Hacking in C

Attacks 3 and memory safety
Thom Wiggers

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printf is Turing complete

Defeating W⊕X

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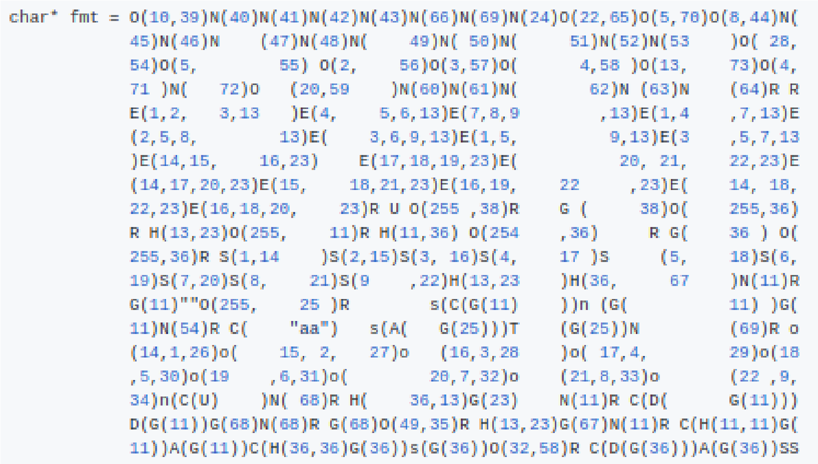

```
char* fmt = O(10,39)N(40)N(41)N(42)N(43)N(66)N(69)N(24)O(22,65)O(5,70)O(8,44)N(
            45)N(46)N    (47)N(48)N(    49)N( 50)N(     51)N(52)N(53    )O( 28,
            54)O(5,        55) O(2,    56)O(3,57)O(      4,58 )O(13,    73)O(4,
            71 )N(   72)O   (20,59    )N(60)N(61)N(       62)N (63)N    (64)R R
            E(1,2,   3,13   )E(4,    5,6,13)E(7,8,9        ,13)E(1,4    ,7,13)E
            (2,5,8,        13)E(    3,6,9,13)E(1,5,         9,13)E(3    ,5,7,13
            )E(14,15,    16,23)    E(17,18,19,23)E(          20, 21,    22,23)E
            (14,17,20,23)E(15,    18,21,23)E(16,19,    22     ,23)E(    14, 18,
            22,23)E(16,18,20,    23)R U O(255 ,38)R    G (     38)O(    255,36)
            R H(13,23)O(255,    11)R H(11,36) O(254    ,36)     R G(    36 ) O(
            255,36)R S(1,14    )S(2,15)S(3, 16)S(4,    17 )S     (5,    18)S(6,
            19)S(7,20)S(8,    21)S(9    ,22)H(13,23    )H(36,     67    )N(11)R
            G(11)""O(255,    25 )R        s(C(G(11)    ))n (G(          11) )G(
            11)N(54)R C(    "aa")   s(A(   G(25)))T    (G(25))N         (69)R o
            (14,1,26)o(    15, 2,   27)o   (16,3,28    )o( 17,4,        29)o(18
            ,5,30)o(19    ,6,31)o(        20,7,32)o    (21,8,33)o       (22 ,9,
            34)n(C(U)    )N( 68)R H(    36,13)G(23)    N(11)R C(D(      G(11)))
            D(G(11))G(68)N(68)R G(68)O(49,35)R H(13,23)G(67)N(11)R C(H(11,11)G(
            11))A(G(11))C(H(36,36)G(36))s(G(36))O(32,58)R C(D(G(36)))A(G(36))SS
```

Figure: tic-tac-toe in a format string

https://github.com/carlini/printf-tac-toe

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- Is W⊕X the end of attacks on programs that do not contain a function `give_me_shell_pls()`?

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- Whole of `libc` usually loaded in most programs.
- Does `libc` contain `give_me_shell_pls()`?
- Answer: Kinda.
- `system`

system

```
int system(const char* command);
```

“The `system()` library function uses `fork()` to create a child process that executes the shell command specified in `command`...”

Return to libc

If we can somehow prepare the argument for `system()`, we can overwrite the return address with the address of `system()` and start the shell...

Back in the days of yore

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   - Alternatively, set up return address to address of `exit()`

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- We call such snippets gadgets

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Note that we write multiple return addresses, which means we need to write `NULL` bytes on AMD64!

Countermeasures

- Can make sure a `0x00` is in the address of `libc`
  - Will stop string functions from reading past it
  - Mainly helps on x86, AMD64 addresses already contain `0x00` bytes
  - Only complicates string-based attacks
- Remove functionality from `libc`
  - What is necessary, and what is not though?
  - Compatibility issues?
  - What code exactly can cause problems?

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- `libc` contains enough gadgets to allow ROP to be Turing-complete
- There are tools to automate the search for gadgets and ROP chains.

ROP: Example

vulnfunc()

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...
retq
```

0xcafebabe

```
...
pop %rdi
retq
```

0xfeedface

```
...
xor %rax, %rax
retq
```

0xdeadbeef

```
...
mov %rdx, %rax
pop %rsi
retq
```

(corrupted) stack

0x7f1229d0f4a0 (execlp)
0x7f1229dd9f20 (‘‘/bin/sh’’)
0xdeadbeef
0xfeedface
0x7f1229dd9f20 (‘‘/bin/sh’’)
0xcafebabe
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registers

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registers

rax	unknown
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rdi	0x7f1229dd9f20
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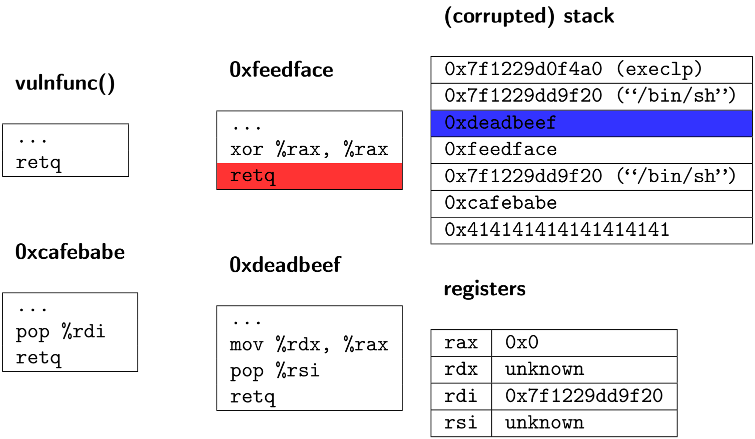
ROP: Example



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Will now jump to `execlp` with arguments in `rdi`, `rsi`, `rdx`
i.e. `execlp(‘‘/bin/sh’’, ‘‘/bin/sh’’, NULL);`

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- Depending on your Linux distribution, these may be turned on by default.

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Largely solved on 64-bit machines

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  - Which of the two threads needs to `free`, ...

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- Also garbage-collected

Rust's solution

Observations

- Fixing bugs takes longer than spending more time on compile-time checks
- You can generate a lot of code with checks and rely on the compiler (LLVM) to optimize any unnecessary bits out.

Arrays

- Fixed-size arrays contain the size in the type of the function

  ```
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- This means that the compiler can turn `array[10]` into a compiler error when it won't find such a function.
- Of course, for `array[var]` you will simply need to check if you're within bounds.
- Buffers for which the size is not known at compile time can only be put in resizable vectors.

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- Yet you do not want to burden the programmer with calling `free`...

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let value = Foo(); // create value
func(value);    // move value into func
value           // <-- compiler error
```

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error[E0597]: `x` does not live long enough
  --> src/main.rs:3:26
3 | { let x = 5; r = &x; }
  |                   ^^  - `x` dropped here
  |                   |
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- About type systems and compiler design

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- Rust shows that you don't need a runtime environment to generate fast code.
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What has Rust learnt

- C specifies undefined behaviour and forces the programmer to avoid it
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    - Master's course

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printf is Turing complete

Defeating W⊕X

ASLR

Memory safety

Some announcements

Exercise 4

A write-up for exercise 4 is available on my website.

Exercise 5

Solutions to exercise 5 will be presented tomorrow, by me, in the tutorial.

Q&A

After the presentation of the solutions, I will have time to answer questions.

Exam

I will also talk a bit more about the exam tomorrow.

The deadline for the exam is on the last day of the exam period, so Friday 3 July.

The exam will be a set of assignments. They will be in varying levels of difficulty.

You will be graded mainly on the write-up that you produce, much less so on if you manage to complete them all. We will be looking for you demonstrating a systematic approach, your analysis of what you see happening, and your understanding of the course material.

Exam (cont.)

The exam assignments will be individual. You can use any normal resource (books, internet); try to include what you use in your write-up and explain why any such thing applies. You are not supposed to work with other people or course participants on these assignments, however.