Hadrien Barral
Georges-Axel Jaloyan

3COLE NORMALE SUPÉRIEURE,
PSL RESEARCH UNIVERSITY

D3FC0N

3MOJI 5HELLCODING: 🛠️, 🧌, AND 🤯

WHO WE ARE

- Hadrien Barral: Hacker  . I like hacking stuff.
- Georges-Axel Jaloyan: PhD ~~student~~. I reverse open source binaries.
- This is our third/second talk at D3FC0N.

WHAT THIS IS ABOUT

- Some generic 🛠️ and methods
- ... with lots of emoji 🧌
- ... to write 🤯 shellcodes.

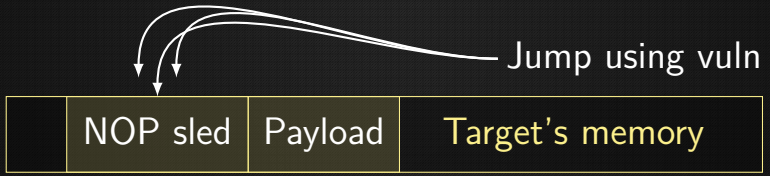
1. WHY WOULD ANYONE WRITE CONSTRAINED SHELLCODES?

SHELLCODE 101

For those hiding in the back

- Code that you wrote (or found) in the target's memory
- That gives you some power (e.g. pop a shell)
- That you can jump to using some vuln (e.g. buffer overflow, UAF...)

Usual scenario: send a carefully crafted string to the target and profit.



SHELLCODE 102

Not as convenient as you may think

- If treated as a C string, no \x00
- If treated as input, no whitespace
- Other constraints (regex)
- Breaks easily (string escaping)
- Does not really look legit 🤔

HAVING FUN WITH X86

rix, Phrack 57, 2001 + Basu et al., ICISS, 2014

Constrained shellcoding on x86 is easy:

ASCII	IA32
'P'	push %eax
'h'	push imm32
'X'	pop %eax
'a'	popa
'A'	inc %eax
'H'	dec %eax
't'	je short disp8
'u'	jnz short disp8
'v'	jbe short disp8
'8'	cmp r/m8 r8
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- `push`/`pop`/`inc`/`dec` have single letter instructions!
- `jmp` and `cmp` are available
- `xor` with many operands are available
- 🤦 for x86-64: just prefix `0x48` (= `H`) to every instruction

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CRAZY PEOPLE EVEN MADE ENGLISH SHELLCODES

Mason et al., CCS, 2009

Click here for the demo

ALPHANUMERIC SHELLCODING: TAKING RISCS

RISC – *reduced* instruction set computer...

- No single character instructions anymore
- Few addressing modes – in particular no memory to memory
- Heavy constraints on operands

Previous technique does not work on RISC architectures! 😱

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Compilation / Emulation / Unpacking

THE ``COMPILATION'' WAY

Idea:

- Compile assembly code to a constrained instruction set

Pros:

- Feasible for one-instruction set computers (e.g Movfuscator on x86)

Cons:

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Pros:

- Feasible for one-instruction set computers (e.g Movfuscator on x86)

Cons:

- Does not work when the constraints are mainly on the operands and not on the opcodes
- ...nobody wants to devote their life to writing such a compiler 😰

THE ``EMULATION'' WAY

Younan et al., Phrack 66, 2009

Idea:

- Write an interpreter for some language

Pros:

- Reusable for different payloads
- e.g. Younan's ARMv7 alphanumeric Brainfuck interpreter

Cons:

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Younan et al., Phrack 66, 2009

Idea:

- Write an interpreter for some language

Pros:

- Reusable for different payloads
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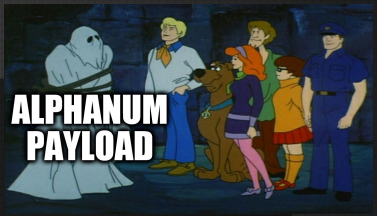
Cons:

- Harmfulness now relies on the interpreter...

THE ``UNPACKING'' WAY

Barral et al., ISPEC 2016



Idea:

- Encode payload in a constraint-compliant way (e.g. alphanumerically)

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Idea:

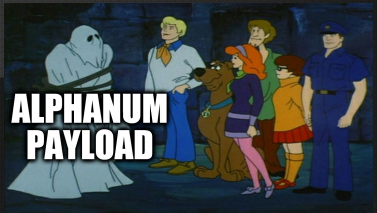
- Encode payload in a constraint-compliant way (e.g. alphanumerically)
- Identify high-level constraint-compliant constructs (zeroing/increasing registers, ...)

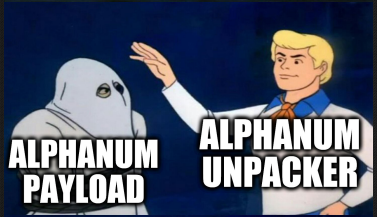
THE ``UNPACKING'' WAY

Barral et al., ISPEC 2016

Idea:

- Encode payload in a constraint-compliant way (e.g. alphanumerically)
- Identify high-level constraint-compliant constructs (zeroing/increasing registers, ...)
- Use this to write a minimal unpacker that decodes and executes payload ☠





ARMV8 DEMO

Click here for the demo

ALPHANUMERIC IS ``SOLVED''

🎉🎉🎉 Even works for RISC-V! 🎉🎉🎉

The ABC of Next-Gen Shellcoding, DEF CON 27

(protip, it is our previous talk)

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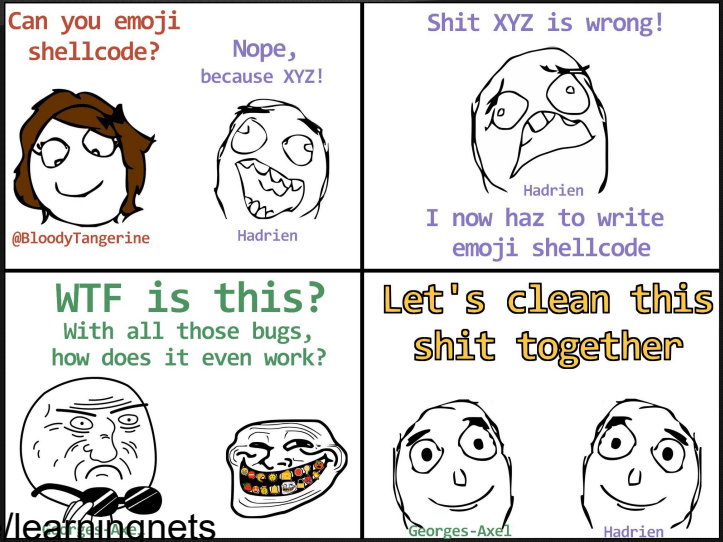
ONCE UPON A TIME... (TRUE STORY)



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2. INSPECTOR GADGET 🕵️

WHAT IS AN EMOJI?

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(or more likely a mess 💩 ...)

WHAT IS AN EMOJI?

✨ Unicode (1987) to the rescue ✨

> "Unicode is a standard for the consistent encoding, representation, and handling of text expressed in most of the world's writing systems."
>
> — Wikipedia

WHAT IS AN EMOJI?

RTFM: https://unicode.org/reports/tr51/

In Unicode, you'll find:

A,

WHAT IS AN EMOJI?

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A, 主,

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A, 🈷, 🧍, 🂫,

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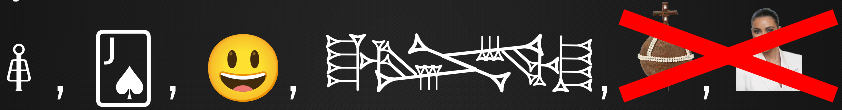
A, ま, 

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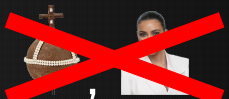
A, 𓀀, 𓀁, 🃏, 😀,  , 

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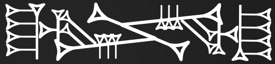
A, ま,  , 🃏, 😃,  , 

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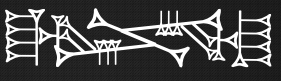
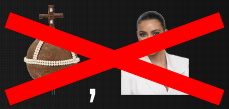
A, 🕴, 🧍, 🃏, 😀,  , 

Definition:

If Unicode says it is a *qualified Emoji*, then it **is** an Emoji!

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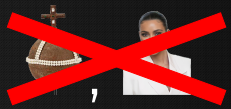
A, 主, 𓀀, 🃏, 😀,  , 

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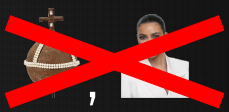
A, 主, 𓀀,  , 😀,  , 

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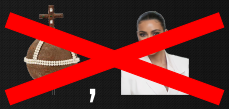
A, 🕴, 🕯, 🃏, 😀,  , 

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And they add new emojis every year! Currently at Unicode version 14.

EXCUSE ME, DO YOU HAVE 2 MINUTES TO TALK ABOUT

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Features:

- Architecture of the future
- Simple, clean RISC Instruction Set Architecture
- Open Source ISA & Open Hardware*
- 2 and 4 byte instructions*, little-endian

*Conditional execution

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- ❌ Emoji RISCV: ❓ : only 10 instructions
  `0xE29D93`

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- ❌ Emoji RISCV: ❓❓: still very few instructions
  `0xE29D93E29D93`

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  `0xE29D93E29D93E29D93...`

We are stuck!

THE INTUITION...

```
auipc ra,0x979ff
```

THE INTUITION...

97 F0 9F 97

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F0 9F 86 97 F0 9F 97

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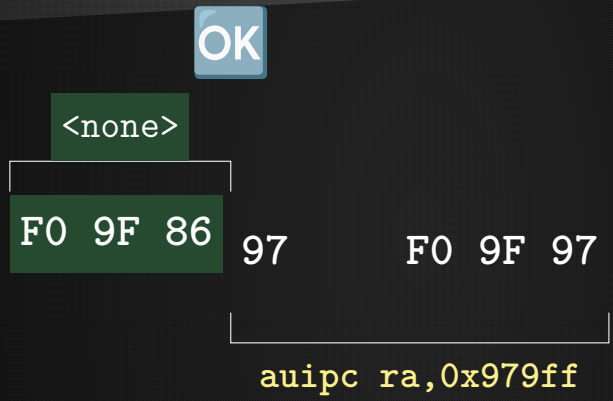

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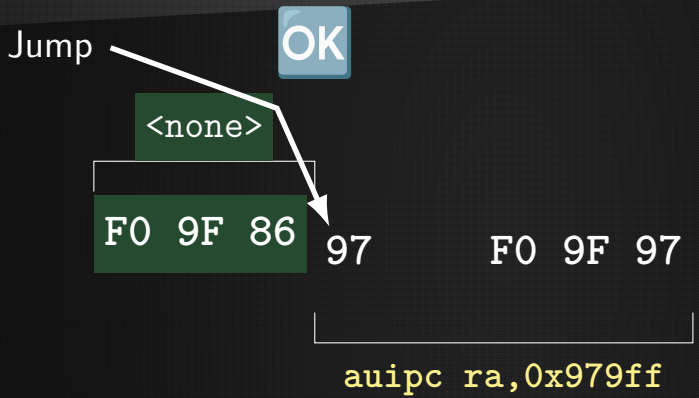

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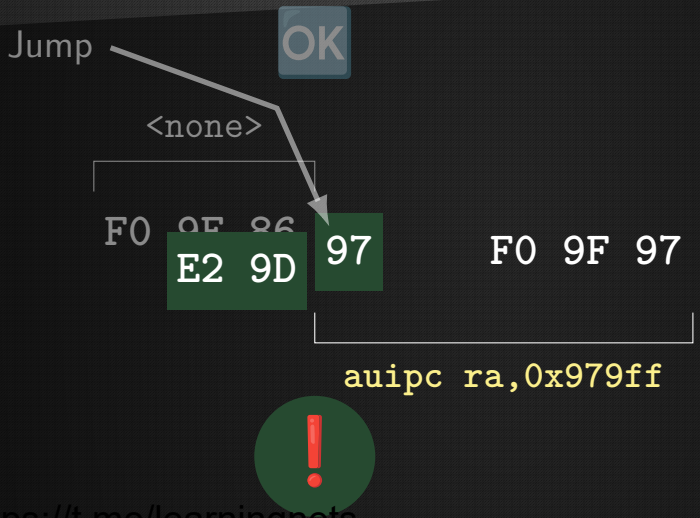

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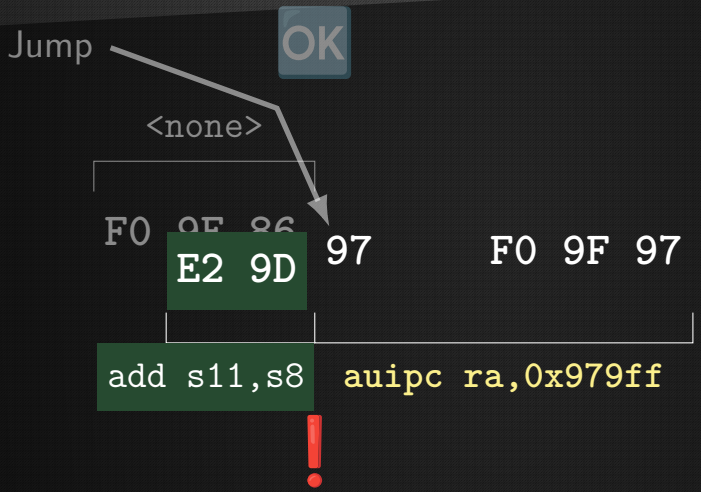

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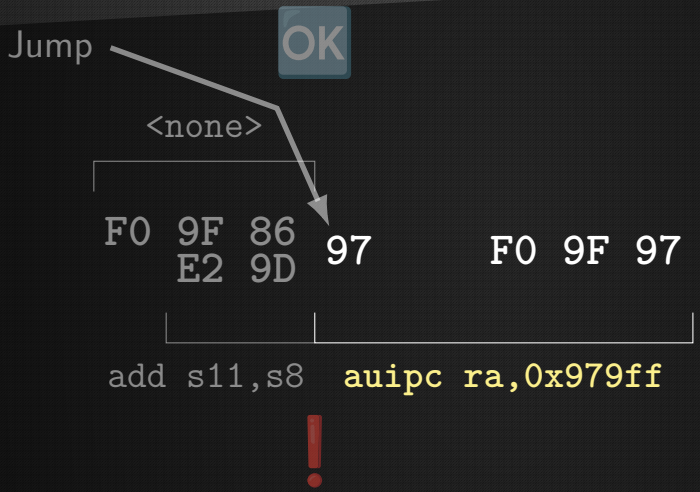

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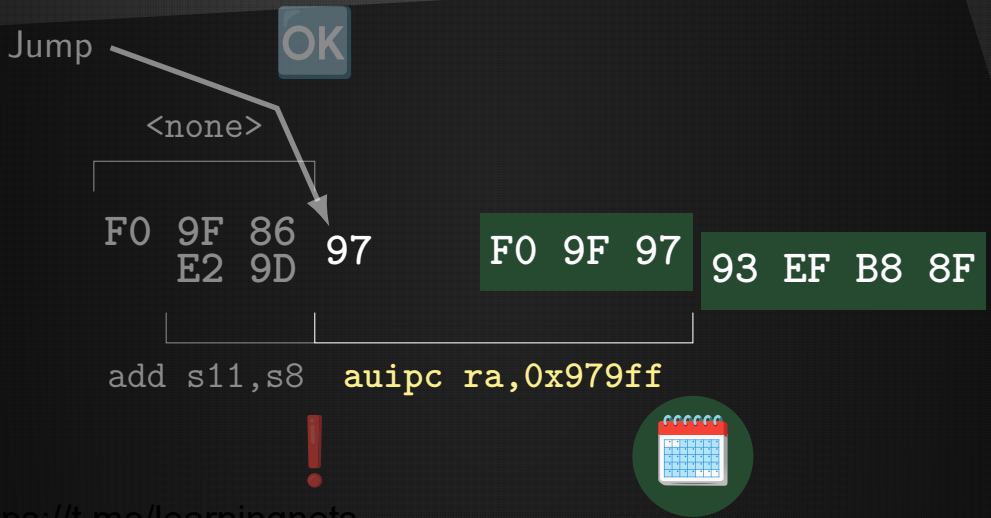

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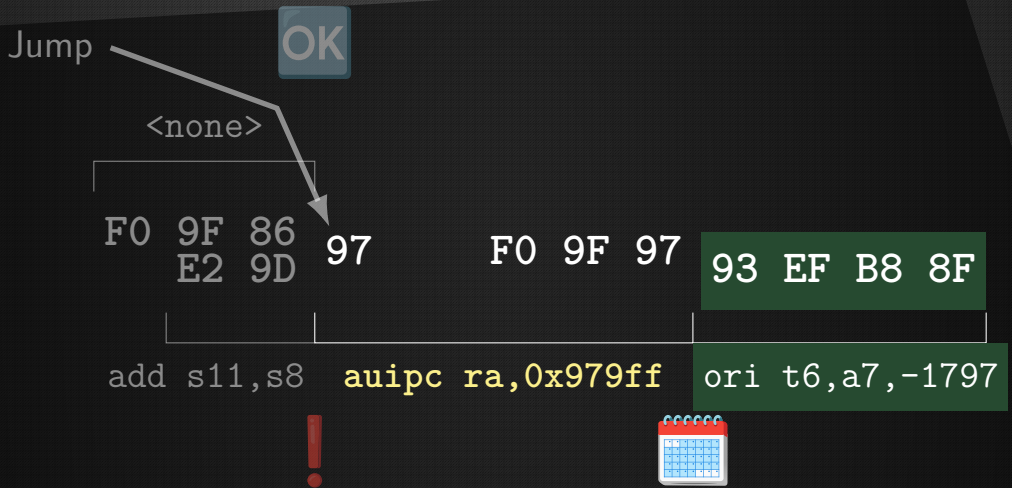

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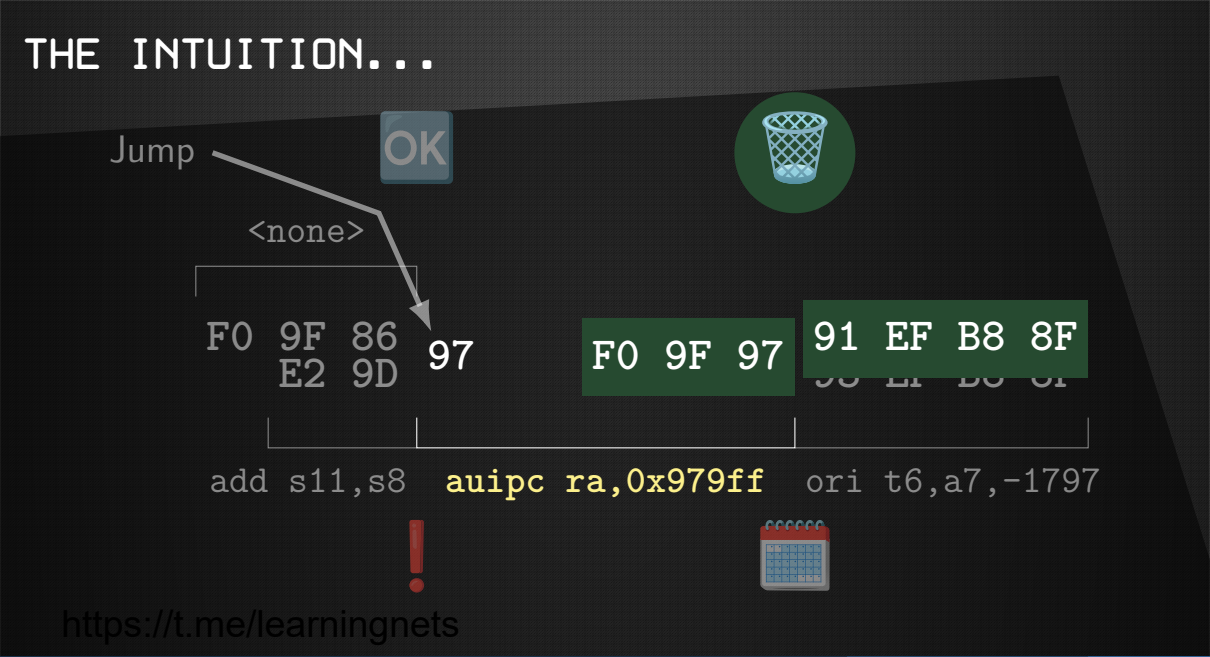

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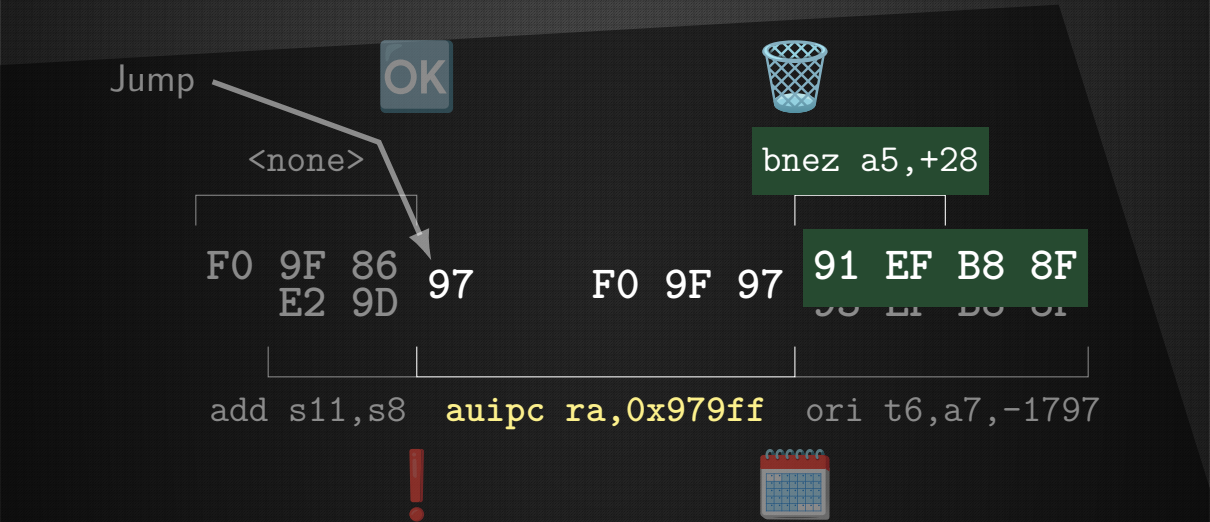

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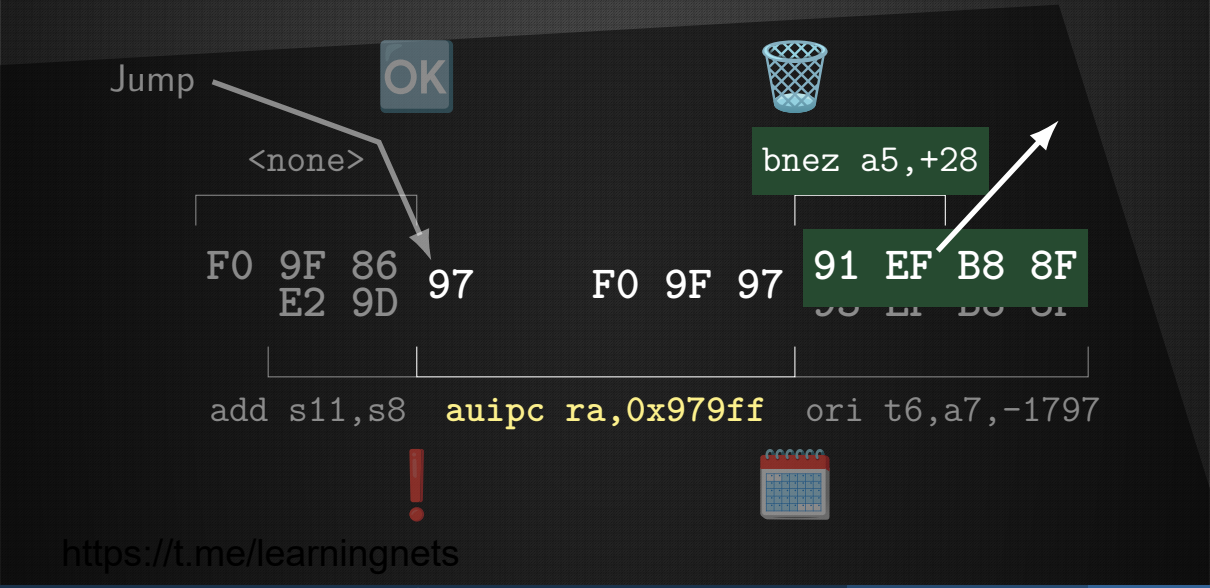

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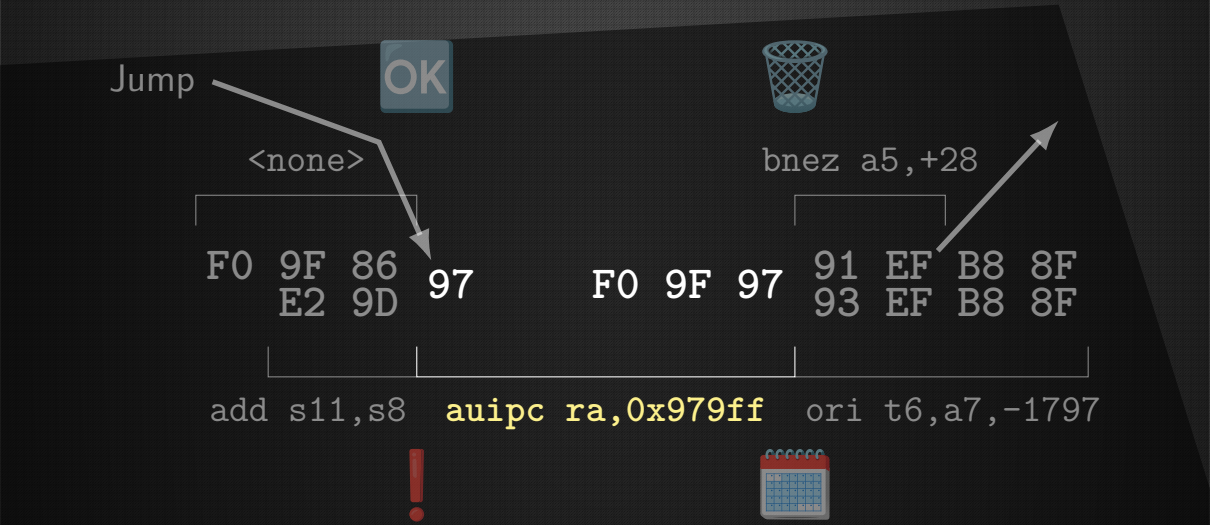

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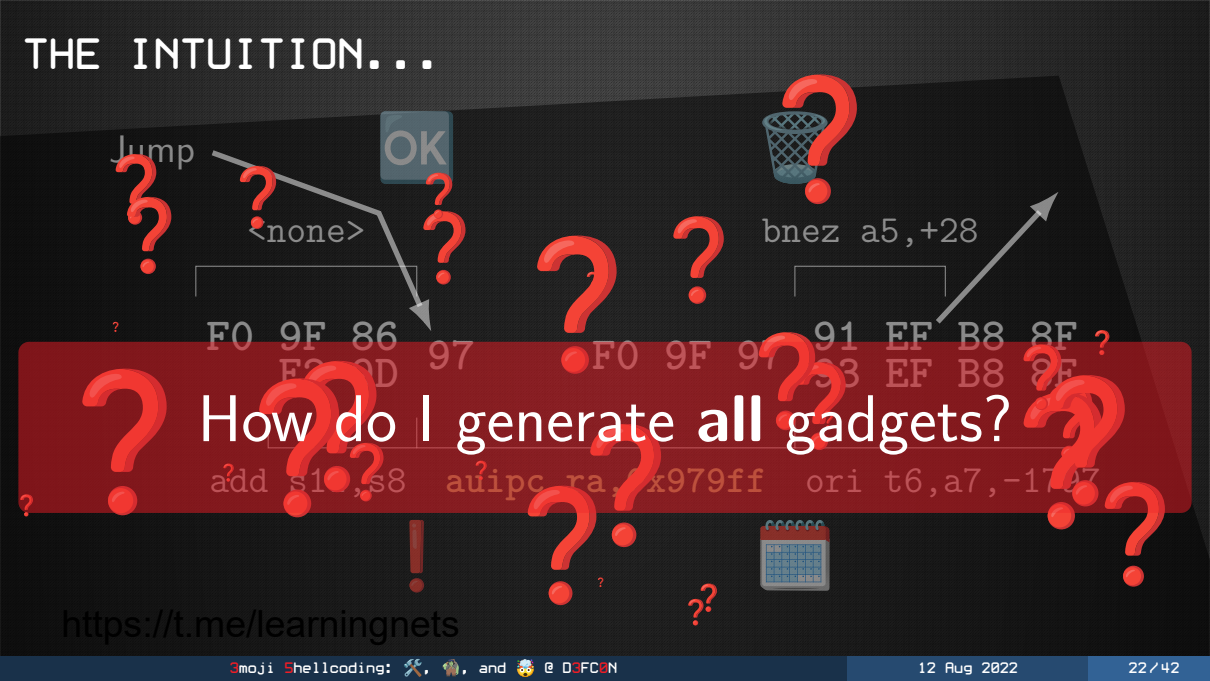

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EMOJI SHELLCODING IS A CODE-REUSE PROBLEM

Source: Trust me, bro.

- Return-Oriented Programming (Shacham et al., 2007):
  1. Scan target binary for reusable code snippets *(gadgets)*
  2. Build your shellcode with gadgets
  3. ???
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  4. Profit
- JIT spraying (Blazakis, 2010): create your own gadgets by controlling JITted bytecode.

```
var y = (
  0x3c54d0d9 ^
  0x3c909058 ^
  0x3c59f46a ^
  ...
```

is turned into:

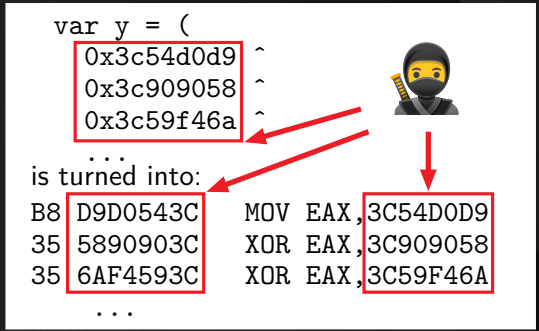
```
B8 D9D0543C    MOV EAX,3C54D0D9
35 5890903C    XOR EAX,3C909058
35 6AF4593C    XOR EAX,3C59F46A
    ...
```

EMOJI SHELLCODING IS A CODE-REUSE PROBLEM

Source: Trust me, bro.

- Return-Oriented Programming (Shacham et al., 2007):
  1. Scan target binary for reusable code snippets *(gadgets)*
  2. Build your shellcode with gadgets
  3. ???
  4. Profit
- JIT spraying (Blazakis, 2010): create your own gadgets by controlling JITted bytecode.

Easy when you control most of the output...



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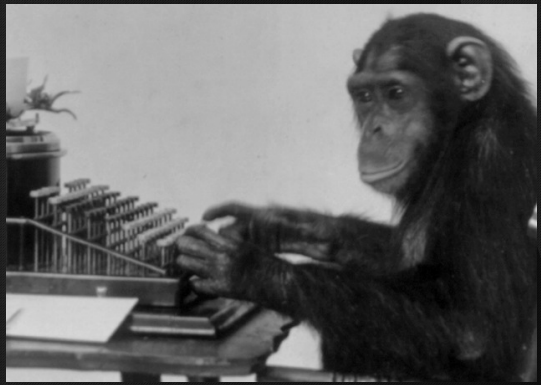
Remember infinite monkey theorem?



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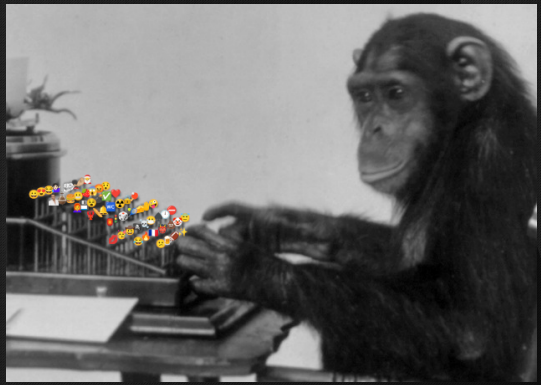
Great! How do I create gadgets from Emoji stream?

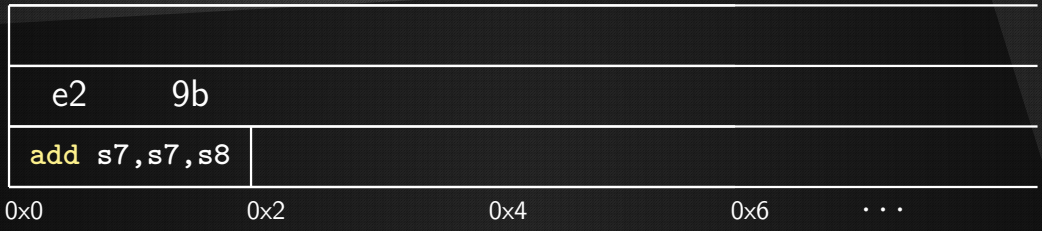
Remember infinite monkey theorem?

They get emoji keyboards now!



⇒ Need to invent a new algorithm.

EMOJI GADGET BUILDING



EMOJI GADGET BUILDING (1ST CASE)

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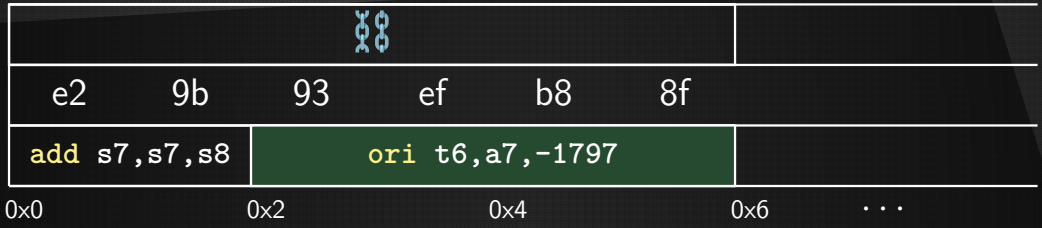

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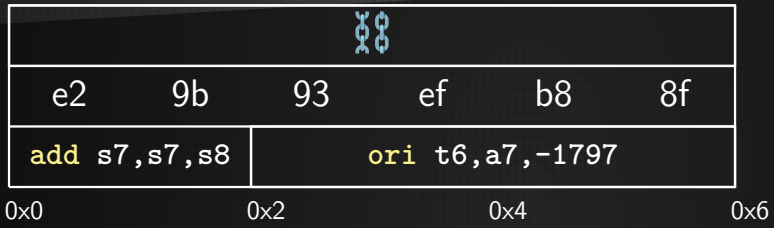


```
1 add s7,s7,s8; ori t6,a7,-1797
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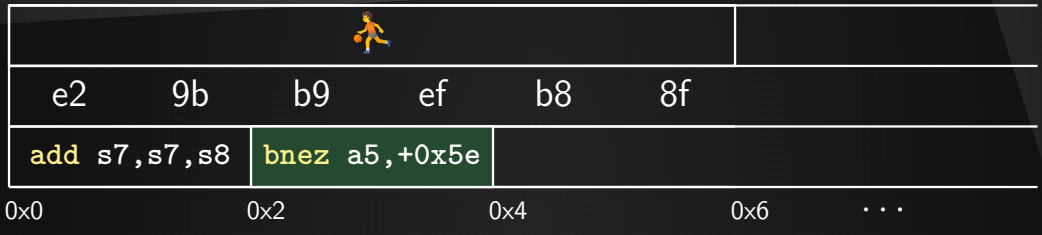


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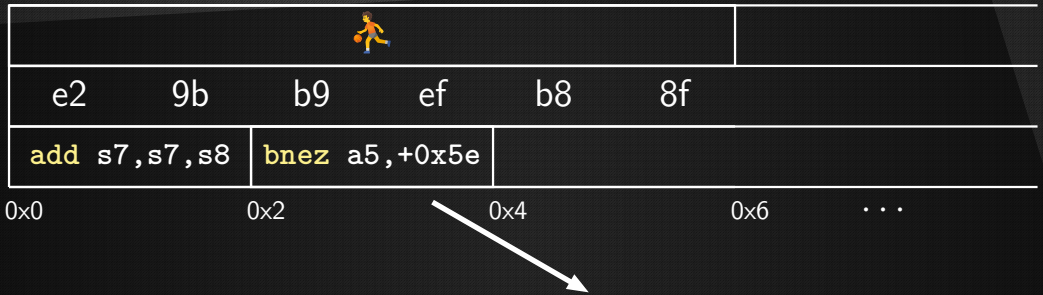


```
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2 add s7,s7,s8; bnez a5,+0x5e; .byte 0xb8,0x8f
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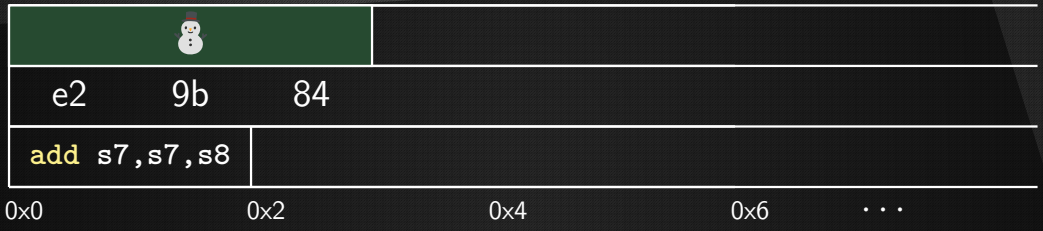


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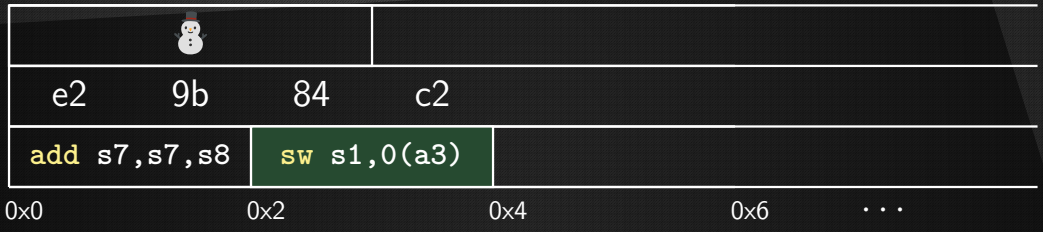


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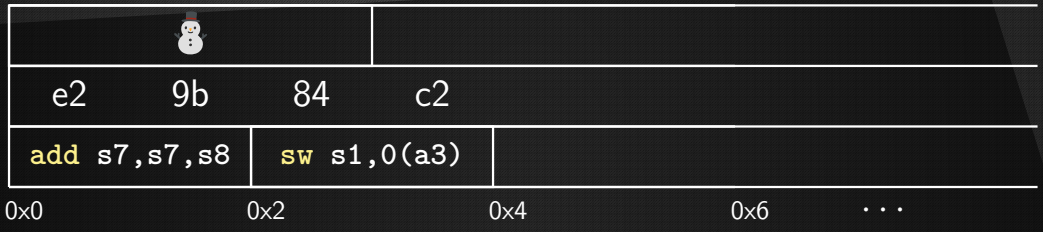


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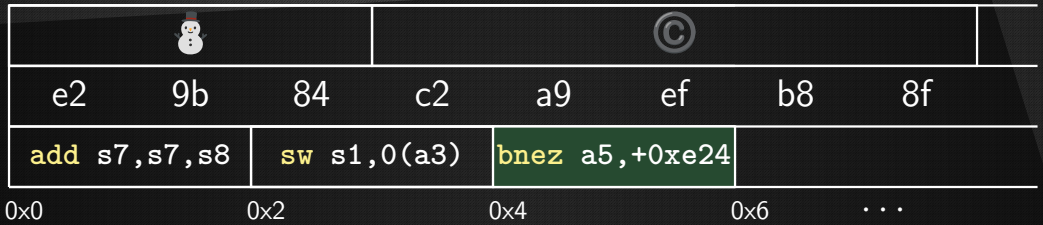


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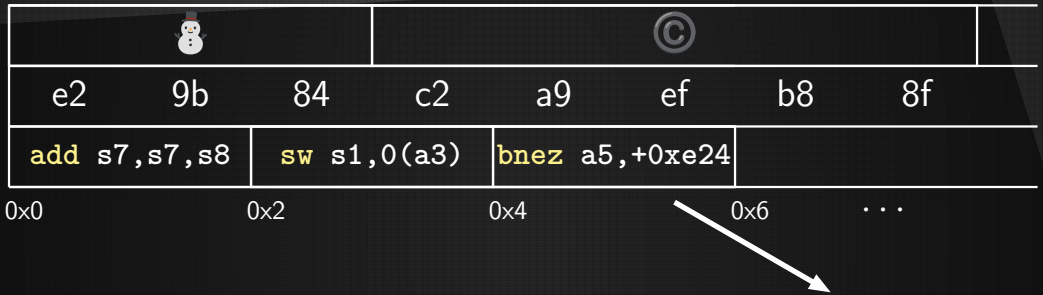


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3 add s7,s7,s8; sw s1,0(a3); bnez a5,+0xe24; .byte 0xb8,0x8f
```

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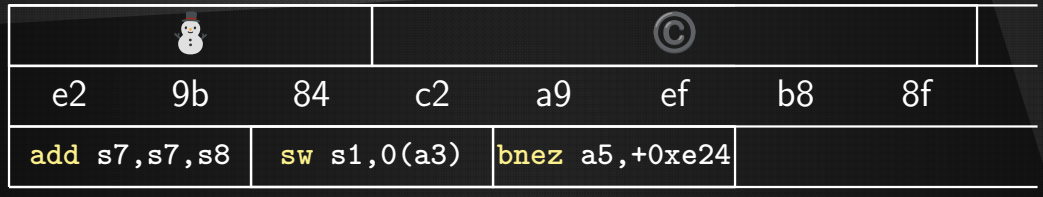


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3 add s7,s7,s8; sw s1,0(a3); bnez a5,+0xe24; .byte 0xb8,0x8f
4 (and so on...)
```

THIS METHOD IS TOTALLY GENERIC

Algorithm follows derivations in the form $S \rightarrow a\ T$

This exactly describes a right-linear grammar!

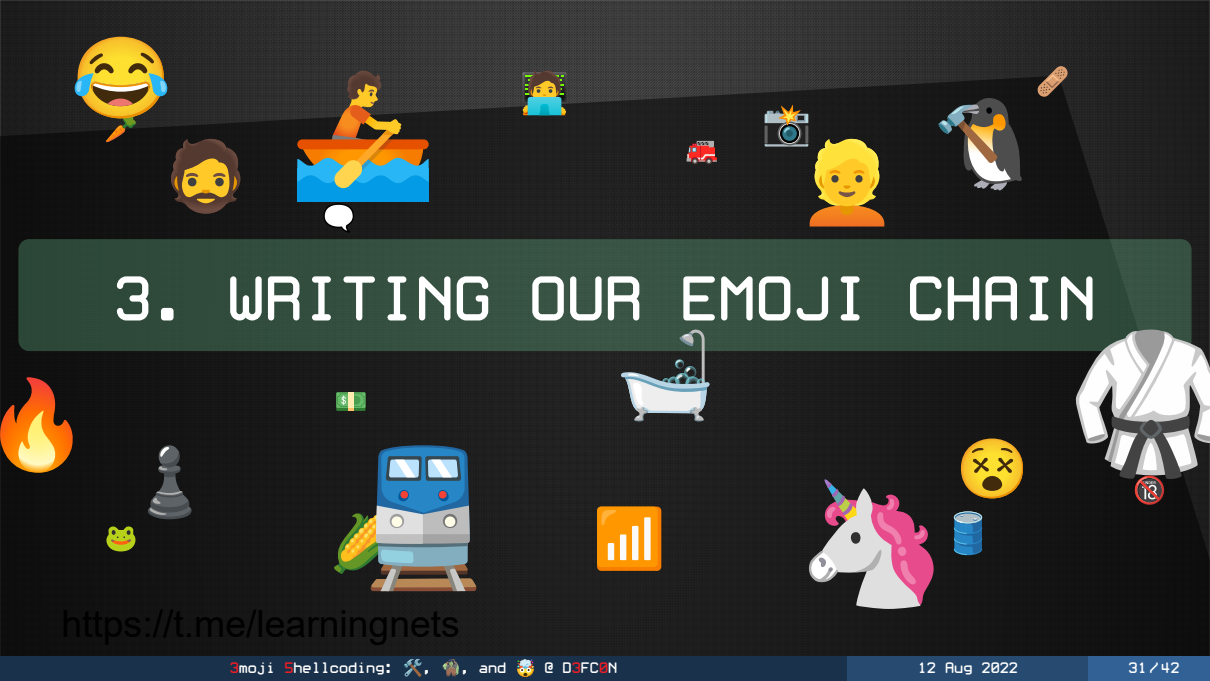
"Any regular expression* can be converted to a right-linear grammar."

*alphanumeric, email address, url, emojis, ... — A.R. Patel, 1971

(adapting the tool is left to the reader as exercise)

Anyway, back to emoji.

We have gadgets, but we still need to chain them!


3. WRITING OUR EMOJI CHAIN
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POKÉDEX OF RISC-V EMOJI GADGETS

- >4000 instructions available in total
- Logic `and`, `add`, `sub`, ...
- Conditional and unconditional branches (forward & backward)
- Many registers: `a1357`, `s1359`, `t0246`, `gp`, `ra` (but no `sp` 😧)
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A tiny bit of everything... looks like a yard sale!

FROM BASIC BLOCKS TO ARBITRARY CODE EXECUTION

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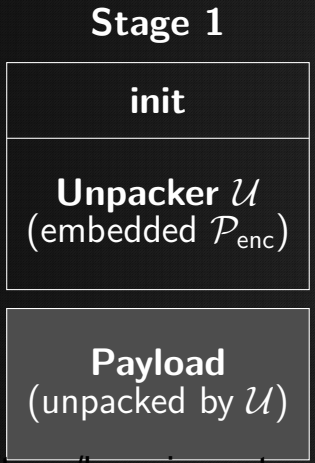

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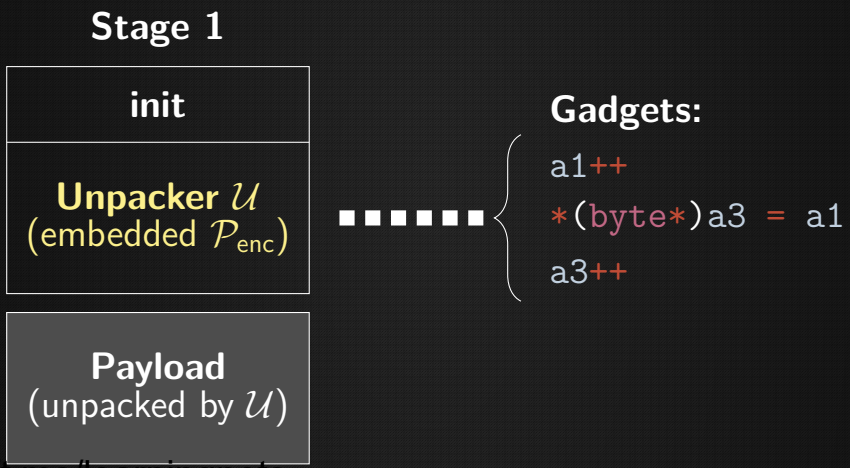

ARBITRARY PAYLOAD ENCODING

Initial Payload:

```
0x03
```

```
0x20
```

```
0x10
```

ARBITRARY PAYLOAD ENCODING

Initial Payload: **Encoded $\mathcal{P}_{\text{enc}}$:**

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0x03	`a1++; a1++; a1++;`
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GDB OVER BEAMER TIME!

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add    a3,a3,t2
```

a1	0000 00AB
a3	0000 8000
t2	0000 0001
a5	B100 D5AC
s3	530F 25F8
s8	03C4 9ECC

...	00	...
...	0x8000	0x8001

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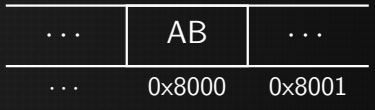

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a1	0000 00AB
a3	0000 8000
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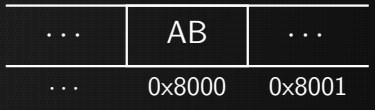
a5	B100 D5AC
s3	5A98 6390
s8	03C4 9ECC



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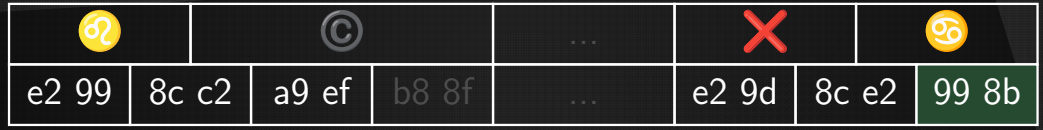


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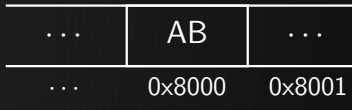

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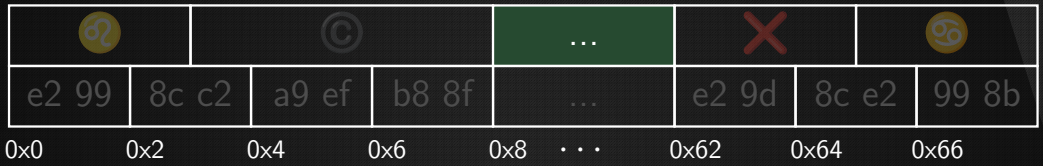
DEMO ON RV64GC SIFIVE UNLEASHED BOARD

Click here for the demo

https://t.me/learninghets

FILLING THE VOIDS



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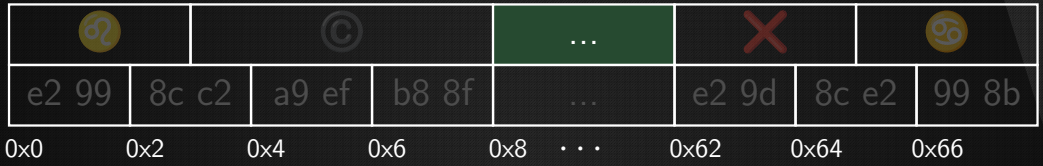

- Just solve a variant of subset sum (RTFM Wikipedia).

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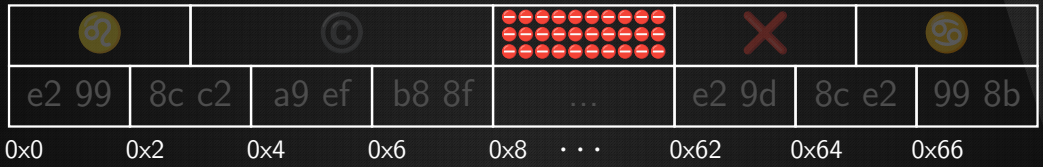

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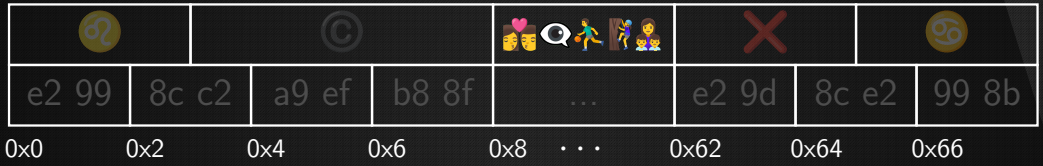
- Fantastic, we get polymorphism for free!

FILLING THE VOIDS



- Just solve a variant of subset sum (RTFM Wikipedia).
  - Trivial if we use only 3 and 4-byte emojis ...
  - ... harder if we want to minimize number of emojis
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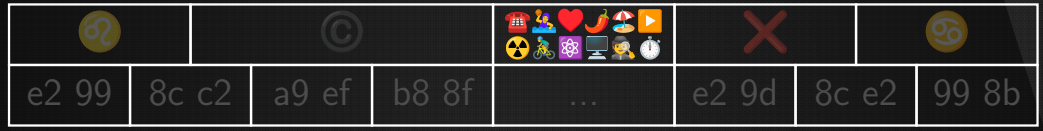

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TRIVIA

Can we do our nop-sled with the  emoji?

https://t.me/learningnets

TRIVIA

Can we do our nop-sled with the 🫳 emoji?

✅

TRIVIA

Can we do our nop-sled with the 👊 emoji?

✅©

https://t.me/learningnets

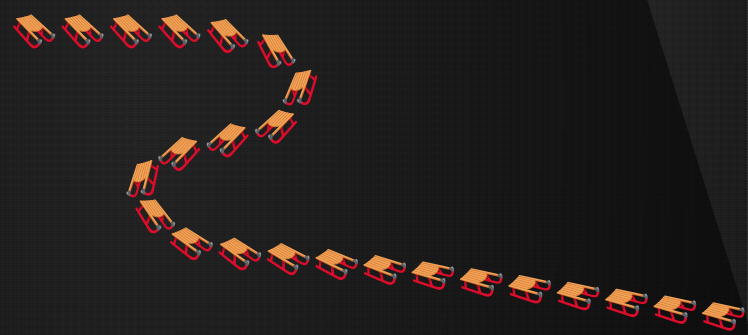
TRIVIA

Can we do our nop-sled with the 🪭 emoji?

TRIVIA

Can we do our nop-sled with the 👇 emoji?

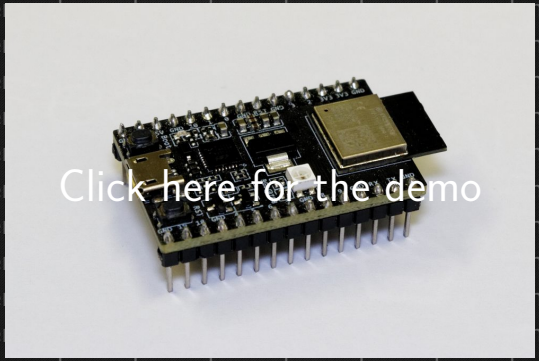
✅©⛔🤷⛔⛔⛔🤷⛔



This is executable code!

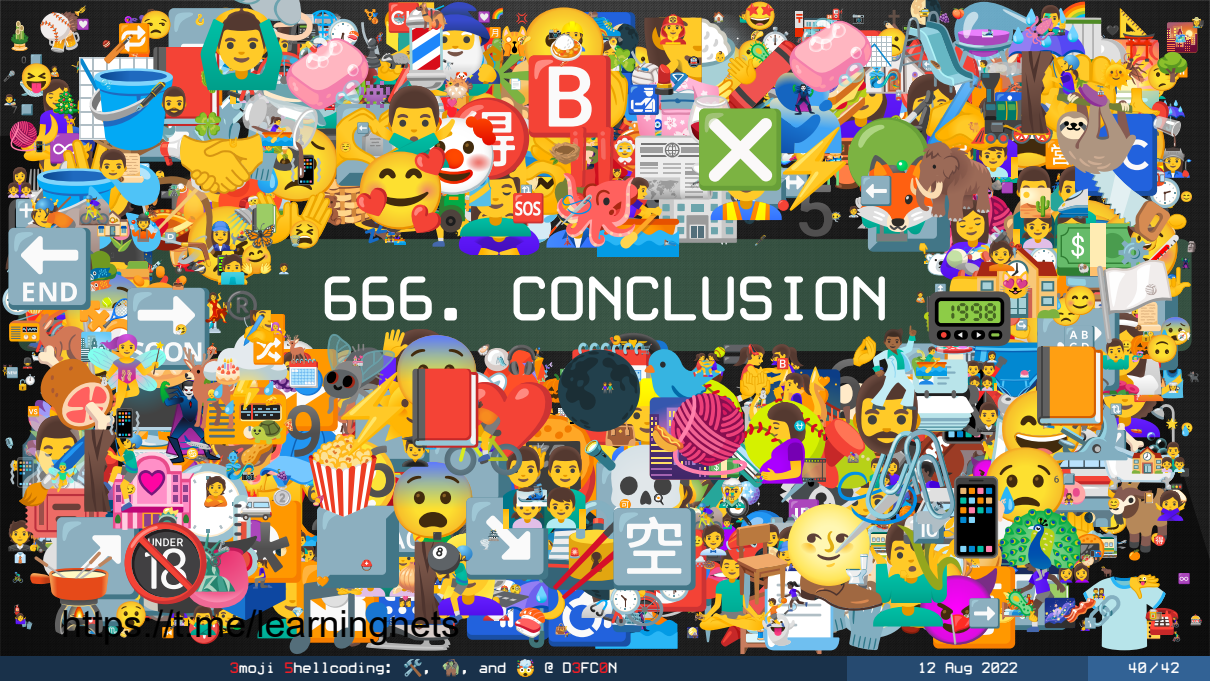
https://t.me/learningnets

DEMO ON RV32 ESPRESSIF ESP32-C3 BOARD



https://t.me/learningriscv

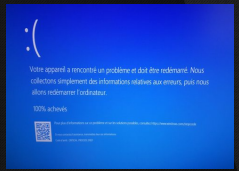
666. CONCLUSION


666. CONCLUSION
https://me/learningnets

ACKNOWLEDGMENTS

The following were harmed during the making of this project:

- LuaLatex (segfault)
- TexStudio (memory leaks, crashes, ...)
- Acrobat Reader (major glitches)
- Various PDF readers (glitches)
- VLC (glitches on demo.mkv)
- Firefox (broke PDF.js persistently)
- xfce4-terminal (utter slowness)
- Noto Emoji (render issues)
- CUPS (crash)
- gcc (segfault)
- Windows (BSOD when compiling slides)



Emoji support **is** hard.

We went all the way to design a new code-reuse technique just to hack you with unsolicited “I 💖 U” texts.

Code and documentation on:

https://github.com/RischardV/emoji-shellcoding

Your friendly neighbourhood hackers

hadrien.barral@ens.fr georges-axel.jaloyan@ens.fr