

CyberSecurity: Principle and Practice

*BSc Degree in Computer Science
2022-2023*

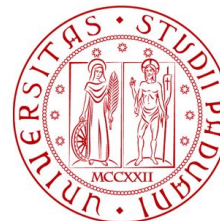
Lesson 13: Debugging

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DIPARTIMENTO
MATEMATICA

All information presented here has the only purpose of teaching how reverse engineering works

Use your mad skillz only in CTFs or other situations in which you are legally allowed to do so

Do not hack the new Playstation. Or maybe do, but be prepared to get legal troubles 😊

Fact:

- Debug is a strong tool that allows inspecting any process
 - Originally: For developers to solve problems
 - For attackers to exploit the vulnerabilities!

Consequence:

- Security Eng. developed techniques to automatically recognize whether a process is under debug
 - And possibly change behaviour based on this
 - (this is called “anti-debug”)

Topics:

- How a debugger works in linux
- Some classic anti-debug techniques
- How to deactivate anti-debug protections

More theory here

<http://www.alexonlinux.com/how-debugger-works>

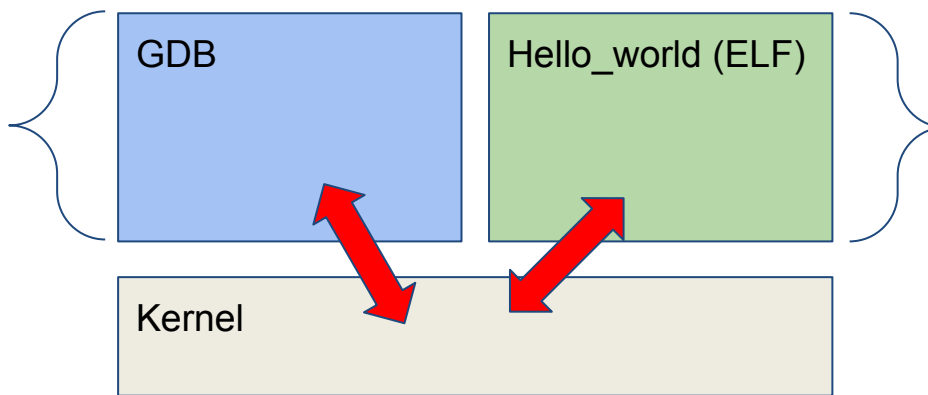
Components and Interactions

Debugger:

(can be any process)

spawn a new process
or
attach existing process

can debug > 1 process



Debuggee:

(can be any process)

can be debugged by
ONLY 1 process

Kernel:

Handles the interaction between
debugger and debugee.

Provides tools to perform the
debug: **ptrace()**

ptrace() aka our swiss-knife

ptrace() is a Linux syscall that allows a process (tracer/**debugger**) to inspect and control another process (tracee/**debuggee**).

So, **debugger** uses **ptrace()** to control **debuggee**, e.g., step-to-step, change variables, insert breakpoints.

signature:

```
long ptrace(enum __ptrace_request request, pid_t pid, void *addr, void *data);
```

args:

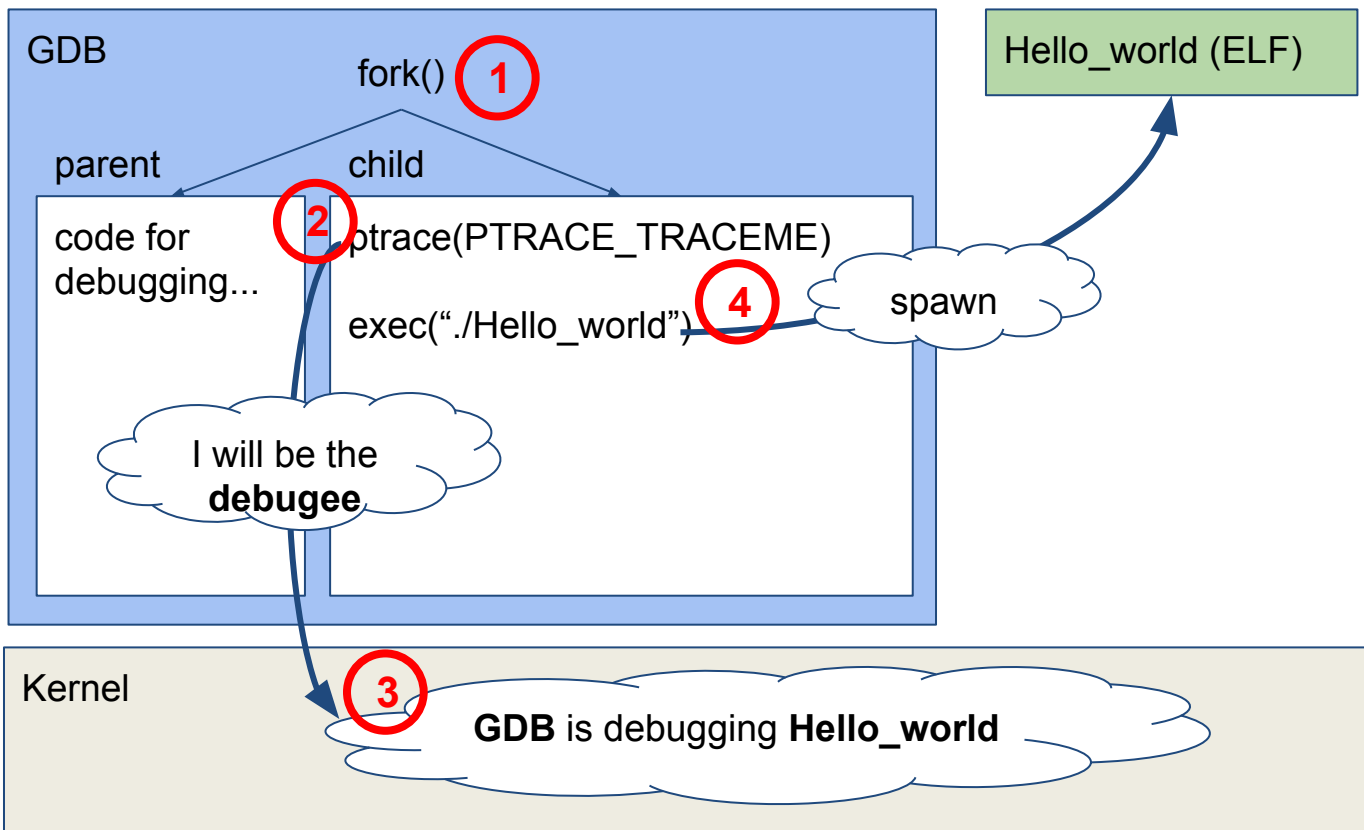
- *request*: type of “action” that a **debugger** performs over **debuggee**
 - (e.g., read from memory, write into memory, get/set registers value)
- *PID*: the process to attach to (can attach to itself)
- *addr* and *data* are used to transfer data from/to **debuggee**

return:

- TL;TR; -1 if something wrong, otherwise depends by **request**

Source: <http://man7.org/linux/man-pages/man2/ptrace.2.html>

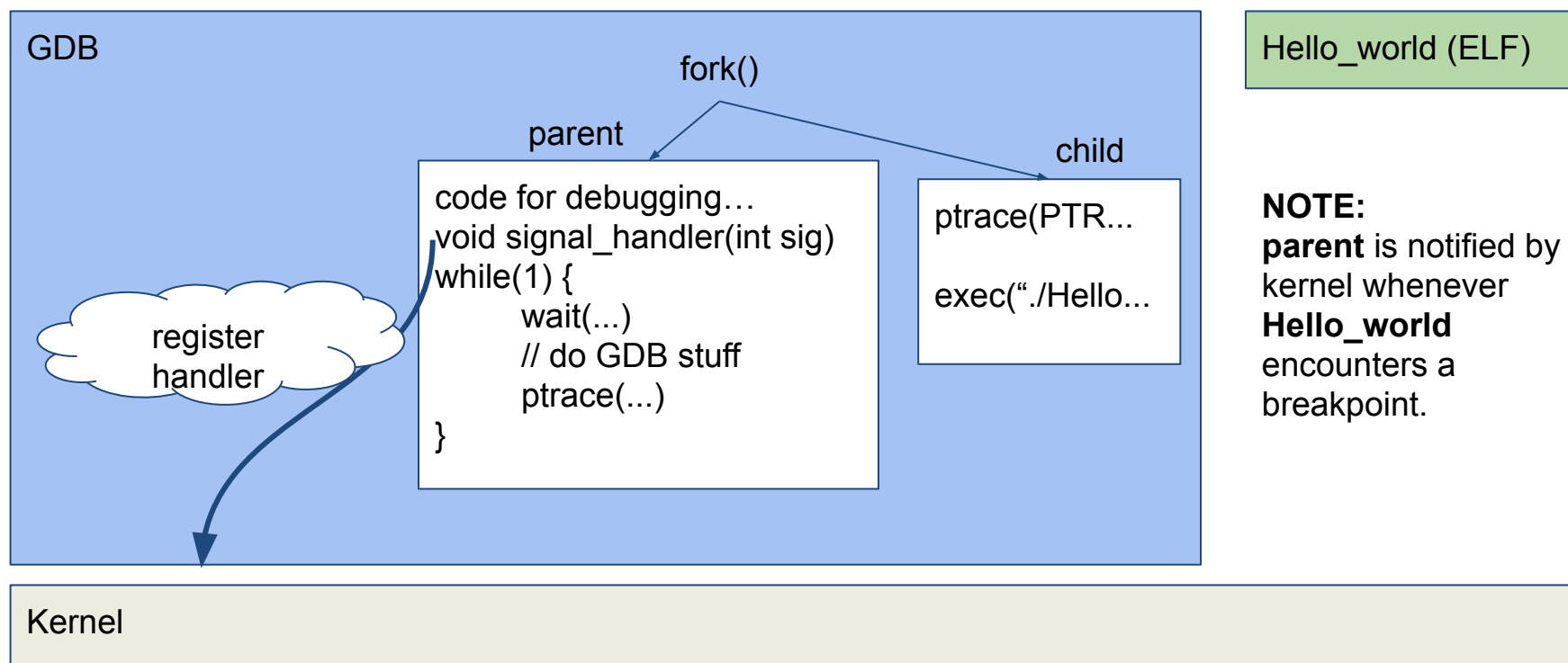
Spawning the debugee process



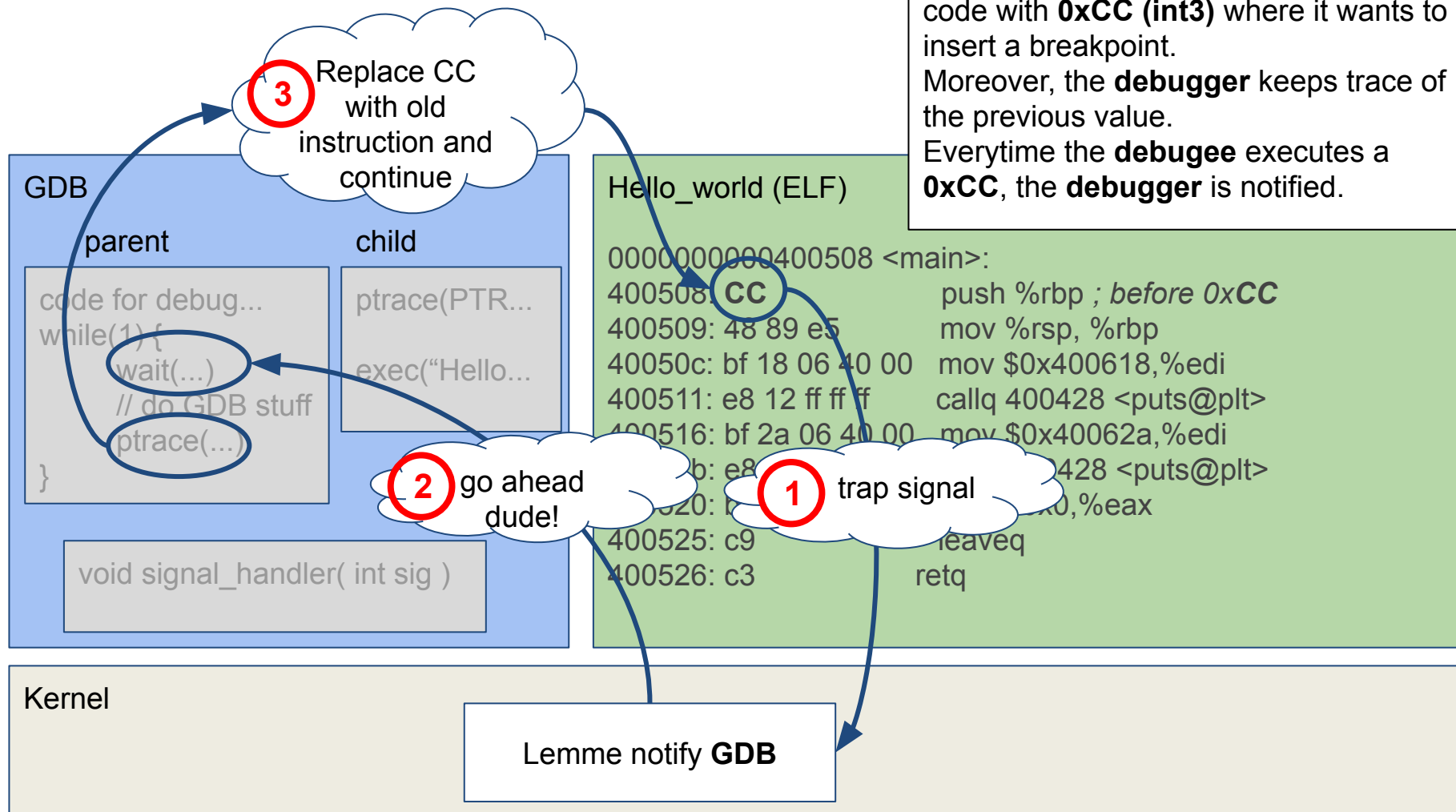
NOTE: `ptrace()` also allows to attach to a process already spawned

Registering signal handler

GDB registers to receive appropriate signals from the kernel... (triggered by the debuggee)



Debugger - Debuggee Interactions



The **debugger** overwrites the assembly code with **0xCC (int3)** where it wants to insert a breakpoint. Moreover, the **debugger** keeps trace of the previous value. Everytime the **debuggee** executes a **0xCC**, the **debugger** is notified.

Debugging - Quick recap



- the debugging process is mediated by the kernel
- **ptrace()** is the swiss-knife to debug processes
- a **debugger** can debug multiple processes
- a **debuggee** can be debugged by only a single **debug**
- breakpoints are nothing but **0xCC** instructions injected in the **debuggee** process
- the **debugger** keeps track of the original values of **debuggee**
- **strace()**, **GDB**, etc., relies on **ptrace()** to work

Again, I don't want somebody to touch my things!

Question: how the program “understand” if somebody is debugging it?

yeeeeeh, depends...

check ptrace()



Very Important and
most common in
challenges!

```
#include <stdio.h>
#include <sys/ptrace.h>
int main(int argc, char** argv) {
    if (ptrace(PTRACE_TRACEME, 0, NULL, NULL) == -1) {
        puts("there is already a debugger");
        return 1;
    }
    ptrace(PTRACE_DETACH, 0, NULL, NULL);
    puts("I am fine!");

    return 0;
}
```

If PTRACE_ME returns an error, someone
is already debugging the program.
Remember: only one debugger at time!

GDB env variable

```
#include <stdio.h>
#include <stdlib.h>
```

GDB creates detectable env variables.
If they exist, GDB is running!

```
int main(int argc, char** argv) {
    if (getenv("LINES") || getenv("COLUMNS"))
        puts("there is already a debugger");
    else
        puts("I am fine!");

    return 0;
}
```

GDB heap relocated

```
#include <stdio.h>
#include <stdlib.h>

int main(int argc, char** argv) {
    //put var in bss (since var has no val)
    static unsigned char var_in_bss;
    //put var in heap and get addr
    unsigned char *probe = malloc(0x10);

    if (probe - &var_in_bss > 0x20000) {
        printf("I am fine\n");
    } else {
        printf("I got you GDB!\n");
    }
    return 0;
}
```

GDB relocates the heap
to the end of the bss section (section
containing variables declared but not
assigned)

NOTE: 0x20000 is standard bss
size, if less -> the heap has
been relocated

GDB no-ASLR (Address Space Layout Randomization)

GDB allocates libraries and text in specific addresses (disabling ASLR) that can be recognized (for example base address of ELF and shared libraries)

If these elements are found in those specific addresses, GDB is detected

Who is my parent?

```
pid_t parent = getppid();  
  
link_target = read("/proc/$parent/exe")  
if (!strcmp(basename(link_target), "gdb"))  
    res = RESULT_YES;  
if (strstr(link_target, "lldb"))  
    res = RESULT_YES;  
if (!strcmp(basename(link_target), "strace"))  
    res = RESULT_YES;  
if (!strcmp(basename(link_target), "ltrace"))  
    res = RESULT_YES;
```

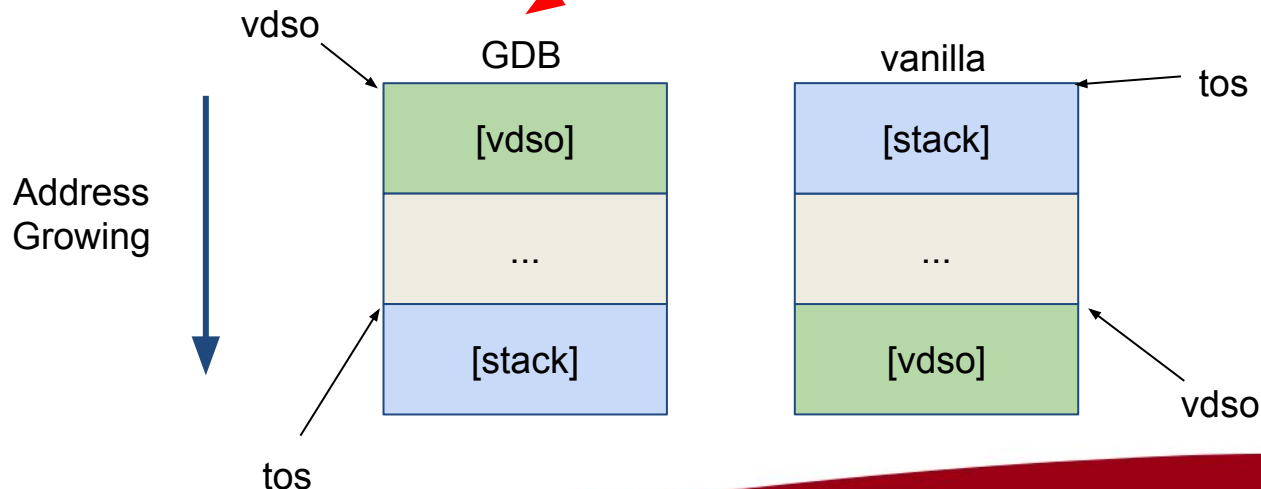
The parent process can be inspected
If my parent is GDB, lldb, strace, ltrace or any debugger, we can detect it!

VSDO (virtual dynamic shared object)

```
unsigned long tos; // top of stack  
unsigned long vdso = getauxval(AT_SYSINFO_EHDR);
```

```
if ((unsigned long)&tos > vdso)  
    return RESULT_YES;  
else  
    return RESULT_NO;
```

GDB moves the VDSO
before the stack
Checking their addresses, we can
detect GDB



How to bypass anti-debug stuffs?



Patch the binary!

Main steps:

- 1) look for implementation of anti-debug techniques
 - e.g., check for ptrace(), 0xCC, getenv(), ...
 - check also non **main** thread:
 - **.init** and **.fini** (and other) sections might also contain implementations of anti-debug techniques
(http://beefchunk.com/documentation/sys-programming/binary_formats/elf/elf_from_the_programmers_perspective/node3.html)
- 2) Use Hex Editor or radare to patch

- 1) john galt is having some problems with his email again. But this time it's not his fault. Can you help him?
- 2) Using a debugging tool will be extremely useful on your missions. Can you run this program in gdb and find the flag?
- 3) The program detects if it is run into a debugger. Please remove the check!
- 4) The program runs several checks to detect a debugging environment. If running into gdb, every test should FAIL. Patch the program to obtain PASS in every check even when running into GDB

Questions? Feedback? Suggestions?



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