0x……………: file blabla.c, line 42
(gdb) command 1
Type commands for when breakpoint 1 is hit, one per
line.
End with a line saying just "end".
> print arg1
> print another_useful_variable
> x/10wd a_global_integer_array
> end
```

Debugging: run & stop

When you have the control of the program execution, you can decide how to proceed:

`(gdb) cont [c]`	continue until the end / next stop
`(gdb) cont` *`count-ignore`*	continue ignoring the next *count-ignore* stops (for instance, a bp)
`(gdb) next [n]` | *`count`* `nexti`	continue to the next src line *in the current stack frame*
`(gdb) step [s]` | *`count`* `stepi`	continue to the next src line
`(gdb) until [u]` | *`count`*	continue until a src line past the current one is reached in the current stack fr.
`(gdb) advance` *`location`*	continue until the specified location is reached

▶ live demo with **`gdb_try_breaks.c`**

Debugging: run & stop

You can also rewind your execution step-by-step

```
(gdb) reverse-continue [rc]

(gdb) reverse-step [count]
      reverse-stepi

(gdb) reverse-next [count]
      reverse-nexti

(gdb) set exec-direction <verse | forward >
```

Debugging: source list

Often, when you are debugging, you may have the need of looking at either the source lines or at the generated assembler:

▶ live demo with `gdb_try_breaks.c`

`(gdb) list` *`linenum`*	print src lines around line *linenum* of the current source file
`(gdb) list` *`function`*	print the source lines of *function*
`(gdb) list` *`location`*	print src lines around *location*
`(gdb) set listsize` *`count`*	control the number of src lines printed
`(gdb) disass [`*`/m`*`][`*`function`*`][`*`location`*`]`	show the assembler

Debugging: stack examination

Examining the stack is often of vital importance. With GDB you can have a quick and detailed inspection of all the stack frames.

`backtrace[args]`	print the backtrace of the whole stack
n	print only the *n* innermost frames
-*n*	print only the *n* outermost frames
full	print local variables value, also
`where, info stack`	additional aliases

▶ live demo with `gdb_try_breaks.c`

Debugging: memory examination

▶ live demo with `gdb_try_breaks.c`

Accessing to the content of memory is a fundamental ability of a debugger. You have several different ways to do that:

`(gdb) print` *`variable`*	print the value of *variable*
`p/F` *`variable`*	print *variable* in a different format (`x,d,u,o,t,a,c,f,s`) *see then manual for advanced location*
`(gdb) x/FMT` *`address`*	Explore memory starting at address *address* -> see at live demo how to use this
`(gdb) display` *`expr`*	Add *expr* to the list of expressions to display each time your program stops
`display/`*`fmt expr`* `display/`*`fmt addr`*	

Debugging: memory examination

Memory can be searched to find a particular value, of a given size

```
(gdb) find [/sn] start, end, val1 [,val2, …]

      find [/sn] start, +len, val1 [,val2, …]
```

Search memory for a particular sequence of bytes.
s is the size of type to be searched
n is the max number of occurrences

Debugging: registers examination

Examining registers may be also useful (although it's something that only quite advanced users can conceive)

`(gdb) info registers`	print the value of all registers
`(gdb) info vector`	print the content of vector registers
`(gdb) print $rsp`	print value of the stack pointer
`(gdb) x/10wd $rsp`	print values of the first 10 4-bytes integers on the stack
`(gdb) x/10i $rip`	print the next 10 asm instructions

Debugging: macro expansion

If there are macros in your code, they can be expanded, provided that you compiled the code with the appropriate option:

-g3 [gdb3][-dwarf-4]

`(gdb) macro expand` *macro*	shows the expansion of macro *macro*; *expression* can be any string of tokens
`(gdb) info macro [-a|-all]` *macro*	shows the current (or all) definition(s) of *macro*
`(gdb) info macros` *location*	shows all macro definitions effective at *location*

Debugging: watch points

▶ live demo with **`gdb_try_watch.c`**

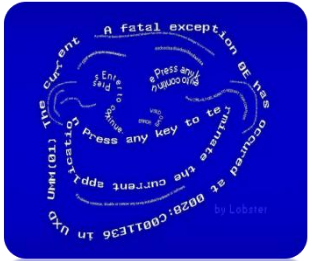
You can set *watchpoints* (aka "keep an eye on this and that") instead of breakpoints, to stop the execution whenever a value of an expression / variable / memory region changes

`(gdb) watch` *`variable`*	keep an eye onto *variable*
`(gdb) watch` *`expression`*	stops when the value of expression changes (the scope of variables is respected)
`(gdb) watch -l` *`expression`*	Interpret *expression* as a memory location to be watched
`(gdb) watch -l` *`expression`* `[mask` *`maskvalue`*`]`	a mask for memory watching: specifies what bits of an address should be ignored (to match more addressese)
`(gdb) rwatch [`*`-l`*`]` *`expr`* `[mask` *`mvalue`*`]`	stops when the value of *expr* is read

Debugging outline

Introduction

Debugging
a code



Inspecting
a code crash

Debugging
a running
process(es)

After a crash : having the core file

It happens that you have code crashes in conditions not easily reproducible when you debug the code itself, for a number of reasons.

However, the O.S. can dump the entire "program status" on a file, called the *core file*:

```
luca@GGG:~/code/tricks% ./gdb_try_watch
no arguments were given, using default: 100

something wrong at point 2
[1]    8435 segmentation fault (core dumped)  ./gdb_try_watch
luca@GGG:~/code/tricks% ls -l core
-rw------- 1 luca luca 413696 nov  8 15:45 core
luca@GGG:~/code/tricks% 
```

In order to allow it to dump the core, you have to check / set the core file size limit:

```
%> ulimit -c [size limit in KB]
```

After a crash : inspect the core file

Once you have a core, you can inspect it with GDB

```
%> gdb executable_name core_file_name
```

Or

```
%> gdb executable_name
  (gdb)core core_file_name
```

The first thing to do, normally, is to unwind the stack frame to understand where the program crashed:

```
  (gdb) bt full
```

Debugging outline

Introduction

Debugging
a code

Inspecting
a code crash

Debugging
a running
process

Attach to a process

In order to debug a running process, you can simply attach gdb to it:

```
%> gdb
(gdb) attach process-id
```

live demo with **gdb_try_attach.c**

and start searching it to understand what is going on

Debugging outline

GUI

for GDB

More friendly interfaces

1. GDB text-user-interface
2. GDB DASHBOARD
3. GDBGUI
4. EMACS
5. DDD
6. NEMIVER, ECLIPSE, NETBEANS, CODEBLOCKS, many others..

GDB built-in **tui**

You can start gdb with a text-user-interface:

```
%> gdb -tui
```

Or you can activate/deactivate it from gdb itself:

`(gdb)ctrl-x a`	
`(gdb)ctrl-x o`	change focus
`(gdb)ctrl-x 2`	shows assembly windows
`(gdb)layout src`	display src and commands
`asm`	display assembly and commands
`split`	display src, asm and commands
`regs`	display registers window

GDB built-in **tui**

```
   ┌─gdb_try_breaks.c──────────────────────────────────────────────────────────────────────
   │372      {
   │373
B+>│374          if ( argc > 1)
   │375            // arg 0 is the name of the program itself
   │376            {
   │377              printf( "\nexploring my %d argument%c:\n", argc-1, (argc>2)?'s':' ' );
   │378                for ( int i = 1; i < argc; i++ )
   │379                  {
   │380                    printf( "\targument %d is : %s\n", i, *(argv+i) );
   │381                  }
   │382                printf( "\n" );
   │383            }
   │384
   │385          else
   │386
   │387            printf ( "no arguments were given, using default: %d\n\n", DEFAULT_ARG1 );
   │388
   │389
   │390          int arg1;
   │391
   │392          if ( argc > 1 )
   │393            arg1 = atoi( *(argv+1) );
   │394
   │395          else
   │396            arg1 = DEFAULT_ARG1;
   │397
   │398          int ret;
   │399
   │400          ret = function_1( arg1 );
   └───────────────────────────────────────────────────────────────────────────────────────
native process 8943 In: main                                          L374   PC: 0x555555554d38
(gdb) l
360     in /home/luca/code/tricks/gdb_try_breaks.c
(gdb) break main
Breakpoint 1 at 0xd38: file gdb_try_breaks.c, line 374.
(gdb) r
Starting program: /home/luca/code/tricks/gdb_try_breaks

Breakpoint 1, main (argc=1, argv=0x7fffffffdaa8) at gdb_try_breaks.c:374
(gdb)
```

GDB built-in **tui**

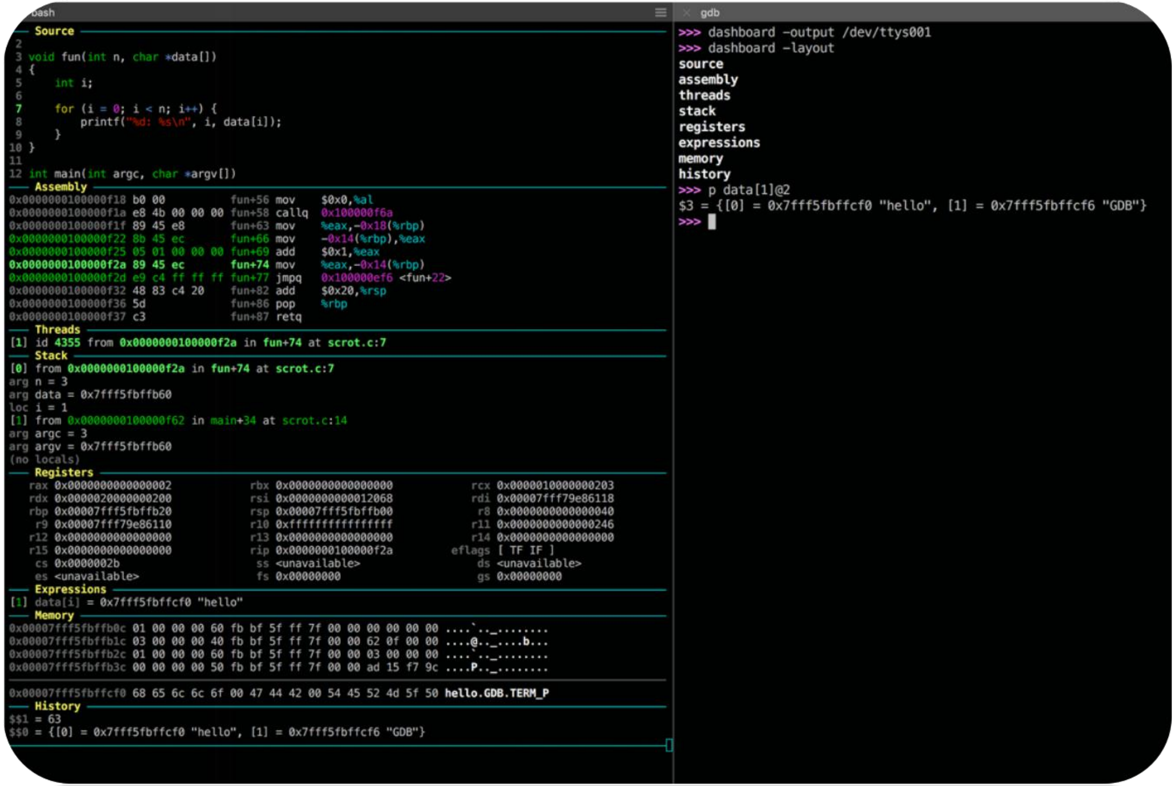
```
  ┌─gdb_try_breaks.c─────────────────────────────────────────────────────────────┐
B+>│374         if ( argc > 1)                                                    │
   │375           // arg 0 is the name of the program itself                      │
   │376           {                                                               │
   │377             printf( "\nexploring my %d argument%c:\n", argc-1, (argc>2)?'s':' ' );
   │378               for ( int i = 1; i < argc; i++ )                            │
   │379                 {                                                         │
   │380                   printf( "\targument %d is : %s\n", i, *(argv+i) );      │
   │381                 }                                                         │
   │382               printf( "\n" );                                             │
   │383           }                                                               │
   │384                                                                           │
   │385         else                                                              │
   │386                                                                           │
   │387           printf ( "no arguments were given, using default: %d\n\n", DEFAULT_ARG1 );
   └──────────────────────────────────────────────────────────────────────────────┘
B+> 0x555555554d38 <main+15>        cmpl   $0x1,-0x14(%rbp)
    0x555555554d3c <main+19>        jle    0x555555554db7 <main+142>
    0x555555554d3e <main+21>        cmpl   $0x2,-0x14(%rbp)
    0x555555554d42 <main+25>        jle    0x555555554d4b <main+34>
    0x555555554d44 <main+27>        mov    $0x73,%edx
    0x555555554d49 <main+32>        jmp    0x555555554d50 <main+39>
    0x555555554d4b <main+34>        mov    $0x20,%edx
    0x555555554d50 <main+39>        mov    -0x14(%rbp),%eax
    0x555555554d53 <main+42>        sub    $0x1,%eax
    0x555555554d56 <main+45>        mov    %eax,%esi
    0x555555554d58 <main+47>        lea    0x2bf(%rip),%rdi        # 0x55555555501e
    0x555555554d5f <main+54>        mov    $0x0,%eax
    0x555555554d64 <main+59>        callq  0x555555554680 <printf@plt>
    0x555555554d69 <main+64>        movl   $0x1,-0xc(%rbp)

native process 9102 In: main                                  L374  PC: 0x555555554d38
(gdb) break main
Breakpoint 1 at 0xd38: file gdb_try_breaks.c, line 374.
(gdb) r
Starting program: /home/luca/code/tricks/gdb_try_breaks

Breakpoint 1, main (argc=1, argv=0x7fffffffdaa8) at gdb_try_breaks.c:374
(gdb) layout split
```

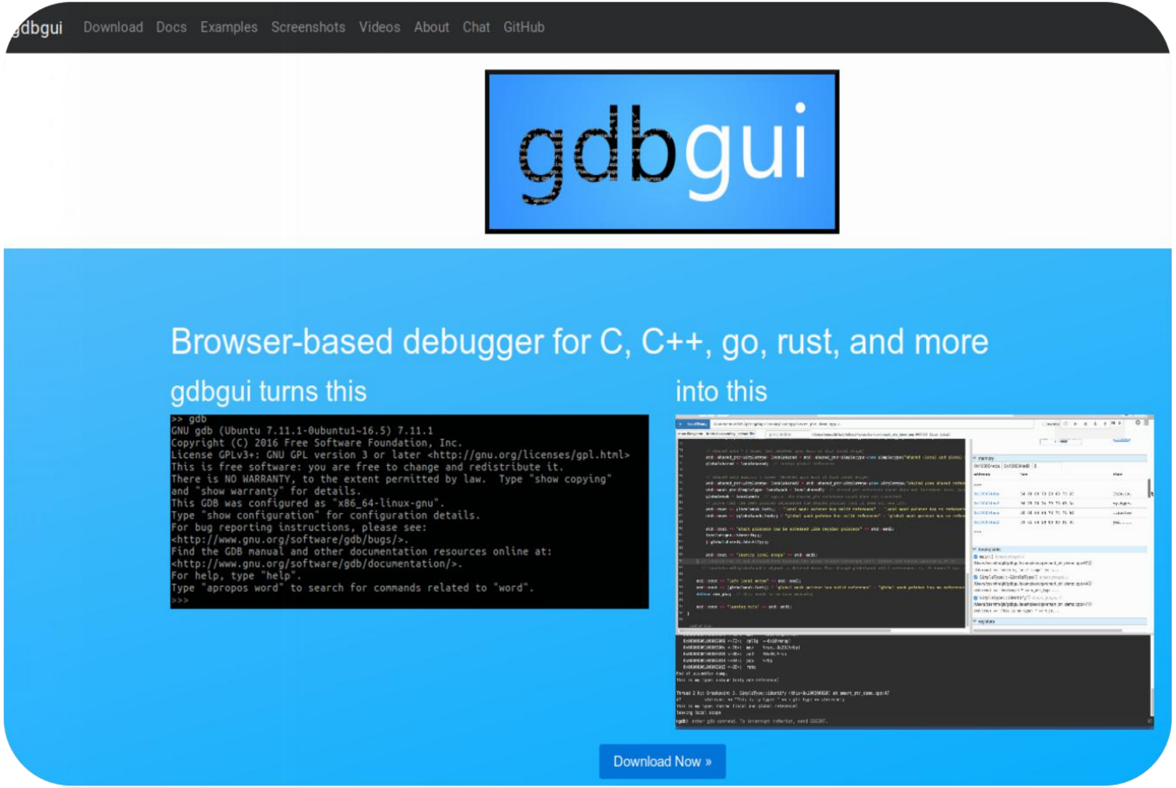
| GDB dashboard

https://github.com/cyrus-and/gdb-dashboard



GDBgui

https://gdbgui.com/



that’s all, have fun