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The Roman Xploit

# A gentle introduction to the art of exploitation

## Part 1 : Buffer overflow 101

by anticlockwise & malweisse

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# About us

The Roman Xpl0it

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Cyberchallengers 2017

We founded TheRomanXpl0it and started pwning right after

Then mHACKeroni with Milan, Venice and Padua guys, to participate to DEFCON CTF

← Microarchitectural attacks

Fuzzing and binary analysis →


# What can possibly go wrong?


what do you see?

```
0x58 0x33 0x58 0x30
```

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# What can possibly go wrong?

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what do you see?

```
0x58 0x33 0x58 0x30
```

ascii?

```
>>> '58335830'.decode('hex')
'X3X0'
```

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# What can possibly go wrong?

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what do you see?

```
0x58 0x33 0x58 0x30
```

an integer?

```
0x30583358 = 811086680
```

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# What can possibly go wrong?

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what do you see?

```
0x58 0x33 0x58 0x30
```

an address?

```
0x30583358  <main>
```

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# What can possibly go wrong?

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what do you see?

```
0x58 0x33 0x58 0x30
```

code?

```
0: 58          pop rax
1: 33 58 30    xor ebx,DWORD PTR [rax+0x30]
```

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# What can possibly go wrong?

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what do you see?

```
0x58 0x33 0x58 0x30
```

kim?

# What can possibly go wrong?

what do you see?

```
0x58 0x33 0x58 0x30
```

they are just bytes!

```
0x58 0x33 0x58 0x30
```

It is just the context that gives the meaning to the bytes

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# What can possibly go wrong?

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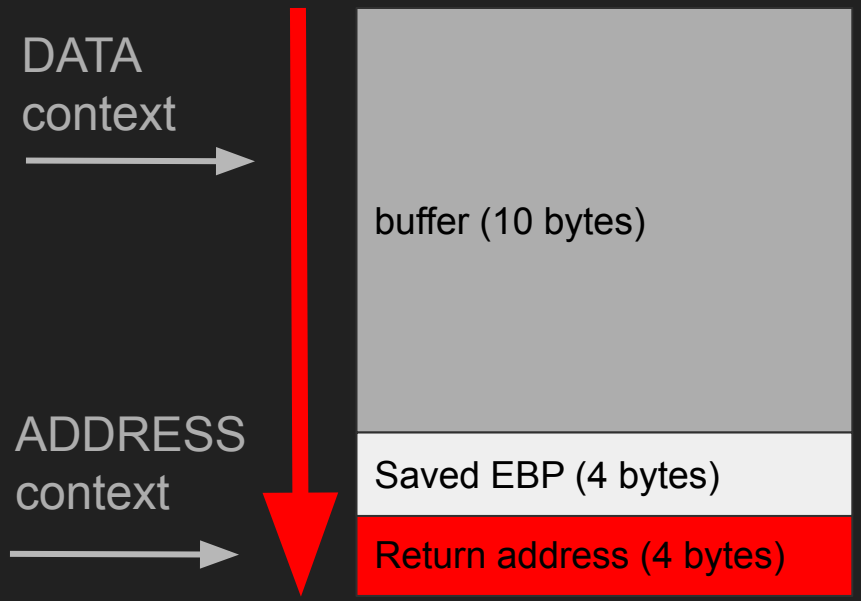
```
0x58 0x33 0x58 0x30
```

Any time you mess with the context you open the window to exploitation

A vulnerability allows us to make the CPU manage bytes in the wrong context

# Buffer overflow

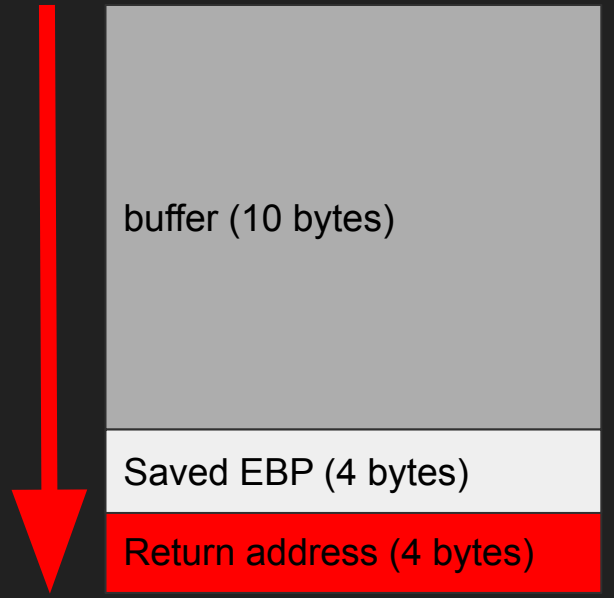
```
void foo() {

    char buffer[10];

    scanf("%s", buffer); //DOH

}
```



# Buffer overflow

Let’s override the return address content!

After foo() the execution will be resumed from the return address.



# Buffer overflow

For example:

“aaaaaaaaaa” + “aaaa” + addr_to_return

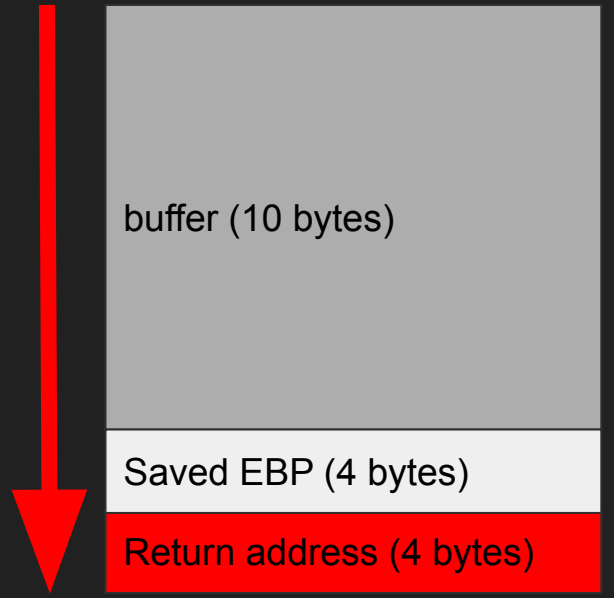
padding (10)  ebp

# Buffer overflow

```
void foo() {
        char buffer[10];
        scanf(“%s”, buffer); //DOH
}
```

⇒ return anywhere you want!

but… Where?



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# Data or Code? Shellcode!

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- Mix up code and data is the worst possible vulnerability!
- A shellcode is the payload you manage to execute

1. Write the shellcode in memory (as DATA  context)
   - es: read(0, buffer, 0x1000)

2. Redirect the execution to the shellcode (as CODE context)
   - es: overwrite the return address with a vulnerability

3. WIN

- Assuming you can write in a RWX page... (Who said “please switch to ROP”?)


# Shellcode?


- Assume:
  1. You can write to RWX memory
  2. You can override the return address to jump to RWX memory

- What do you write?

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# Shellcode?

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- Assume:
  1. You can write to RWX memory
  2. You can override the return address to jump to RWX memory

- What do you write?

⇒ Usually the goal is to spawn a shell in the victim server

`system("/bin/sh")` will do the job!

But, how do you call it, if is not present in the binary?

⇒ Implement it with your shellcode!

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# Spawn a Shell!

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Let's dissect system!

Browse the source code of glibc/sysdeps/posix/system.c
do_system

```
116 #ifdef FORK
117   pid = FORK ();
118 #else
119   pid = __fork ();
120 #endif
121   if (pid == (pid_t) 0)
122     {
123       /* Child side.  */
124       const char *new_argv[4];
125       new_argv[0] = SHELL_NAME;
126       new_argv[1] = "-c";
127       new_argv[2] = line;
128       new_argv[3] = NULL;
129
130       /* Restore the signals.  */
131       (void) __sigaction (SIGINT, &intr, (struct sigaction *) NULL);
132       (void) __sigaction (SIGQUIT, &quit, (struct sigaction *) NULL);
133       (void) __sigprocmask (SIG_SETMASK, &omask, (sigset_t *) NULL);
134       INIT_LOCK ();
135
136       /* Exec the shell.  */
137       (void) __execve (SHELL_PATH, (char *const *) new_argv, __environ);
138       _exit (127);
139     }
```

# Spawn a Shell!

`__execve` is the stub for the execve system call: the system call that transforms the calling process into a new process to execute.

It sets for `32 bits`:

`eax` -> `0x0b`
`ebx` -> address of “`/bin/sh`”
`ecx` -> `NULL`
`edx` -> `NULL`

then executes:

`int 0x80`

or for `64 bits`:

`rax` -> `0x3b`
`rdi` -> address of “`/bin/sh`”
`rsi` -> `NULL`
`rdx` -> `NULL`

then executes:

`syscall`

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# Spawn a Shell!

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Therefore our shellcode will be something like:

```
push 0x68732f    ←
push 0x6e69622f  ← Write /bin/sh into the stack
mov    ebx, esp
mov    ecx, 0x0
mov    edx, 0x0
mov    eax ,0xb
int    0x80
```

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# Spawn a Shell!

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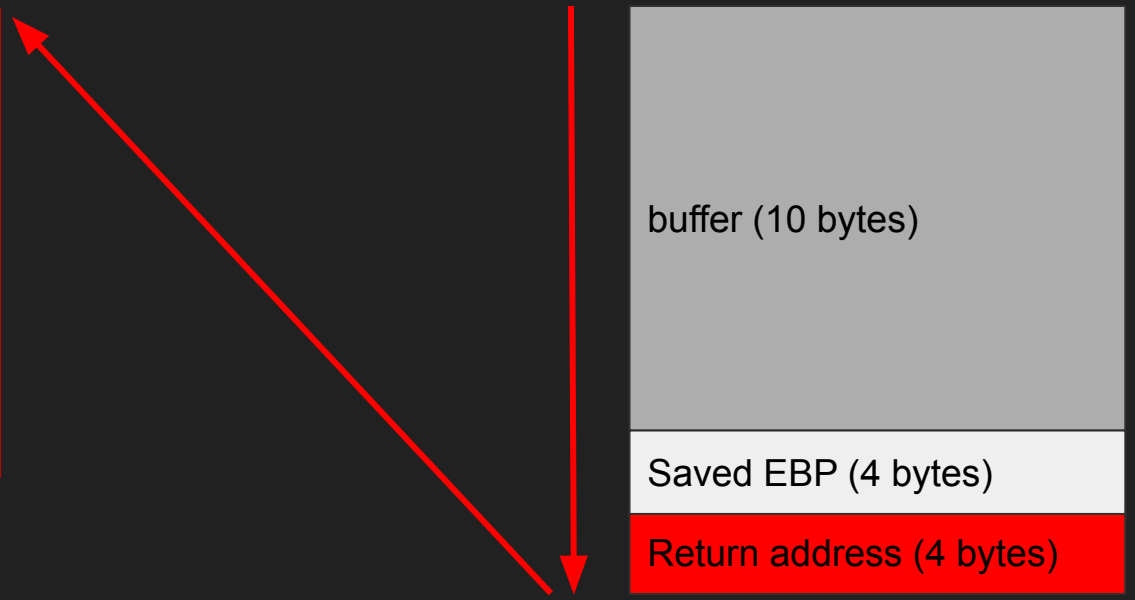
Write the shellcode in RWX memory and jump to it!

```
push 0x68732f
push 0x6e69622f
mov    ebx, esp
mov    ecx, 0x0
mov    edx, 0x0
mov    eax ,0xb
int    0x80
```




# Are shellcodes dead?


- All modern OS enforce NX protection:
  - No region in the binary can be writable and executable at the same time when compiling -> no RWX regions!


# Are shellcodes dead?


- All modern OS enforce NX protection:
  - No region in the binary can be writable and executable at the same time when compiling -> no RWX regions!

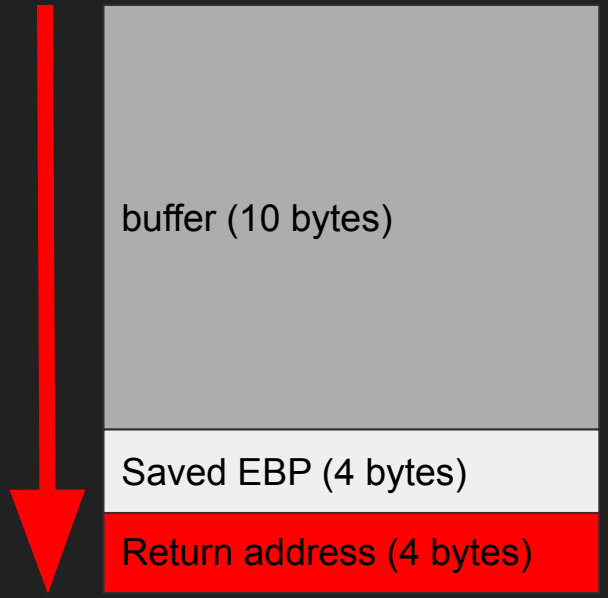
- But any self modifying program will need writable and executable pages!
  - Browser JIT compilers
  - Browser WASM compilers
  - QEMU (sometimes not enforces neither ASLR nor NX)

⇒ Still useful to know how shellcodes work

# Buffer overflow returned

```
void foo() {
        char buffer[10];
        scanf(“%s”, buffer); //DOH
}
```

⇒ Now we have NX so we cannot jump to shellcode!

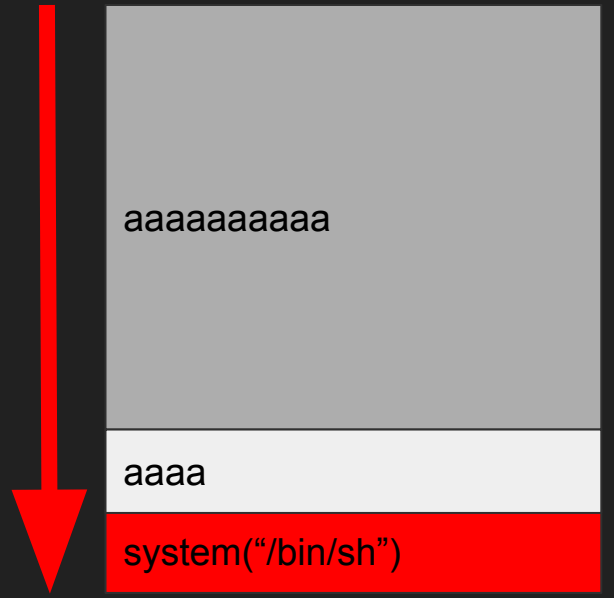


# Buffer overflow

We can still put anything we want in addr_to_return!

Calling system(“/bin/sh”) will execute a shell in the current context

But what if we don’t have system available to call?



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# Spawn a Shell!

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We need to execute something similar to:

```
mov     ebx, /bin/sh_string_address
mov     ecx, 0x0
mov     edx, 0x0
mov     eax ,0xb
int     0x80
```

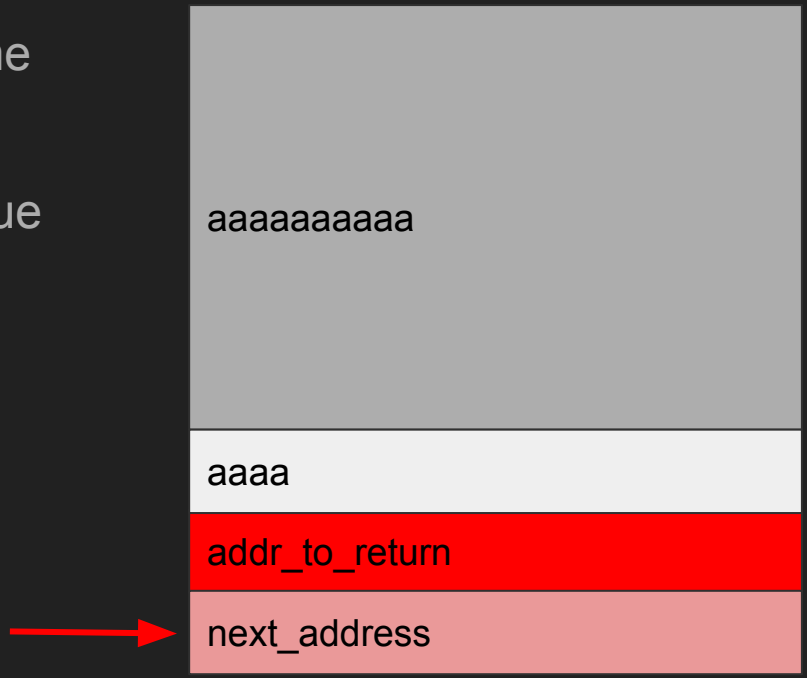
But how?

… Let’s notice something

# Composing a chain

If addr_to_return point to some code that ends in “ret”

the execution will then continue from the address after




...and we can iterate again and again

# Composing a chain

So why we don’t insert more than one address to return to?

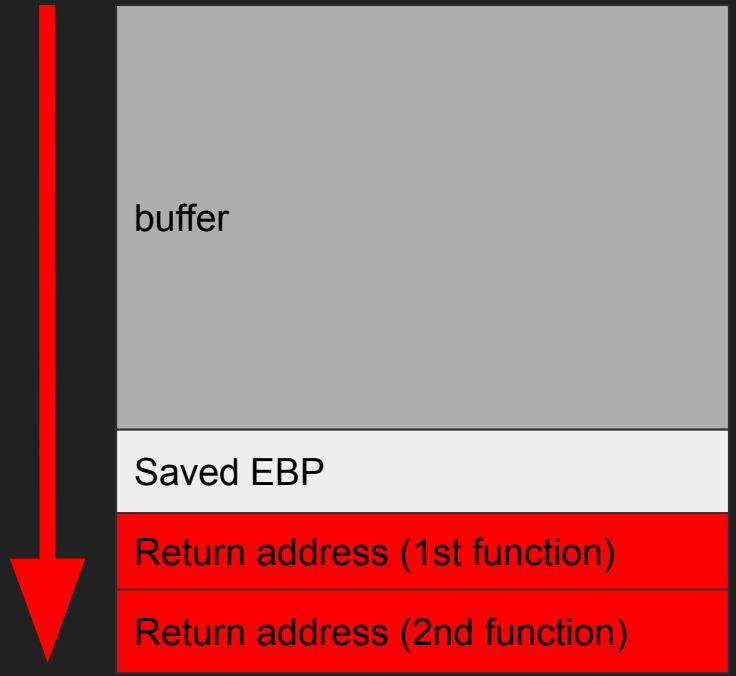
For example:

“aaaaaaaaaa” + “aaaa” + fn1_addr + fn2_addr

padding (10) ebp

# Composing a chain

```
fn1:
        mov eax, 0xabadcafe
        ret
fn2:
        mov ecx, eax
        ret
```



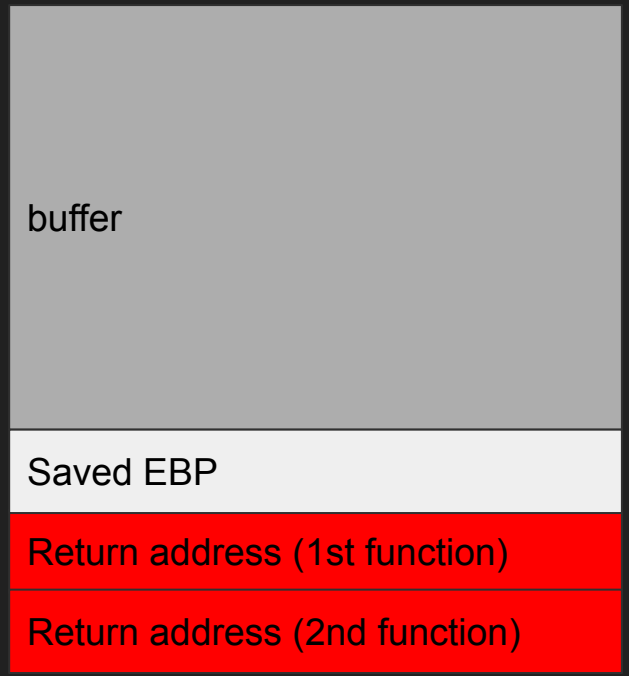
# Composing a chain

```
foo:

    …

    ret
```

EIP

EAX: ?
ECX: ?

ESP



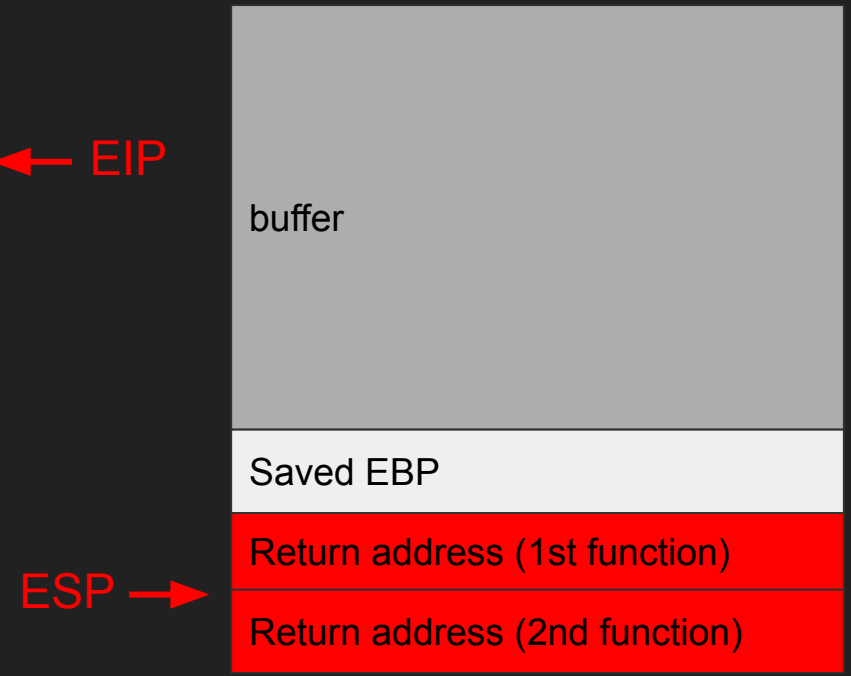
# Composing a chain

fn1:

mov eax, 0xabadcafe ← EIP

ret

EAX: ?
ECX: ?

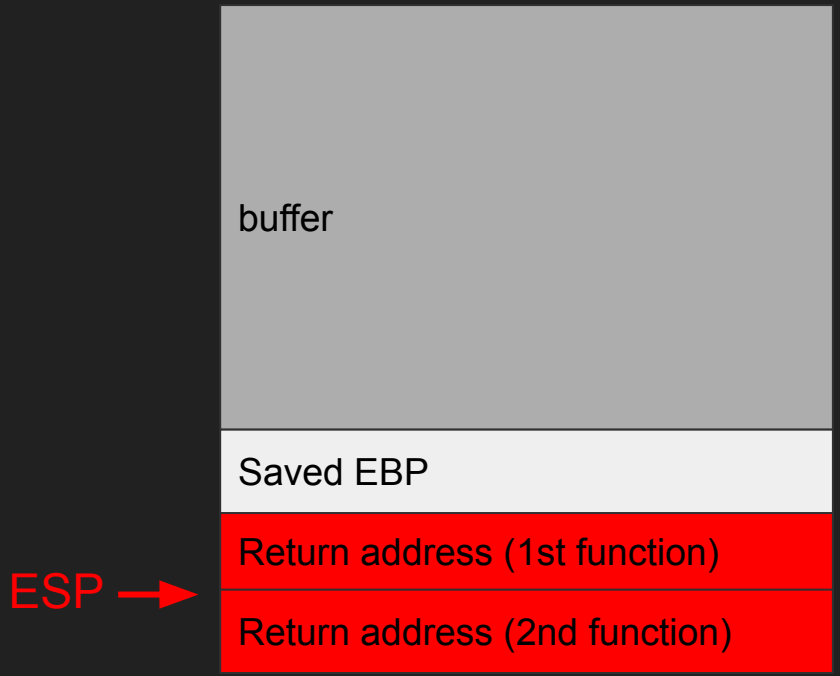


# Composing a chain

```
fn1:
    mov eax, 0xabadcafe
    ret
```

EIP

EAX: 0xabadcafe
ECX: ?

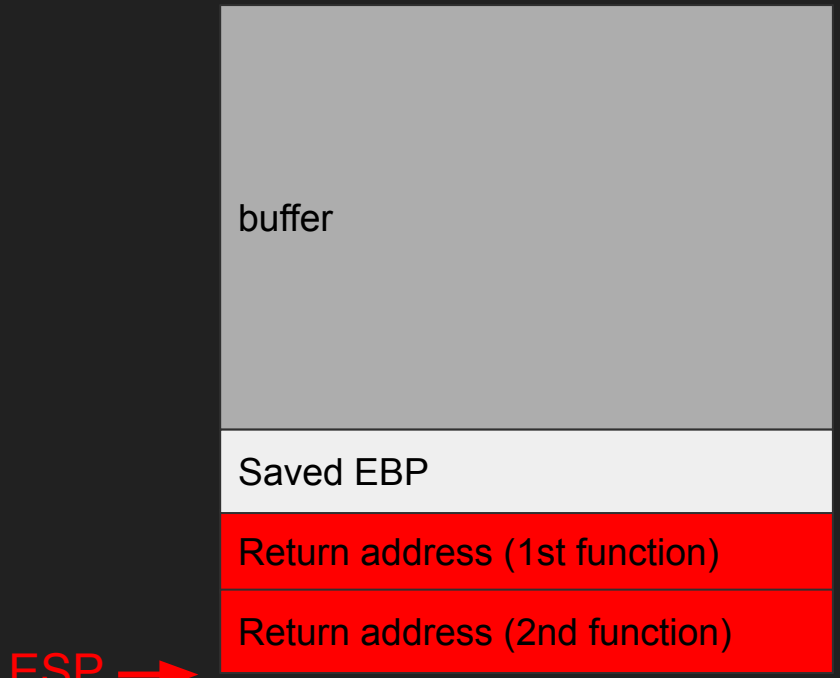


# Composing a chain

```
fn2:
    mov ecx, eax
    ret
```

EIP

EAX: 0xabadcafe
ECX: ?



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# Composing a chain

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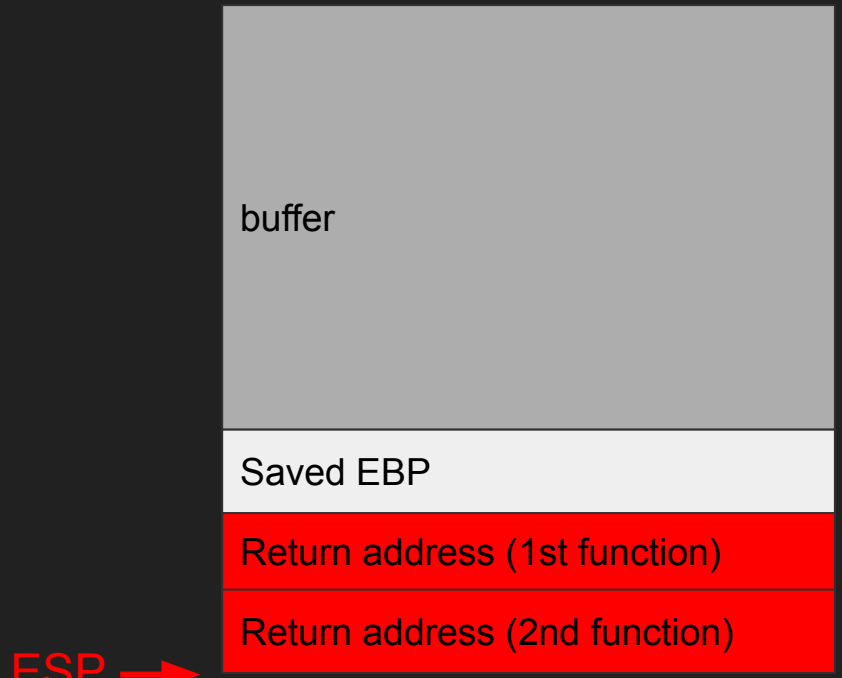
```
fn2:
    mov ecx, eax
    ret
```

EIP

EAX: 0xabadcafe
ECX: 0xabadcafe



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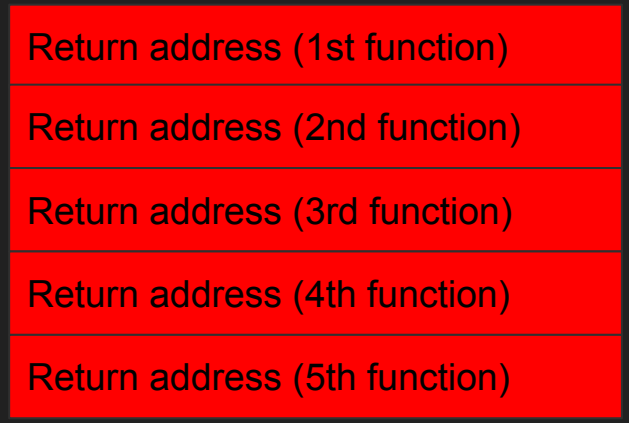
# Composing a chain

The Roman Xploit

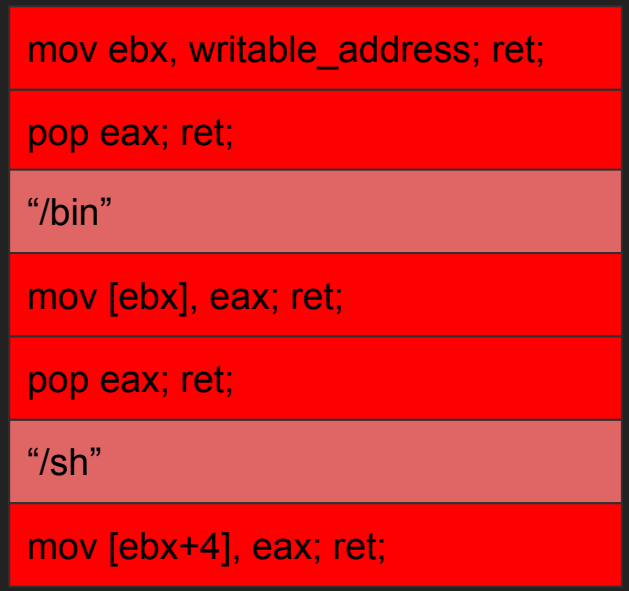
We can insert addresses to return to execute, as long as we want!

BUT: every piece of code we execute must end with a ret instruction, to continue the chain



# Composing a chain

For example, let’s load ebx with the address of a /bin/sh string




Now ebx points to the /bin/sh string

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# Gadgets

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x86 instructions are not aligned:

mov ah, 90; ret ---> b4 5a c3 pop edx; ret ---> 5a c3

Every sequence of bytes endings with ret (0xc3) can be used to build a chain.

Find these sequences with tools like ROPGadget or ropper.

$ ROPGadget --binary <bin_to_pwn>
or
$ ropper -f <bin_to_pwn>


# Existing Countermeasures


- ASLR
- Stack Canary
- NX
- PIE

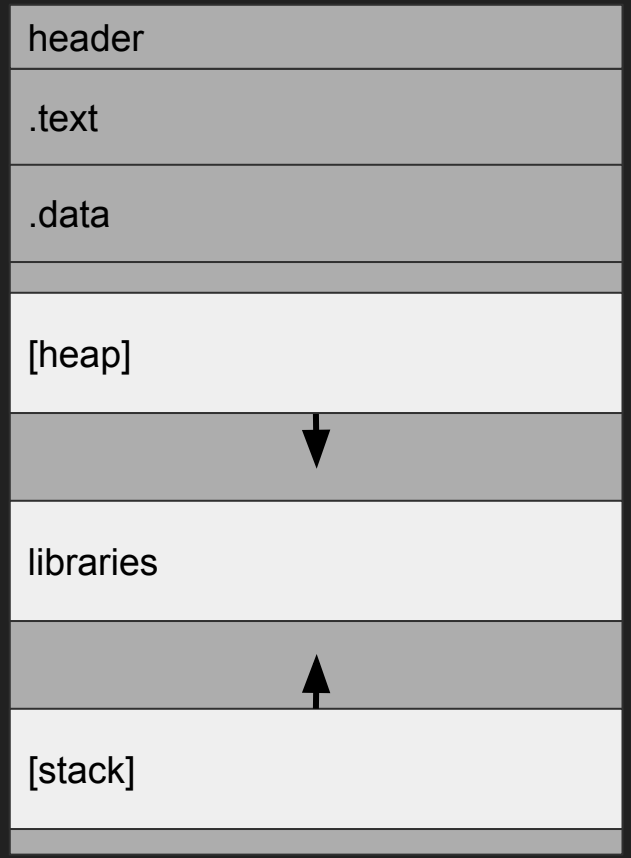
# ASLR

Address Space Layout Randomization

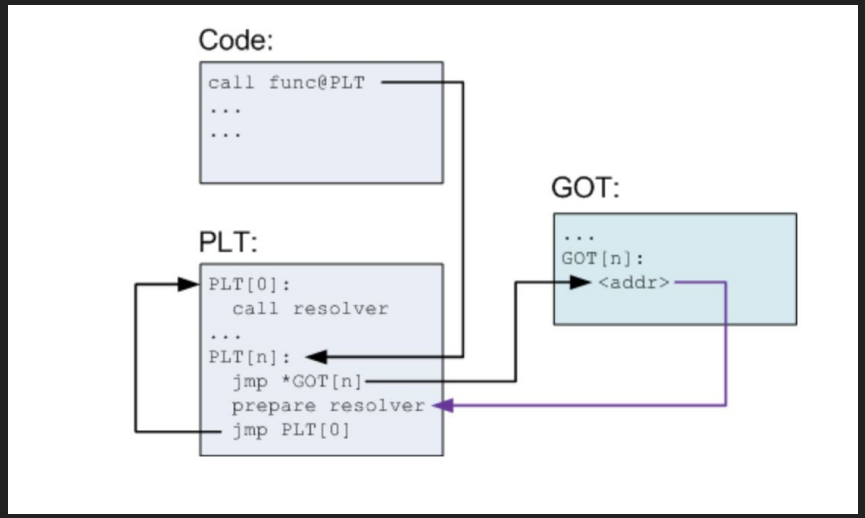
is a protection technique that randomizes

the base address of stack, heap and

library code



# The GOT and the PLT

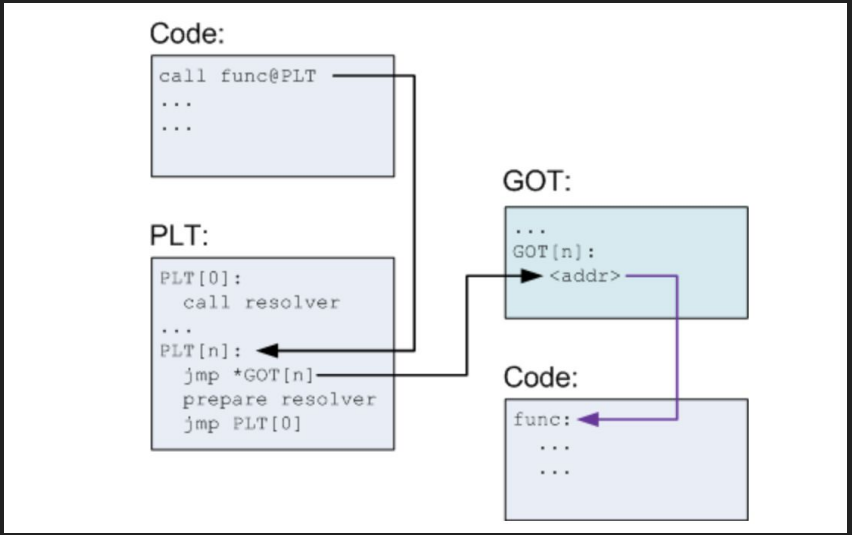



when called for the first time, func@PLT will jump to the corresponding

got_entry:<func_loader_stub>

that will call the loader for the function

# The GOT and the PLT




then the loader will replace the entry with the right address, consulting at runtime the symbol map of the library, to resolve the randomized address

got_entry: <address of func in libc>

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# Stack Canary

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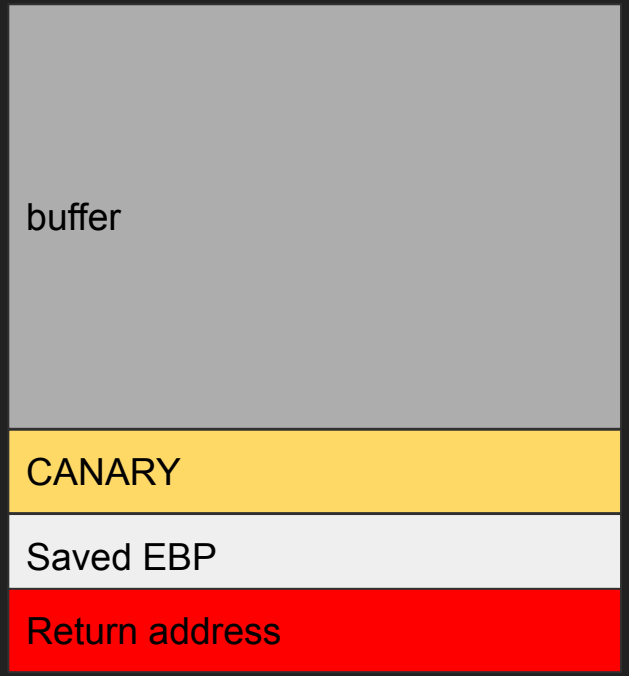
A random value is automatically inserted before any return address and checked that remained the same before doing any ret instruction.

To modify the return address need to overwrite the canary.

The program is crashed if the canary is modified!



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# NX

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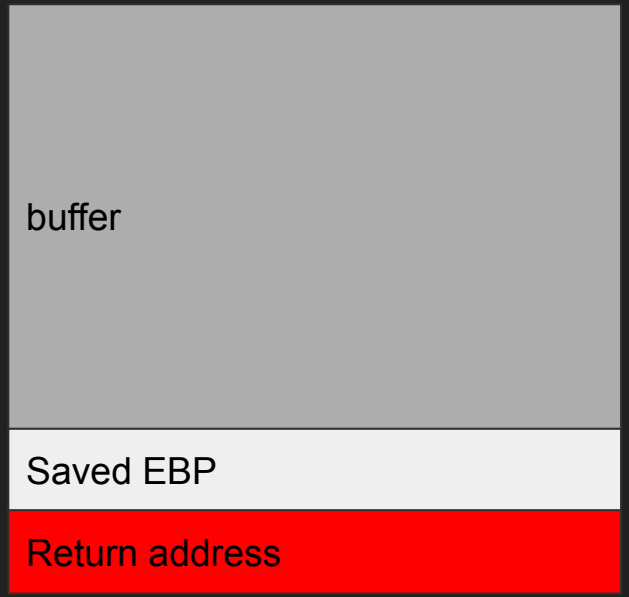
No region in the binary can be writable and executable at the same time when compiling.

ROP is not affected by this protection in any way ;)

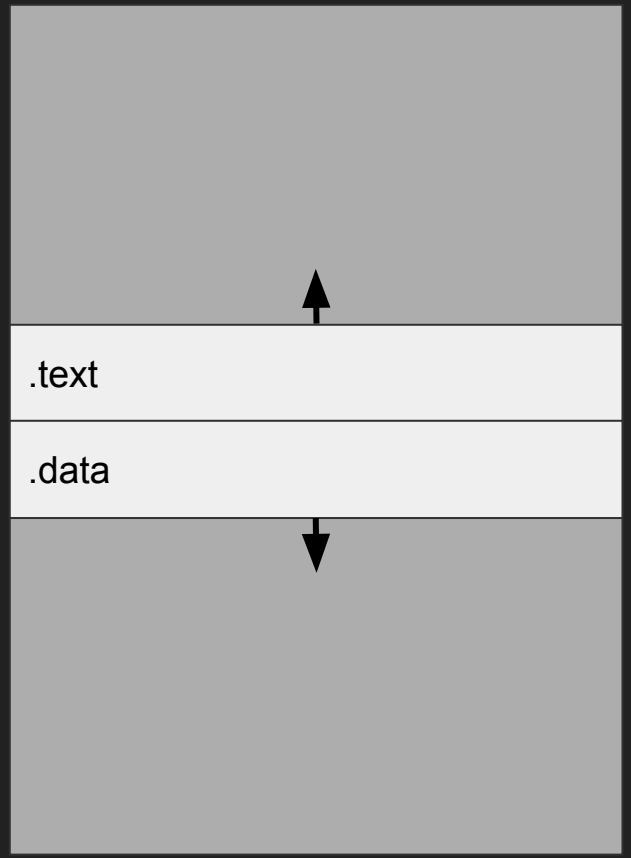
Only against classical shellcodes



# PIE

Position Independent Executables (PIE) are binaries made entirely by position independent code. The base of the whole executable is loaded at random memory position.

ROP mitigation, since need to discover the base address before the exploit can begin.



# Other Protections



- Partial RelRO
- Full RelRO

  See https://mudongliang.github.io/2016/07/11/relro-a-not-so-well-known-memory-corruption-mitigation-technique.html

- Control flow integrity

  See https://nebelwelt.net/blog/20160913-ControlFlowIntegrity.html

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# Ultimate Protection

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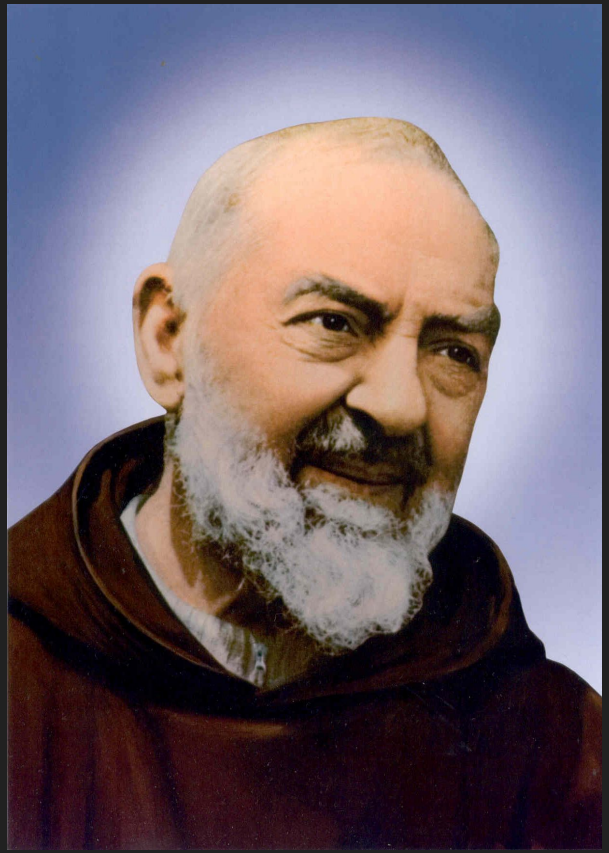

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# Ultimate Protection 2020 version

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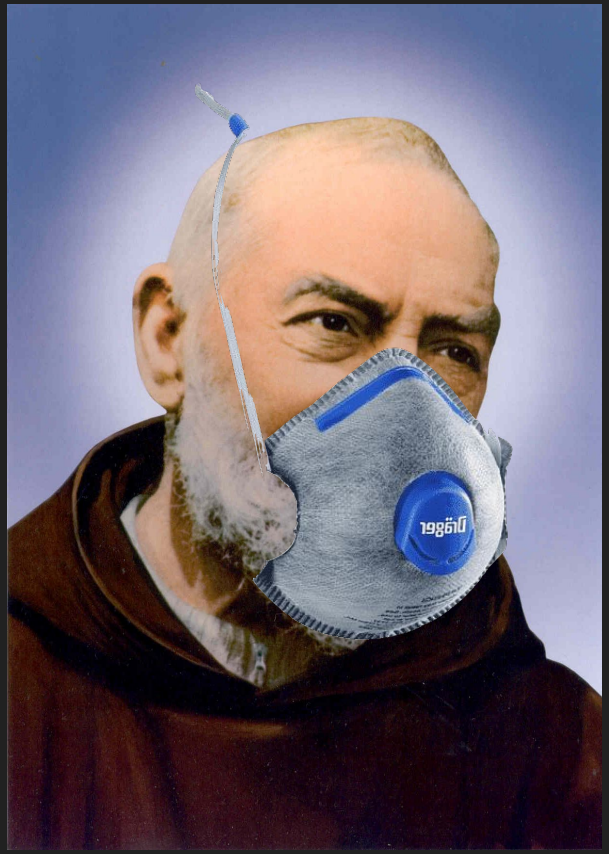

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# Now it’s your turn!

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https://cyberchallenge.diag.uniroma1.it


# TODO


```
pip2 install ropper

pip2 install pwntools

install gef: https://gef.readthedocs.io/en/master/
```