Introduction to malware reversing with radare2

@apasamar
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www.incide.es

first is first

Consulta las c.c.
en c0r0n4con.com

#EstoLoParamosHackeando

who am I

- Abraham Pasamar
- DFIR consultant for +15 years
- 70%BLUE+30%RED
- Founder and CEO INCIDE (2005) -> Defensive + Offensive
- I'm lecturer of *malware analysis* at *Universidad Politécnica Barcelona*
- I'm not a reverse engineering professional/expert
- malware analysis is sometimes part of IR cases

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Objective

- show you the basics of malware reversing using radare2 [r2]

Outline

INTRODUCTION

Outline

INTRODUCTION

Computer Architecture

Outline

INTRODUCTION

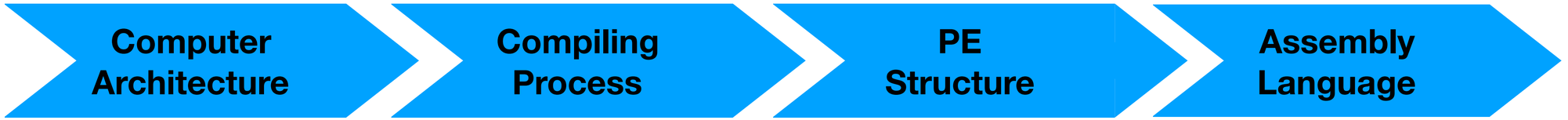
Computer Architecture → **Compiling Process**

Outline

INTRODUCTION

Outline

INTRODUCTION



Outline

INTRODUCTION

Computer Architecture → **Compiling Process** → **PE Structure** → **Assembly Language** → **C code in assembly**

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Disassembly of PE binaries

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Disassembly of PE binaries → **Windows API** → **Malware protection Methods**

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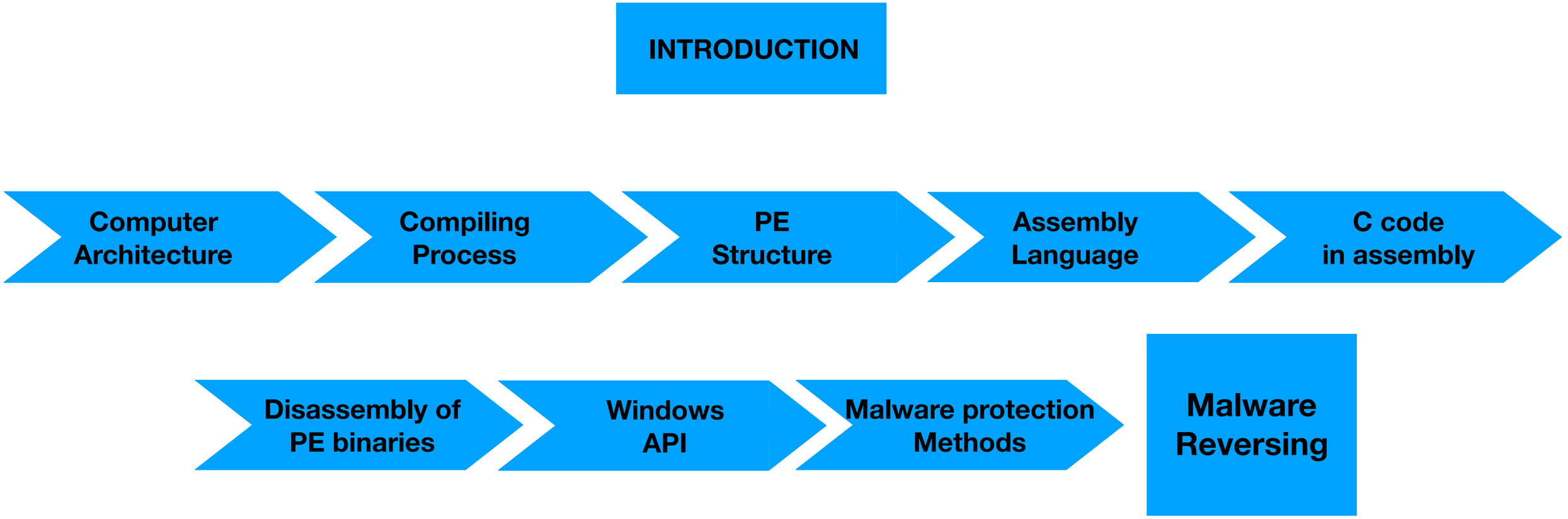
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Malware Reversing

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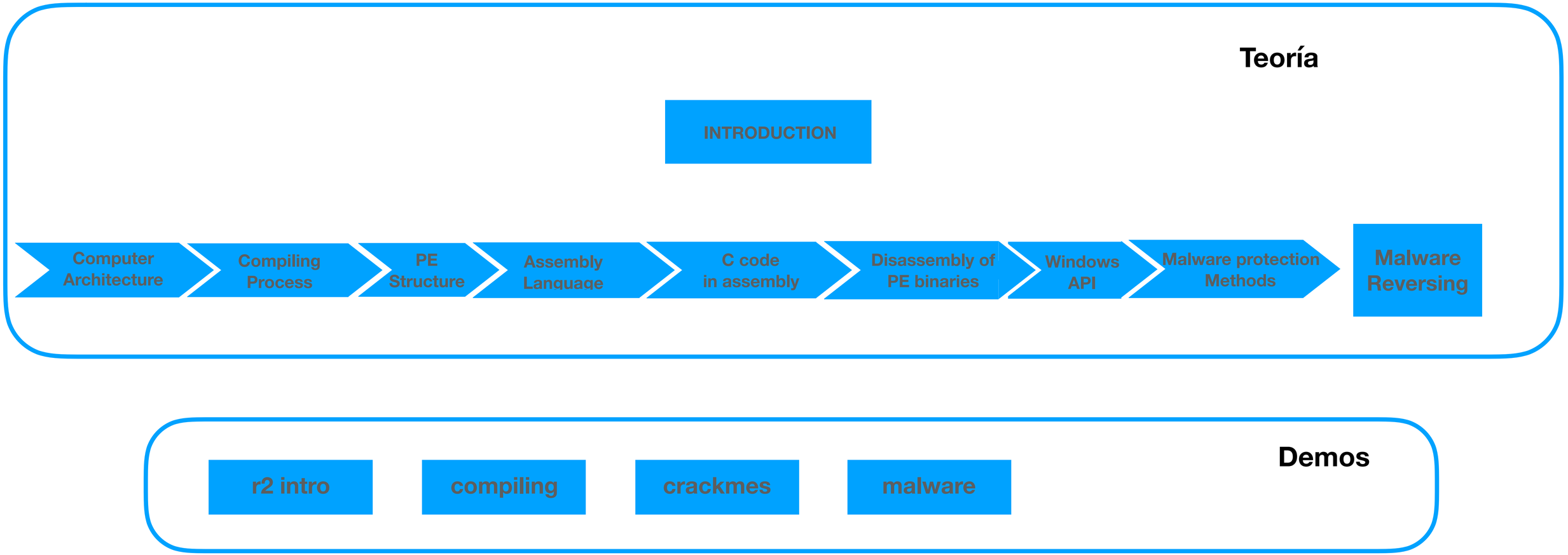
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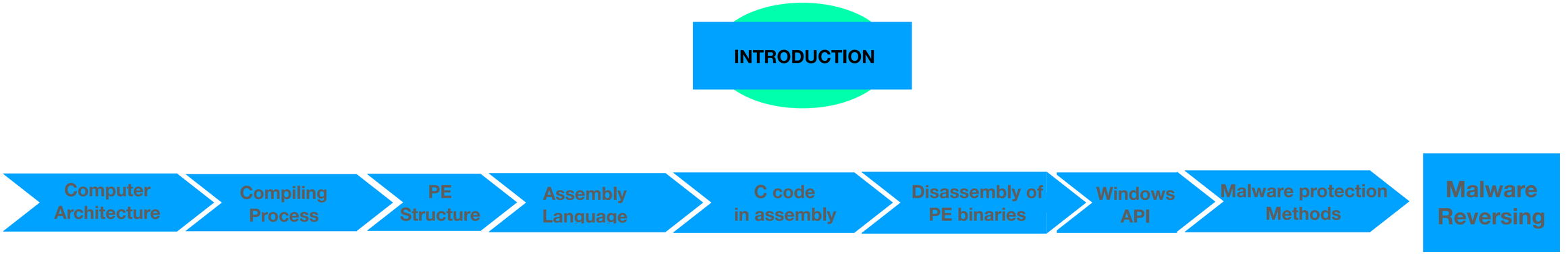
Demos
r2 intro
compiling
crackmes
malware

relax and enjoy the journey

Outline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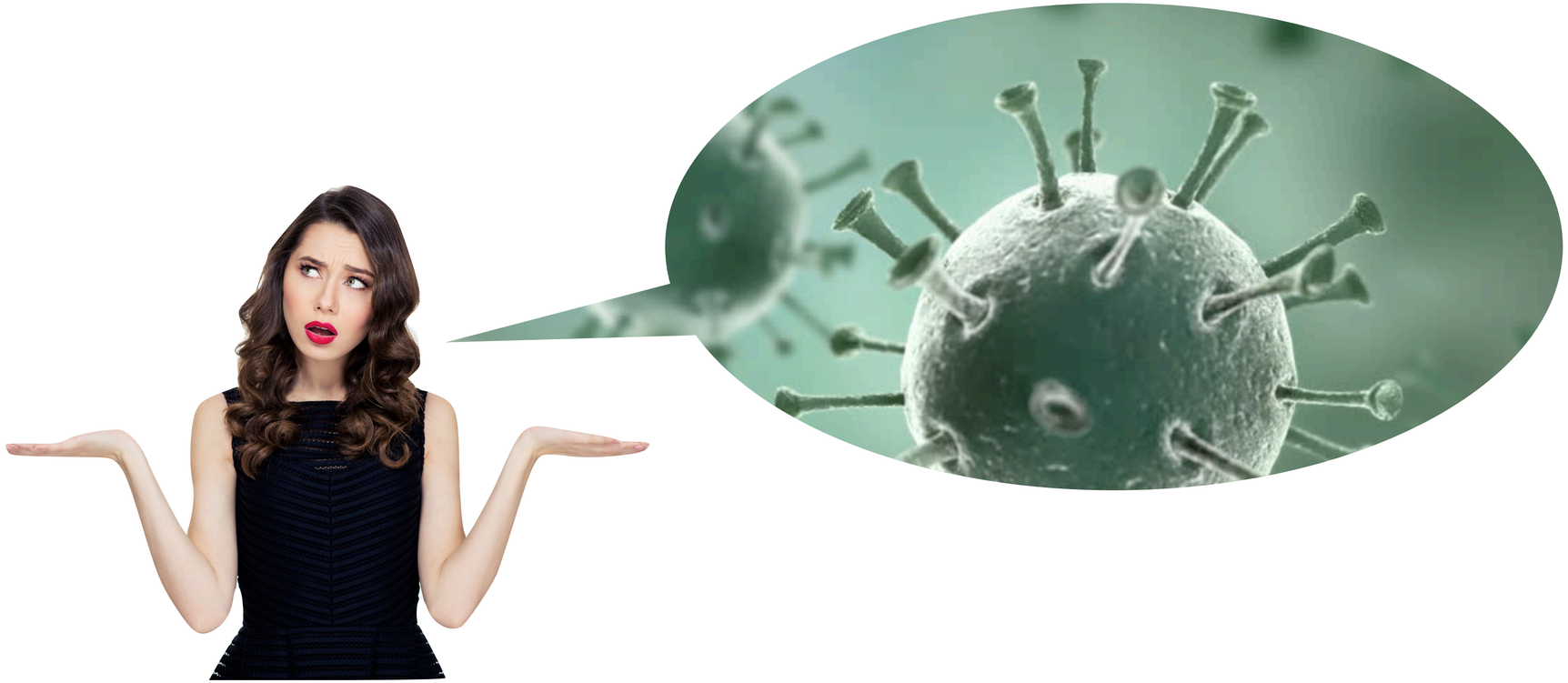
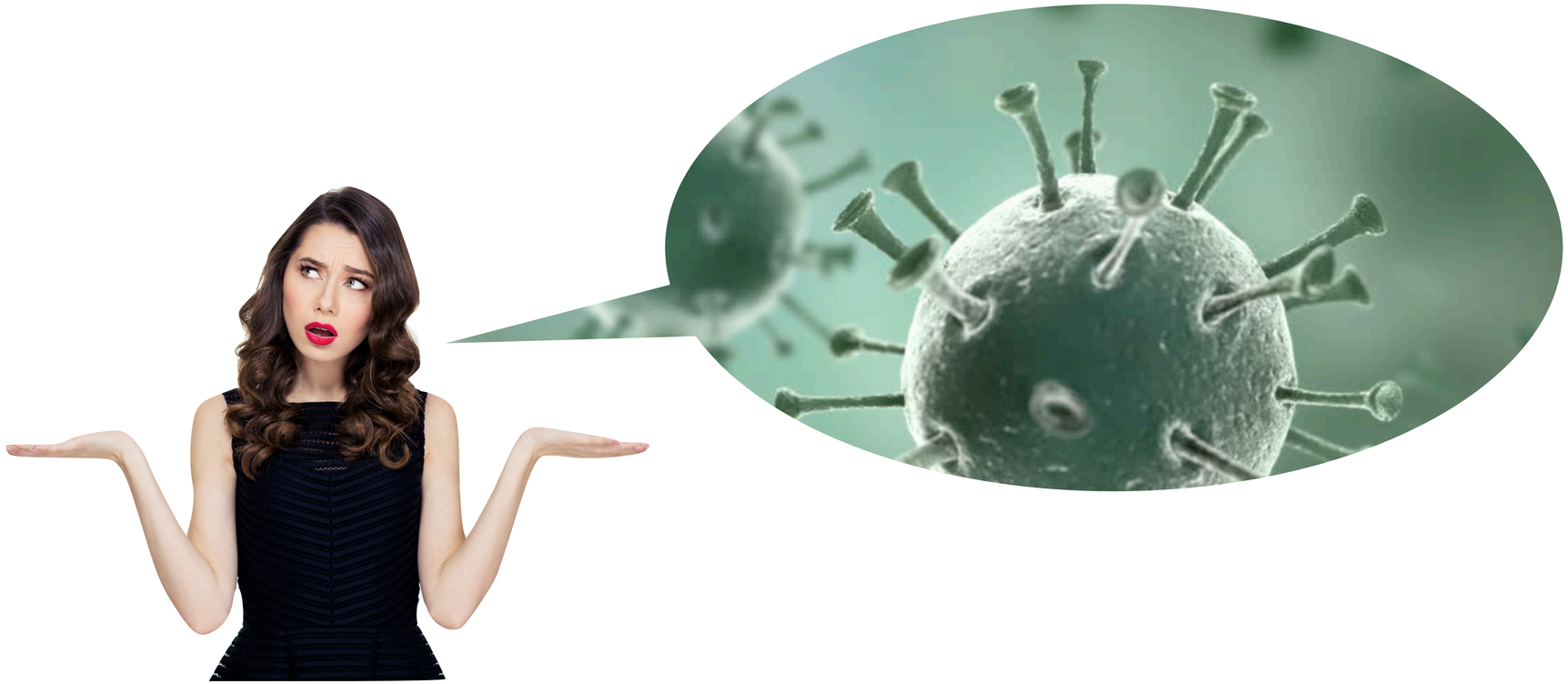
What is Malware?

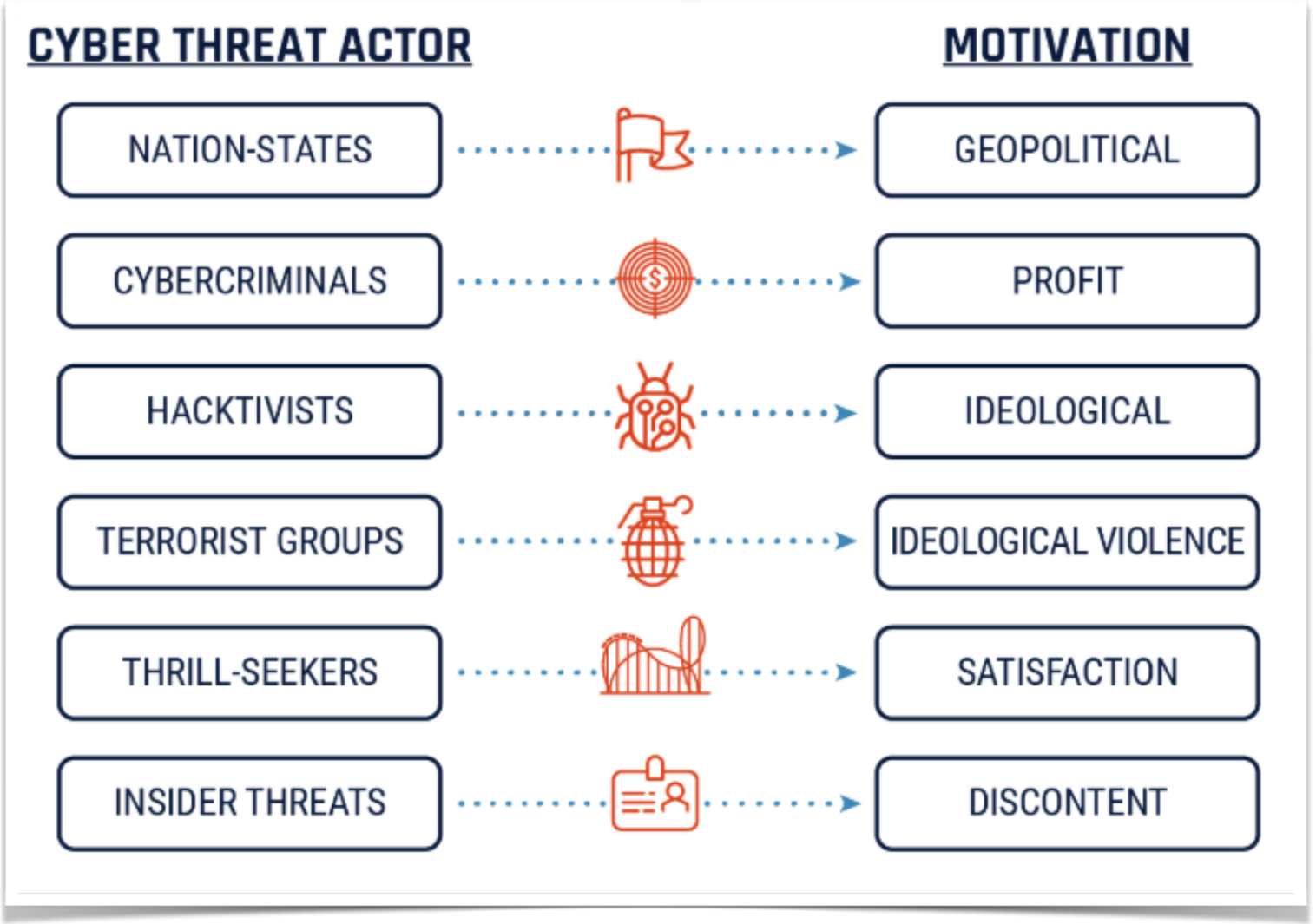


What is Malware?



Software that performs unwanted actions by the user, usually in a hidden or discrete manner, and that are harmful to the user or to third parties.

Malware


CYBER THREAT ACTOR
MOTIVATION
NATION-STATES
GEOPOLITICAL
CYBERCRIMINALS
PROFIT
HACKTIVISTS
IDEOLOGICAL
TERRORIST GROUPS
IDEOLOGICAL VIOLENCE
THRILL-SEEKERS
SATISFACTION
INSIDER THREATS
DISCONTENT

Incident Response

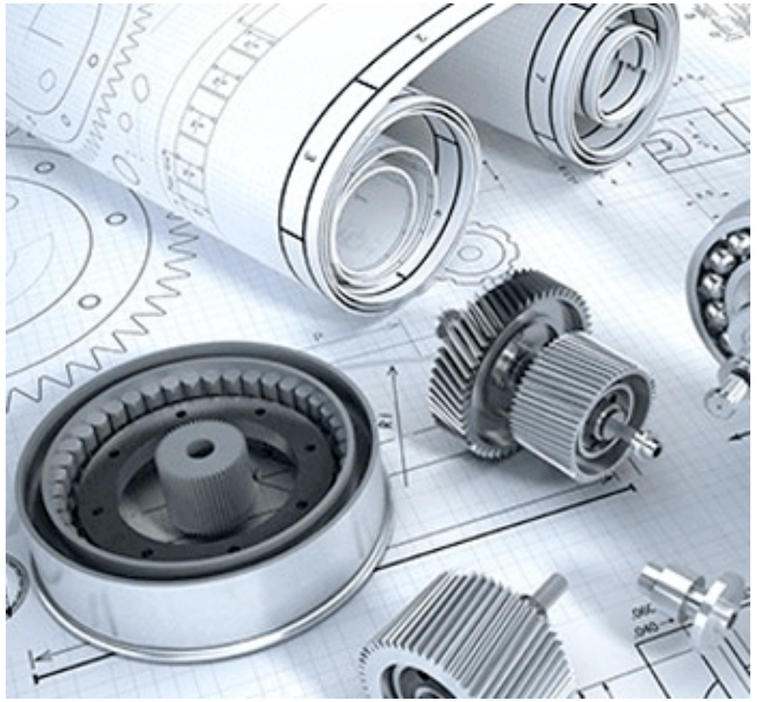
In the context of a Security Incident you have to deal with some form of malware analysis:

- Static
- Dynamic

Malware reversing is and advanced malware analysis technique

Reverse Engineering

Is the process by which a man-made object is deconstructed to reveal its designs, architecture, or to extract knowledge from the object



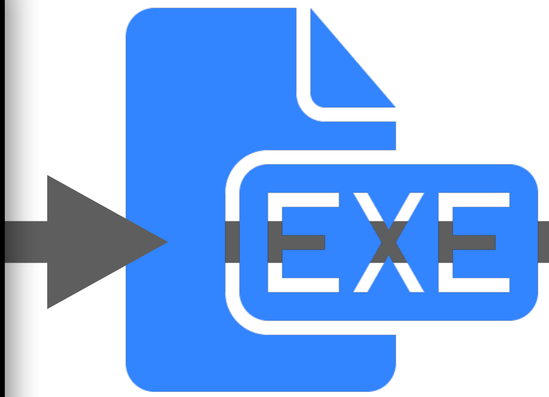
What is Disassembly?

Compiling process:

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

int sum(int a, int b){
  long c=a+b;
  return c;
}

int main(int argc,char* argv[]){
  int a = strtol(argv[1], NULL, 10);
  int b = strtol(argv[2], NULL, 10);
  int c=sum(a,b);
  return c;
}
```




```
- offset -   0 1  2 3  4 5  6 7  8 9  A B  C D  E F  0123456789ABCDEF
0x00401546  5589 e583 e4f0 83ec 20e8 0c01 0000 8b45  U....... .....E
0x00401556  0c83 c004 8b00 c744 2408 0a00 0000 c744  .......D$......D
0x00401566  2404 0000 0000 8904 24e8 9010 0000 8944  $.......$......D
0x00401576  241c 8b45 0c83 c008 8b00 c744 2408 0a00  $..E.......D$...
0x00401586  0000 c744 2404 0000 0000 8904 24e8 6c10  ...D$.......$.l.
0x00401596  0000 8944 2418 8b44 2418 8944 2404 8b44  ...D$..D$..D$..D
0x004015a6  241c 8904 24e8 80ff ffff 8944 2414 8b44  $...$......D$..D
0x004015b6  2414 c9c3 9090 6690 6690 a104 3040 008b  $.....f.f...0@..
0x004015c6  0085 c074 2583 ec0c 6690 ffd0 a104 3040  ...t%...f.....0@
0x004015d6  008d 5004 8b40 0489 1504 3040 0085 c075  ..P..@....0@...u
0x004015e6  e983 c40c c38d 7426 0090 c38d b426 0000  ......t&.....&..
0x004015f6  0000 8db4 2600 0000 0090 5383 ec18 8b1d  ....&.....S.....
0x00401606  f026 4000 83fb ff74 2985 db74 118d 7426  .&@....t)..t..t&
0x00401616  0090 ff14 9df0 2640 0083 eb01 75f4 c704  ......&@....u...
0x00401626  24c0 1540 00e8 b0fe ffff 83c4 185b c38d  $..@.........[..
0x00401636  7600 31c0 8db6 0000 0000 89c3 83c0 018b  v.1.............
```

C code

machine code

What is Disassembly?

```
- offset -   0 1  2 3  4 5  6 7  8 9  A B  C D  E F  0123456789ABCDEF
0x00401546  5589 e583 e4f0 83ec 20e8 0c01 0000 8b45  U....... ......E
0x00401556  0c83 c004 8b00 c744 2408 0a00 0000 c744  .......D$......D
0x00401566  2404 0000 0000 8904 24e8 9010 0000 8944  $.......$......D
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0x00401596  0000 8944 2418 8b44 2418 8944 2404 8b44  ...D$..D$..D$..D
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0x004015b6  2414 c9c3 9090 6690 6690 a104 3040 008b  $.....f.f...0@..
0x004015c6  0085 c074 2583 ec0c 6690 ffd0 a104 3040  ...t%...f.....0@
0x004015d6  008d 5004 8b40 0489 1504 3040 0085 c075  ..P..@....0@...u
0x004015e6  e983 c40c c38d 7426 0090 c38d b426 0000  ......t&.....&..
0x004015f6  0000 8db4 2600 0000 0090 5383 ec18 8b1d  ....&.....S.....
0x00401606  f026 4000 83fb ff74 2985 db74 118d 7426  .&@....t)..t..t&
0x00401616  0090 ff14 9df0 2640 0083 eb01 75f4 c704  ......&@....u...
0x00401626  24c0 1540 00e8 b0fe ffff 83c4 185b c38d  $..@.........[..
0x00401636  7600 31c0 8db6 0000 0000 89c3 83c0 018b  v.1.............
```

machine code

```
[0x401546]
  ; CALL XREF from entry0 @ 0x401381
  ;-- _main:
116: int main (char **str);
; arg char **str @ ebp+0xc
; var char * *endptr @ esp+0x4
; var int32_t base @ esp+0x8
; var int32_t var_10h @ esp+0x14
; var long var_ch @ esp+0x18
; var long var_8h @ esp+0x1c
0x00401546 55              push ebp
0x00401547 89e5            mov ebp, esp
0x00401549 83e4f0          and esp, 0xfffffff0
0x0040154c 83ec20          sub esp, 0x20
0x0040154f e80c010000      call sym.___main;[oa]
0x00401554 8b450c          mov eax, dword [str]
0x00401557 83c004          add eax, 4
0x0040155a 8b00            mov eax, dword [eax]
```

assembly language

Disassembly is a great **Reverse Engineering** tool

Disassembly

- During this talk/demo I will only do static analysis
- Debugging means executing malware, it could be dangerous
- I recommend everyone to practice disassembly before debugging. It is the best way to start with malware reversing

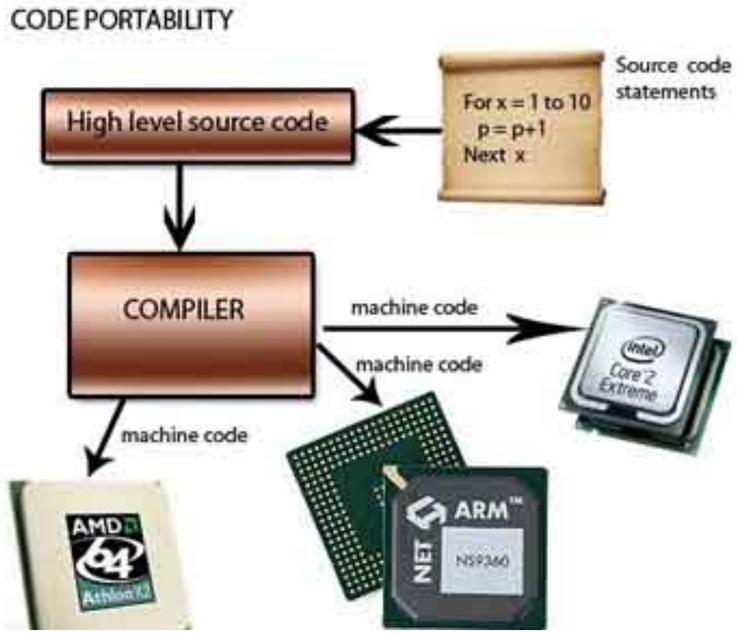
Computer Architecture

Computer Architecture

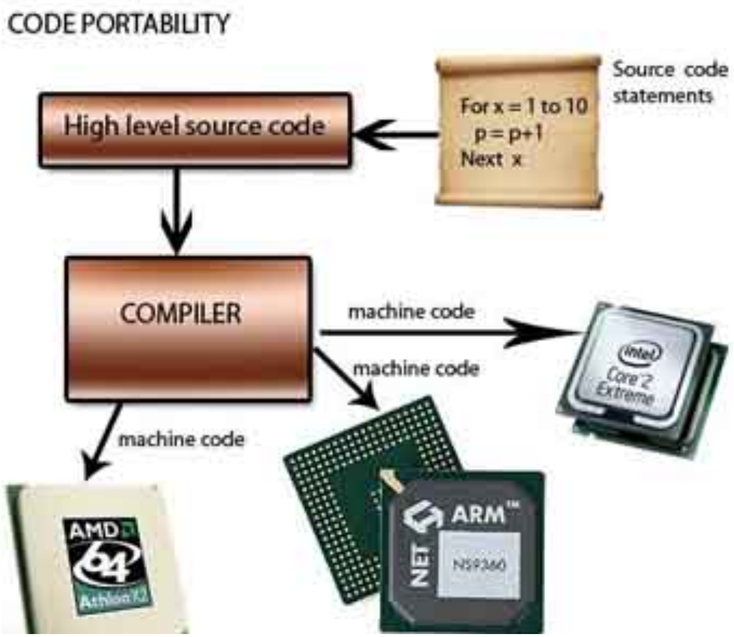
- Intel **32**/64 bits **x86** / x86_64
- registers
- flags
- memory (stack/heap)

Computer Architecture

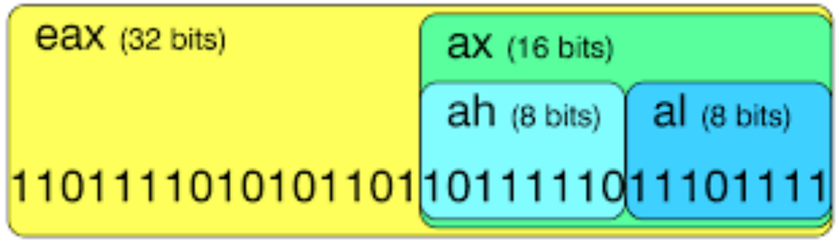
Computer Architecture



Computer Architecture



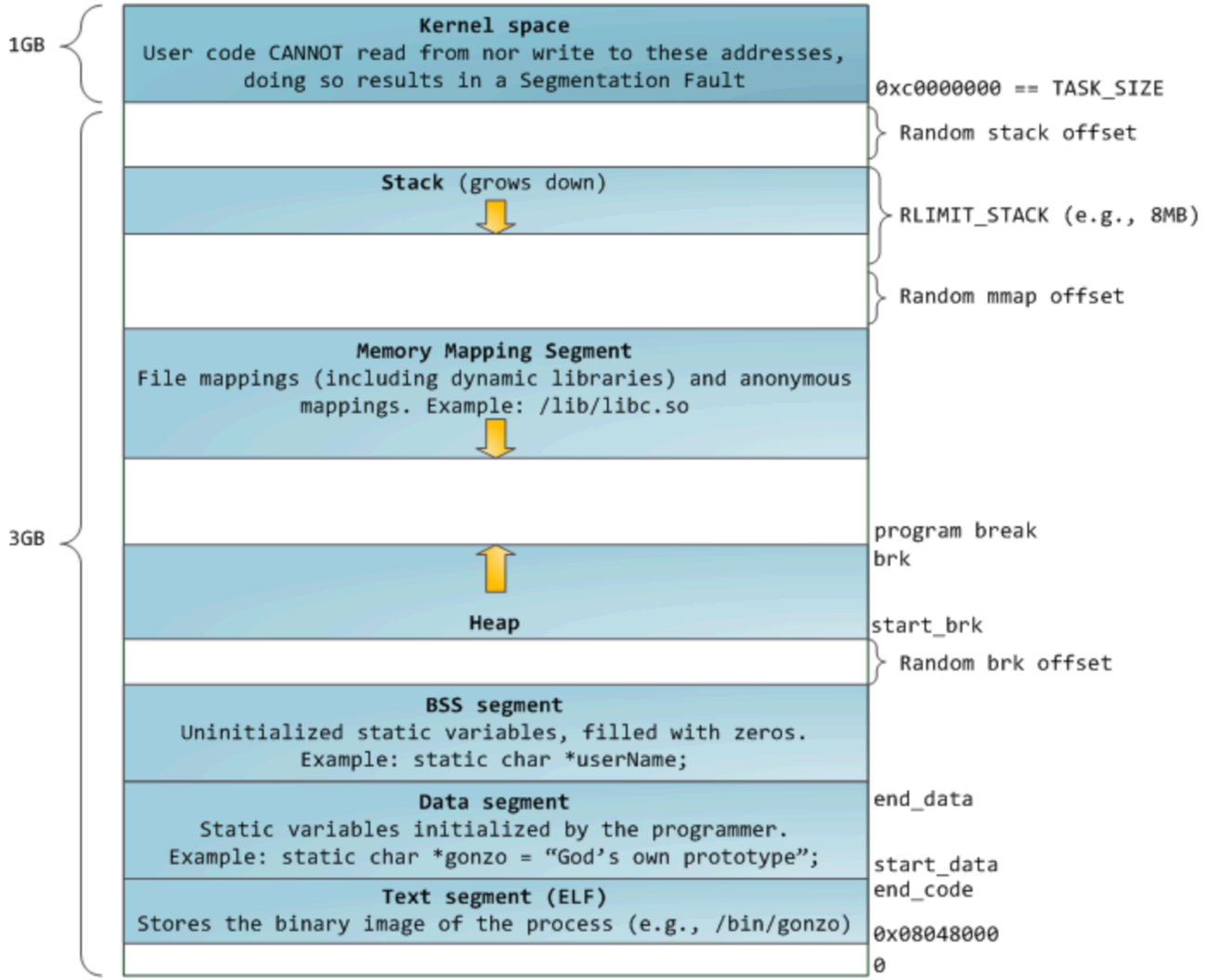
Register aliasing / sub-registers

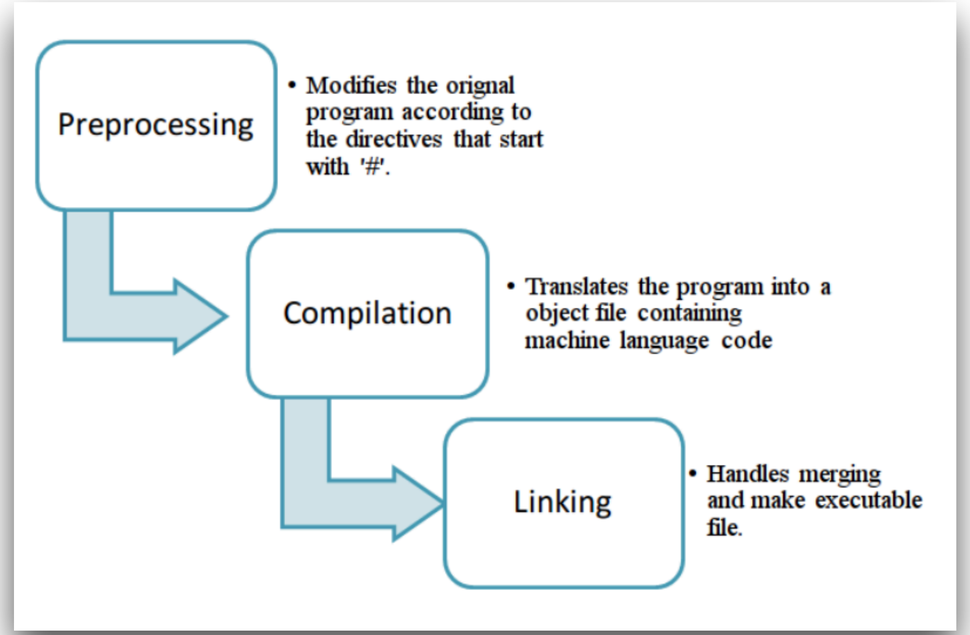


Computer Architecture

Intel x86 FLAGS register[1]						
Bit #	**Mask**	**Abbreviation**	**Description**	**Category**	**=1**	**=0**
FLAGS						
0	0x0001	CF	Carry flag	Status	CY(Carry)	NC(No Carry)
1	0x0002		Reserved, always 1 in **EFLAGS** [2][3]			
2	0x0004	PF	Parity flag	Status	PE(Parity Even)	PO(Parity Odd)
3	0x0008		Reserved[3]			
4	0x0010	AF	Adjust flag	Status	AC(Auxiliary Carry)	NA(No Auxiliary Carry)
5	0x0020		Reserved[3]			
6	0x0040	ZF	Zero flag	Status	ZR(Zero)	NZ(Not Zero)
7	0x0080	SF	Sign flag	Status	NG(Negative)	PL(Positive)
8	0x0100	TF	Trap flag (single step)	Control		
9	0x0200	IF	Interrupt enable flag	Control	EI(Enable Interrupt)	DI(Disable Interrupt)
10	0x0400	DF	Direction flag	Control	DN(Down)	UP(Up)
11	0x0800	OF	Overflow flag	Status	OV(Overflow)	NV(Not Overflow)
12-13	0x3000	IOPL	I/O privilege level (286+ only), always 1 [*clarification needed*] on 8086 and 186	System		
14	0x4000	NT	Nested task flag (286+ only), always 1 on 8086 and 186	System		
15	0x8000		Reserved, always 1 on 8086 and 186, always 0 on later models			

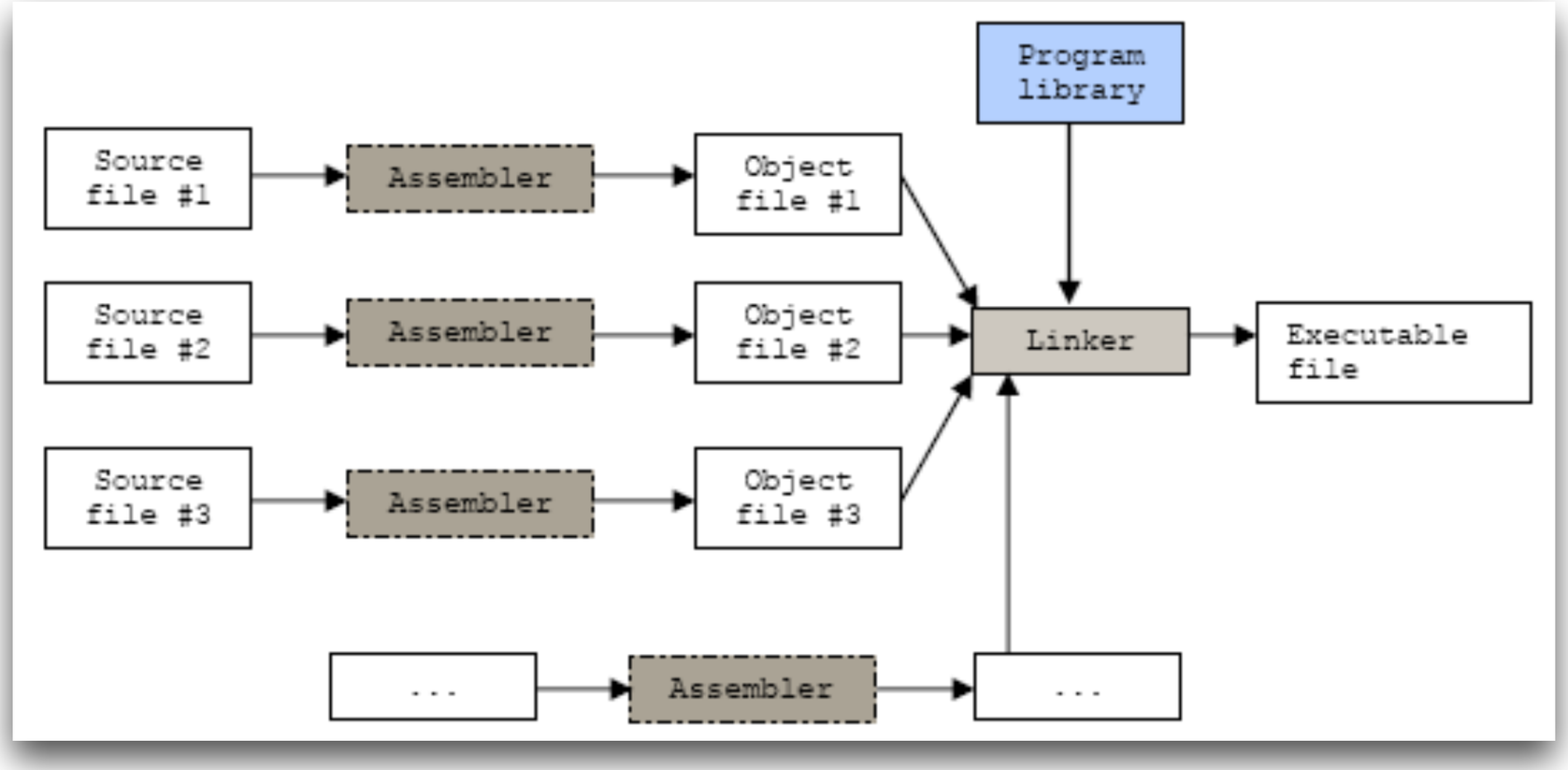
Computer Architecture





Compiling & Linking

Compiling and linking

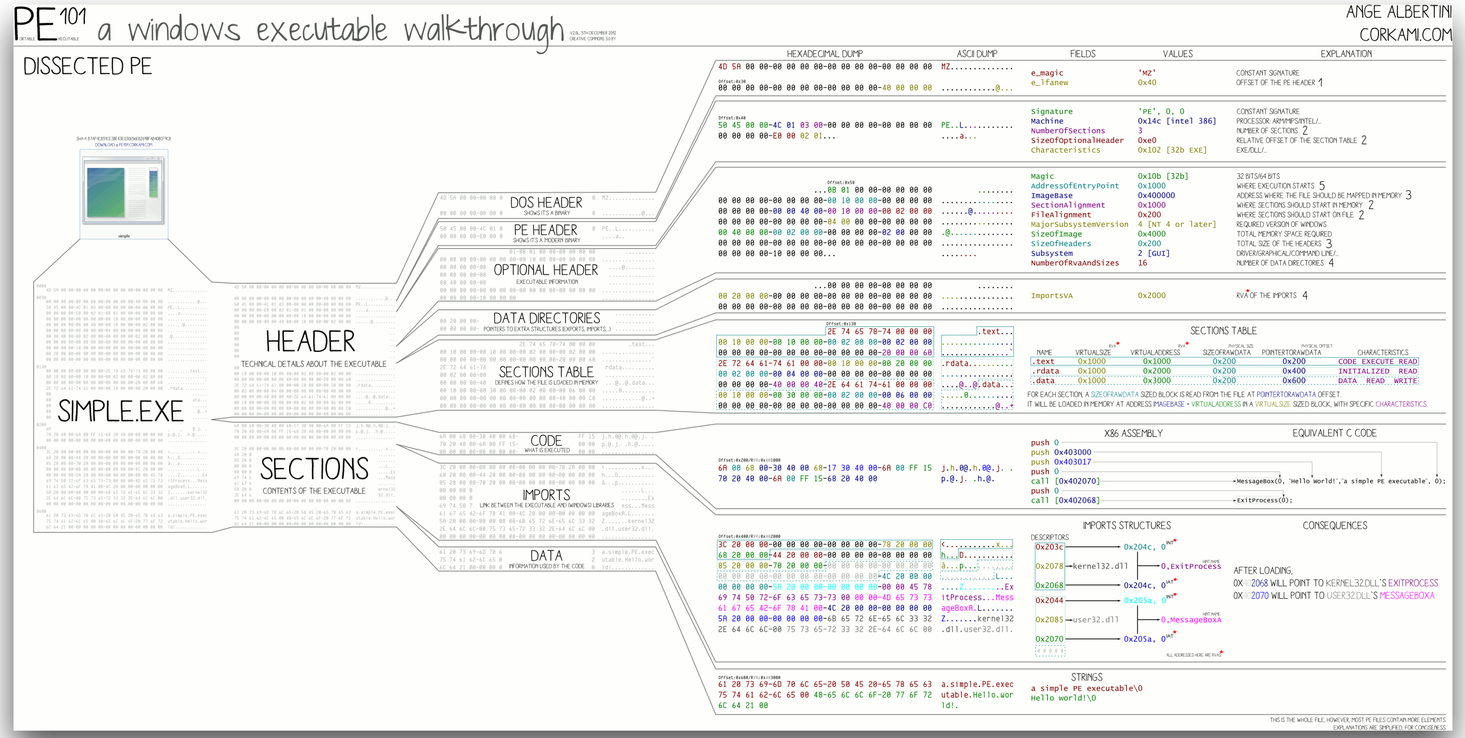


Compiling and linking

- **is it a reversible process? —> DECOMPILING**
  - Java, .NET -> YES, because of the very specific nature of the virtual machines that these runtimes use.
  - C, C++, Obj-C, Delphi, Pascal (truly compiled languages) -> the task get **much more complicated**

Compiling and linking

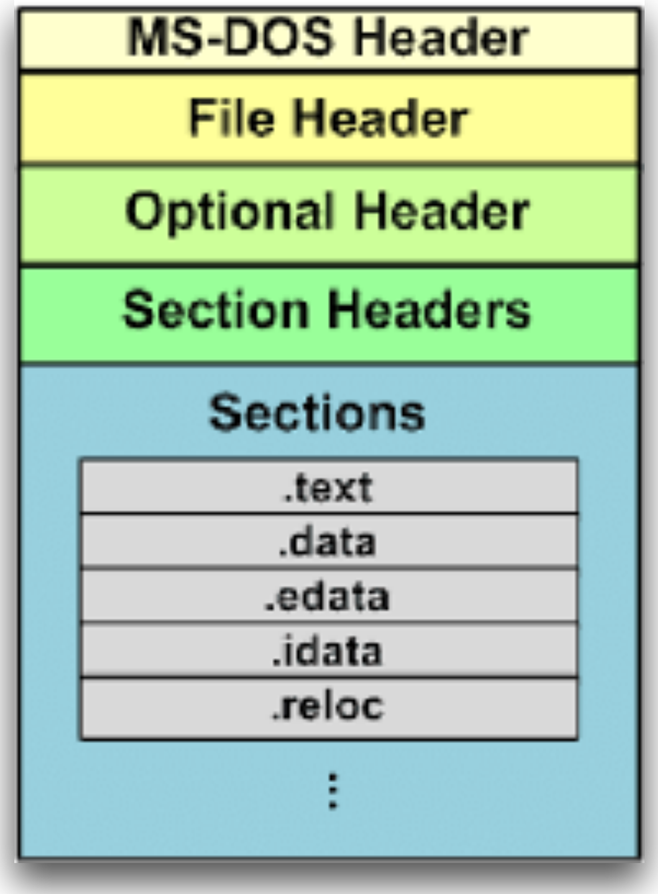
- to understand a compiled program of which we don't have the source code, we need to **reverse engineering** it
- we use **disassembly** for that purpose



PE file structure

PE file structure

- PE format Borns in 1993, with Windows 3.1
- PE modified version of UNIX COFF file format.
- extentions: cpl, .exe, .dll, .ocx, .sys, .scr, .drv
- works in x86 & x64 Intel 32/64 bits architecture, also MIPS and ARM.
- similar files in other O.S.: ELF (linux), Mach-O (OSX/Darwin).
- REF: https://docs.microsoft.com/es-es/windows/win32/debug/pe-format



PE file structure

- Header

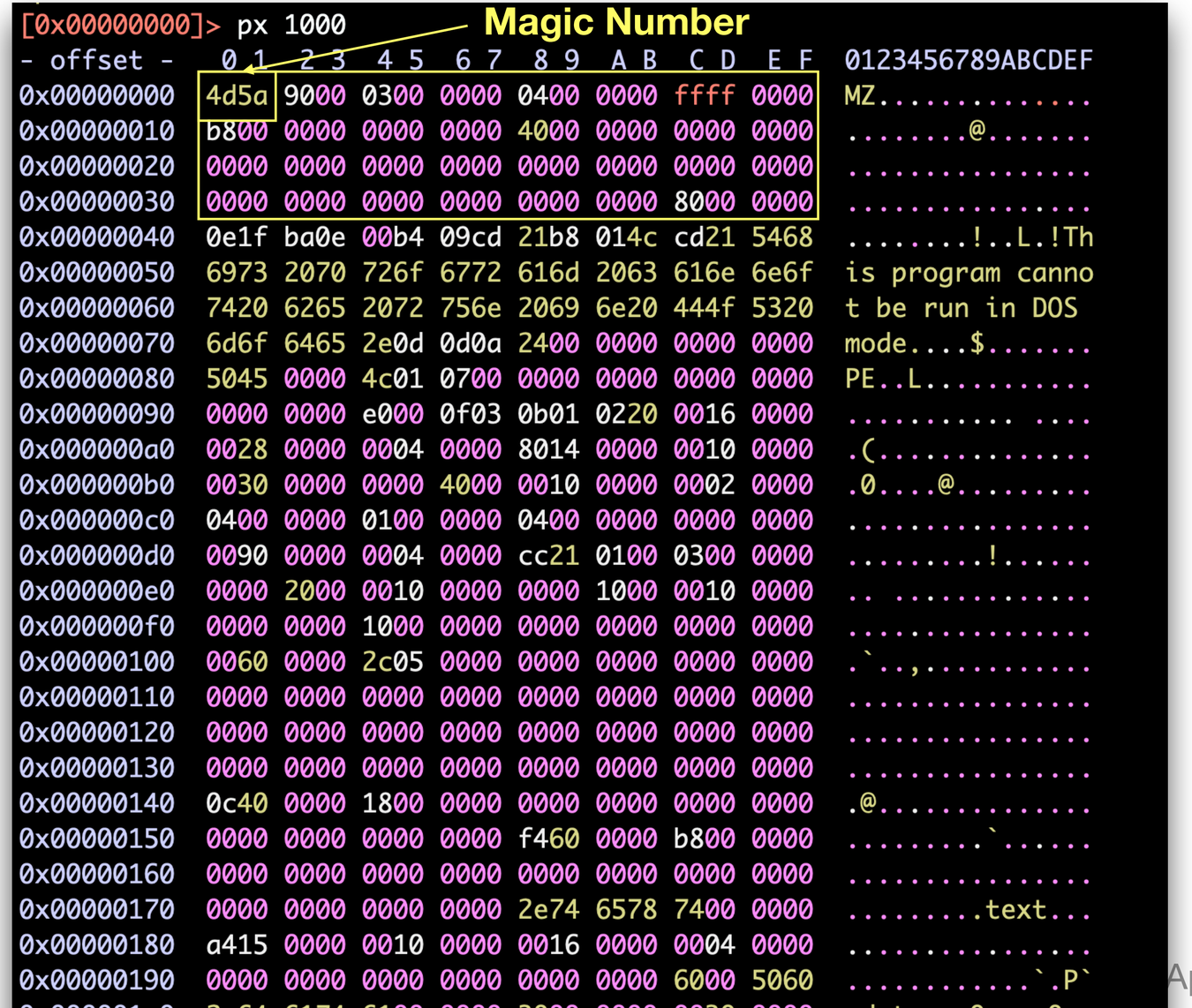
PE file structure

- Header

```
[0x00000000]> px 1000
- offset -   0 1  2 3  4 5  6 7  8 9  A B  C D  E F  0123456789ABCDEF
0x00000000  4d5a 9000 0300 0000 0400 0000 ffff 0000  MZ..............
0x00000010  b800 0000 0000 0000 4000 0000 0000 0000  ........@.......
0x00000020  0000 0000 0000 0000 0000 0000 0000 0000  ................
0x00000030  0000 0000 0000 0000 0000 0000 8000 0000  ................
0x00000040  0e1f ba0e 00b4 09cd 21b8 014c cd21 5468  ........!..L.!Th
0x00000050  6973 2070 726f 6772 616d 2063 616e 6e6f  is program canno
0x00000060  7420 6265 2072 756e 2069 6e20 444f 5320  t be run in DOS
0x00000070  6d6f 6465 2e0d 0d0a 2400 0000 0000 0000  mode....$.......
0x00000080  5045 0000 4c01 0700 0000 0000 0000 0000  PE..L...........
0x00000090  0000 0000 e000 0f03 0b01 0220 0016 0000  ........... ....
0x000000a0  0028 0000 0004 0000 8014 0000 0010 0000  .(..............
0x000000b0  0030 0000 0000 4000 0010 0000 0002 0000  .0....@.........
0x000000c0  0400 0000 0100 0000 0400 0000 0000 0000  ................
0x000000d0  0090 0000 0004 0000 cc21 0100 0300 0000  .........!......
0x000000e0  0000 2000 0010 0000 0000 1000 0010 0000  .. .............
0x000000f0  0000 0000 1000 0000 0000 0000 0000 0000  ................
0x00000100  0060 0000 2c05 0000 0000 0000 0000 0000  .`..,...........
0x00000110  0000 0000 0000 0000 0000 0000 0000 0000  ................
0x00000120  0000 0000 0000 0000 0000 0000 0000 0000  ................
0x00000130  0000 0000 0000 0000 0000 0000 0000 0000  ................
0x00000140  0c40 0000 1800 0000 0000 0000 0000 0000  .@..............
0x00000150  0000 0000 0000 0000 f460 0000 b800 0000  .........`......
0x00000160  0000 0000 0000 0000 0000 0000 0000 0000  ................
0x00000170  0000 0000 0000 0000 2e74 6578 7400 0000  .........text...
0x00000180  a415 0000 0010 0000 0016 0000 0004 0000  ................
0x00000190  0000 0000 0000 0000 0000 0000 6000 5060  ............`.P`
```

PE file structure

- Header



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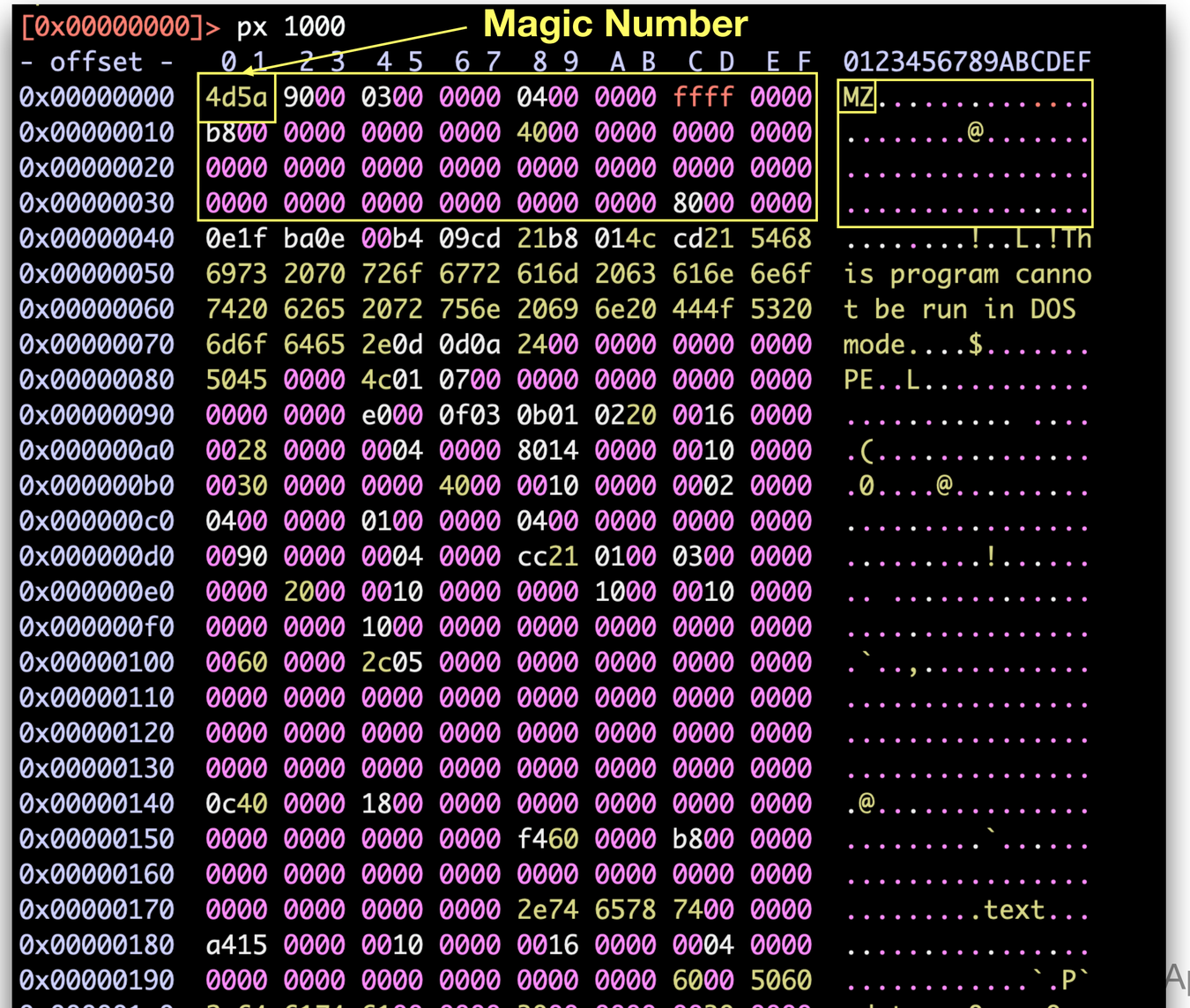

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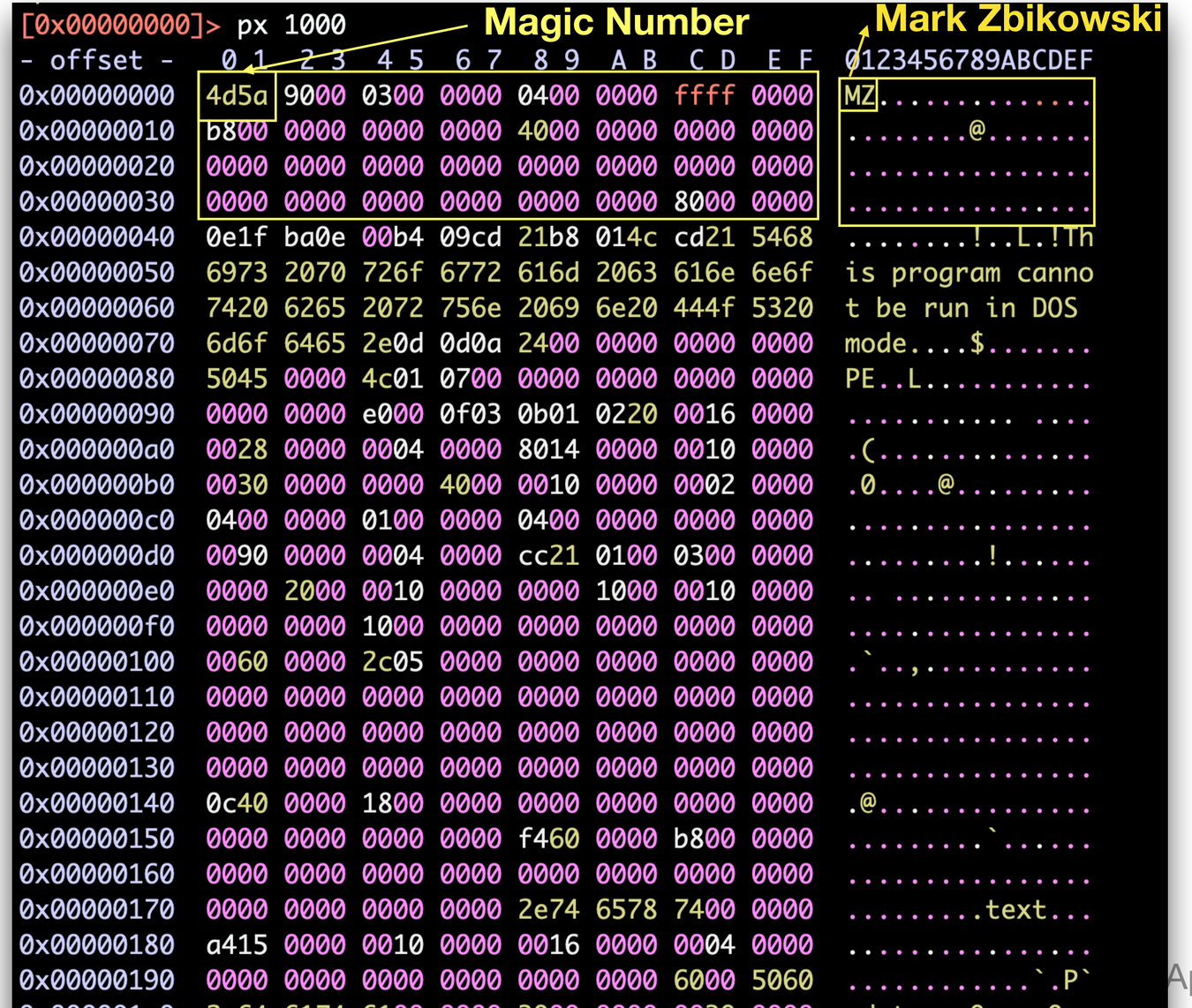

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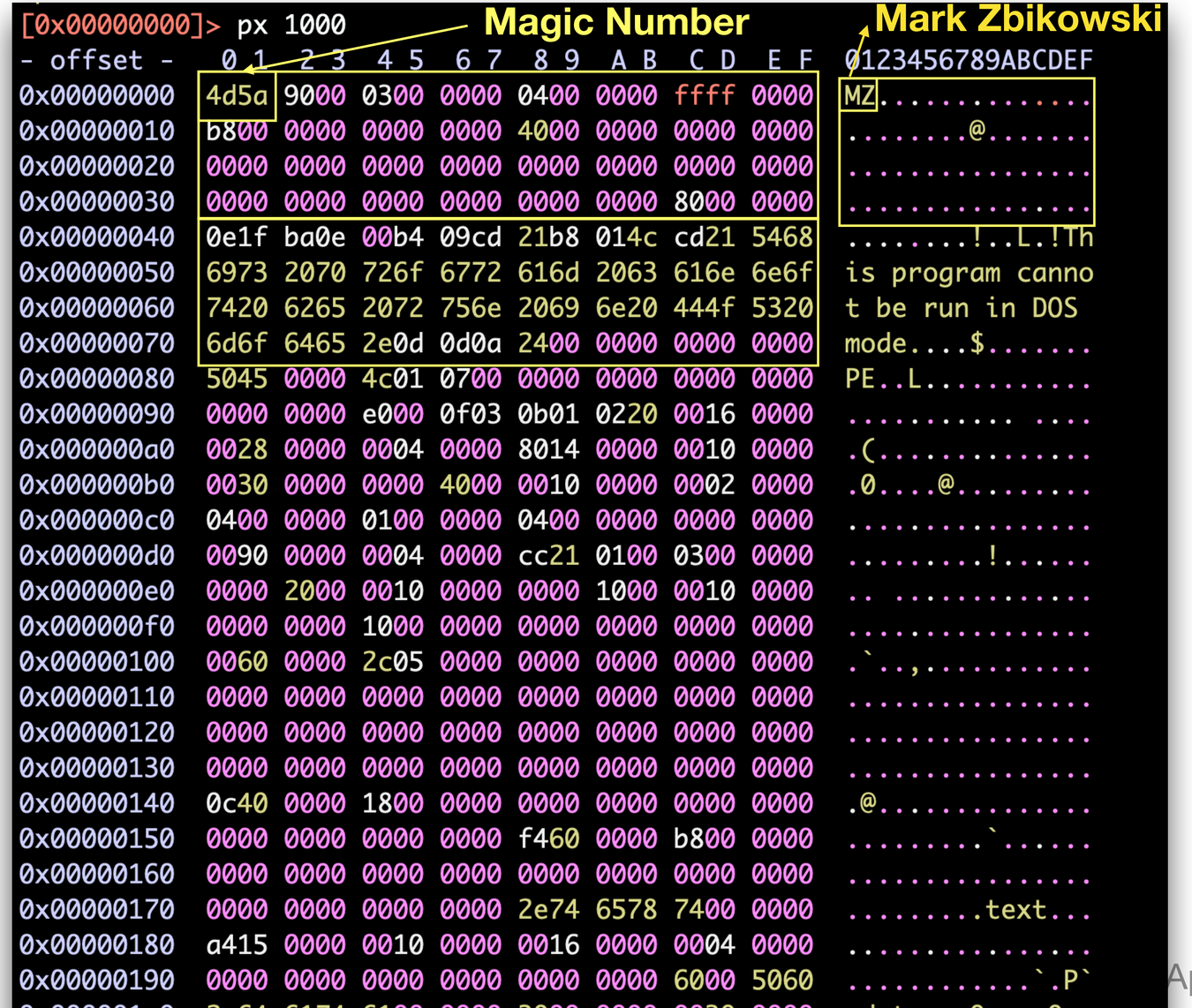

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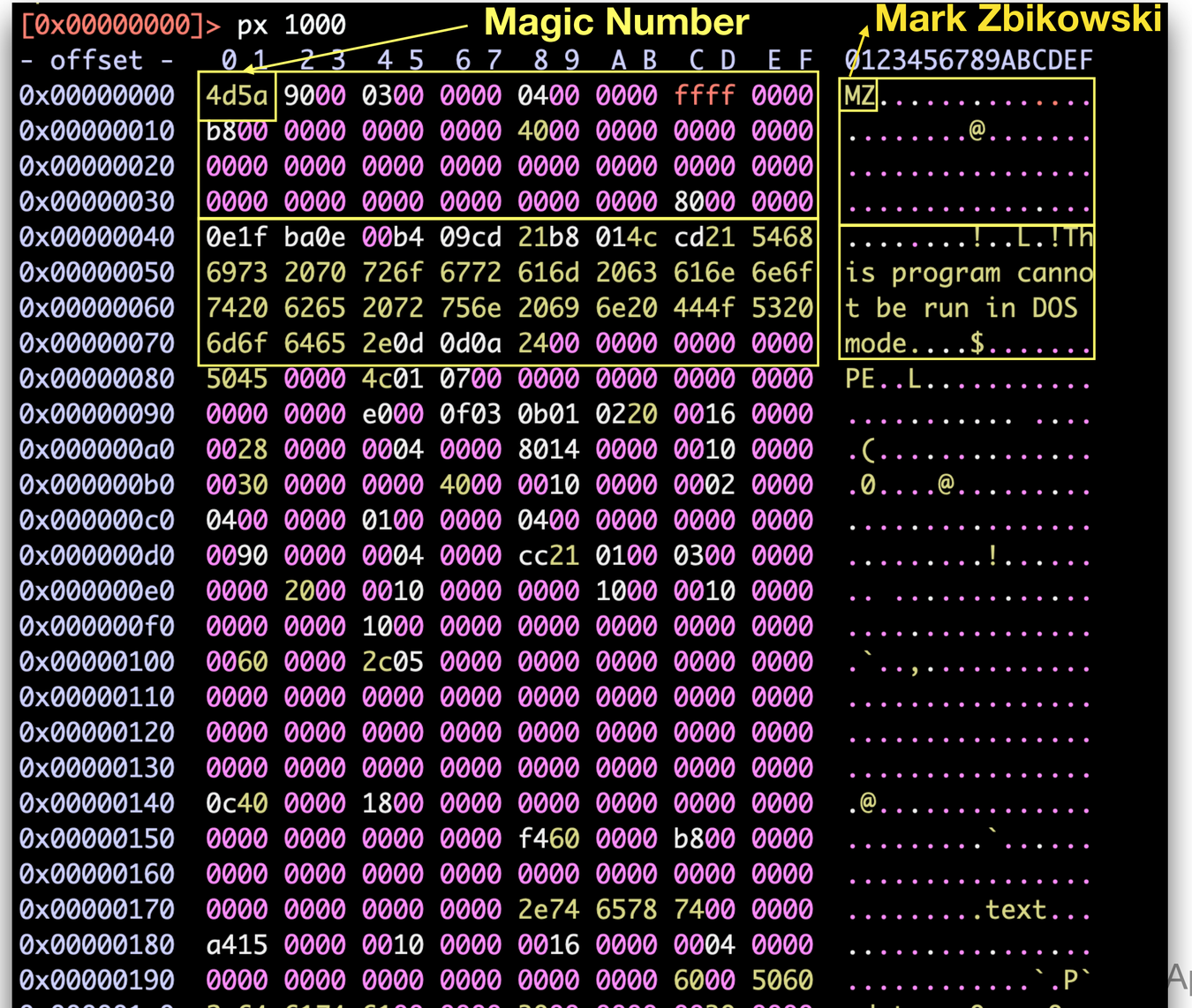

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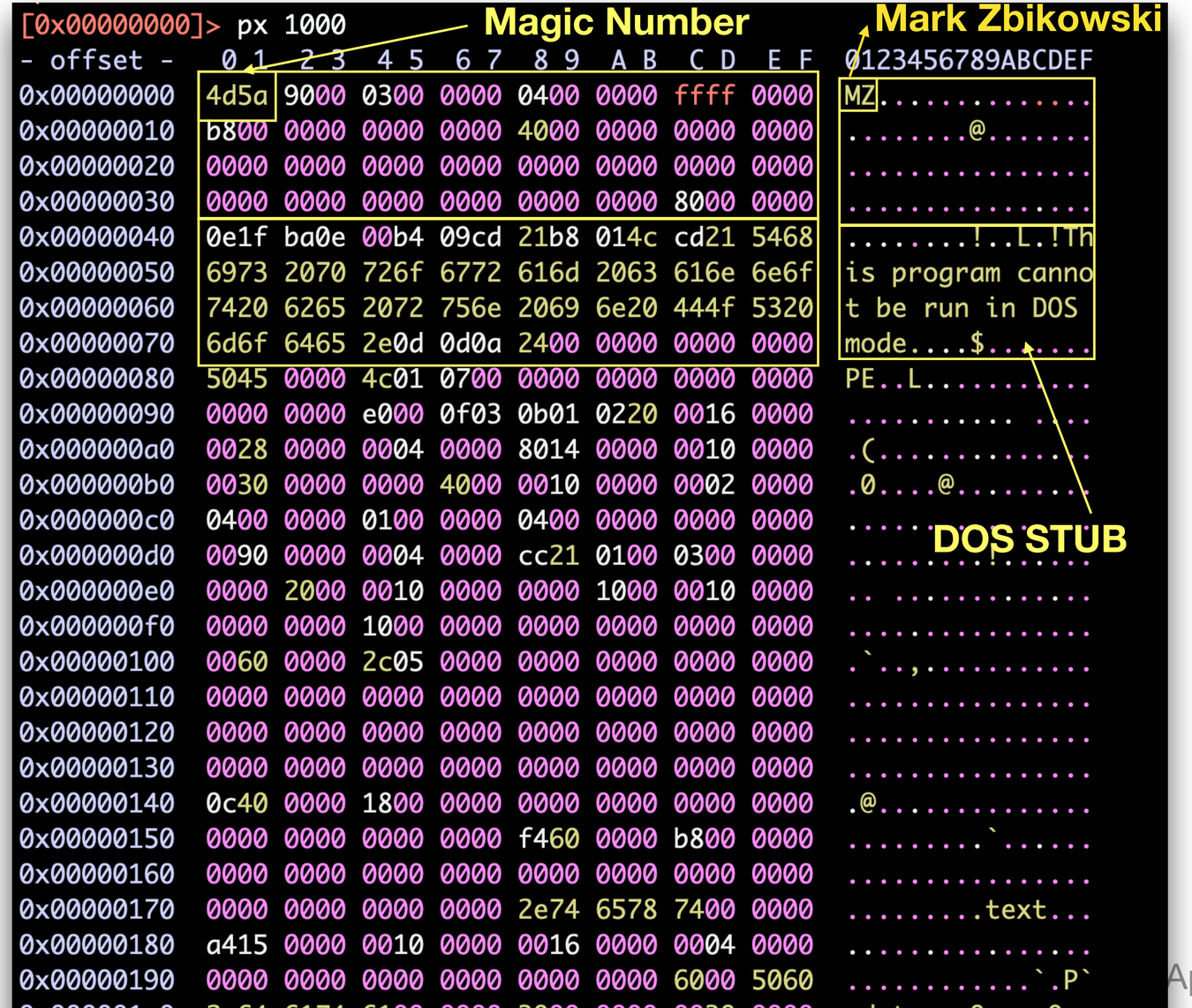

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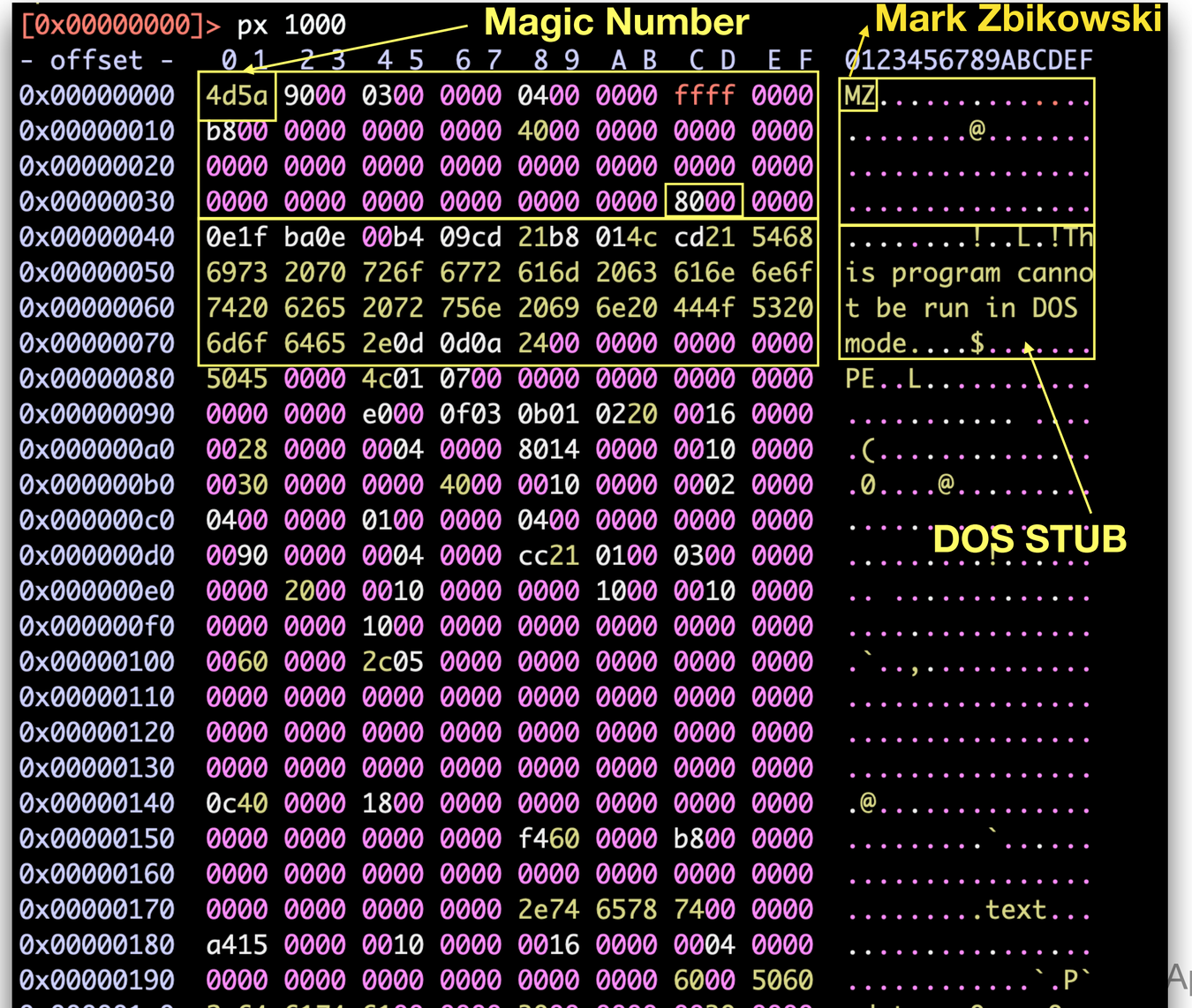

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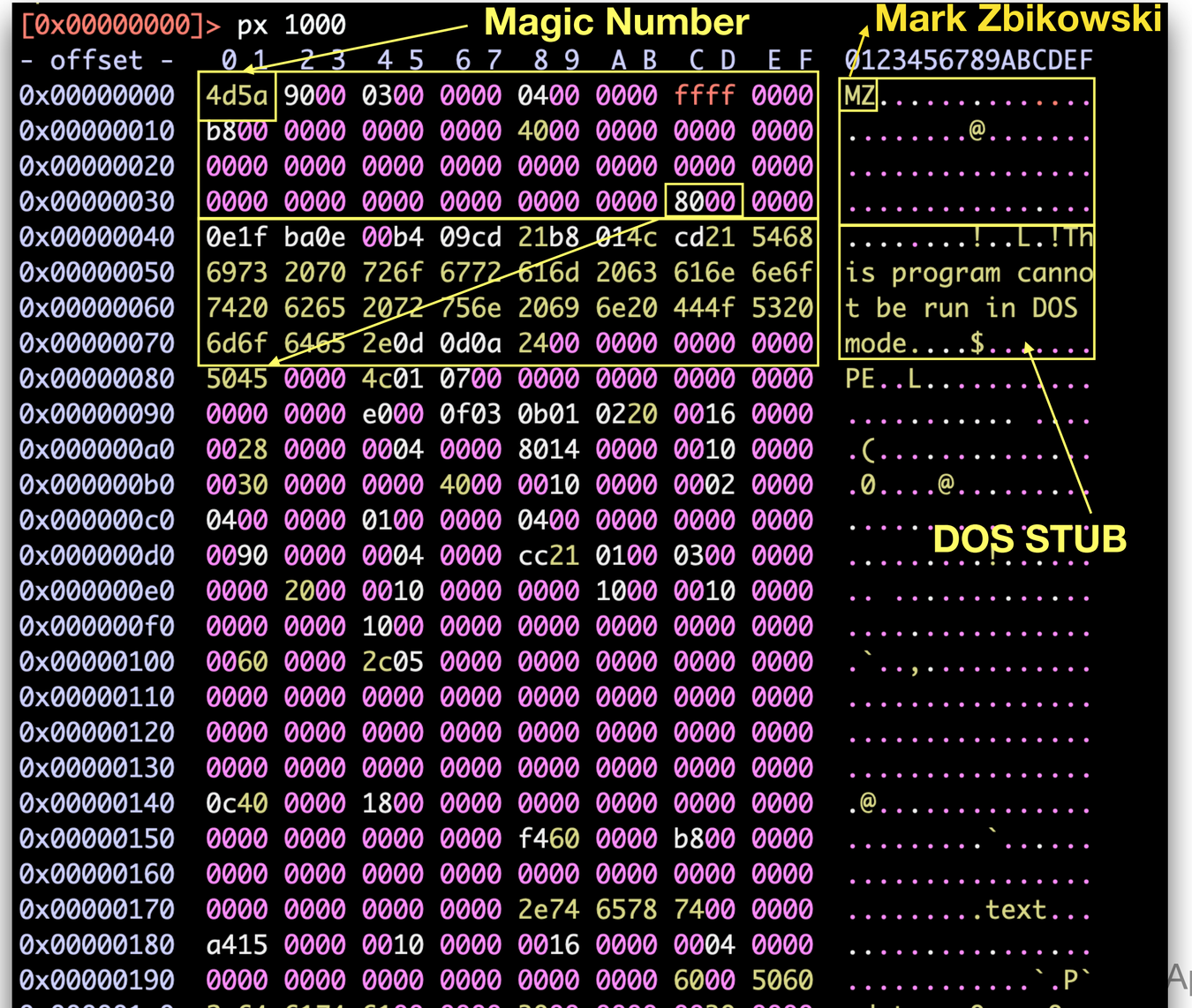

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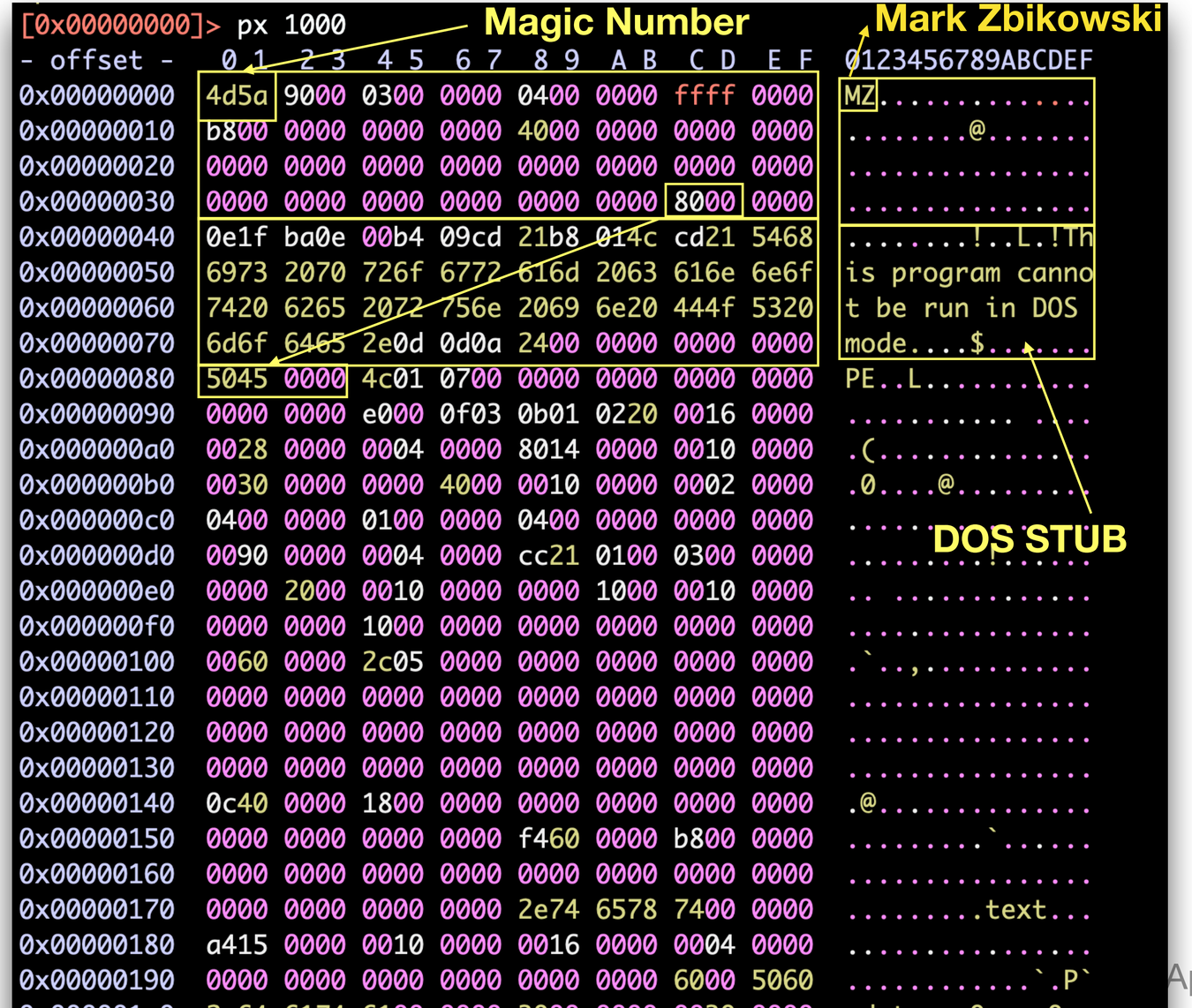

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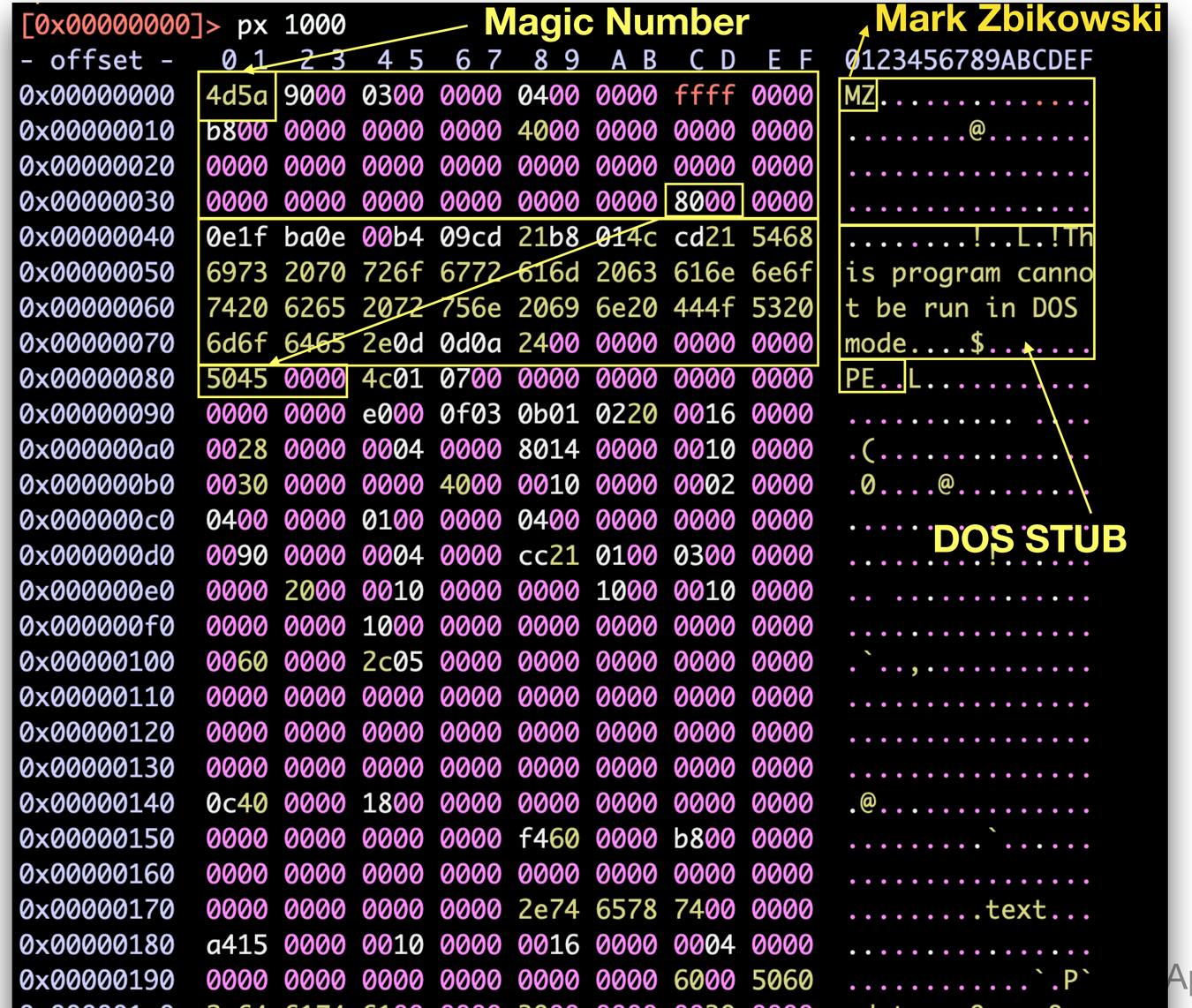
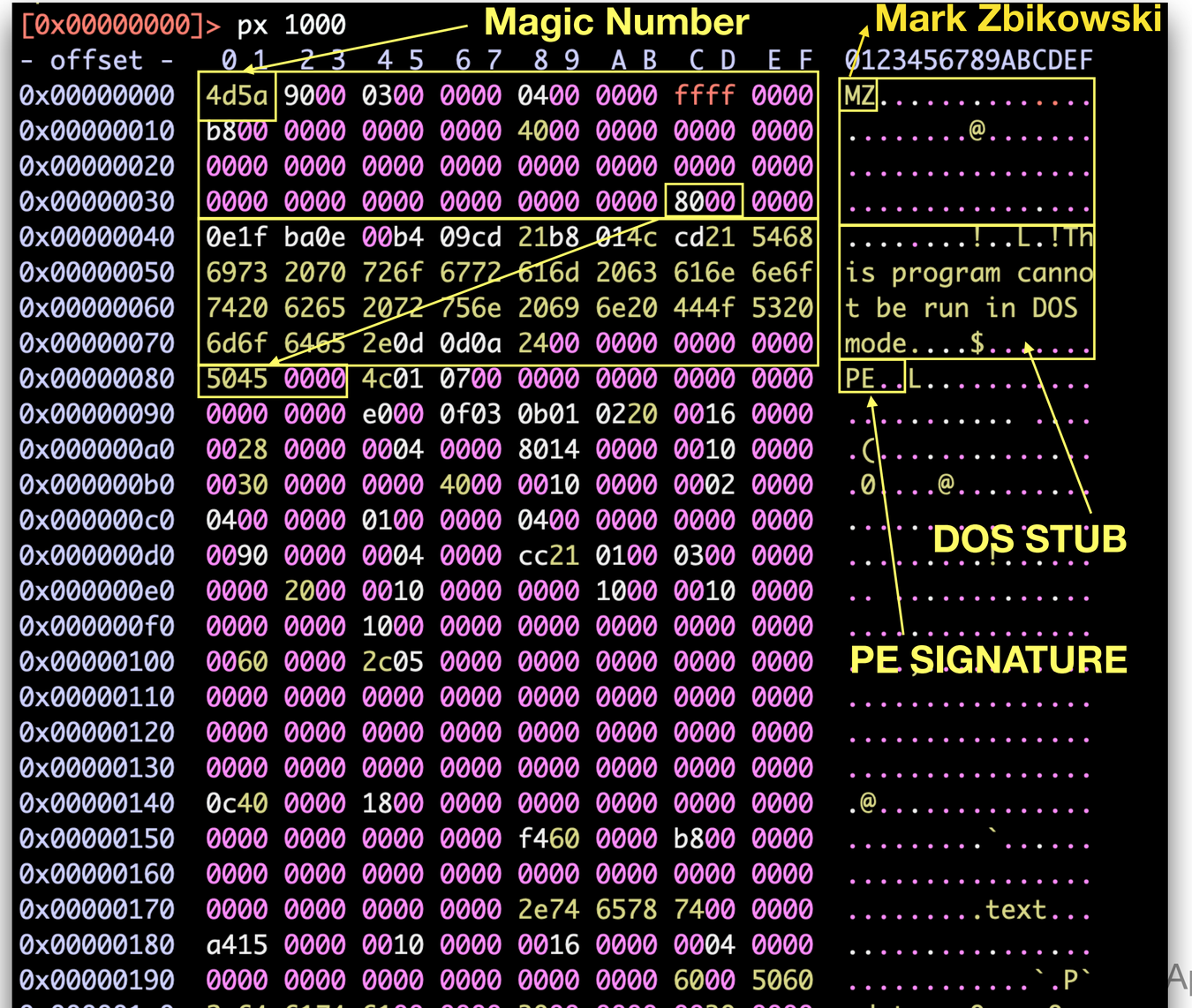
- Header



PE file structure

- Header



PE file structure

- Sections
  - .text -> executable code
  - .data -> initialized data
  - .rdata -> read-only initialised data
  - ...
  - .rsrc -> resource directory

PE file structure

PE file structure

```
[Sections]
Nm Paddr       Size Vaddr       Memsz Perms Name
00 0x00000400  5632 0x00401000  8192 -r-x .text
01 0x00001a00   512 0x00403000  4096 -rw- .data
02 0x00001c00  1536 0x00404000  4096 -r-- .rdata
03 0x00000000     0 0x00405000  4096 -rw- .bss
04 0x00002200  1536 0x00406000  4096 -rw- .idata
05 0x00002800   512 0x00407000  4096 -rw- .CRT
06 0x00002a00   512 0x00408000  4096 -rw- .tls
```

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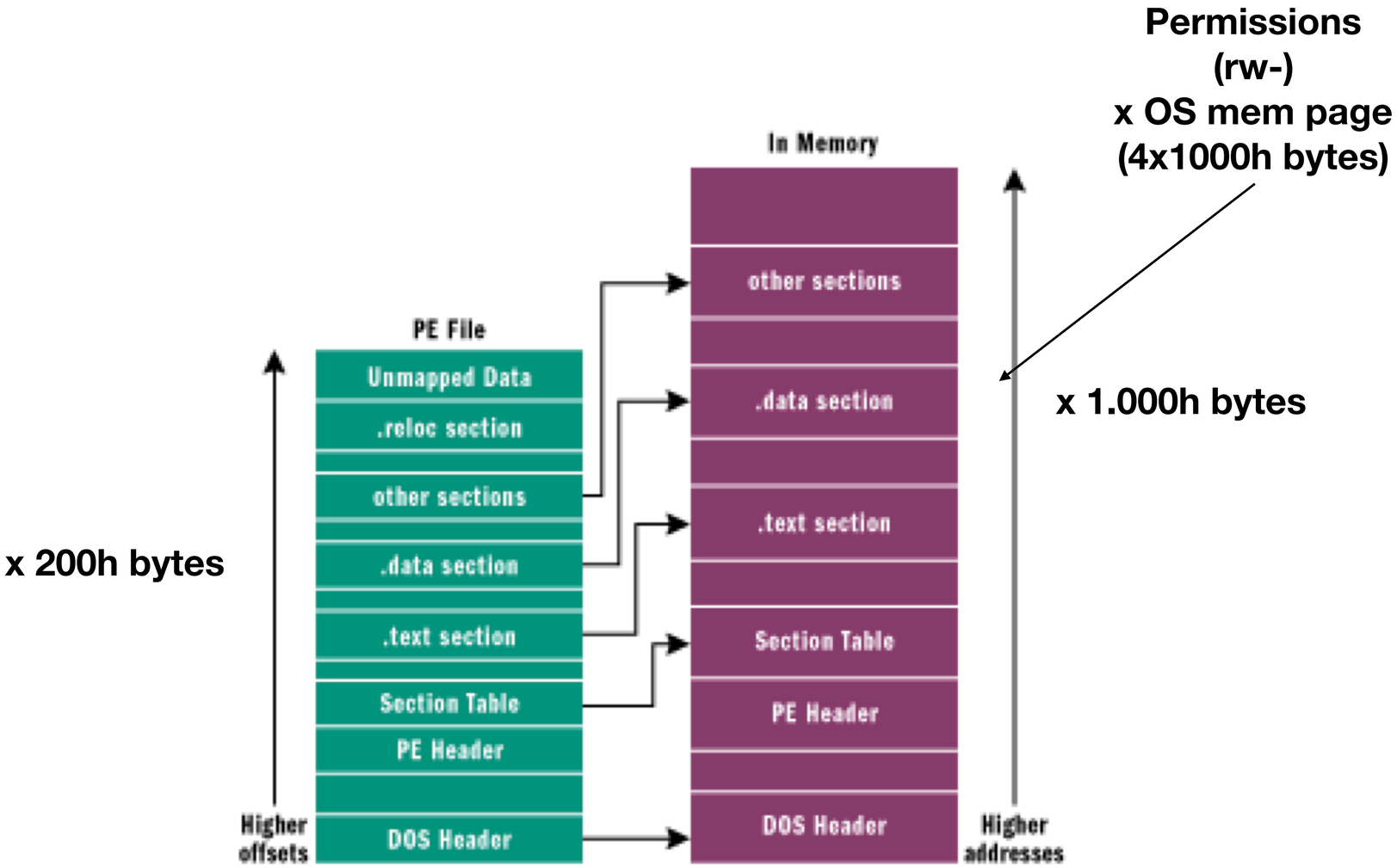
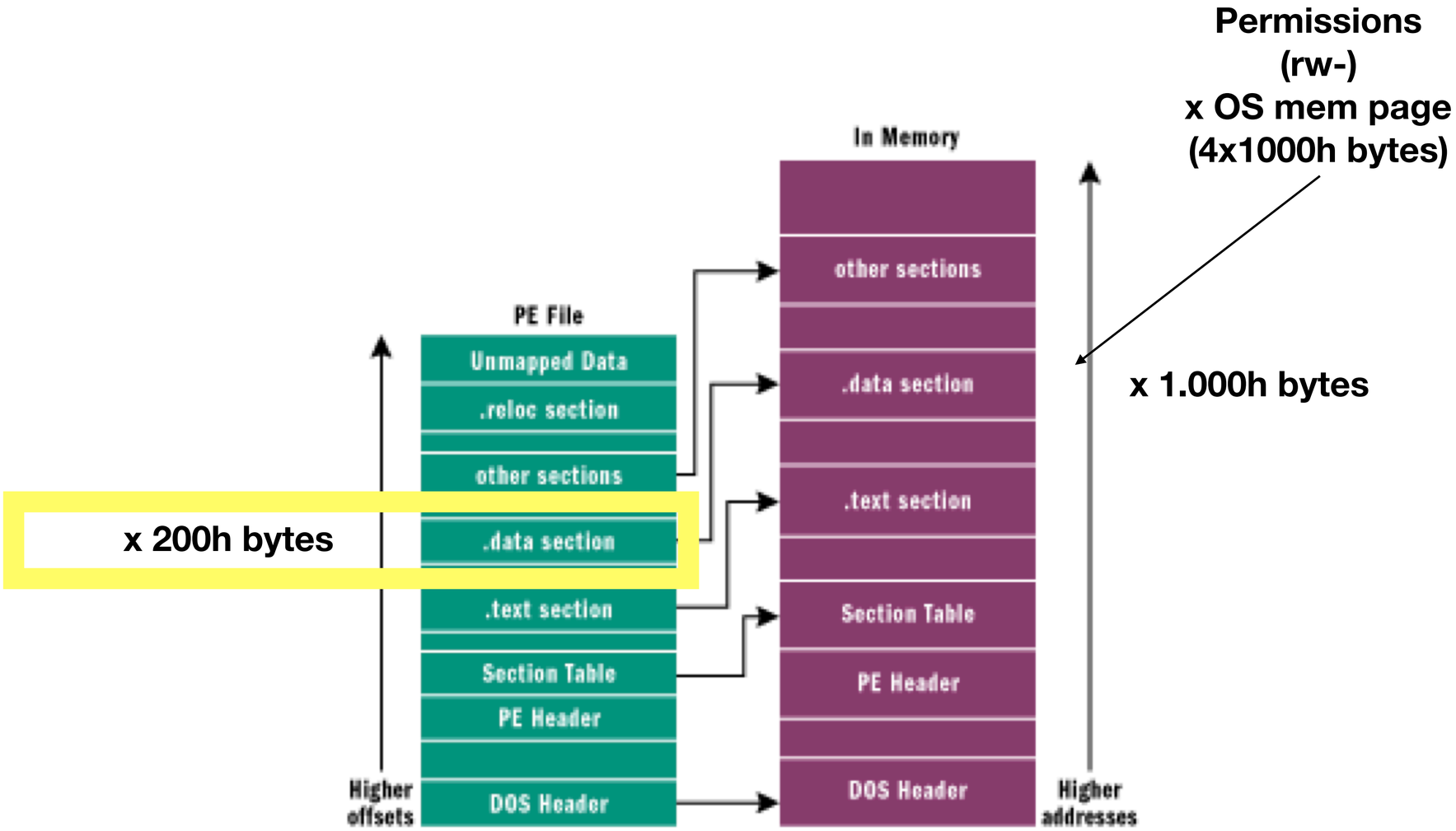
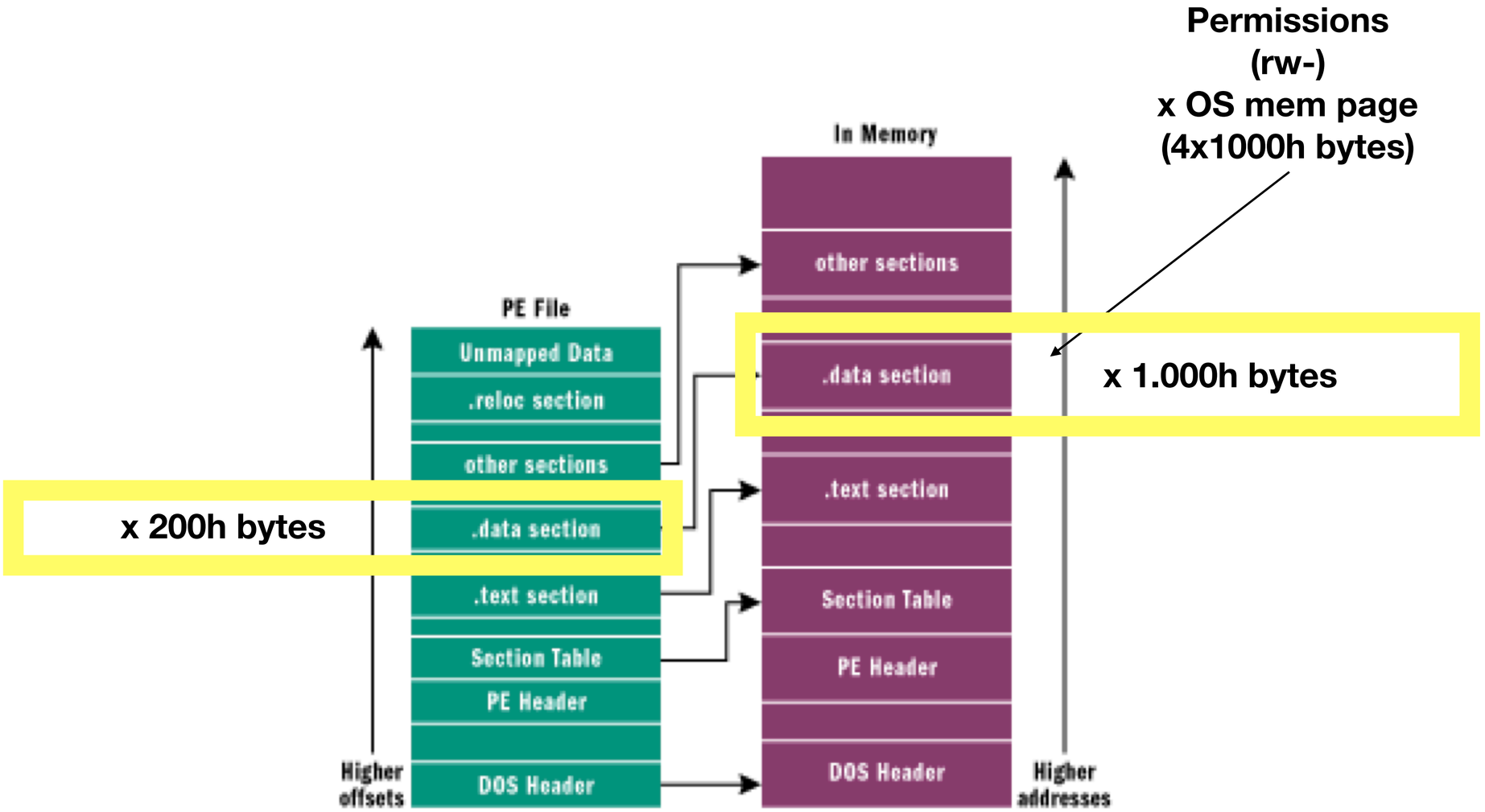
PE file structure



PE file structure



PE file structure



PE file structure

Loading process

❶ Headers

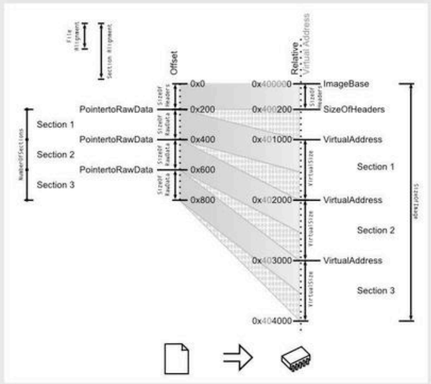
the *DOS Header* is parsed
the *PE Header* is parsed
(its offset is *DOS Header*´s e_lfanew)
the *Optional Header* is parsed
(it follows the *PE Header*)

❷ Sections table

Sections table is parsed
(it is located at: offset (*OptionalHeader*) + *SizeOfOptionalHeader*)
it contains *NumberOfSections* elements
it is checked for validity with alignments:
FileAlignments and *SectionAlignments*

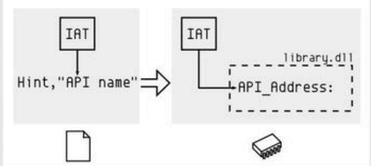
❸ Mapping

the file is mapped in memory according to:
the *ImageBase*
the *SizeOfHeaders*
the Sections table



❹ Imports

DataDirectories are parsed
they follow the *OptionalHeader*
their number is *NumOfRVAAndSizes*
imports are always #2
Imports are parsed
each descriptor specifies a *DLLname*
this DLL is loaded in memory
IAT and *INT* are parsed simultaneously
for each API in *INT*
its address is written in the *IAT* entry



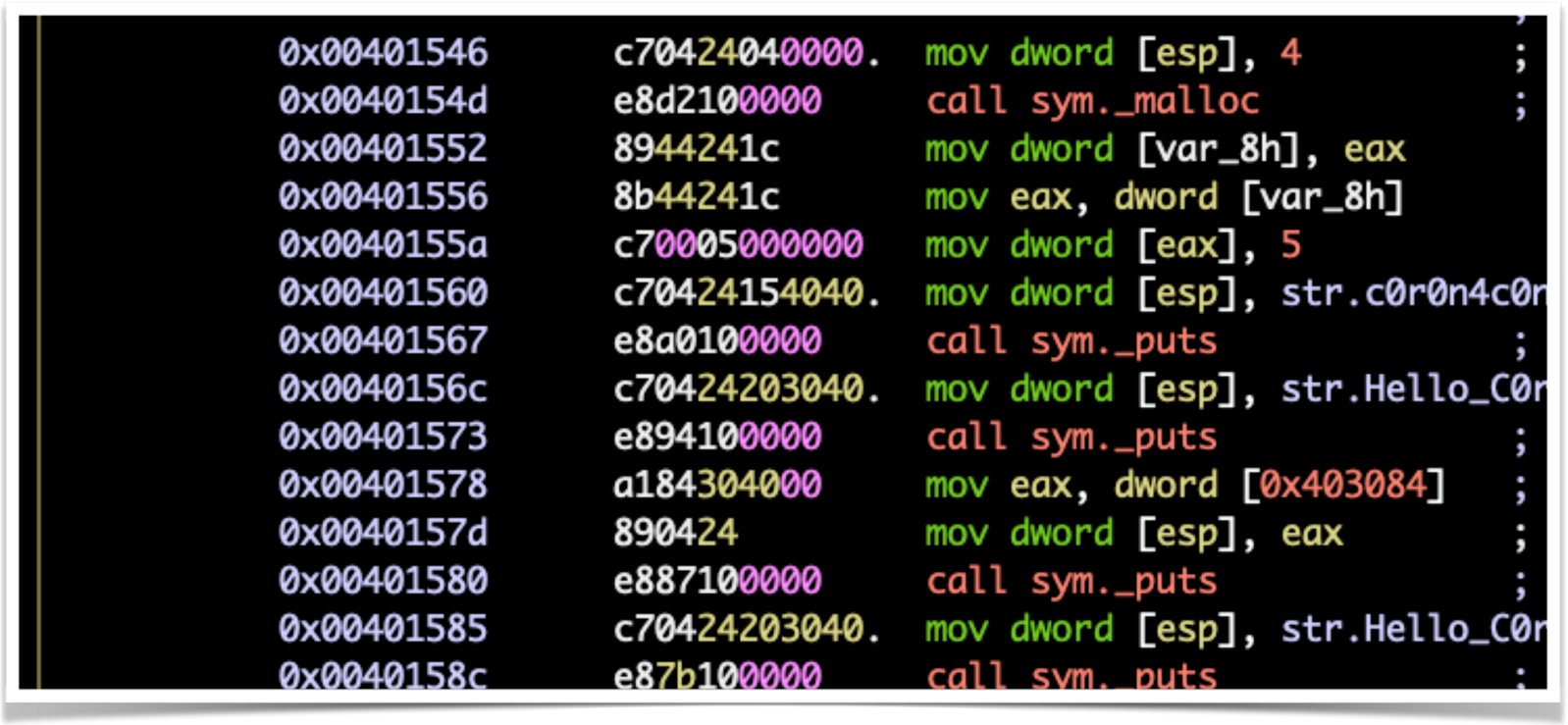
❺ Execution

Code is called at the *EntryPoint*
the calls of the code go via the IAT to the APIs

Notes

MZ HEADER *aka* DOS_HEADER
Starts with 'MZ' (initials of *Mark Zbikowski* MS-DOS developer)
PE HEADER *aka* IMAGE_FILE_HEADERS / COFF file header
Starts with 'PE' (Portable Executable)
OPTIONAL HEADER *aka* IMAGE_OPTIONAL_HEADER
Optional only for non-standard PEs but required for executables
RVA Relative Virtual Address
Address relative to ImageBase (at ImageBase, RVA = 0)
Almost all addresses of the headers are RVAs
In code, addresses are *not* relative.

INT Import Name Table
Null-terminated list of pointers to Hint, Name structures
IAT Import Address Table
Null-terminated list of pointers
On file it is a copy of the INT
After loading it points to the imported APIs
HINT
Index in the exports table of a DLL to be imported
Not required but provides a speed-up by reducing look-up



Assembly language

Assembly Language

- Low-level programming language
- designed for a specific type of processor
- Compiling high level lang. (C/C++) -> Assembly
- Can also be written from scratch

Assembly Language

c

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

#define MYWORD "c0r0n4c0n"

char array[100]="Hello C0r0n4c0n!";
char *p="bye, bye, c0r0n4c0n!";

int main(){
        char local[4]="hi!";
        int *q=malloc(sizeof(int));
        *q=5;
        printf("%s\n",MYWORD);
        printf("%s\n",array);
        printf("%s\n",p);
        printf("%s\n",array);
        printf("%d\n",q);
}
```

Assembly

```
_array:
        .ascii "Hello C0r0n4c0n!\0"
        .space 83
        .globl  _p
        .section .rdata,"dr"
LC0:
        .ascii "bye, bye, c0r0n4c0n!\0"
        .data
        .align 4
_p:
        .long   LC0
        .def    ___main;        .scl    2;      .type   32;     .endef
        .section .rdata,"dr"
LC1:
        .ascii "c0r0n4c0n\0"
LC2:
        .ascii "%d\12\0"
        .text
        .globl  _main
        .def    _main;  .scl    2;      .type   32;     .endef
_main:
        push    ebp
        mov     ebp, esp
        and     esp, -16
        sub     esp, 32
        call    ___main
        mov     DWORD PTR [esp+24], 2189672
        mov     DWORD PTR [esp], 4
        call    _malloc
        mov     DWORD PTR [esp+28], eax
        mov     eax, DWORD PTR [esp+28]
        mov     DWORD PTR [eax], 5
        mov     DWORD PTR [esp], OFFSET FLAT:LC1
        call    _puts
        mov     DWORD PTR [esp], OFFSET FLAT:_array
        call    _puts
        mov     eax, DWORD PTR _p
        mov     DWORD PTR [esp], eax
        call    _puts
```

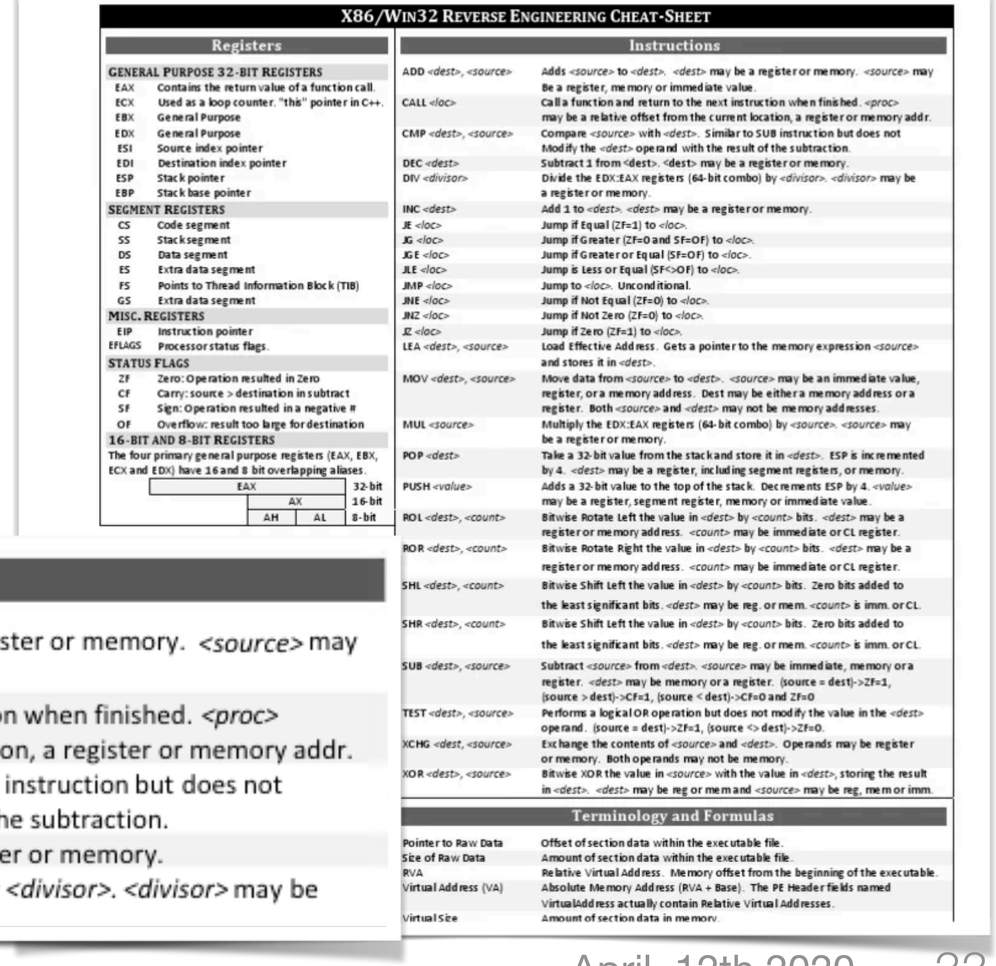
Assembly Language

Assembly vs. machine code

Machine code bytes	Assembly language statements
	foo:
B8 22 11 00 FF	movl $0xFF001122, %eax
01 CA	addl %ecx, %edx
31 F6	xorl %esi, %esi
53	pushl %ebx
8B 5C 24 04	movl 4(%esp), %ebx
8D 34 48	leal (%eax,%ecx,2), %esi
39 C3	cmpl %eax, %ebx
72 EB	jnae foo
C3	retl

Instruction stream

```
B8 22 11 00 FF 01 CA 31
04 8D 34 48 39 C3 72 EB
```



Instructions

ADD <*dest*>, <*source*>	Adds <*source*> to <*dest*>. <*dest*> may be a register or memory. <*source*> may Be a register, memory or immediate value.
CALL <*loc*>	Call a function and return to the next instruction when finished. <*proc*> may be a relative offset from the current location, a register or memory addr.
CMP <*dest*>, <*source*>	Compare <*source*> with <*dest*>. Similar to SUB instruction but does not Modify the <*dest*> operand with the result of the subtraction.
DEC <*dest*>	Subtract 1 from <dest>. <dest> may be a register or memory.
DIV <*divisor*>	Divide the EDX:EAX registers (64-bit combo) by <*divisor*>. <*divisor*> may be a register or memory

Assembly Language

This table summarizes the main differences between Intel and AT&T syntax:

	Intel	AT&T
Comments	`;`	`//`
Instructions	Untagged `add`	Tagged with operand sizes: `addq`
Registers	`eax`, `ebx`, etc.	`%eax`, `%ebx`, etc.
Immediates	0x100	$0x100
Indirect	`[eax]`	`(%eax)`
General indirect	`[base + reg + reg * scale + displacement]`	`displacement(reg, reg, scale)`

Assembly Language

- `push eax -> mov dword [esp],eax`
- Function prologue:

```
push ebp
mov ebp, esp
sub esp, N
```

- Function epilogue:

```
leave -> mov esp, ebp ; pop ebp
ret
```

recognising C code constructs in assembly

Recognising C code in assembly

- Recognising C code is very important in malware reversing
- Where are the variables and data?
- How does a pointer look like?

Recognising C code in assembly

- pointers

pointers.c

```c
#include <stdio.h>


char *p="Hello world!";

int main(){
    printf("%s\n",p);
    return 0;
}

```

.rdata

```
- offset -   0 1  2 3  4 5  6 7  8 9  A B  C D  E F  0123456789ABCDEF
0x00404000  4865 6c6c 6f20 776f 726c 6421 0000 0000  Hello world!....
0x00404010  2053 4000 4050 4000 e017 4000 0080 4000   S@.@P@...@...@.
```

.data

```
- offset -   0 1  2 3  4 5  6 7  8 9  A B  C D  E F  0123456789ABCDEF
0x00403000  0a00 0000 0040 4000 a026 4000 ffff ffff  .....@@..&@.....
0x00403010  ffff ffff ff00 0000 0200 0000 ffff ffff  ................
```

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Recognising C code in assembly

- global variables

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[0x004014f0]> px 16 @0x00403000
- offset -   0 1  2 3  4 5  6 7  8 9  A B  C D  E F  0123456789ABCDEF
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[0x004014f0]>
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[0x004014f0]>
```

```
[0x004014f0]> pdf
┌ (fcn) main 28
│   int main (int argc, char **argv, char **envp);
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      e895000000      call fcn.00401590
│           0x004014fb      c70504304000.   mov dword [0x403004], 8     ; [0x403004:4]=7
│           0x00401505      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=7
│           0x0040150a      c9              leave
└           0x0040150b      c3              ret
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│           0x0040150a      c9              leave
└           0x0040150b      c3              ret
```

Recognising C code in assembly

- local variables

```
1  int main(){
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fcn) main 44
 int main (int argc, char **argv, char **envp);
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         0x004014f0      55              push ebp
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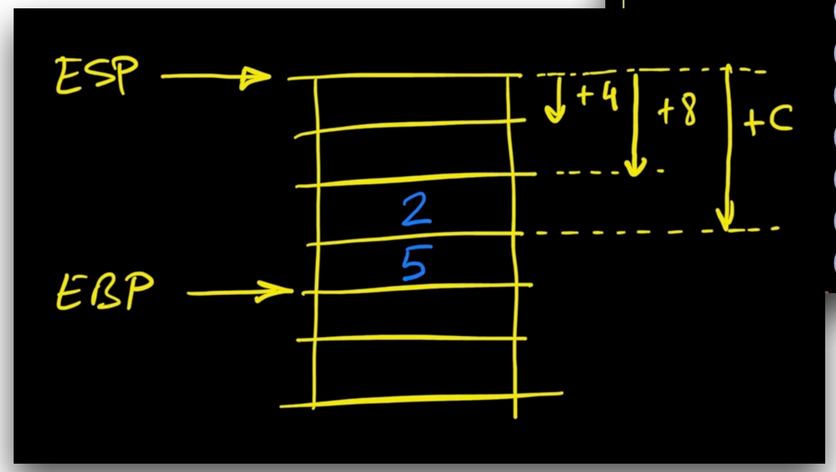
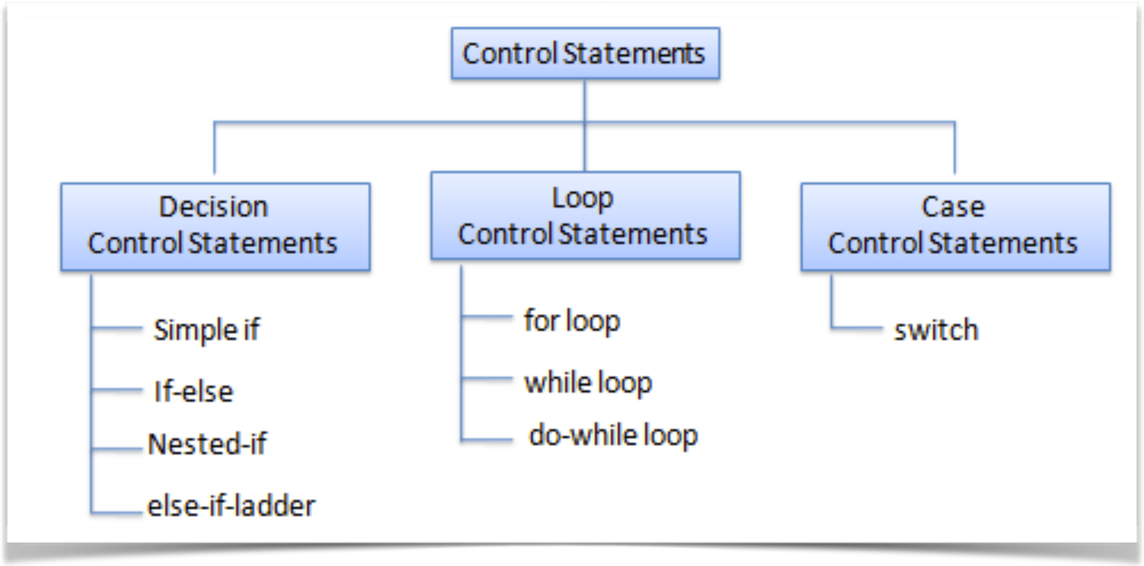




recognising C control statements in assembly

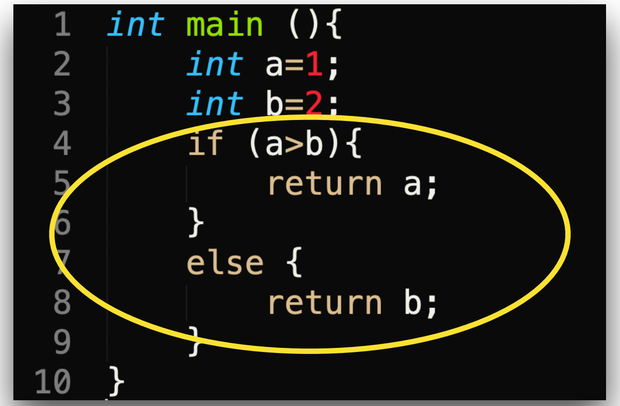
Recognising C code in assembly

- if statement

```
1  int main (){
2      int a=1;
3      int b=2;
4      if (a>b){
5          return a;
6      }
7      else {
8          return b;
9      }
10 }
```

Recognising C code in assembly

- if statement



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```

Recognising C code in assembly

- if statement

```c
int main (){
    int a=1;
    int b=2;
    if (a>b){
        return a;
    }
    else {
        return b;
    }
}
```

```
[0x004014f0]> pdf
┌ (fcn) main 52
│   int main (int argc, char **argv, char **envp);
│           ; var signed int var_8h @ esp+0x8
│           ; var int32_t var_ch @ esp+0xc
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8b2000000      call fcn.004015b0
│           0x004014fe      c744240c0100.   mov dword [var_ch], 1
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│           0x0040150e      8b44240c        mov eax, dword [var_ch]
│           0x00401512      3b442408        cmp eax, dword [var_8h]
│       ┌─< 0x00401516      7e06            jle 0x40151e
│       │   0x00401518      8b44240c        mov eax, dword [var_ch]
│      ┌──< 0x0040151c      eb04            jmp 0x401522
│      │    ; CODE XREF from main @ 0x401516
│      └──> 0x0040151e      8b442408        mov eax, dword [var_8h]
│           ; CODE XREF from main @ 0x40151c
│           0x00401522      c9              leave
└           0x00401523      c3              ret
```

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│      │   ; CODE XREF from main @ 0x40151c
│      └─> 0x00401522      c9              leave
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```

eax=1

Recognising C code in assembly

- if statement

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│       ┌< 0x00401516      7e06            jle 0x40151e
│       │   0x00401518      8b44240c        mov eax, dword [var_ch]
│      ┌< 0x0040151c      eb04            jmp 0x401522
│      ││  ; CODE XREF from main @ 0x401516
│      │└> 0x0040151e      8b442408        mov eax, dword [var_8h]
│      │   ; CODE XREF from main @ 0x40151c
│      └─> 0x00401522      c9              leave
└           0x00401523      c3              ret
```

eax=1

1<2

Recognising C code in assembly

- if statement

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│       ┌< 0x00401516      7e06            jle 0x40151e
│           0x00401518      8b44240c        mov eax, dword [var_ch]
│      ┌< 0x0040151c      eb04            jmp 0x401522
│      │    ; CODE XREF from main @ 0x401516
│      └─> 0x0040151e      8b442408        mov eax, dword [var_8h]
│           ; CODE XREF from main @ 0x40151c
│           0x00401522      c9              leave
└           0x00401523      c3              ret
```

eax=1

1<2

Recognising C code in assembly

- if statement

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1  int main (){
2      int a=1;
3      int b=2;
4      if (a>b){
5          return a;
6      }
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┌ (fcn) main 52
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│      ┌< 0x0040151c      eb04            jmp 0x401522
│      │   ; CODE XREF from main @ 0x401516
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```

eax=1

1<2

Recognising C code in assembly

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│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8b2000000      call fcn.004015b0
│           0x004014fe      c744240c0100.   mov dword [var_ch], 1
│           0x00401506      c74424080200.   mov dword [var_8h], 2
│           0x0040150e      8b44240c        mov eax, dword [var_ch]
│           0x00401512      3b442408        cmp eax, dword [var_8h]
│       ┌< 0x00401516      7e06            jle 0x40151e 1<2
│           0x00401518      8b44240c        mov eax, dword [var_ch]
│      ┌< 0x0040151c      eb04            jmp 0x401522
│      │   ; CODE XREF from main @ 0x401516
│      └> 0x0040151e      8b442408        mov eax, dword [var_8h]
│      │   ; CODE XREF from main @ 0x40151c
│      └> 0x00401522      c9              leave
└           0x00401523      c3              ret
```

eax=1

Recognising C code in assembly

- if statement

```
1  int main (){
2      int a=1;
3      int b=2;
4      if (a>b){
5          return a;
6      }
7      else {
8          return b;
9      }
10 }
```

```
[0x004014f0]> pdf
┌ (fcn) main 52
│   int main (int argc, char **argv, char **envp);
│           ; var signed int var_8h @ esp+0x8
│           ; var int32_t var_ch @ esp+0xc
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8b2000000      call fcn.004015b0
│           0x004014fe      c744240c0100.   mov dword [var_ch], 1
│           0x00401506      c74424080200.   mov dword [var_8h], 2
│           0x0040150e      8b44240c        mov eax, dword [var_ch]
│           0x00401512      3b442408        cmp eax, dword [var_8h]
│       ┌< 0x00401516      7e06            jle 0x40151e 1<2
│           0x00401518      8b44240c        mov eax, dword [var_ch]
│      ┌< 0x0040151c      eb04            jmp 0x401522
│      │   ; CODE XREF from main @ 0x401516
│      └─> 0x0040151e      8b442408        mov eax, dword [var_8h]
│          ; CODE XREF from main @ 0x40151c
│          0x00401522      c9              leave
└          0x00401523      c3              ret
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eax=1

Recognising C code in assembly

- if statement

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1  int main (){
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7      else {
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[0x004014f0]> pdf
┌ (fcn) main 52
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│           0x004014f0      55              push ebp
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│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8b2000000      call fcn.004015b0
│           0x004014fe      c744240c0100.   mov dword [var_ch], 1
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│           0x0040150e      8b44240c        mov eax, dword [var_ch]
│           0x00401512      3b442408        cmp eax, dword [var_8h]
│       ┌<  0x00401516      7e06            jle 0x40151e
│       │   0x00401518      8b44240c        mov eax, dword [var_ch]
│      ┌<   0x0040151c      eb04            jmp 0x401522
│      ;-- CODE XREF from main @ 0x401516
│      │    0x0040151e      8b442408        mov eax, dword [var_8h]
│      ;-- CODE XREF from main @ 0x40151c
│      └->  0x00401522      c9              leave
└           0x00401523      c3              ret
```

eax=1

1<2

if

Recognising C code in assembly

- if statement

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┌ (fcn) main 52
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│           0x004014f9      e8b2000000      call fcn.004015b0
│           0x004014fe      c744240c0100.   mov dword [var_ch], 1
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│           0x0040150e      8b44240c        mov eax, dword [var_ch]
│           0x00401512      3b442408        cmp eax, dword [var_8h]
│       ┌<  0x00401516      7e06            jle 0x40151e
│       │   0x00401518      8b44240c        mov eax, dword [var_ch]
│      ┌<   0x0040151c      eb04            jmp 0x401522
│      ││   ; CODE XREF from main @ 0x401516
│       └>  0x0040151e      8b442408        mov eax, dword [var_8h]
│           ; CODE XREF from main @ 0x40151c
│           0x00401522      c9              leave
└           0x00401523      c3              ret
```

eax=1

1<2

if

return a

Recognising C code in assembly

- if statement

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1  int main (){
2      int a=1;
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4      if (a>b){
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[0x004014f0]> pdf
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│           0x004014f0      55              push ebp
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│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8b2000000      call fcn.004015b0
│           0x004014fe      c744240c0100.   mov dword [var_ch], 1
│           0x00401506      c74424080200.   mov dword [var_8h], 2
│           0x0040150e      8b44240c        mov eax, dword [var_ch]
│           0x00401512      3b442408        cmp eax, dword [var_8h]
│       ┌< 0x00401516      7e06            jle 0x40151e
│       │   0x00401518      8b44240c        mov eax, dword [var_ch]
│      ┌──< 0x0040151c      eb04            jmp 0x401522
│      ││   ; CODE XREF from main @ 0x401516
│      │└─> 0x0040151e      8b442408        mov eax, dword [var_8h]
│      │    ; CODE XREF from main @ 0x40151c
│      └──> 0x00401522      c9              leave
└           0x00401523      c3              ret
```

eax=1

1<2

if

return a

else

Recognising C code in assembly

- if statement

```
1  int main (){
2      int a=1;
3      int b=2;
4      if (a>b){
5          return a;
6      }
7      else {
8          return b;
9      }
10 }
```

```
[0x004014f0]> pdf
┌ (fcn) main 52
│   int main (int argc, char **argv, char **envp);
│           ; var signed int var_8h @ esp+0x8
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│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8b2000000      call fcn.004015b0
│           0x004014fe      c744240c0100.   mov dword [var_ch], 1
│           0x00401506      c74424080200.   mov dword [var_8h], 2
│           0x0040150e      8b44240c        mov eax, dword [var_ch]
│           0x00401512      3b442408        cmp eax, dword [var_8h]
│       ┌< 0x00401516      7e06            jle 0x40151e
│       │   0x00401518      8b44240c        mov eax, dword [var_ch]
│      ┌┌< 0x0040151c      eb04            jmp 0x401522
│      ││   ; CODE XREF from main @ 0x401516
│      └└> 0x0040151e      8b442408        mov eax, dword [var_8h]
│           ; CODE XREF from main @ 0x40151c
│           0x00401522      c9              leave
└           0x00401523      c3              ret
```

eax=1

1<2

if

return a

else

return b

Recognising C code in assembly

- if

```
1  ir
2
3
4
5
6
7
8
9
10 }
```

```
[0x4014f0]
(fcn) main 52
  int main (int argc, char **argv, char **envp);
; var signed int var_8h @ esp+0x8
; var int32_t var_ch @ esp+0xc
; CALL XREF from entry0 @ 0x40135e
push ebp
mov ebp, esp
and esp, 0xfffffff0
sub esp, 0x10
call fcn.004015b0;[oa]
mov dword [var_ch], 1
mov dword [var_8h], 2
mov eax, dword [var_ch]
cmp eax, dword [var_8h]
jle 0x40151e
```

f t

```
 0x401518 [oc]
mov eax, dword [var_ch]
jmp 0x401522
```

```
 0x40151e [od]
; CODE XREF from main @ 0x401516
mov eax, dword [var_8h]
```

v v

```
envp);
}

se
ush ebp
ov ebp, esp
nd esp, 0xfffffff0
ub esp, 0x10
all fcn.004015b0
ov dword [var_ch], 1
ov dword [var_8h], 2
ov eax, dword [var_ch]
mp eax, dword [var_8h]
e 0x40151e
ov eax, dword [var_ch]
mp 0x401522
ov eax, dword [var_8h]
eave
et
```

eax=1

1<2

return a

return b

Recognising C code in assembly

- if

```
[0x4014f0]
(fcn) main 52
  int main (int argc, char **argv, char **envp);
; var signed int var_8h @ esp+0x8
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; CALL XREF from entry0 @ 0x40135e
push ebp
mov ebp, esp
and esp, 0xfffffff0
sub esp, 0x10
call fcn.004015b0;[oa]
mov dword [var_ch], 1
mov dword [var_8h], 2
mov eax, dword [var_ch]
cmp eax, dword [var_8h]
jle 0x40151e
```

eax=1

f t

```
 0x401518 [oc]
mov eax, dword [var_ch]
jmp 0x401522
```

```
 0x40151e [od]
; CODE XREF from main @ 0x401516
mov eax, dword [var_8h]
```

eax=1

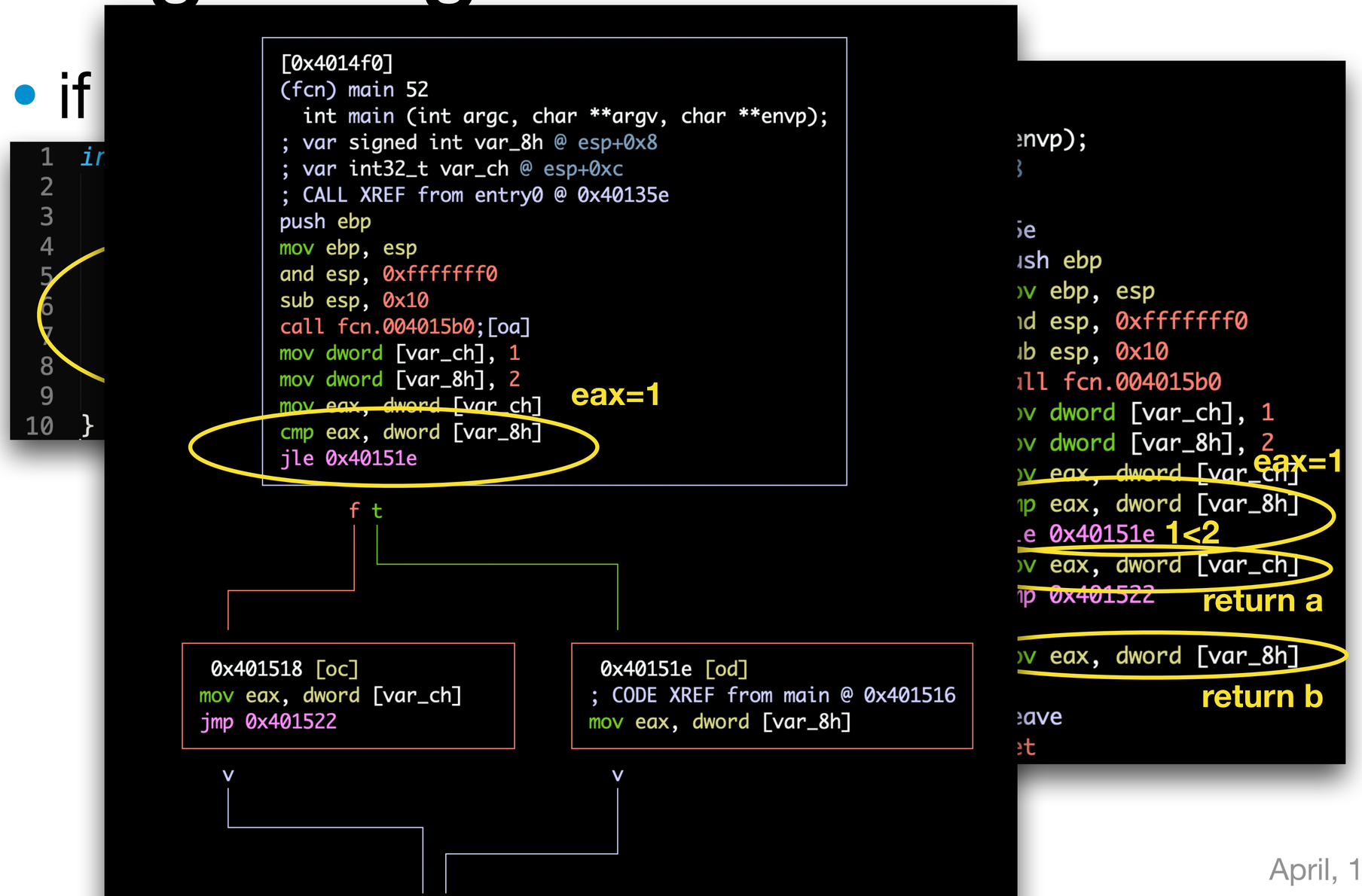
1<2

return a

return b

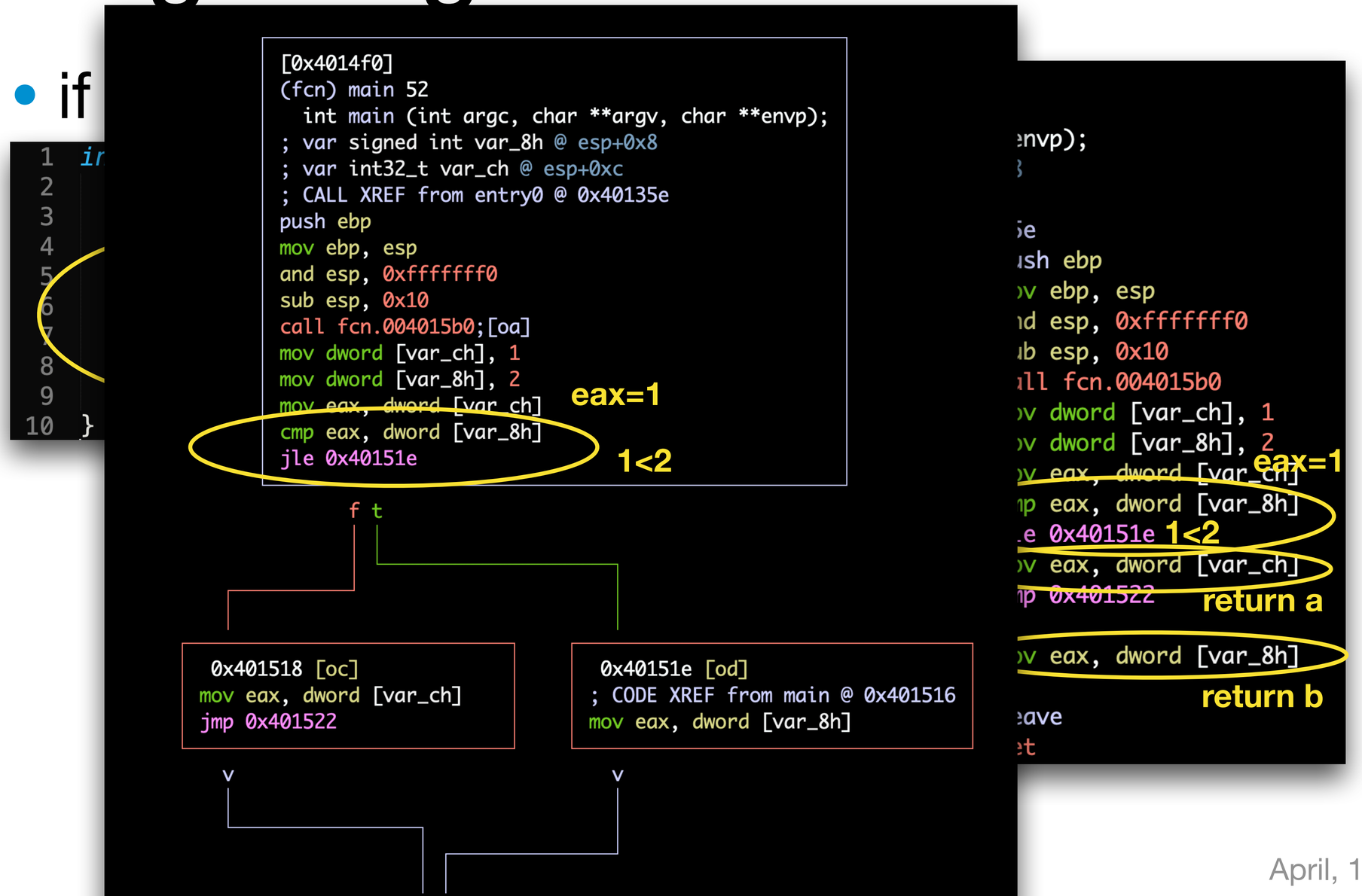
Recognising C code in assembly

- if



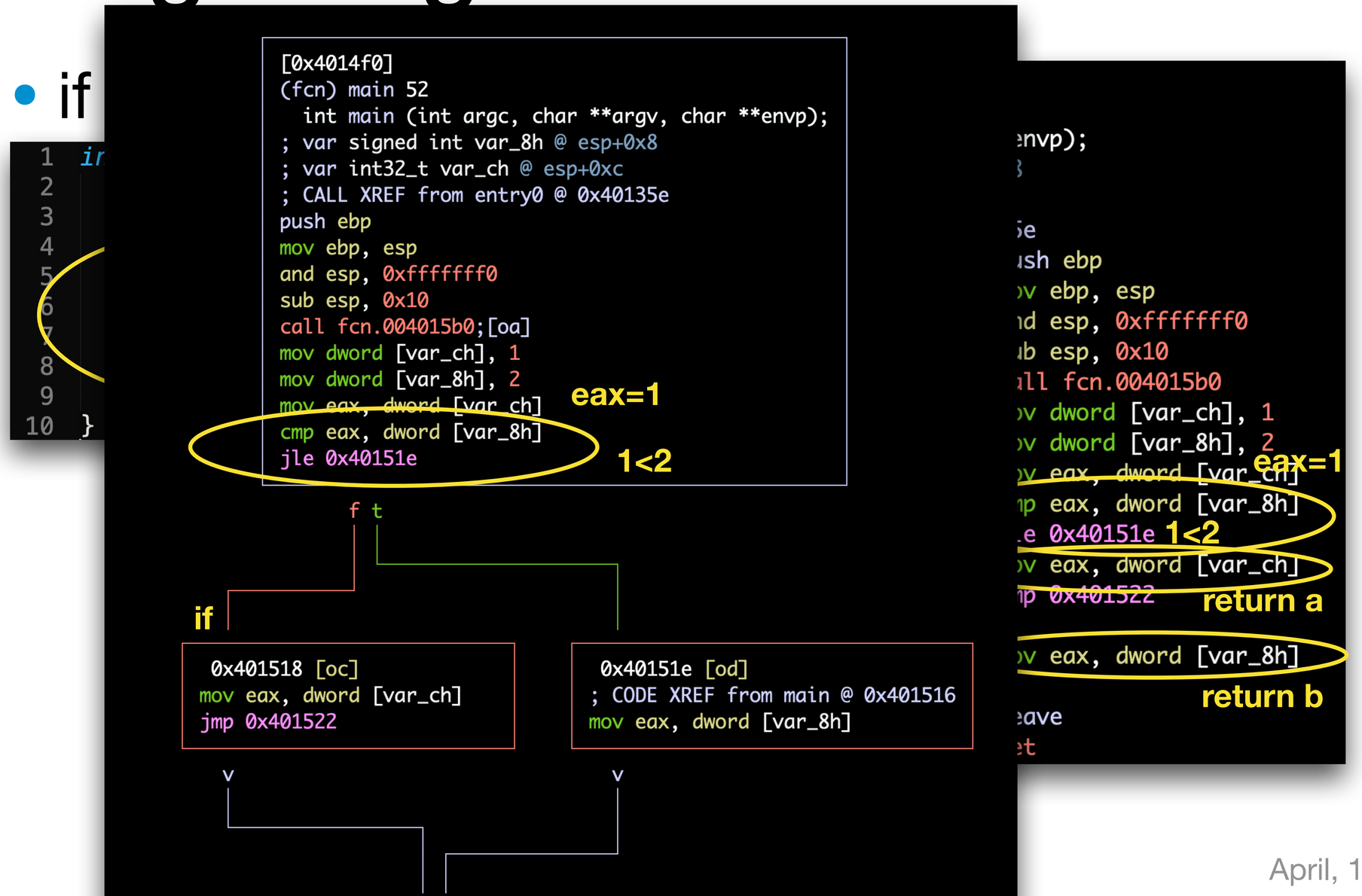
Recognising C code in assembly

- if



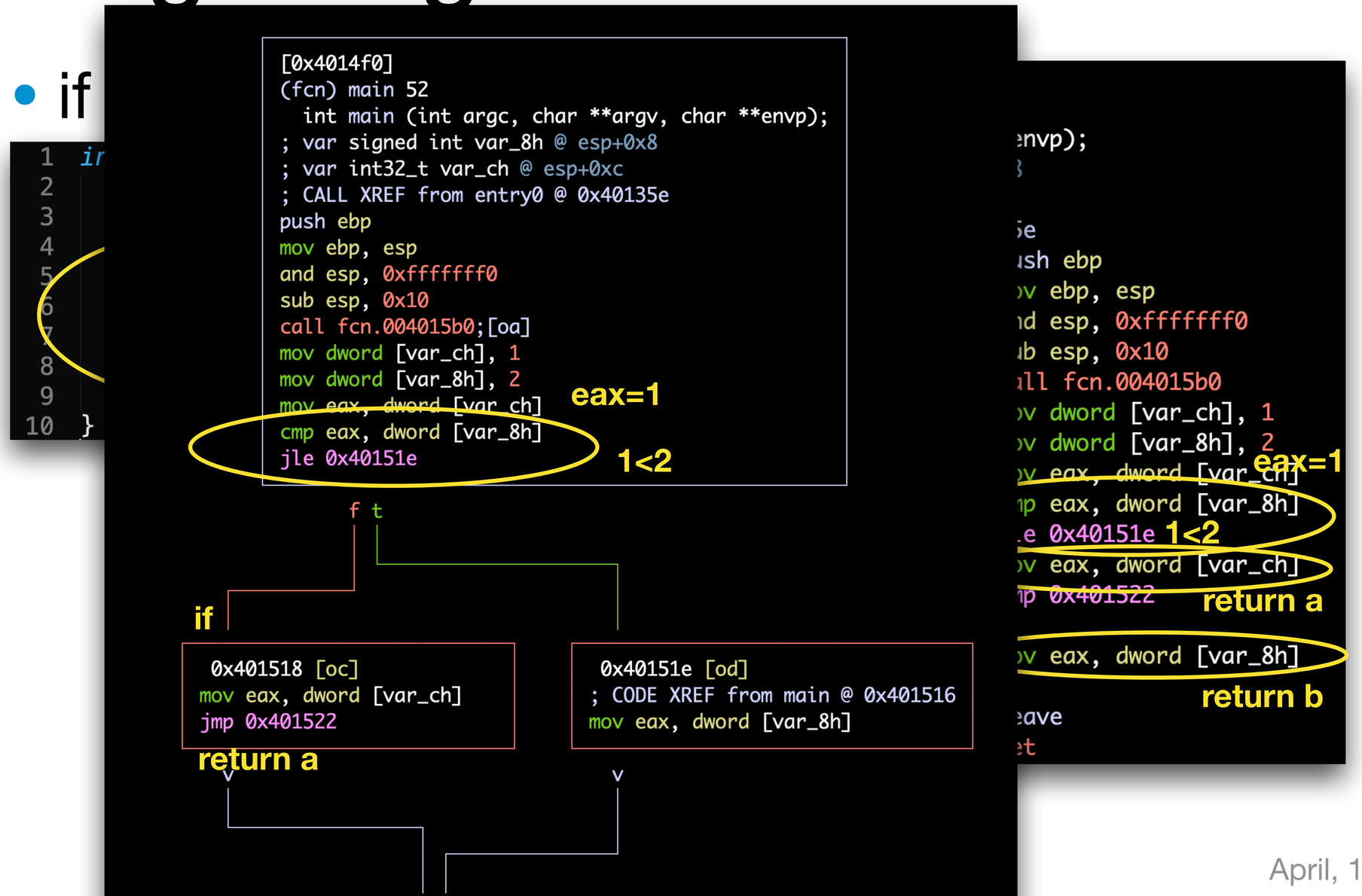
Recognising C code in assembly

- if



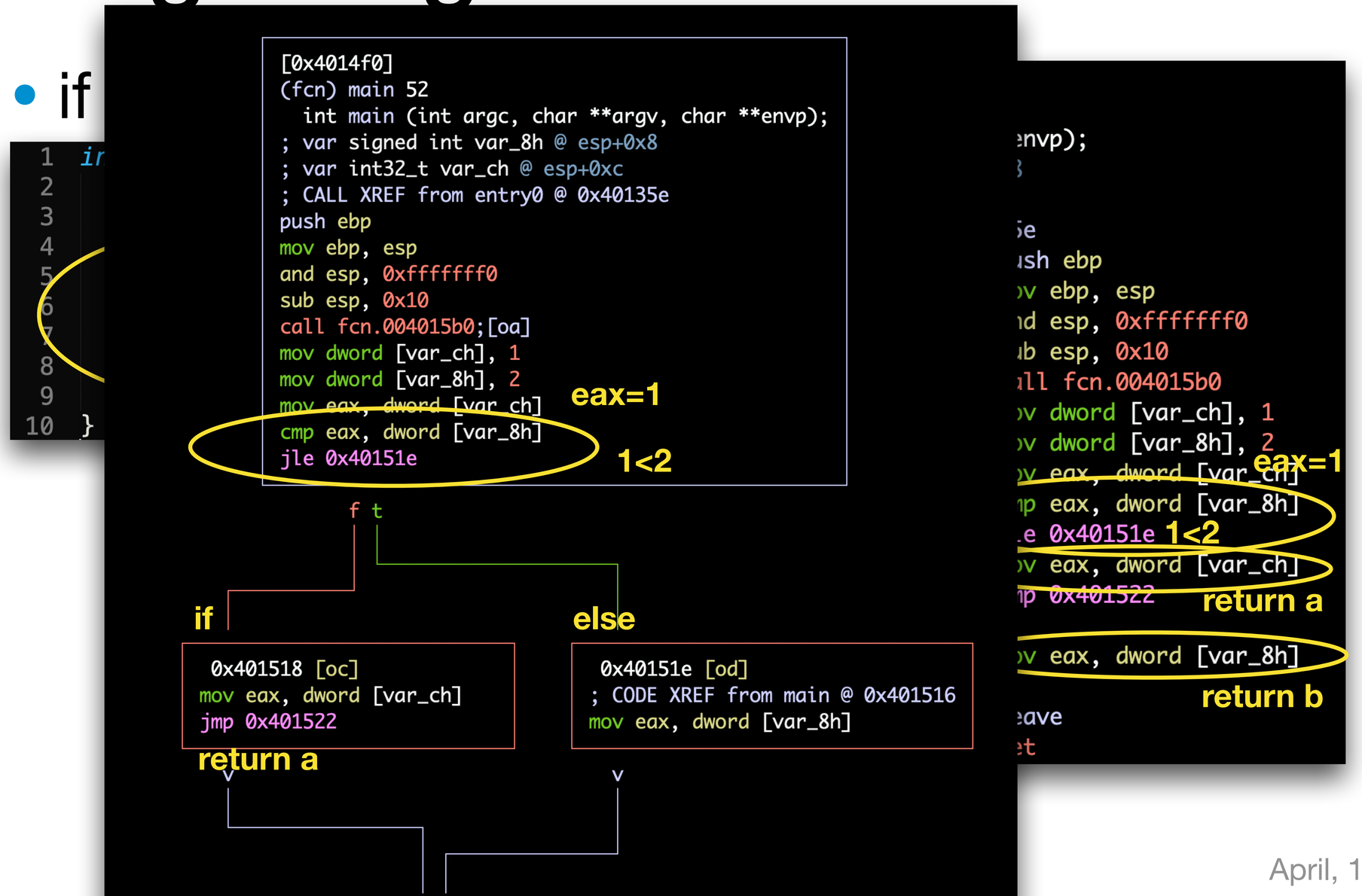
Recognising C code in assembly

- if



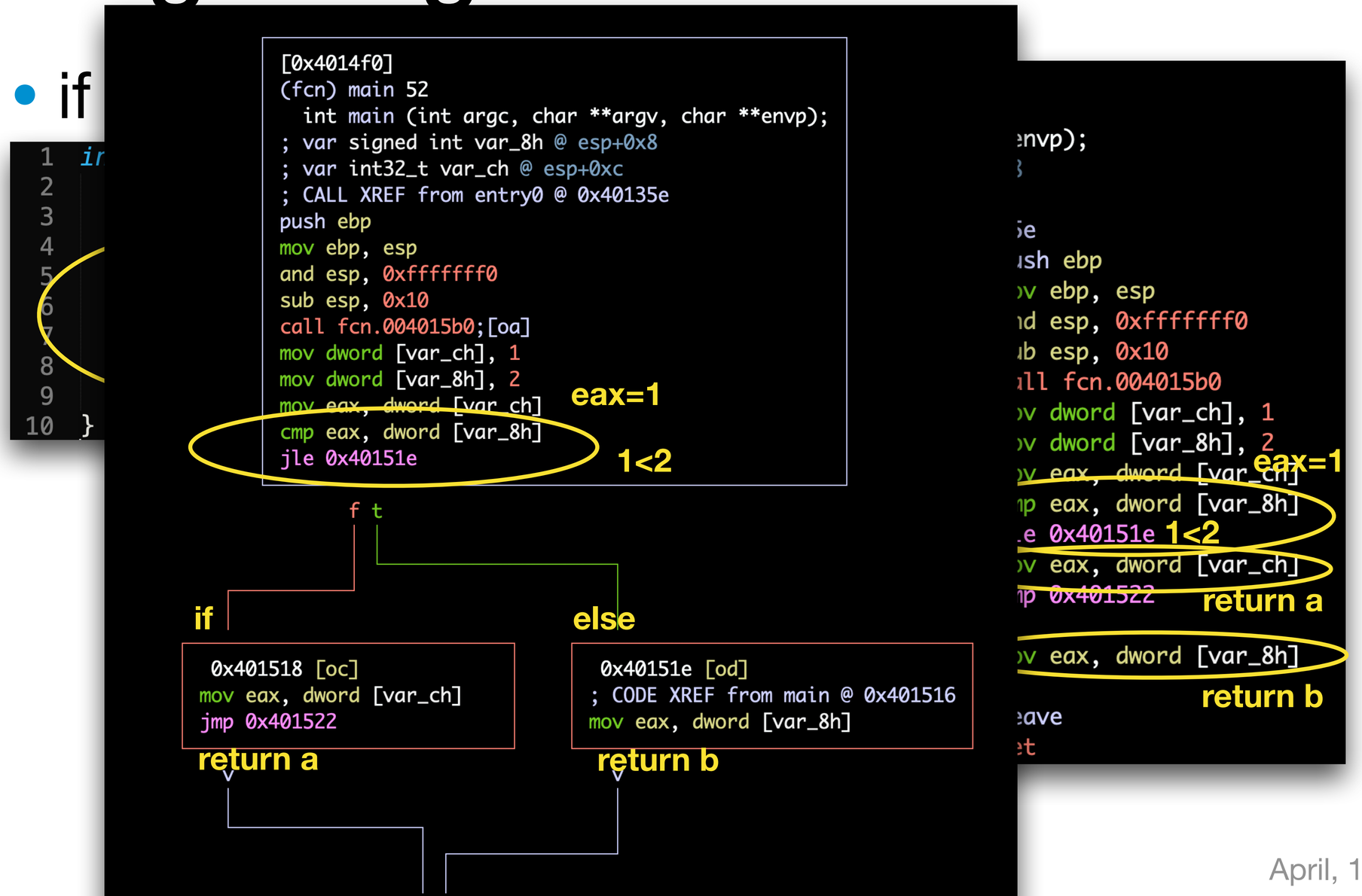
Recognising C code in assembly

- if



Recognising C code in assembly

- if



Recognising C code in assembly

- for statement

```
1  int main (){
2      int count=8;
3      int result=0;
4      for (int i = 0; i < count; ++i){
5          result+=result*2+3;
6      }
7      return result;
8  }
```

Recognising C code in assembly

- for statement

```
1  int main (){
2      int count=8;
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5          result+=result*2+3;
6      }
7      return result;
8  }
```

Recognising C code in assembly

- for statement

```c
int main (){
    int count=8;
    int result=0;
    for (int i = 0; i < count;
        result+=result*2+3;
    }
    return result;
}
```

```
[0x004014f0]> pdf
┌ (fcn) main 74
│   int main (int argc, char **argv, char **envp);
│           ; var signed int var_4h @ esp+0x4
│           ; var int32_t var_8h @ esp+0x8
│           ; var int32_t var_ch @ esp+0xc
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8c2000000      call fcn.004015c0
│           0x004014fe      c74424040800.   mov dword [var_4h], 8
│           0x00401506      c744240c0000.   mov dword [var_ch], 0
│           0x0040150e      c74424080000.   mov dword [var_8h], 0
│       ┌─< 0x00401516      eb12            jmp 0x40152a
│       │   ; CODE XREF from main @ 0x401532
│      ┌──> 0x00401518      8b44240c        mov eax, dword [var_ch]
│      ╎│   0x0040151c      01c0            add eax, eax
│      ╎│   0x0040151e      83c003          add eax, 3
│      ╎│   0x00401521      0144240c        add dword [var_ch], eax
│      ╎│   0x00401525      8344240801      add dword [var_8h], 1
│      ╎│   ; CODE XREF from main @ 0x401516
│      ╎└─> 0x0040152a      8b442408        mov eax, dword [var_8h]
│      ╎    0x0040152e      3b442404        cmp eax, dword [var_4h]
│      └──< 0x00401532      7ce4            jl 0x401518
│           0x00401534      8b44240c        mov eax, dword [var_ch]
│           0x00401538      c9              leave
└           0x00401539      c3              ret
```

Recognising C code in assembly

- for statement

```c
int main (){
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    }
    return result;
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```
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│   int main (int argc, char **argv, char **envp);
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│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8c2000000      call fcn.004015c0
│           0x004014fe      c74424040800.   mov dword [var_4h], 8
│           0x00401506      c744240c0000.   mov dword [var_ch], 0
│           0x0040150e      c74424080000.   mov dword [var_8h], 0
│       ┌─< 0x00401516      eb12            jmp 0x40152a
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│           0x00401534      8b44240c        mov eax, dword [var_ch]
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Recognising C code in assembly

- for statement

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│      ╎│   0x00401521      0144240c        add dword [var_ch], eax
│      ╎│   0x00401525      8344240801      add dword [var_8h], 1
│      ╎│   ; CODE XREF from main @ 0x401516
│      ╎└─> 0x0040152a      8b442408        mov eax, dword [var_8h]
│      ╎    0x0040152e      3b442404        cmp eax, dword [var_4h]
│      └──< 0x00401532      7ce4            jl 0x401518
│           0x00401534      8b44240c        mov eax, dword [var_ch]
│           0x00401538      c9              leave
└           0x00401539      c3              ret
```

Recognising C code in assembly

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│           ; var int32_t var_8h @ esp+0x8
│           ; var int32_t var_ch @ esp+0xc
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8c2000000      call fcn.004015c0
│           0x004014fe      c74424040800.   mov dword [var_4h], 8
│           0x00401506      c744240c0000.   mov dword [var_ch], 0
│           0x0040150e      c74424080000.   mov dword [var_8h], 0
│       ┌─< 0x00401516      eb12            jmp 0x40152a
│       │   ; CODE XREF from main @ 0x401532
│      ┌──> 0x00401518      8b44240c        mov eax, dword [var_ch]
│      ╎│   0x0040151c      01c0            add eax, eax
│      ╎│   0x0040151e      83c003          add eax, 3
│      ╎│   0x00401521      0144240c        add dword [var_ch], eax
│      ╎│   0x00401525      8344240801      add dword [var_8h], 1
│      ╎│   ; CODE XREF from main @ 0x401516
│      ╎└─> 0x0040152a      8b442408        mov eax, dword [var_8h]
│      ╎    0x0040152e      3b442404        cmp eax, dword [var_4h]
│      └──< 0x00401532      7ce4            jl 0x401518
│           0x00401534      8b44240c        mov eax, dword [var_ch]
│           0x00401538      c9              leave
└           0x00401539      c3              ret
```

first time

Recognising C code in assembly

- for statement

```
1  int main (){
2      int count=8;
3      int result=0;
4      for (int i = 0; i < count;
5          result+=result*2+3;
6      }
7      return result;
8  }
```

```
[0x004014f0]> pdf
┌ (fcn) main 74
│   int main (int argc, char **argv, char **envp);
│           ; var signed int var_4h @ esp+0x4
│           ; var int32_t var_8h @ esp+0x8
│           ; var int32_t var_ch @ esp+0xc
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8c2000000      call fcn.004015c0
│           0x004014fe      c74424040800.   mov dword [var_4h], 8
│           0x00401506      c744240c0000.   mov dword [var_ch], 0
│           0x0040150e      c74424080000.   mov dword [var_8h], 0
│       ┌─< 0x00401516      eb12            jmp 0x40152a
│       │   ; CODE XREF from main @ 0x401532
│      ┌──> 0x00401518      8b44240c        mov eax, dword [var_ch]
│      ╎│   0x0040151c      01c0            add eax, eax
│      ╎│   0x0040151e      83c003          add eax, 3
│      ╎│   0x00401521      0144240c        add dword [var_ch], eax
│      ╎│   0x00401525      8344240801      add dword [var_8h], 1
│      ╎│   ; CODE XREF from main @ 0x401516
│      ╎└─> 0x0040152a      8b442408        mov eax, dword [var_8h]
│      ╎    0x0040152e      3b442404        cmp eax, dword [var_4h]
│      └──< 0x00401532      7ce4            jl 0x401518
│           0x00401534      8b44240c        mov eax, dword [var_ch]
│           0x00401538      c9              leave
└           0x00401539      c3              ret
```

first time

if i<8

Recognising C code in assembly

- for statement

```
1  int main (){
2      int count=8;
3      int result=0;
4      for (int i = 0; i < count;
5          result+=result*2+3;
6      }
7      return result;
8  }
```

```
[0x004014f0]> pdf
┌ (fcn) main 74
│   int main (int argc, char **argv, char **envp);
│           ; var signed int var_4h @ esp+0x4
│           ; var int32_t var_8h @ esp+0x8
│           ; var int32_t var_ch @ esp+0xc
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8c2000000      call fcn.004015c0
│           0x004014fe      c74424040800.   mov dword [var_4h], 8
│           0x00401506      c744240c0000.   mov dword [var_ch], 0
│           0x0040150e      c74424080000.   mov dword [var_8h], 0
│       ┌─< 0x00401516      eb12            jmp 0x40152a
│           ; CODE XREF from main @ 0x401532
│      ┌──> 0x00401518      8b44240c        mov eax, dword [var_ch]
│      ╎    0x0040151c      01c0            add eax, eax
│      ╎    0x0040151e      83c003          add eax, 3
│      ╎    0x00401521      0144240c        add dword [var_ch], eax
│      ╎    0x00401525      8344240801      add dword [var_8h], 1
│           ; CODE XREF from main @ 0x401516
│      ╎┌─> 0x0040152a      8b442408        mov eax, dword [var_8h]
│      ╎╎   0x0040152e      3b442404        cmp eax, dword [var_4h]
│      └──< 0x00401532      7ce4            jl 0x401518
│       ╎   0x00401534      8b44240c        mov eax, dword [var_ch]
│       ╎   0x00401538      c9              leave
└       ╎   0x00401539      c3              ret
```

first time

if i<8

@apasamar
c0r0n4con
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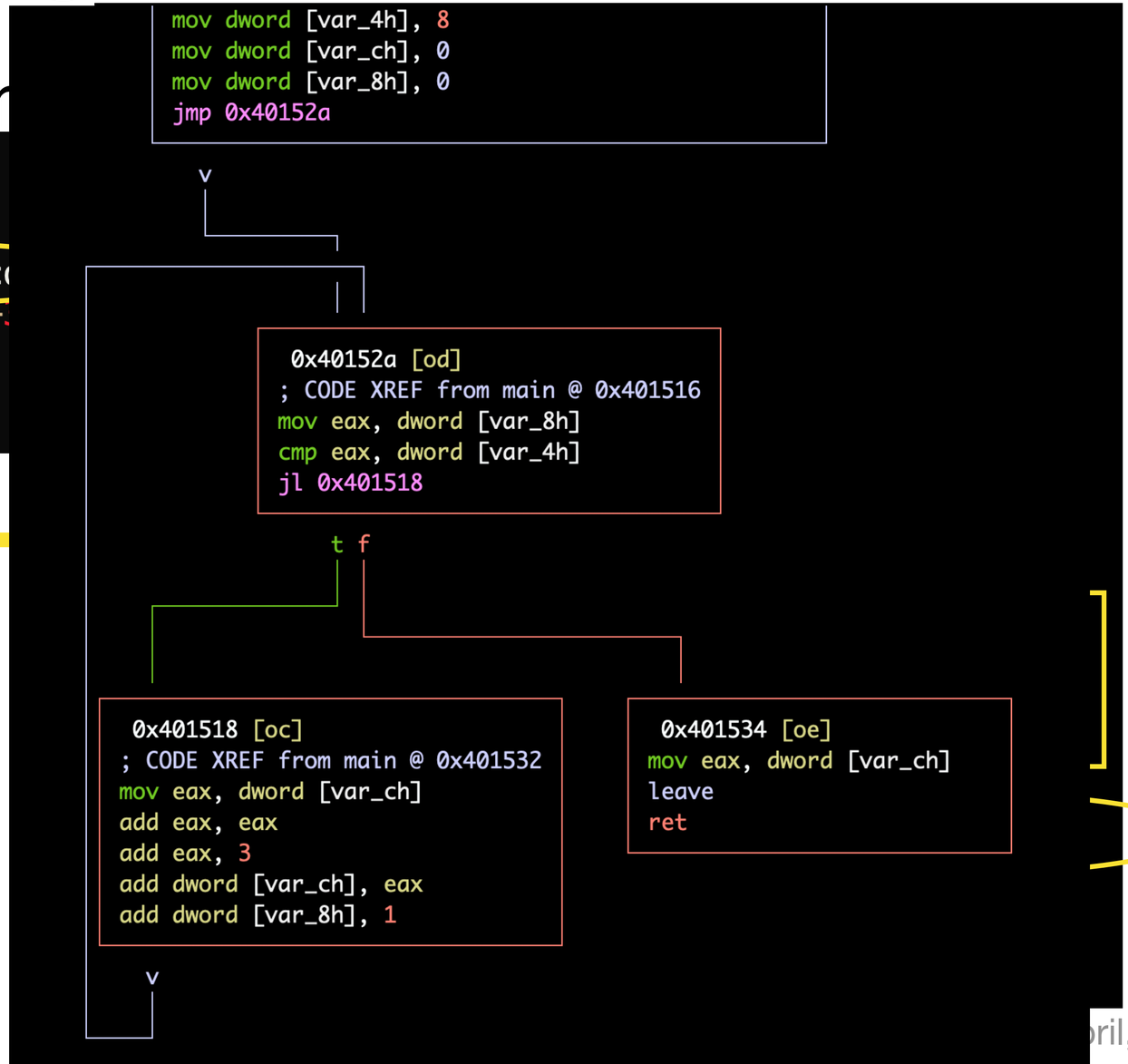
Recognising C code in assembly

- for statemer

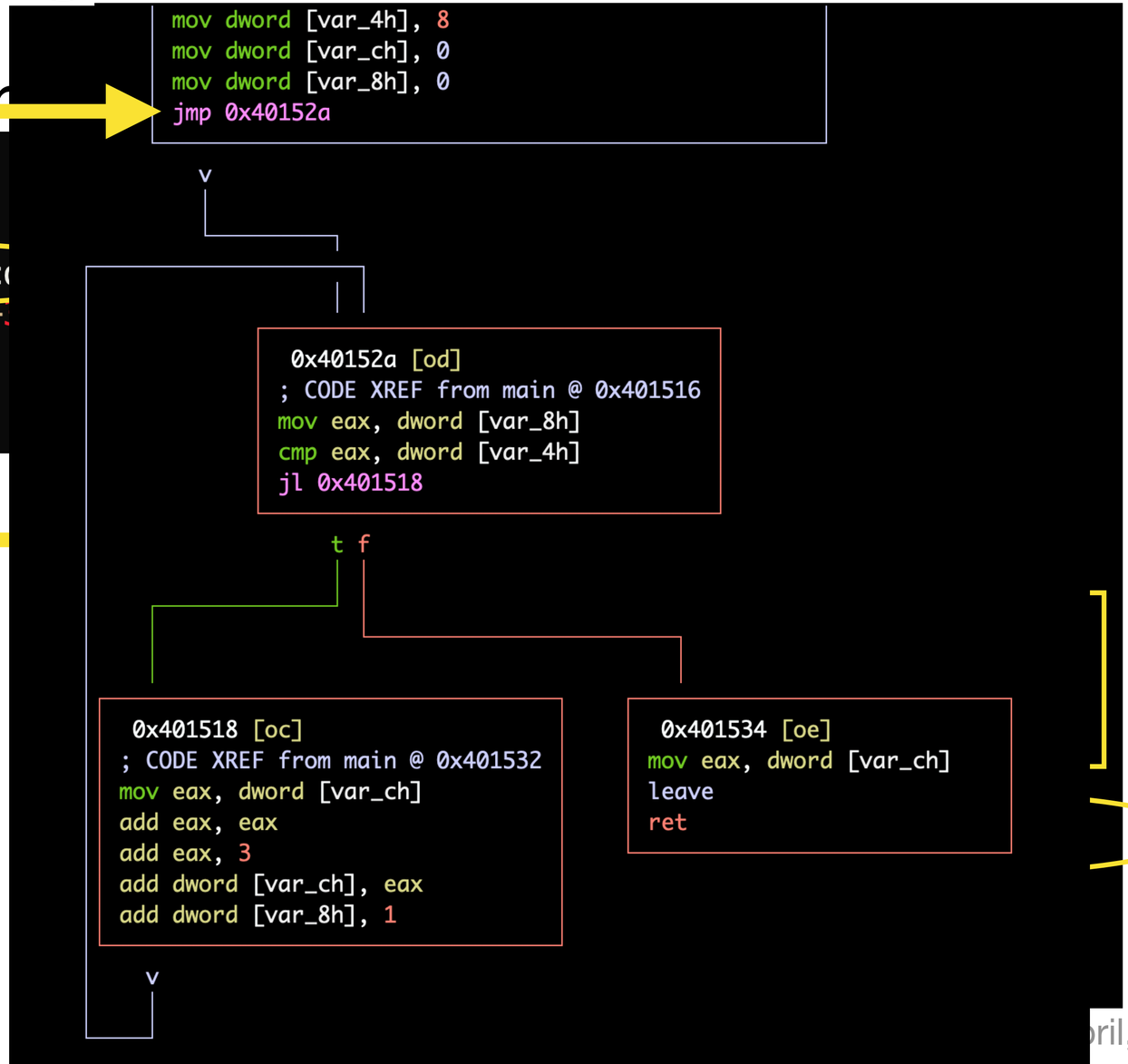
```
1  int main (){
2      int count=8;
3      int result=0;
4      for (int i = 0; i < c
5          result+=result*2+
6      }
7      return result;
8  }
```



Recognising C code in assembly

- for statemer

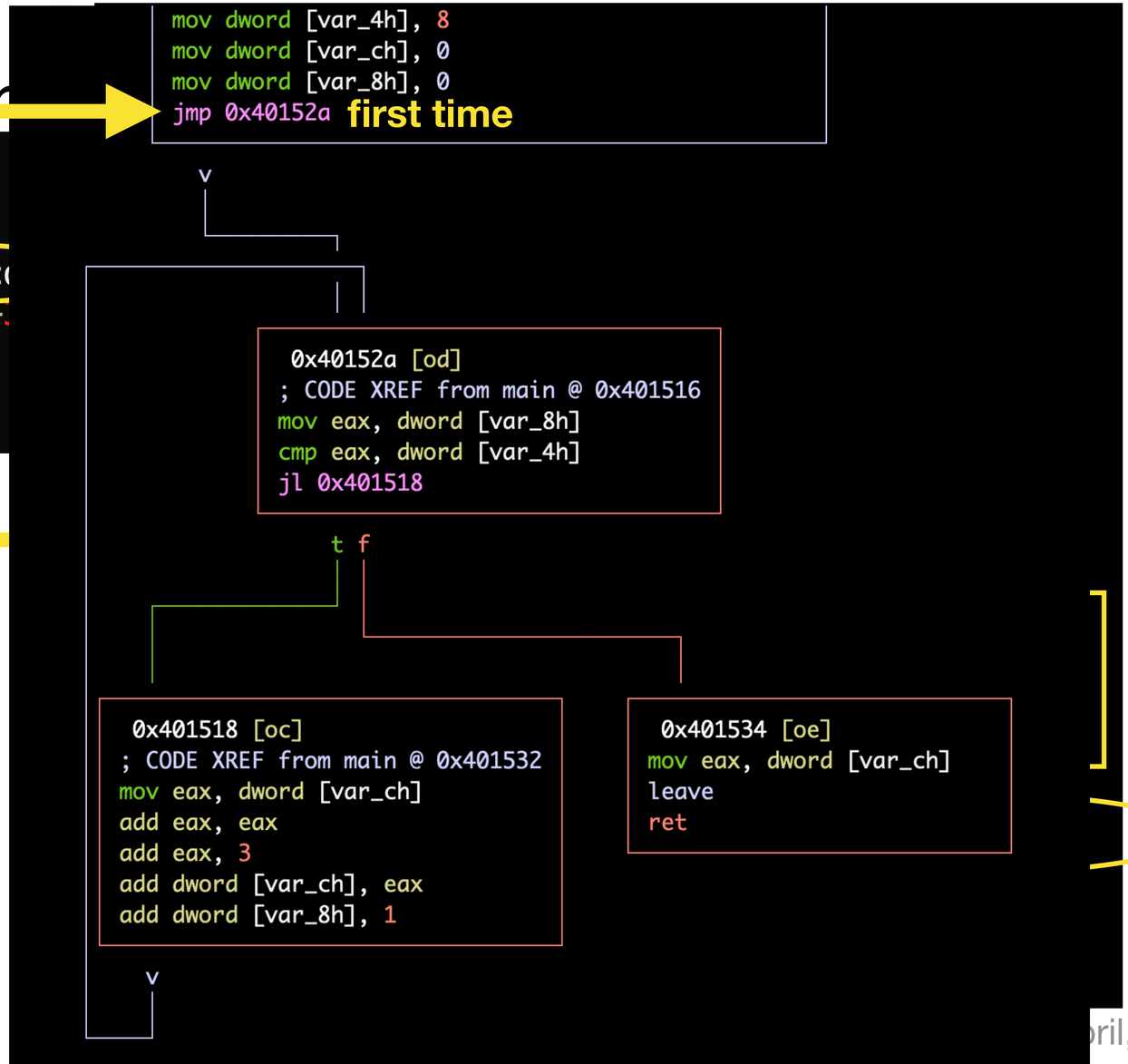
```
1  int main (){
2      int count=8;
3      int result=0;
4      for (int i = 0; i < c
5          result+=result*2+
6      }
7      return result;
8  }
```



Recognising C code in assembly

- for statemer

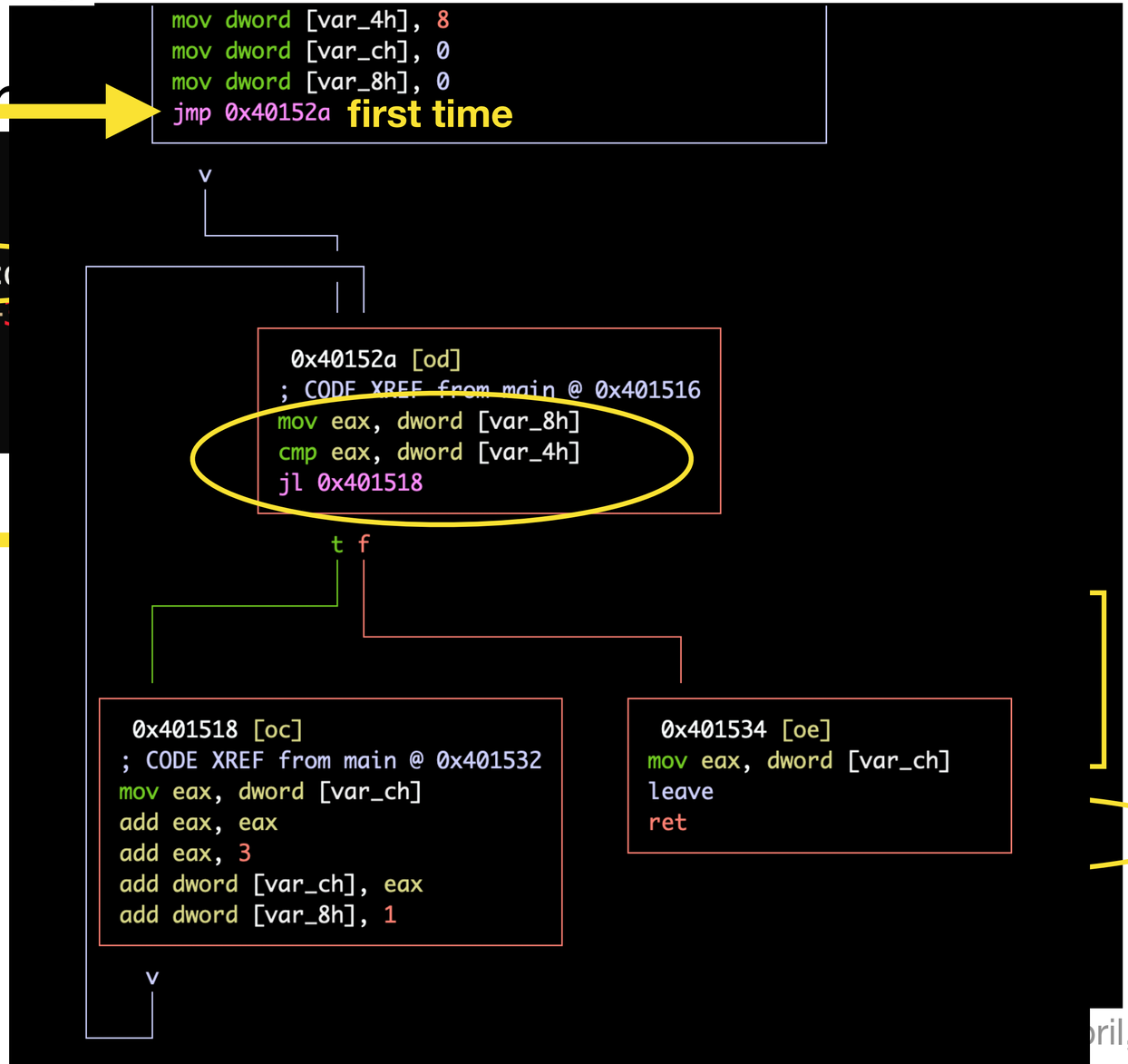
```
1  int main (){
2      int count=8;
3      int result=0;
4      for (int i = 0; i < c
5          result+=result*2+
6      }
7      return result;
8  }
```



Recognising C code in assembly

- for statemer

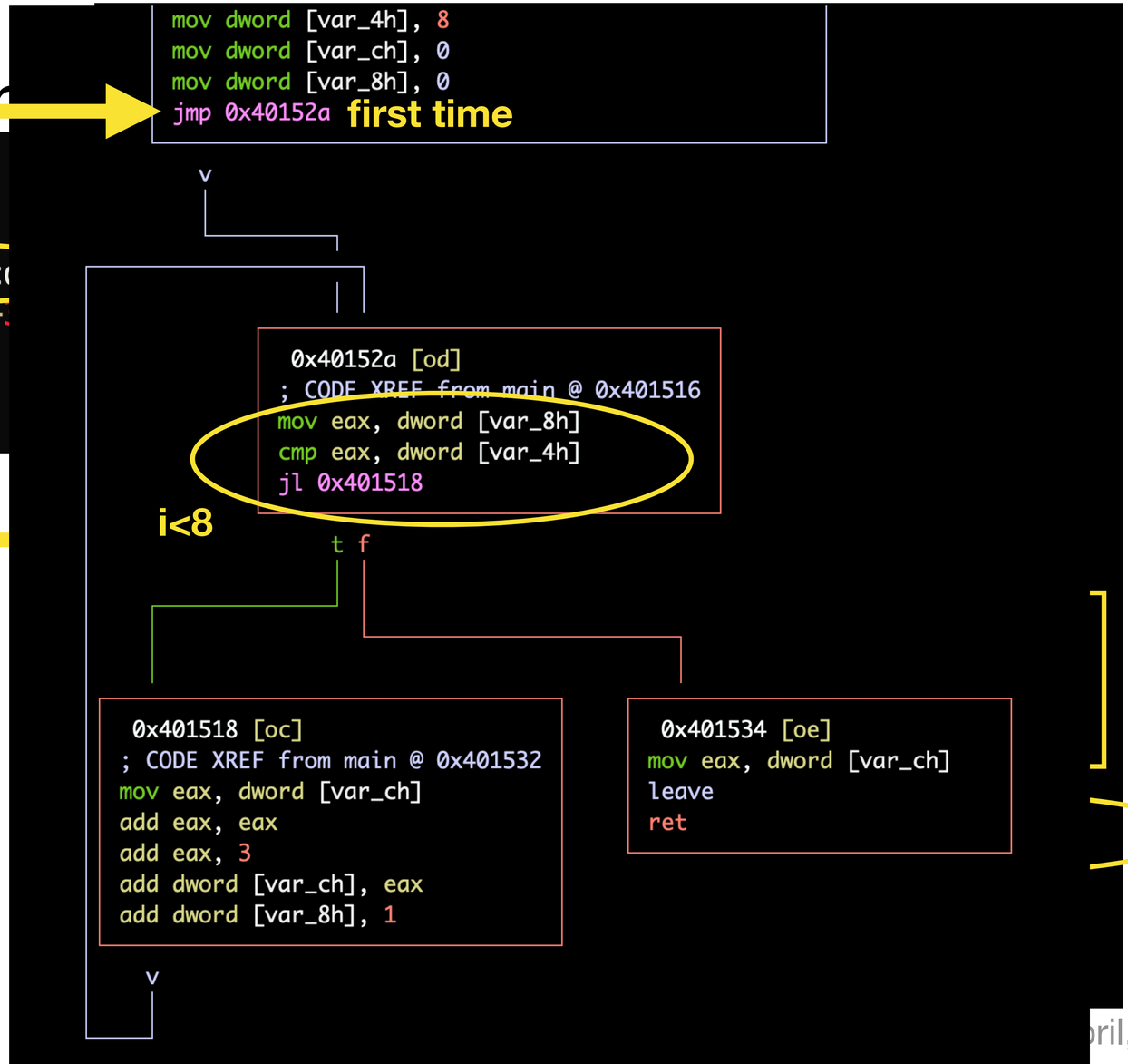
```
1  int main (){
2      int count=8;
3      int result=0;
4      for (int i = 0; i < c
5          result+=result*2+
6      }
7      return result;
8  }
```



Recognising C code in assembly

- for statemer

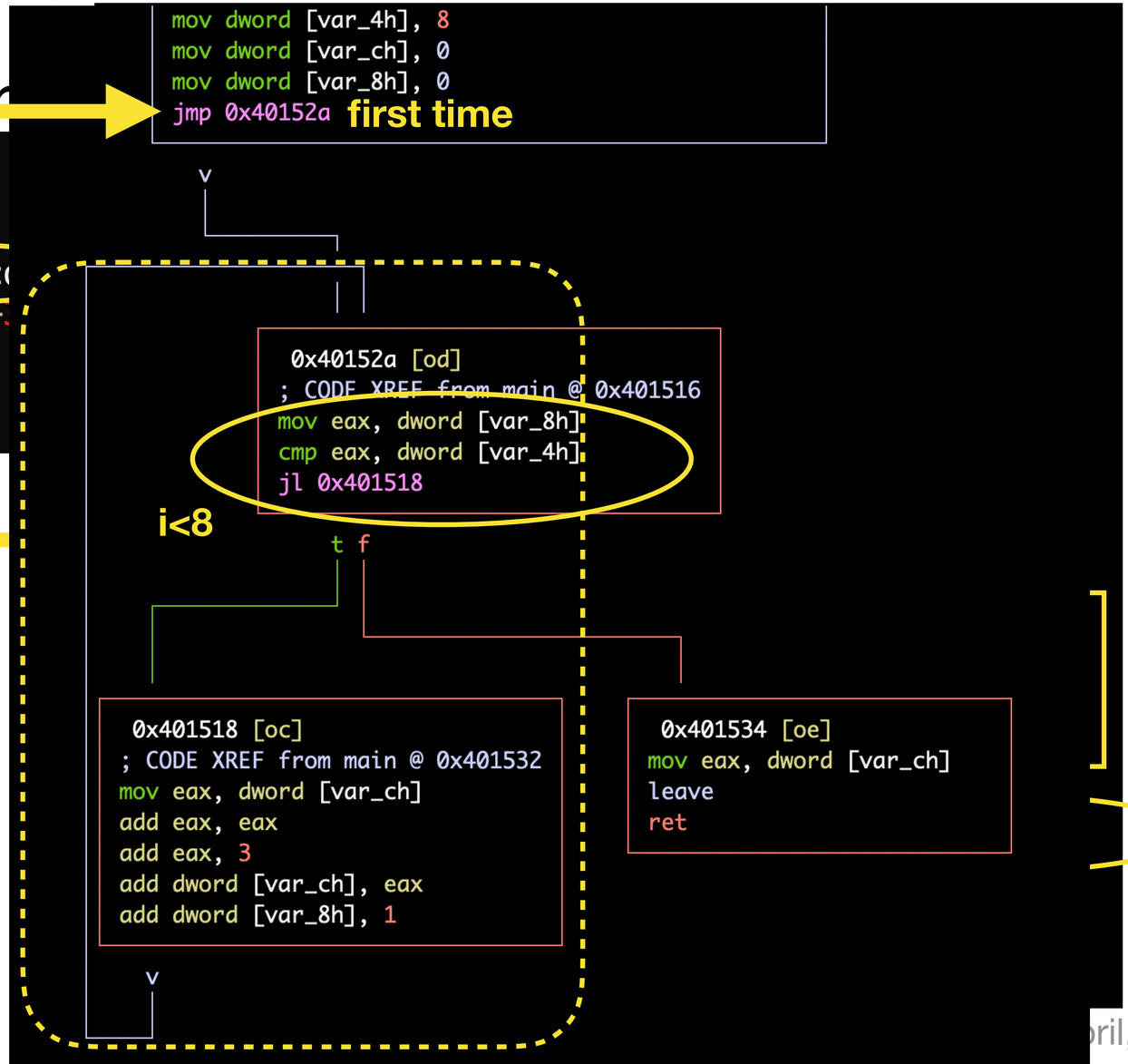
```
1  int main (){
2      int count=8;
3      int result=0;
4      for (int i = 0; i < c
5          result+=result*2+
6      }
7      return result;
8  }
```



Recognising C code in assembly

- for statemer

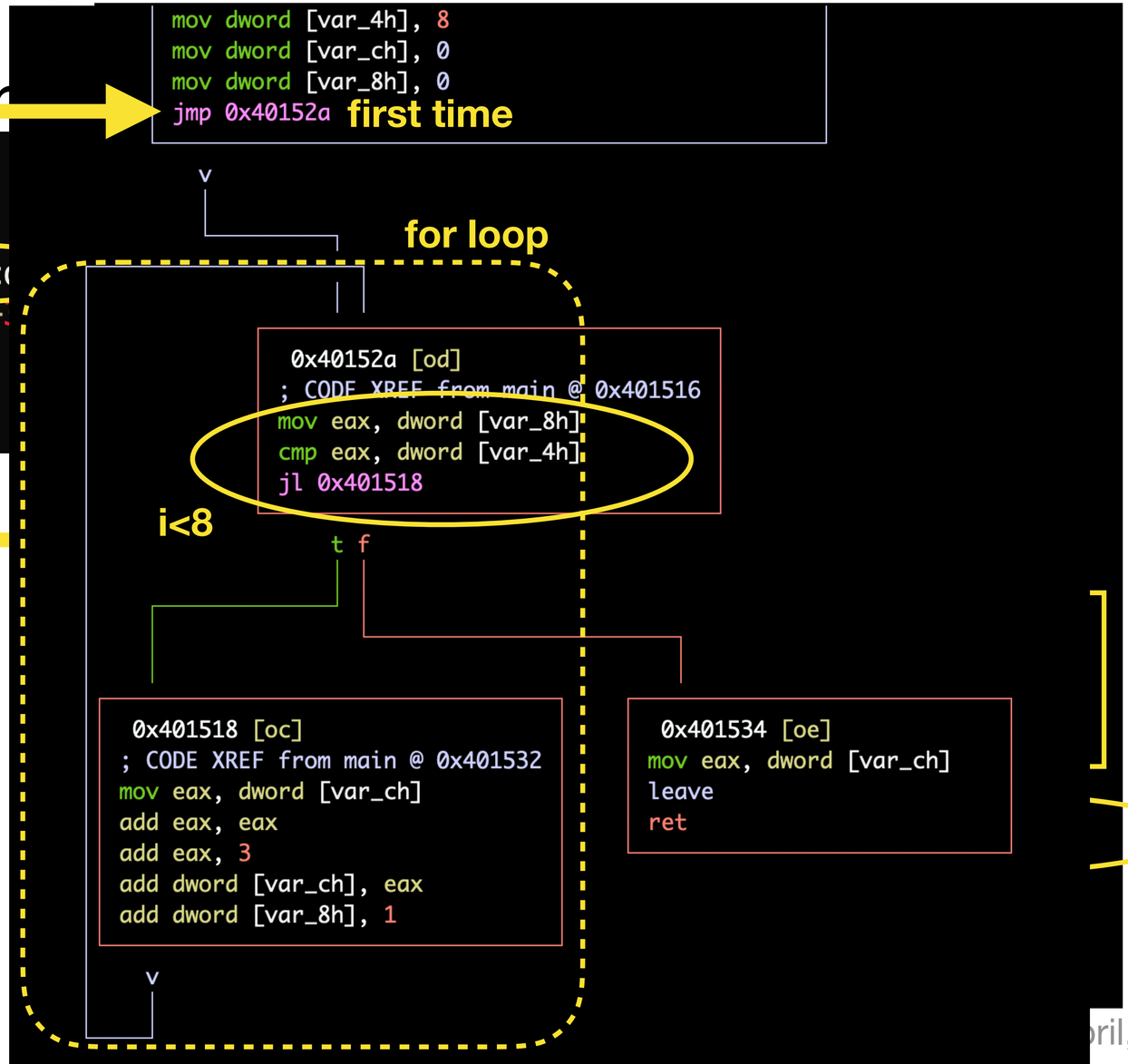
```
1  int main (){
2      int count=8;
3      int result=0;
4      for (int i = 0; i < c
5          result+=result*2+
6      }
7      return result;
8  }
```



Recognising C code in assembly

- for statemer

```
1  int main (){
2      int count=8;
3      int result=0;
4      for (int i = 0; i < c
5          result+=result*2+
6      }
7      return result;
8  }
```



Recognising C code in assembly

- while statement

```
1  int main (){
2      int counter=10;
3      int number=6;
4      int result;
5      while(counter>0){
6          result+=counter*number;
7          counter--;
8      }
9      return result;
10 }
```

Recognising C code in assembly

- while statement

```
1  int main (){
2      int counter=10;
3      int number=6;
4      int result;
5      while(counter>0){
6          result+=counter*number;
7          counter--;
8      }
9      return result;
10 }
```

Recognising C code in assembly

- while statement

```c
int main (){
    int counter=10;
    int number=6;
    int result;
    while(counter>0){
        result+=counter*num
        counter--;
    }
    return result;
}
```

```
[0x004014f0]> pdf
┌ (fcn) main 63
│   int main (int argc, char **argv, char **envp);
│           ; var signed int var_4h @ esp+0x4
│           ; var int32_t var_8h @ esp+0x8
│           ; var signed int var_ch @ esp+0xc
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8b2000000      call fcn.004015b0
│           0x004014fe      c744240c0a00.   mov dword [var_ch], 0xa
│           0x00401506      c74424040600.   mov dword [var_4h], 6
│       ┌─< 0x0040150e      eb12            jmp 0x401522
│       │   ; CODE XREF from main @ 0x401527
│      ┌──> 0x00401510      8b44240c        mov eax, dword [var_ch]
│      ╎│   0x00401514      0faf442404      imul eax, dword [var_4h]
│      ╎│   0x00401519      01442408        add dword [var_8h], eax
│      ╎│   0x0040151d      836c240c01      sub dword [var_ch], 1
│      ╎│   ; CODE XREF from main @ 0x40150e
│      ╎└─> 0x00401522      837c240c00      cmp dword [var_ch], 0
│      └──< 0x00401527      7fe7            jg 0x401510
│           0x00401529      8b442408        mov eax, dword [var_8h]
│           0x0040152d      c9              leave
```

Recognising C code in assembly

- while statement

```
1  int main (){
2      int counter=10;
3      int number=6;
4      int result;
5      while(counter>0){
6          result+=counter*num
7          counter--;
8      }
9      return result;
10 }
```

```
[0x004014f0]> pdf
┌ (fcn) main 63
│   int main (int argc, char **argv, char **envp);
│           ; var signed int var_4h @ esp+0x4
│           ; var int32_t var_8h @ esp+0x8
│           ; var signed int var_ch @ esp+0xc
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8b2000000      call fcn.004015b0
│           0x004014fe      c744240c0a00.   mov dword [var_ch], 0xa
│           0x00401506      c74424040600.   mov dword [var_4h], 6
│       ┌─< 0x0040150e      eb12            jmp 0x401522
│       │   ; CODE XREF from main @ 0x401527
│      ┌──> 0x00401510      8b44240c        mov eax, dword [var_ch]
│      ╎│   0x00401514      0faf442404      imul eax, dword [var_4h]
│      ╎│   0x00401519      01442408        add dword [var_8h], eax
│      ╎│   0x0040151d      836c240c01      sub dword [var_ch], 1
│      ╎│   ; CODE XREF from main @ 0x40150e
│      ╎└─> 0x00401522      837c240c00      cmp dword [var_ch], 0
│      ╎└─< 0x00401527      7fe7            jg 0x401510
│      ╎    0x00401529      8b442408        mov eax, dword [var_8h]
│      ╎    0x0040152d      c9              leave
```

Recognising C code in assembly

- while statement

```
1  int main (){
2      int counter=10;
3      int number=6;
4      int result;
5      while(counter>0){
6          result+=counter*num
7          counter--;
8      }
9      return result;
10 }
```

```
[0x004014f0]> pdf
┌ (fcn) main 63
│   int main (int argc, char **argv, char **envp);
│           ; var signed int var_4h @ esp+0x4
│           ; var int32_t var_8h @ esp+0x8
│           ; var signed int var_ch @ esp+0xc
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8b2000000      call fcn.004015b0
│           0x004014fe      c744240c0a00.   mov dword [var_ch], 0xa
│           0x00401506      c74424040600.   mov dword [var_4h], 6
│           0x0040150e      eb12            jmp 0x401522
│           ; CODE XREF from main @ 0x401527
│           0x00401510      8b44240c        mov eax, dword [var_ch]
│           0x00401514      0faf442404      imul eax, dword [var_4h]
│           0x00401519      01442408        add dword [var_8h], eax
│           0x0040151d      836c240c01      sub dword [var_ch], 1
│           ; CODE XREF from main @ 0x40150e
│           0x00401522      837c240c00      cmp dword [var_ch], 0
│           0x00401527      7fe7            jg 0x401510
│           0x00401529      8b442408        mov eax, dword [var_8h]
│           0x0040152d      c9              leave
```

first time

Recognising C code in assembly

- while statement

```
1  int main (){
2      int counter=10;
3      int number=6;
4      int result;
5      while(counter>0){
6          result+=counter*num
7          counter--;
8      }
9      return result;
10 }
```

```
[0x004014f0]> pdf
┌ (fcn) main 63
│   int main (int argc, char **argv, char **envp);
│           ; var signed int var_4h @ esp+0x4
│           ; var int32_t var_8h @ esp+0x8
│           ; var signed int var_ch @ esp+0xc
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8b2000000      call fcn.004015b0
│           0x004014fe      c744240c0a00.   mov dword [var_ch], 0xa
│           0x00401506      c74424040600.   mov dword [var_4h], 6
│       ┌─< 0x0040150e      eb12            jmp 0x401522
│       │   ; CODE XREF from main @ 0x401527
│      ┌──> 0x00401510      8b44240c        mov eax, dword [var_ch]
│      ╎│   0x00401514      0faf442404      imul eax, dword [var_4h]
│      ╎│   0x00401519      01442408        add dword [var_8h], eax
│      ╎│   0x0040151d      836c240c01      sub dword [var_ch], 1
│      ╎│   ; CODE XREF from main @ 0x40150e
│      ╎└─> 0x00401522      837c240c00      cmp dword [var_ch], 0
│      ╎└─< 0x00401527      7fe7            jg 0x401510
│      ╎    0x00401529      8b442408        mov eax, dword [var_8h]
└      ╎    0x0040152d      c9              leave
```

first time

Recognising C code in assembly

- while statement

```
1  int main (){
2      int counter=10;
3      int number=6;
4      int result;
5      while(counter>0){
6          result+=counter*num
7          counter--;
8      }
9      return result;
10 }
```

```
[0x004014f0]> pdf
┌ (fcn) main 63
│   int main (int argc, char **argv, char **envp);
│           ; var signed int var_4h @ esp+0x4
│           ; var int32_t var_8h @ esp+0x8
│           ; var signed int var_ch @ esp+0xc
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8b2000000      call fcn.004015b0
│           0x004014fe      c744240c0a00.   mov dword [var_ch], 0xa
│           0x00401506      c74424040600.   mov dword [var_4h], 6
│       ┌─< 0x0040150e      eb12            jmp 0x401522
│           ; CODE XREF from main @ 0x401527
│      ┌──> 0x00401510      8b44240c        mov eax, dword [var_ch]
│      ╎│   0x00401514      0faf442404      imul eax, dword [var_4h]
│      ╎│   0x00401519      01442408        add dword [var_8h], eax
│      ╎│   0x0040151d      836c240c01      sub dword [var_ch], 1
│           ; CODE XREF from main @ 0x40150e
│      ╎└─> 0x00401522      837c240c00      cmp dword [var_ch], 0
│      └──< 0x00401527      7fe7            jg 0x401510
│           0x00401529      8b442408        mov eax, dword [var_8h]
└           0x0040152d      c9              leave
```

first time

counter>0

Recognising C code in assembly

- while statement

```
1  int main (){
2      int counter=10;
3      int number=6;
4      int result;
5      while(counter>0){
6          result+=counter*num
7          counter--;
8      }
9      return result;
10 }
```

```
[0x004014f0]> pdf
┌ (fcn) main 63
│   int main (int argc, char **argv, char **envp);
│           ; var signed int var_4h @ esp+0x4
│           ; var int32_t var_8h @ esp+0x8
│           ; var signed int var_ch @ esp+0xc
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8b2000000      call fcn.004015b0
│           0x004014fe      c744240c0a00.   mov dword [var_ch], 0xa
│           0x00401506      c74424040600.   mov dword [var_4h], 6
│           0x0040150e      eb12            jmp 0x401522
│           ; CODE XREF from main @ 0x401527
│           0x00401510      8b44240c        mov eax, dword [var_ch]
│           0x00401514      0faf442404      imul eax, dword [var_4h]
│           0x00401519      01442408        add dword [var_8h], eax
│           0x0040151d      836c240c01      sub dword [var_ch], 1
│           ; CODE XREF from main @ 0x40150e
│           0x00401522      837c240c00      cmp dword [var_ch], 0
│           0x00401527      7fe7            jg 0x401510
│           0x00401529      8b442408        mov eax, dword [var_8h]
└           0x0040152d      c9              leave
```

first time

if true

counter>0

@apasamar
c0r0n4con
incide.es

Recognising C code in assembly

- while statement

```
1  int main (){
2      int counter=10;
3      int number=6;
4      int result;
5      while(counter>0){
6          result+=counter*num
7          counter--;
8      }
9      return result;
10 }
```

```
[0x004014f0]> pdf
┌ (fcn) main 63
│   int main (int argc, char **argv, char **envp);
│           ; var signed int var_4h @ esp+0x4
│           ; var int32_t var_8h @ esp+0x8
│           ; var signed int var_ch @ esp+0xc
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      83ec10          sub esp, 0x10
│           0x004014f9      e8b2000000      call fcn.004015b0
│           0x004014fe      c744240c0a00.   mov dword [var_ch], 0xa
│           0x00401506      c74424040600.   mov dword [var_4h], 6
│           0x0040150e      eb12            jmp 0x401522
│           ; CODE XREF from main @ 0x401527
│           0x00401510      8b44240c        mov eax, dword [var_ch]
│           0x00401514      0faf442404      imul eax, dword [var_4h]
│           0x00401519      01442408        add dword [var_8h], eax
│           0x0040151d      836c240c01      sub dword [var_ch], 1
│           ; CODE XREF from main @ 0x40150e
│           0x00401522      837c240c00      cmp dword [var_ch], 0
│           0x00401527      7fe7            jg 0x401510
│           0x00401529      8b442408        mov eax, dword [var_8h]
│           0x0040152d      c9              leave
```

first time

if true

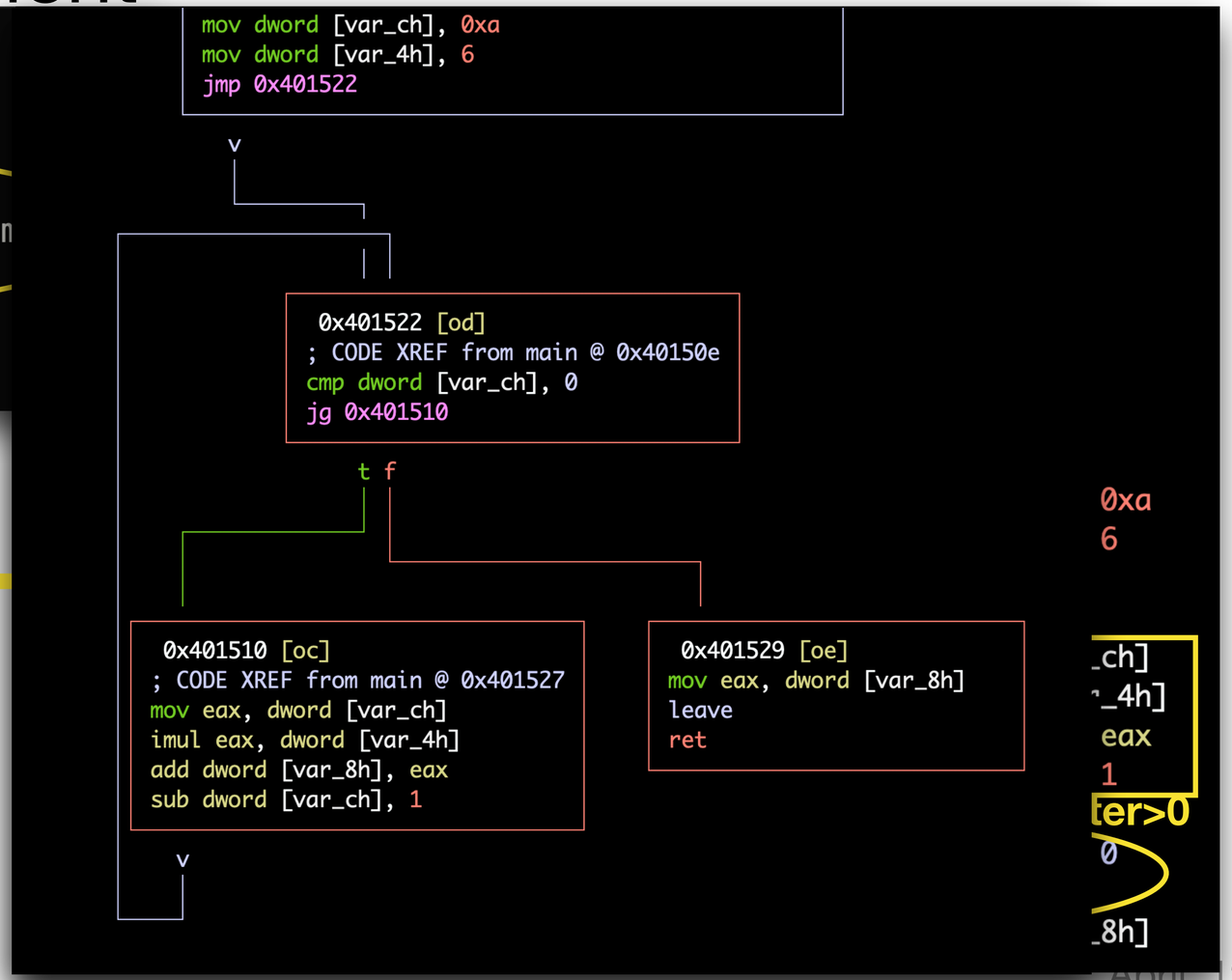
counter>0

@apasamar
c0r0n4con
incide.es

Recognising C code in assembly

- while statement

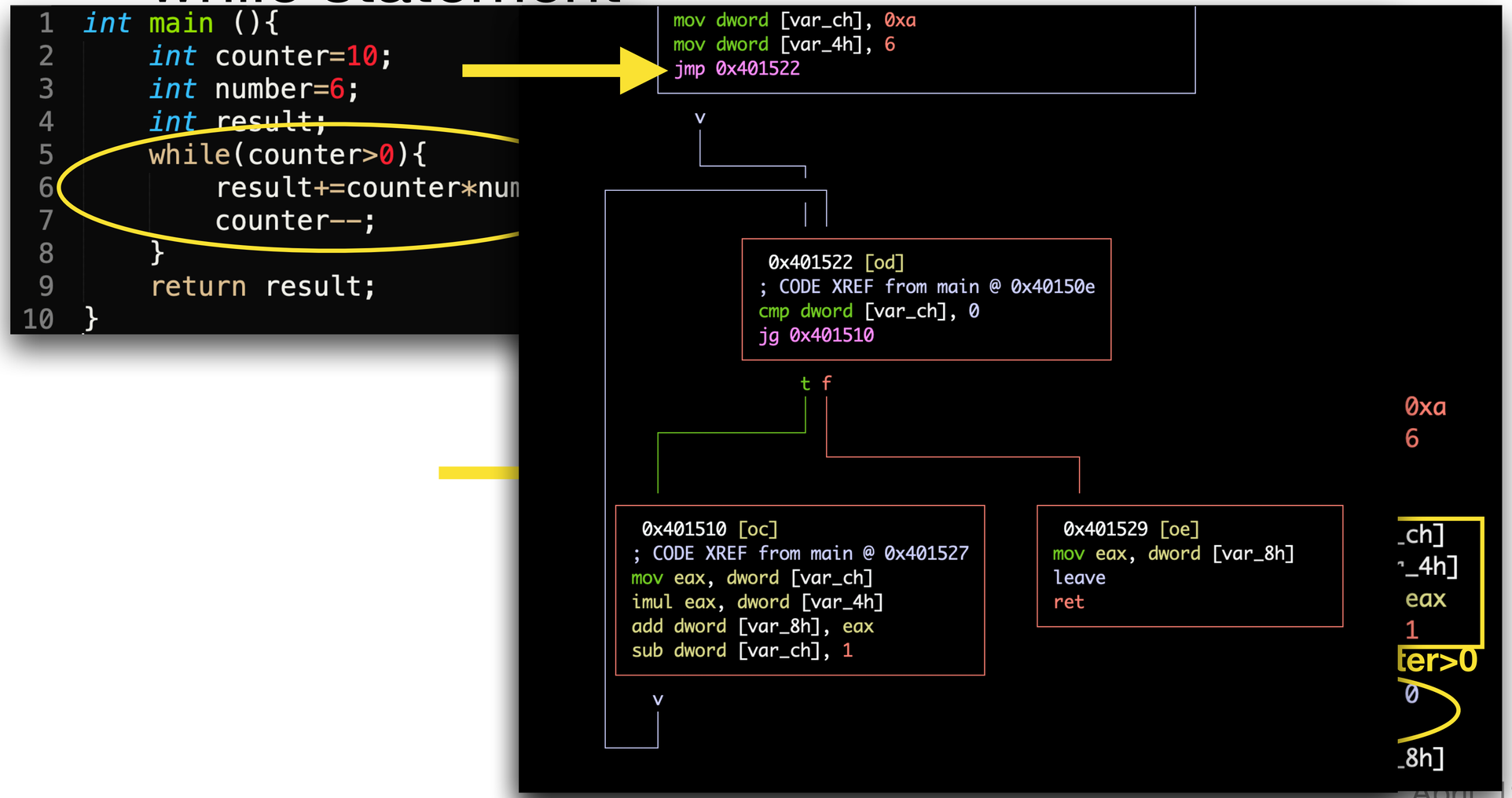
```
1  int main (){
2      int counter=10;
3      int number=6;
4      int result;
5      while(counter>0){
6          result+=counter*num
7          counter--;
8      }
9      return result;
10 }
```



Recognising C code in assembly

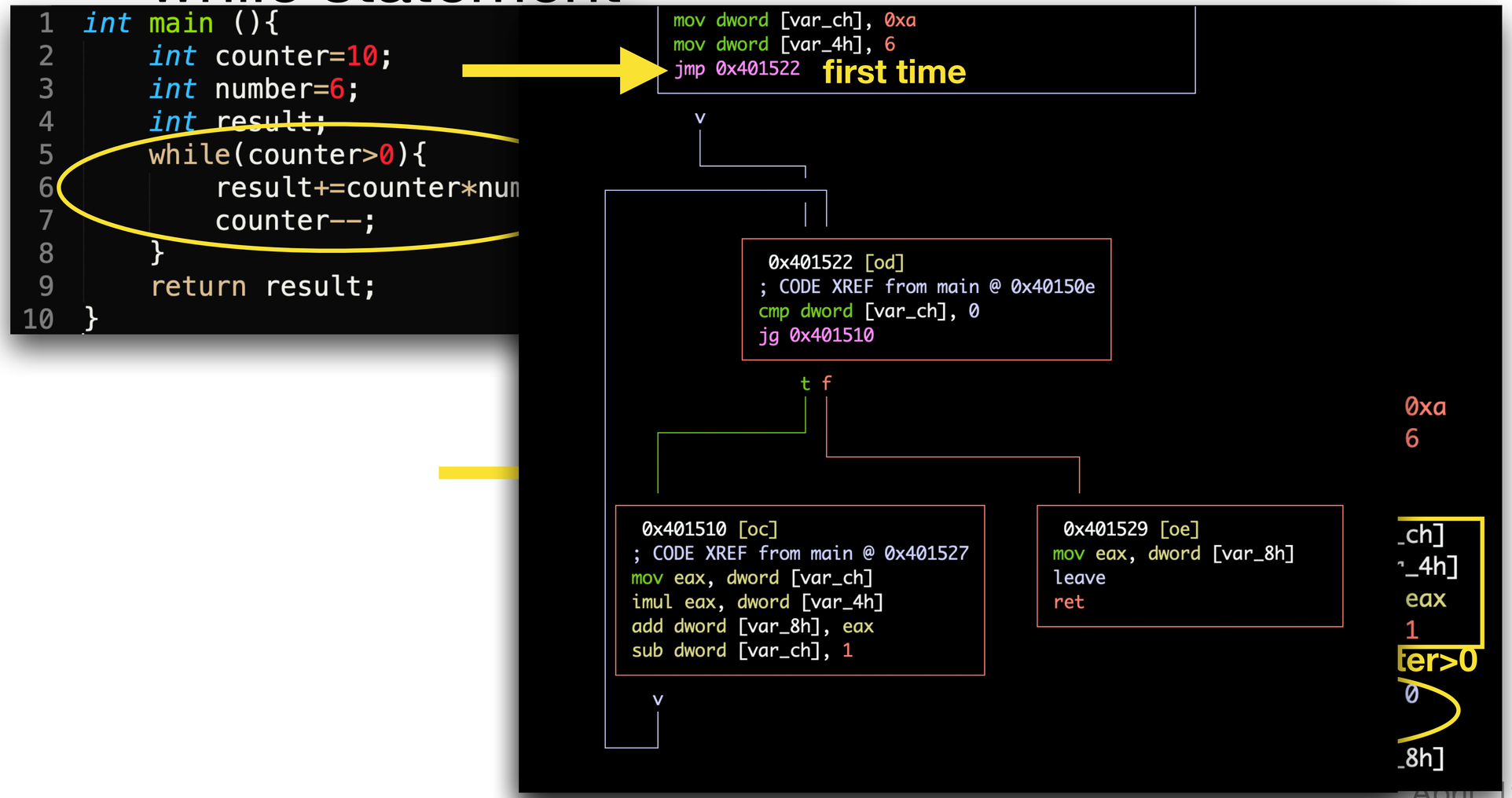
- while statement

```
1  int main (){
2      int counter=10;
3      int number=6;
4      int result;
5      while(counter>0){
6          result+=counter*num
7          counter--;
8      }
9      return result;
10 }
```



Recognising C code in assembly

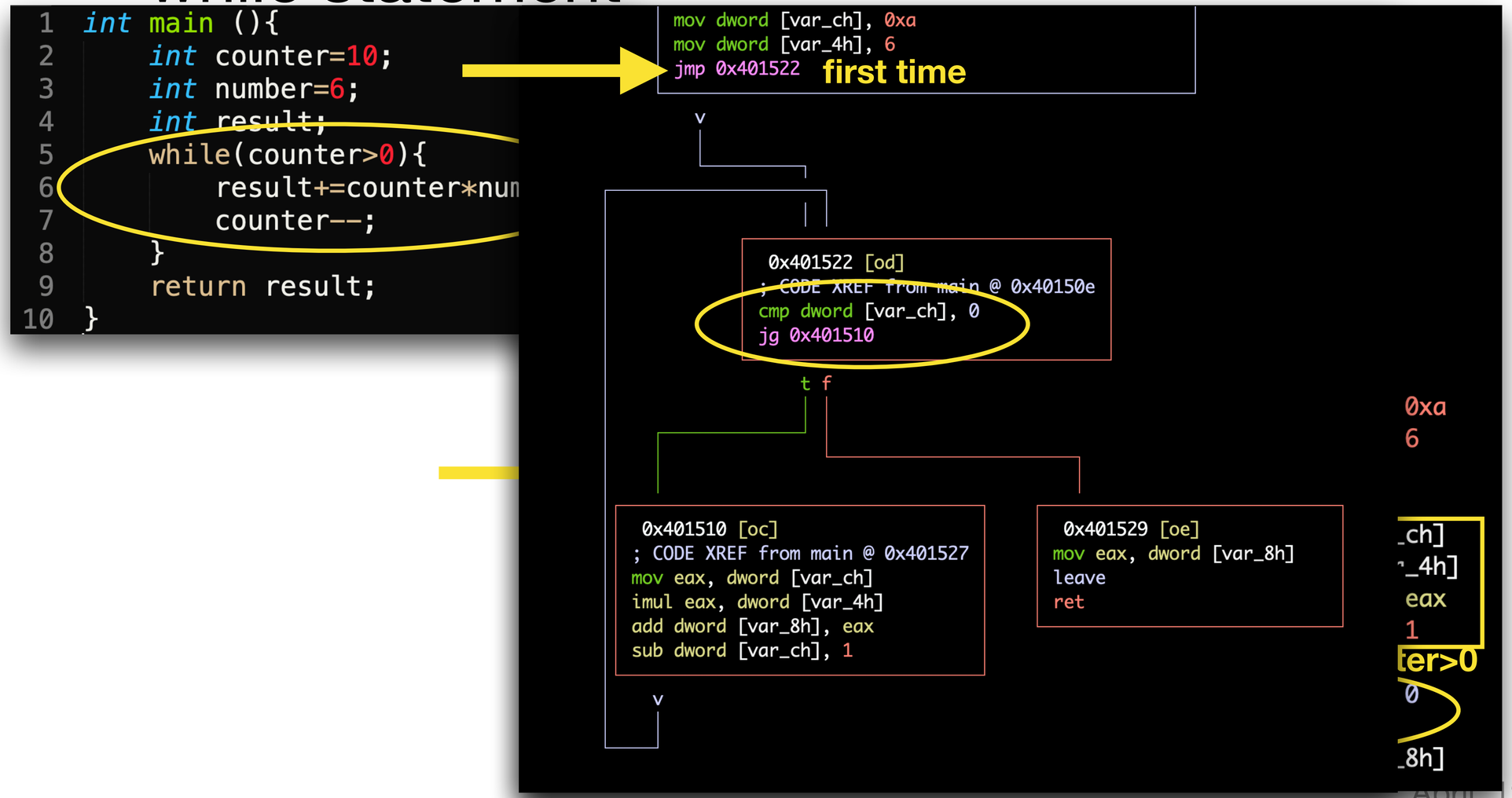
- while statement



Recognising C code in assembly

- while statement

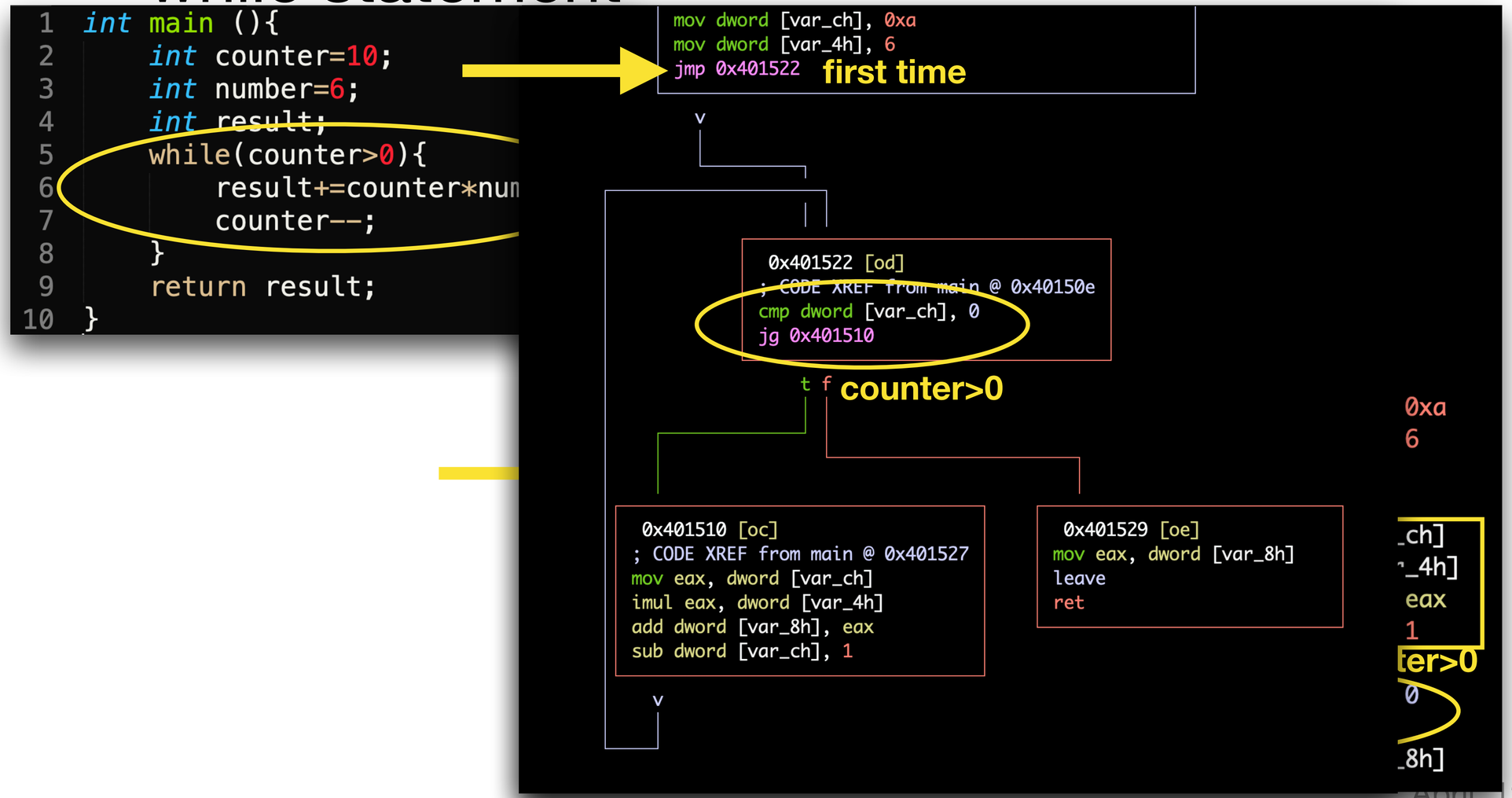
```
1  int main (){
2      int counter=10;
3      int number=6;
4      int result;
5      while(counter>0){
6          result+=counter*num
7          counter--;
8      }
9      return result;
10 }
```



Recognising C code in assembly

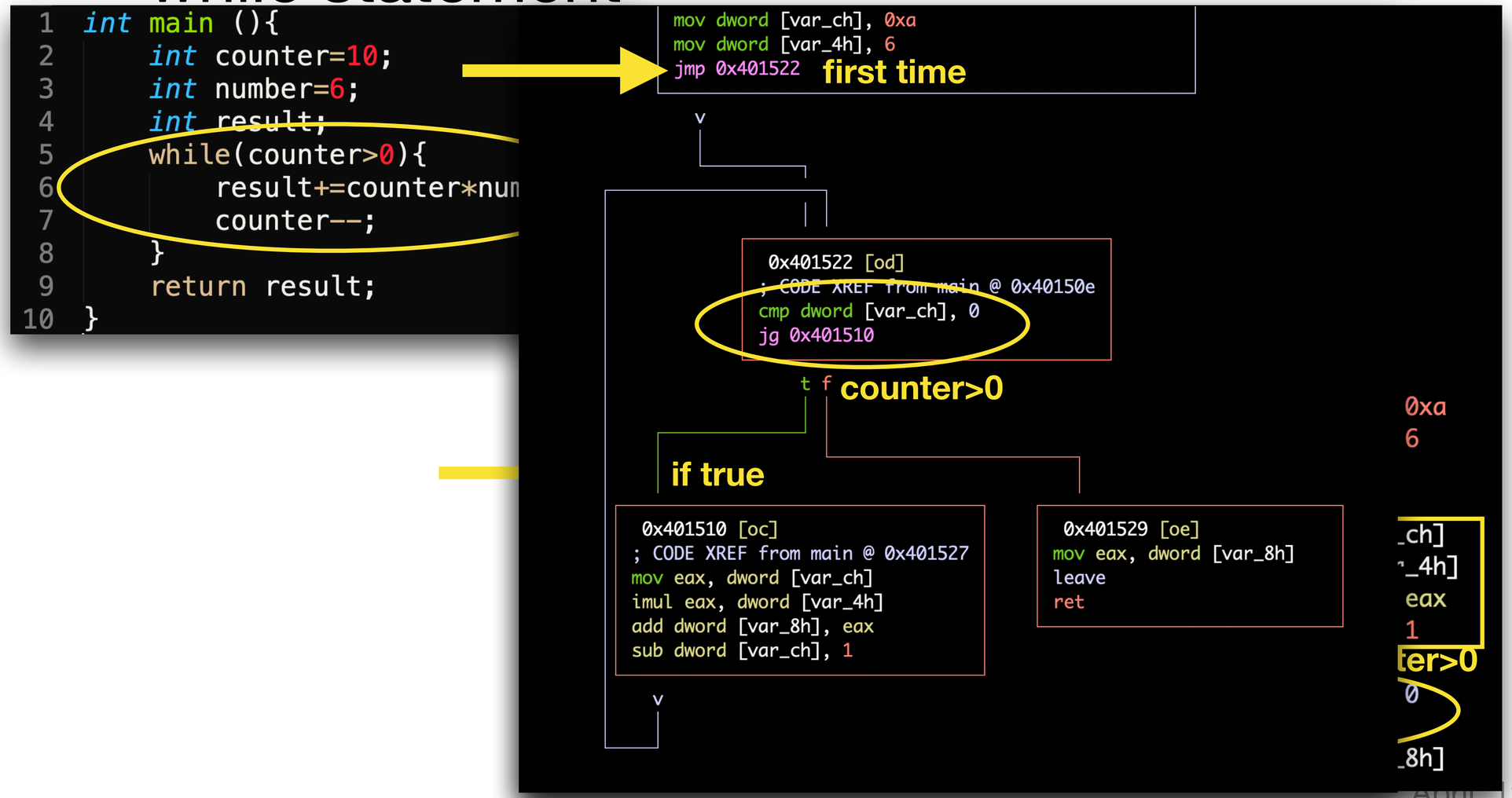
- while statement

```
1  int main (){
2      int counter=10;
3      int number=6;
4      int result;
5      while(counter>0){
6          result+=counter*num
7          counter--;
8      }
9      return result;
10 }
```



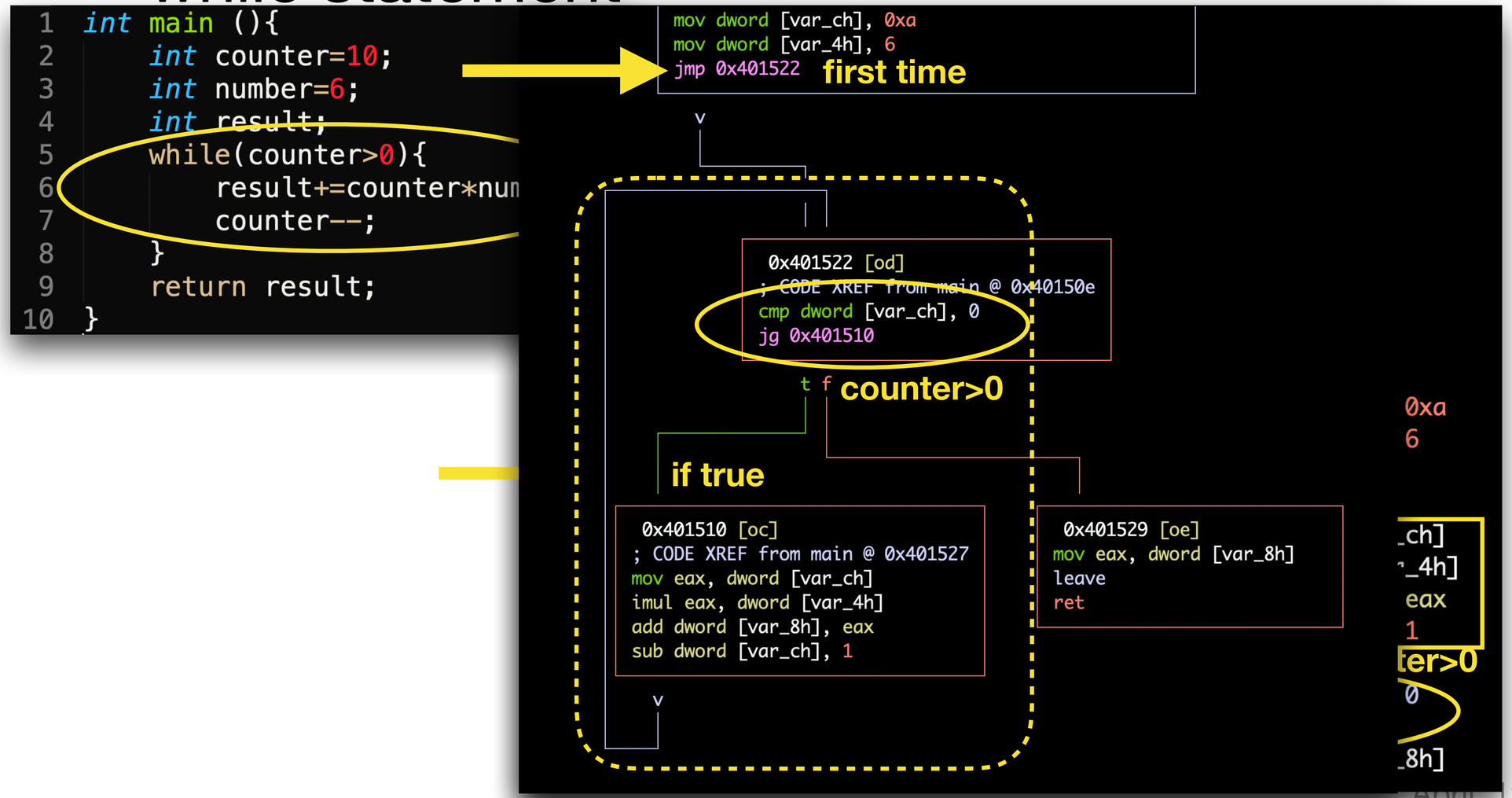
Recognising C code in assembly

- while statement



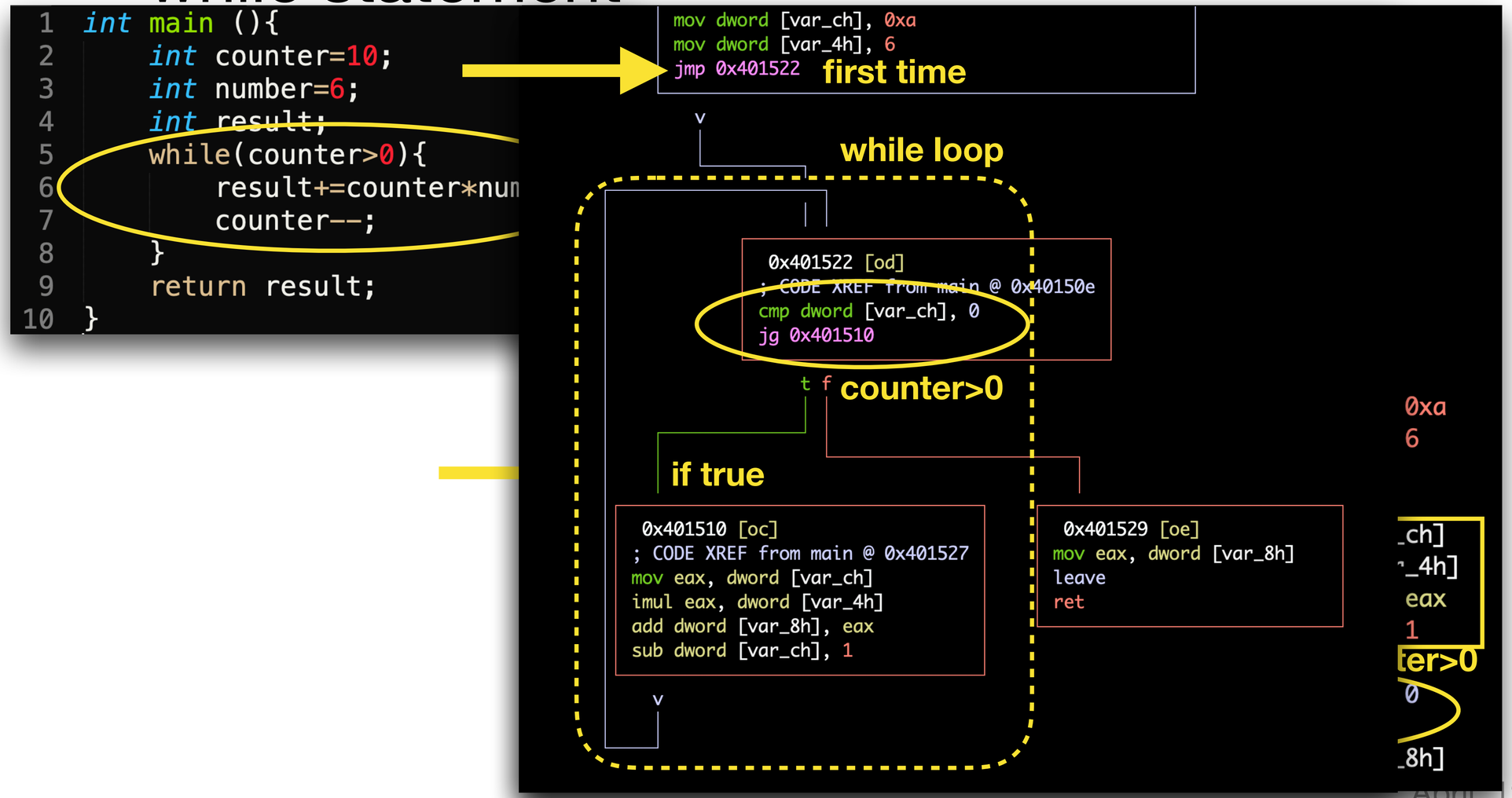
Recognising C code in assembly

- while statement



Recognising C code in assembly

- while statement



Recognising C code in assembly

- switch statement

```
1  int a=2;
2
3  int main (){
4      switch(a){
5          case 1:
6              a++;
7              break;
8          case 2:
9              a=a+2;
10             break;
11         default:
12             a=a+10;
13     }
14     return a;
15 }
```

Recognising C code in assembly

- switch statement

```
1  int a=2;
2
3  int main (){
4      switch(a){
5          case 1:
6              a++;
7              break;
8          case 2:
9              a=a+2;
10             break;
11         default:
12             a=a+10;
13     }
14     return a;
15 }
```

Recognising C code in assembly

- switch statement

```c
int a=2;

int main (){
    switch(a){
        case 1:
            a++;
            break;
        case 2:
            a=a+2;
            break;
        default:
            a=a+10;
    }
    return a;
}
```

```
[0x004014f0]> pdf
┌ (fcn) main 78
│   int main (int argc, char **argv, char **envp);
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      e8c5000000      call fcn.004015c0
│           0x004014fb      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│           0x00401500      83f801          cmp eax, 1                  ; 1
│       ┌─< 0x00401503      7407            je 0x40150c
│       │   0x00401505      83f802          cmp eax, 2                  ; 2
│      ┌──< 0x00401508      7411            je 0x40151b
│      │┌─< 0x0040150a      eb1e            jmp 0x40152a
│      ││   ; CODE XREF from main @ 0x401503
│      ││┌─> 0x0040150c      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│      ├│└─  0x00401511      83c001          add eax, 1
│      ├│    0x00401514      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│      ├│┌─< 0x00401519      eb1c            jmp 0x401537
│      ├│└─  ; CODE XREF from main @ 0x401508
│      ├└──> 0x0040151b      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│      ├ │   0x00401520      83c002          add eax, 2
│      ├ │   0x00401523      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│      ├ │┌─< 0x00401528      eb0d            jmp 0x401537
│      ├ ││   ; CODE XREF from main @ 0x40150a
│      └─ │└─> 0x0040152a      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│        ├ │   0x0040152f      83c00a          add eax, 0xa
│        ├ │   0x00401532      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│        ├ │   ; CODE XREFS from main @ 0x401519, 0x401528
│        └ └─> 0x00401537      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│          ├   0x0040153c      c9              leave
└          └   0x0040153d      c3              ret
```

Recognising C code in assembly

- switch statement

```c
int a=2;

int main (){
    switch(a){
        case 1:
            a++;
            break;
        case 2:
            a=a+2;
            break;
        default:
            a=a+10;
    }
    return a;
}
```

```
[0x004014f0]> pdf
┌ (fcn) main 78
│   int main (int argc, char **argv, char **envp);
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      e8c5000000      call fcn.004015c0
│           0x004014fb      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│           0x00401500      83f801          cmp eax, 1                  ; 1
│       ┌─< 0x00401503      7407            je 0x40150c
│           0x00401505      83f802          cmp eax, 2                  ; 2
│      ┌──< 0x00401508      7411            je 0x40151b
│      │┌─< 0x0040150a      eb1e            jmp 0x40152a
│      ││   ; CODE XREF from main @ 0x401503
│      │└─> 0x0040150c      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│      │    0x00401511      83c001          add eax, 1
│      │    0x00401514      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│      │┌─< 0x00401519      eb1c            jmp 0x401537
│      ││   ; CODE XREF from main @ 0x401508
│      └──> 0x0040151b      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│       │    0x00401520      83c002          add eax, 2
│       │    0x00401523      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│       │┌─< 0x00401528      eb0d            jmp 0x401537
│       ││   ; CODE XREF from main @ 0x40150a
│       └──> 0x0040152a      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│        │    0x0040152f      83c00a          add eax, 0xa
│        │    0x00401532      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│        │    ; CODE XREFS from main @ 0x401519, 0x401528
│        └──> 0x00401537      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│             0x0040153c      c9              leave
└             0x0040153d      c3              ret
```

Recognising C code in assembly

- switch statement

```c
int a=2;

int main (){
    switch(a){
        case 1:
            a++;
            break;
        case 2:
            a=a+2;
            break;
        default:
            a=a+10;
    }
    return a;
}
```

```
[0x004014f0]> pdf
┌ (fcn) main 78
│   int main (int argc, char **argv, char **envp);
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      e8c5000000      call fcn.004015c0
│           0x004014fb      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│           0x00401500      83f801          cmp eax, 1                  ; 1
│       ┌─< 0x00401503      7407            je 0x40150c
│           0x00401505      83f802          cmp eax, 2                  ; 2
│      ┌──< 0x00401508      7411            je 0x40151b
│     ┌───< 0x0040150a      eb1e            jmp 0x40152a
│     │     ; CODE XREF from main @ 0x401503
│     └───> 0x0040150c      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│           0x00401511      83c001          add eax, 1
│           0x00401514      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│       ┌─< 0x00401519      eb1c            jmp 0x401537
│       │   ; CODE XREF from main @ 0x401508
│       └─> 0x0040151b      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│           0x00401520      83c002          add eax, 2
│           0x00401523      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│       ┌─< 0x00401528      eb0d            jmp 0x401537
│       │   ; CODE XREF from main @ 0x40150a
│     ┌─└─> 0x0040152a      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│     │     0x0040152f      83c00a          add eax, 0xa
│     │     0x00401532      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│     │     ; CODE XREFS from main @ 0x401519, 0x401528
│     └───> 0x00401537      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│           0x0040153c      c9              leave
└           0x0040153d      c3              ret
```

Recognising C code in assembly

- switch statement

```c
int a=2;

int main (){
    switch(a){
        case 1:
            a++;
            break;
        case 2:
            a=a+2;
            break;
        default:
            a=a+10;
    }
    return a;
}
```

```
[0x004014f0]> pdf
┌ (fcn) main 78
│   int main (int argc, char **argv, char **envp);
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      e8c5000000      call fcn.004015c0
│           0x004014fb      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│           0x00401500      83f801          cmp eax, 1                  ; 1
│       ┌─< 0x00401503      7407            je 0x40150c
│           0x00401505      83f802          cmp eax, 2                  ; 2
│      ┌──< 0x00401508      7411            je 0x40151b
│      │┌─< 0x0040150a      eb1e            jmp 0x40152a
│      ││   ; CODE XREF from main @ 0x401503
│      │└─> 0x0040150c      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│      │    0x00401511      83c001          add eax, 1
│      │    0x00401514      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│      │┌─< 0x00401519      eb1c            jmp 0x401537
│      ││   ; CODE XREF from main @ 0x401508
│      └──> 0x0040151b      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│       │    0x00401520      83c002          add eax, 2
│       │    0x00401523      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│       │┌─< 0x00401528      eb0d            jmp 0x401537
│       ││   ; CODE XREF from main @ 0x40150a
│       └──> 0x0040152a      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│        │    0x0040152f      83c00a          add eax, 0xa
│        │    0x00401532      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│        │    ; CODE XREFS from main @ 0x401519, 0x401528
│        └──> 0x00401537      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│             0x0040153c      c9              leave
└             0x0040153d      c3              ret
```

Recognising C code in assembly

- switch statement

```c
int a=2;

int main (){
    switch(a){
        case 1:
            a++;
            break;
        case 2:
            a=a+2;
            break;
        default:
            a=a+10;
    }
    return a;
}
```

```
[0x004014f0]> pdf
┌ (fcn) main 78
│   int main (int argc, char **argv, char **envp);
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      83e4f0          and esp, 0xfffffff0
│           0x004014f6      e8c5000000      call fcn.004015c0
│           0x004014fb      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│           0x00401500      83f801          cmp eax, 1                  ; 1
│       ┌─< 0x00401503      7407            je 0x40150c
│           0x00401505      83f802          cmp eax, 2                  ; 2
│      ┌──< 0x00401508      7411            je 0x40151b
│      │┌─< 0x0040150a      eb1e            jmp 0x40152a
│      ││   ; CODE XREF from main @ 0x401503
│      │└─> 0x0040150c      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│      │    0x00401511      83c001          add eax, 1
│      │    0x00401514      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│      │┌─< 0x00401519      eb1c            jmp 0x401537
│      ││   ; CODE XREF from main @ 0x401508
│      └──> 0x0040151b      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│       │    0x00401520      83c002          add eax, 2
│       │    0x00401523      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│       │┌─< 0x00401528      eb0d            jmp 0x401537
│       ││   ; CODE XREF from main @ 0x40150a
│       └──> 0x0040152a      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│        │    0x0040152f      83c00a          add eax, 0xa
│        │    0x00401532      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
│        │    ; CODE XREFS from main @ 0x401519, 0x401528
│        └──> 0x00401537      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
│             0x0040153c      c9              leave
└             0x0040153d      c3              ret
```

Recognising C code in assembly

- switch statement

```c
int a=2;

int main (){
    switch(a){
        case 1:
            a++;
            break;
        case 2:
            a=a+2;
            break;
        default:
            a=a+10;
    }
    return a;
}
```

```
[0x004014f0]> pdf
 (fcn) main 78
   int main (int argc, char **argv, char **envp);
           ; CALL XREF from entry0 @ 0x40135e
           0x004014f0      55              push ebp
           0x004014f1      89e5            mov ebp, esp
           0x004014f3      83e4f0          and esp, 0xfffffff0
           0x004014f6      e8c5000000      call fcn.004015c0
           0x004014fb      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
           0x00401500      83f801          cmp eax, 1                  ; 1
       ,=< 0x00401503      7407            je 0x40150c
           0x00401505      83f802          cmp eax, 2                  ; 2
      ,==< 0x00401508      7411            je 0x40151b
     ,===< 0x0040150a      eb1e            jmp 0x40152a
     |||   ; CODE XREF from main @ 0x401503
     |||,> 0x0040150c      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
     |||:  0x00401511      83c001          add eax, 1
     |||:  0x00401514      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
     |||:  0x00401519      eb1c            jmp 0x401537
     |||   ; CODE XREF from main @ 0x401508
     ||`-> 0x0040151b      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
     ||:   0x00401520      83c002          add eax, 2
     ||:   0x00401523      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
     ||:   0x00401528      eb0d            jmp 0x401537
     ||    ; CODE XREF from main @ 0x40150a
     |`--> 0x0040152a      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
     |:    0x0040152f      83c00a          add eax, 0xa
     |:    0x00401532      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
     |:    ; CODE XREFS from main @ 0x401519, 0x401528
     `--> 0x00401537      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
          0x0040153c      c9              leave
          0x0040153d      c3              ret
```

Recognising C code in assembly

- switch statement

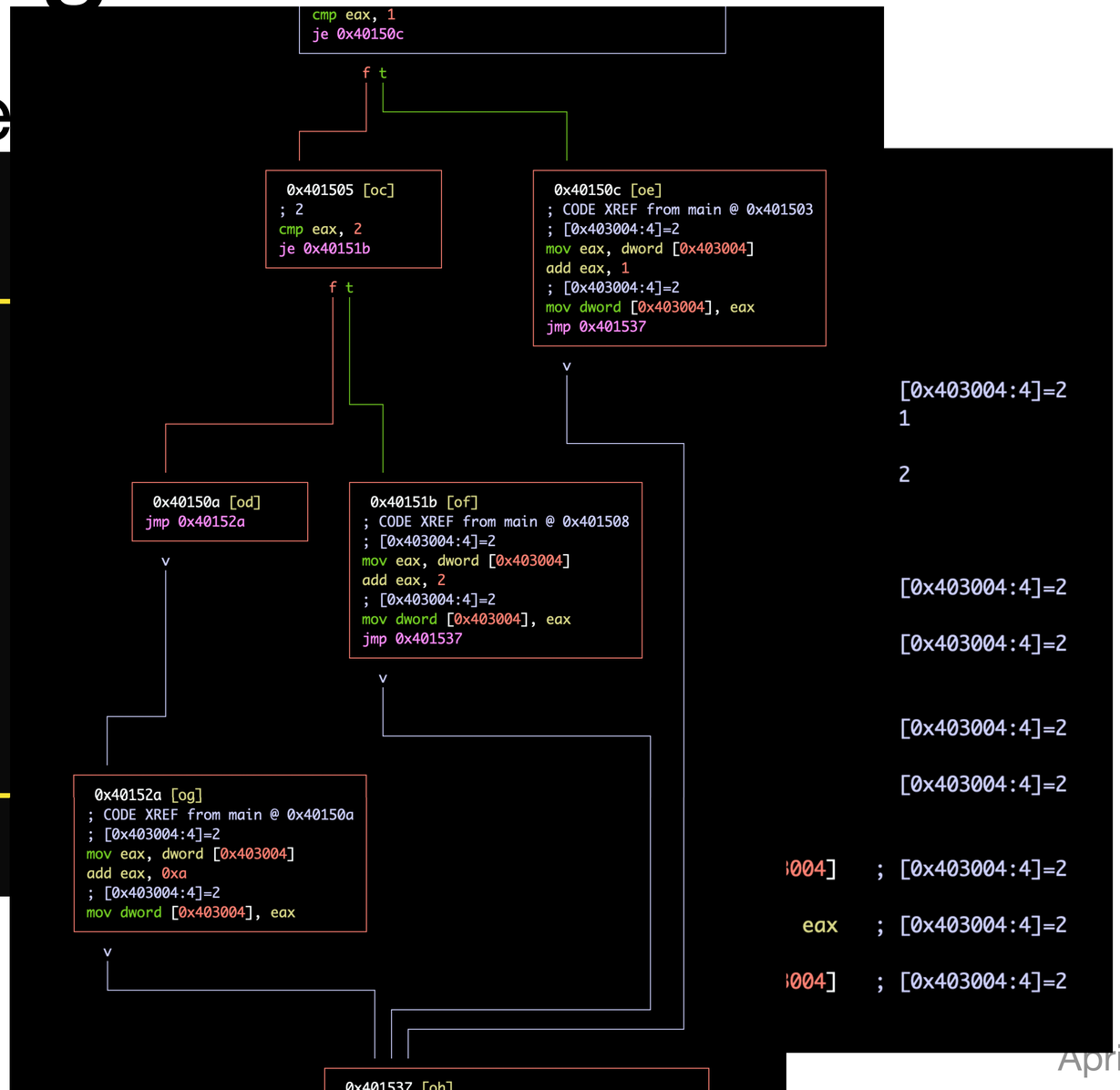
```c
int a=2;

int main (){
    switch(a){
        case 1:
            a++;
            break;
        case 2:
            a=a+2;
            break;
        default:
            a=a+10;
    }
    return a;
}
```

```
[0x004014f0]> pdf
 (fcn) main 78
   int main (int argc, char **argv, char **envp);
           ; CALL XREF from entry0 @ 0x40135e
           0x004014f0      55              push ebp
           0x004014f1      89e5            mov ebp, esp
           0x004014f3      83e4f0          and esp, 0xfffffff0
           0x004014f6      e8c5000000      call fcn.004015c0
           0x004014fb      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
           0x00401500      83f801          cmp eax, 1                  ; 1
       ,=< 0x00401503      7407            je 0x40150c
           0x00401505      83f802          cmp eax, 2                  ; 2
       ,=< 0x00401508      7411            je 0x40151b
       ,=< 0x0040150a      eb1e            jmp 0x40152a
           ; CODE XREF from main @ 0x401503
       |   0x0040150c      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
       |   0x00401511      83c001          add eax, 1
       |   0x00401514      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
       |,=< 0x00401519      eb1c            jmp 0x401537
           ; CODE XREF from main @ 0x401508
       |   0x0040151b      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
       |   0x00401520      83c002          add eax, 2
       |   0x00401523      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
       |,=< 0x00401528      eb0d            jmp 0x401537
           ; CODE XREF from main @ 0x40150a
       |   0x0040152a      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
       |   0x0040152f      83c00a          add eax, 0xa
       |   0x00401532      a304304000      mov dword [0x403004], eax   ; [0x403004:4]=2
           ; CODE XREFS from main @ 0x401519, 0x401528
       `-> 0x00401537      a104304000      mov eax, dword [0x403004]   ; [0x403004:4]=2
           0x0040153c      c9              leave
           0x0040153d      c3              ret
```

Recognising C code in assembly

- switch state

```
1  int a=2;
2
3  int main (){
4      switch(a){
5          case 1:
6              a++;
7              break;
8          case 2:
9              a=a+2;
10             break;
11         default:
12             a=a+10;
13     }
14     return a;
15 }
```



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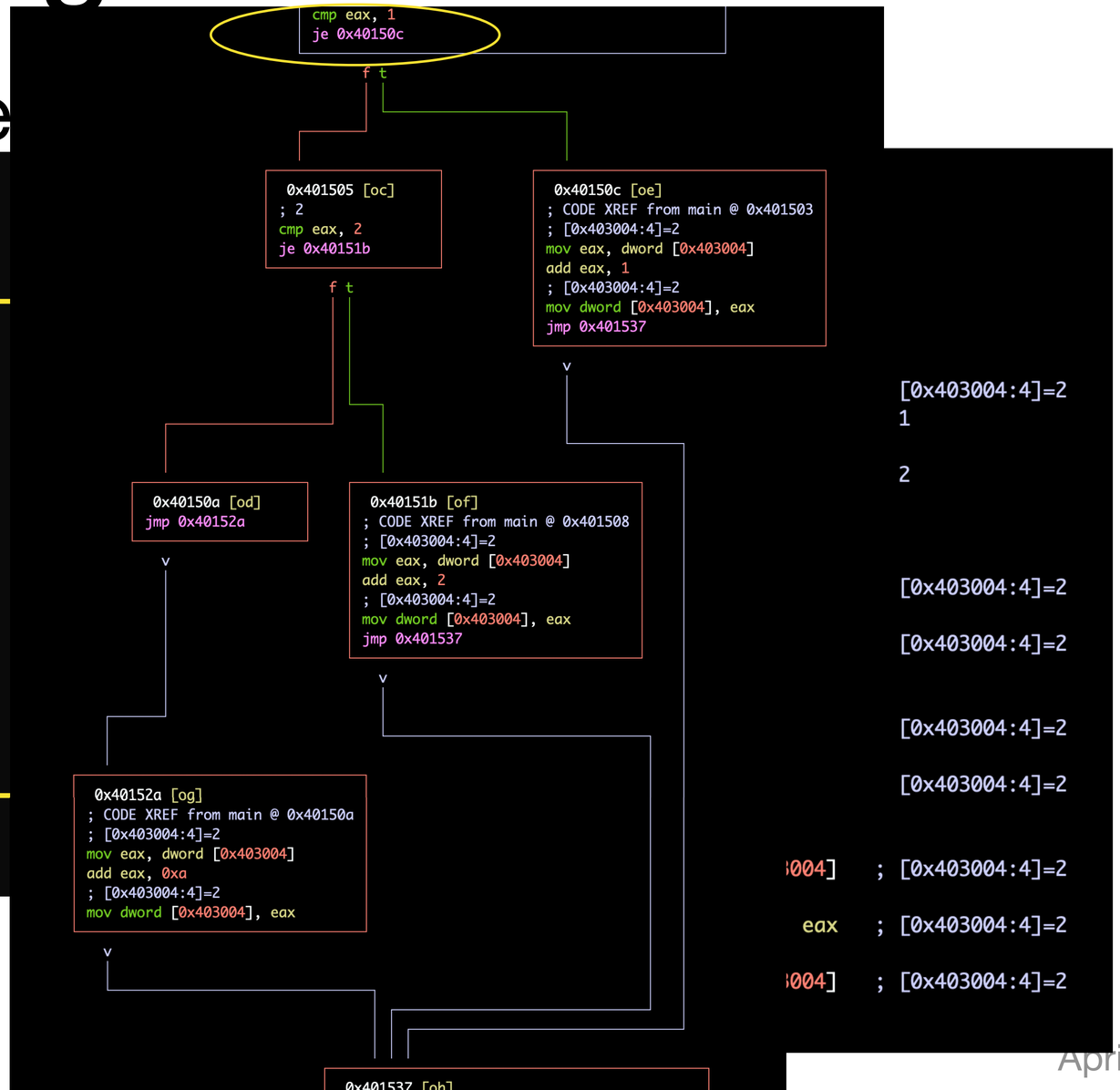

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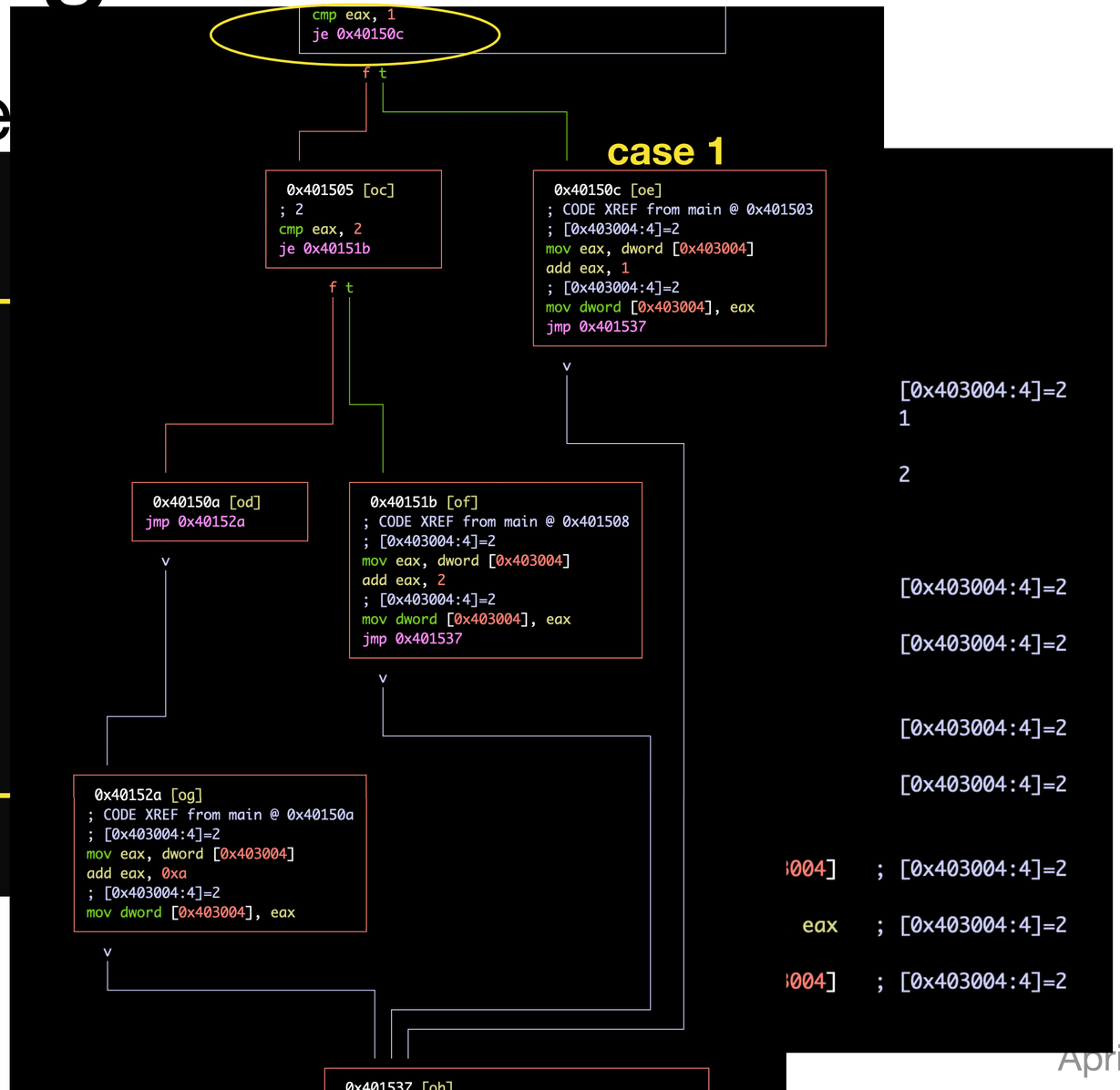

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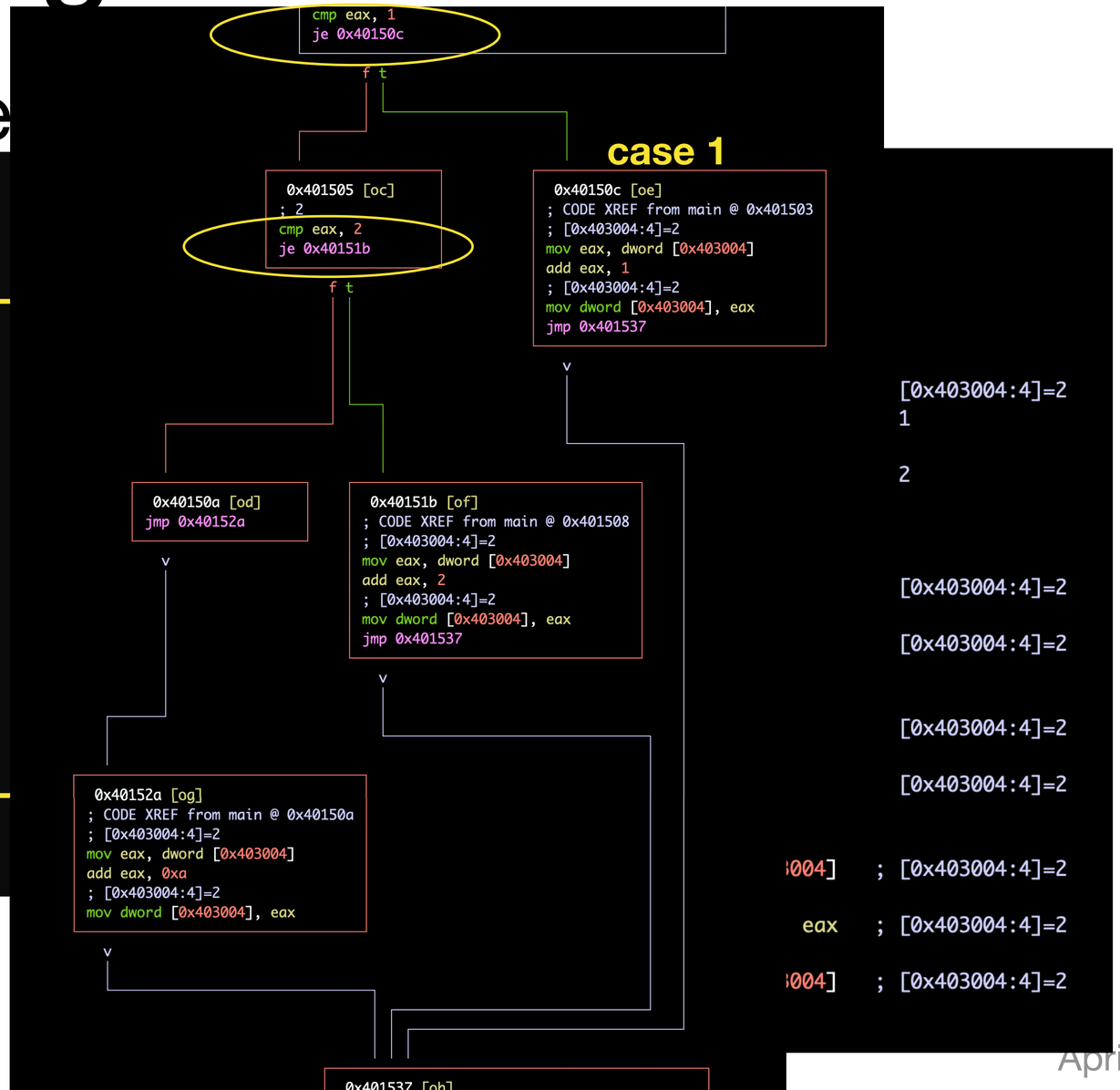

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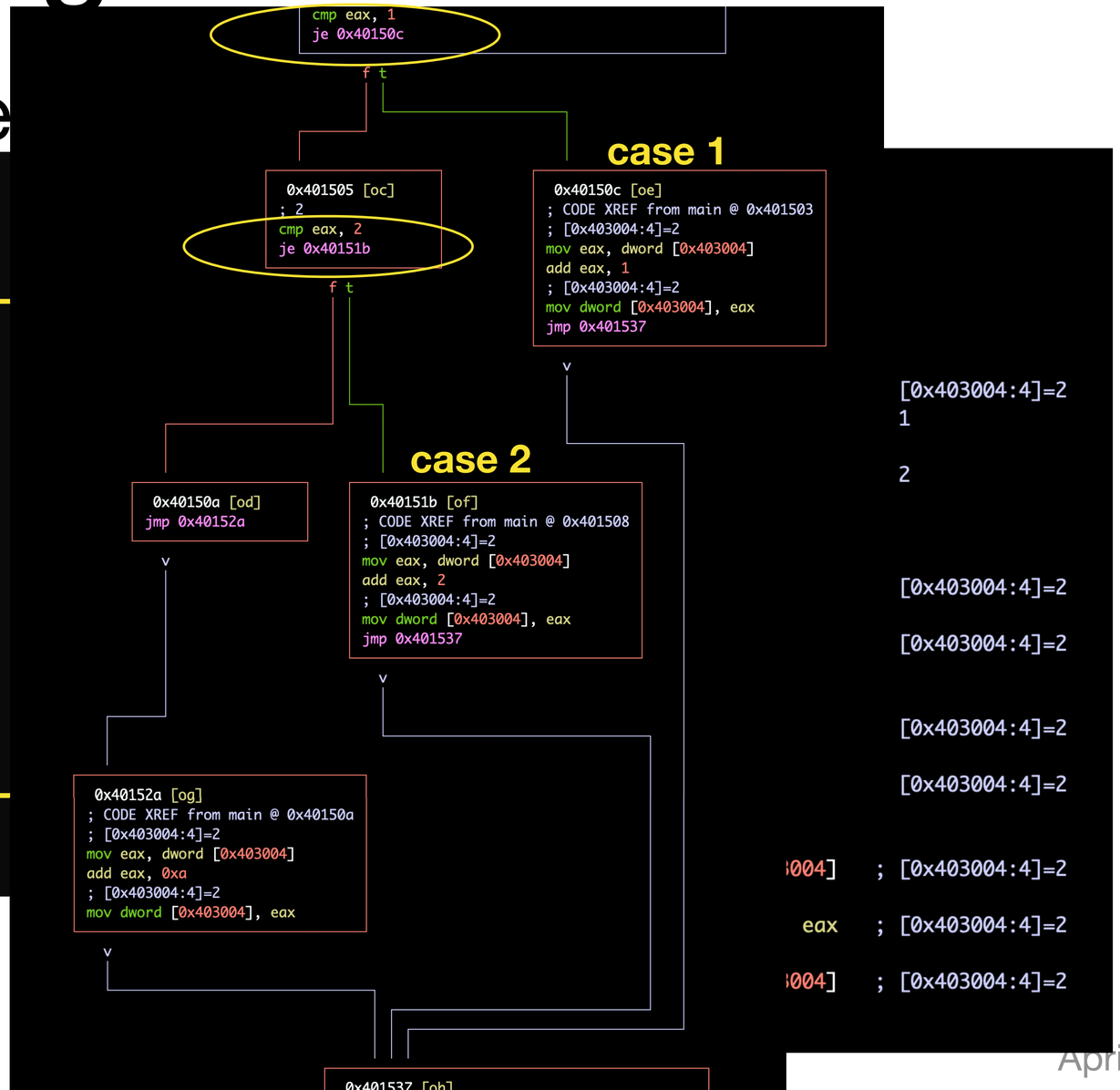

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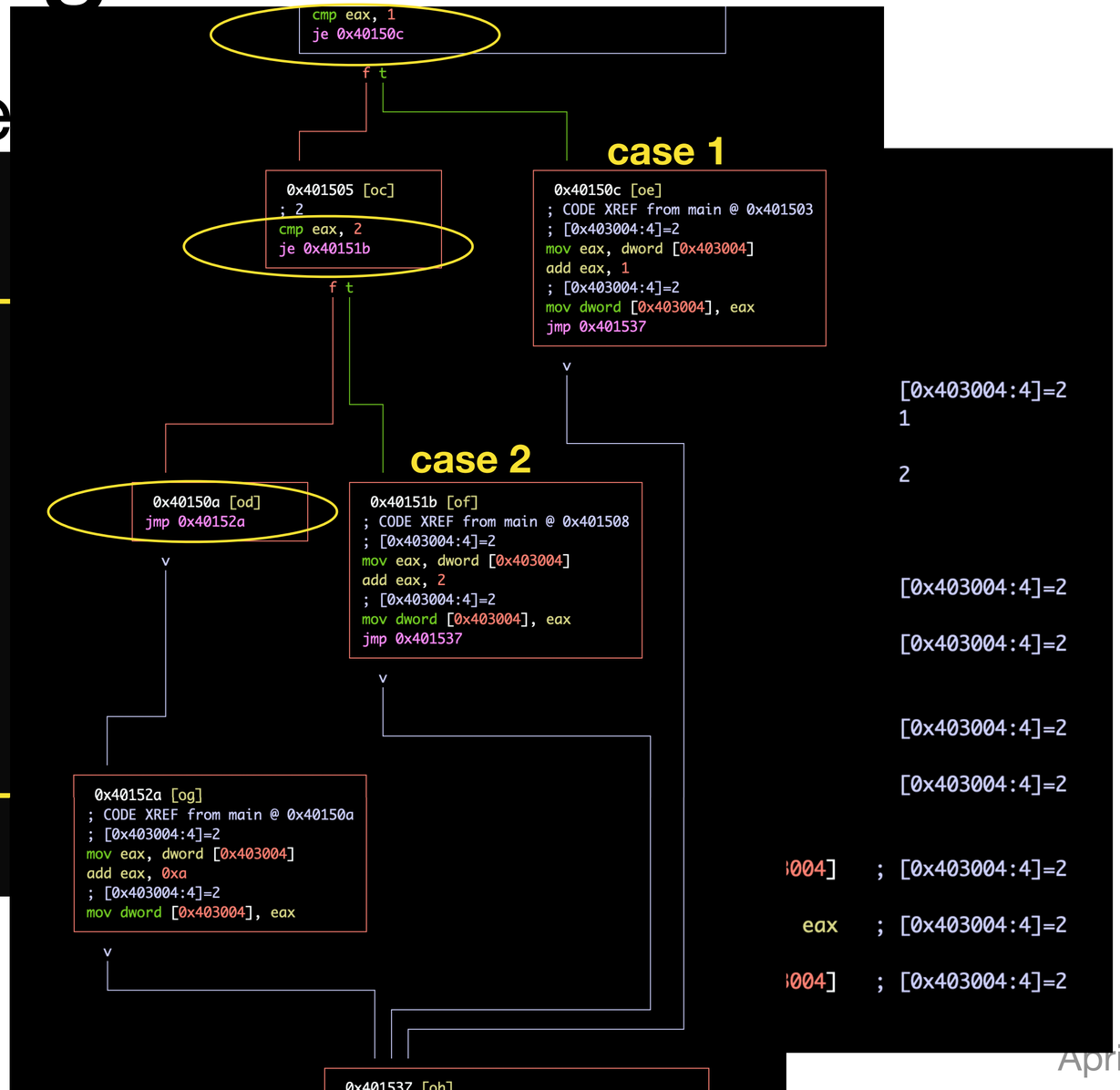

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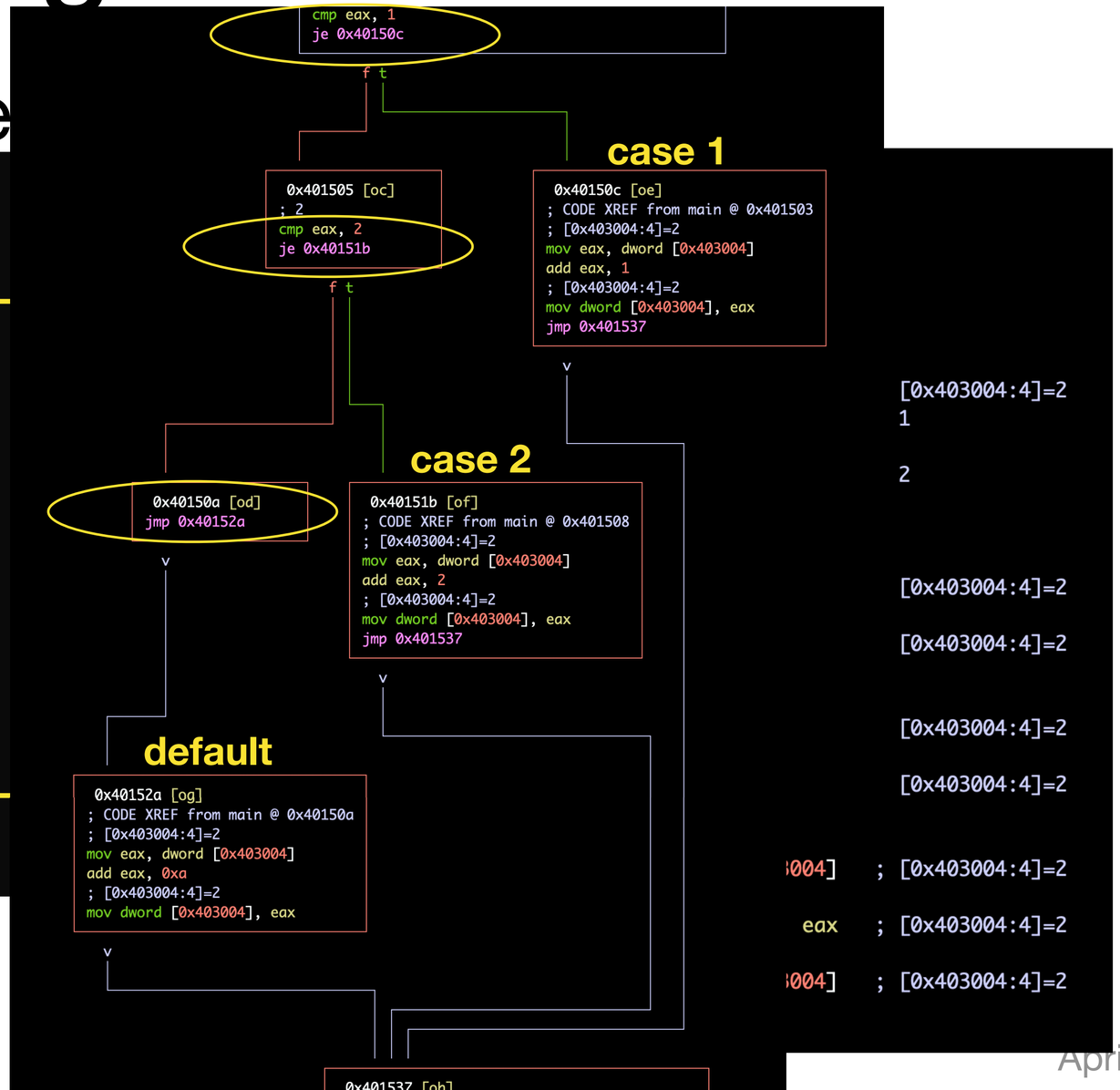

Recognising C code in assembly

- Calling conventions

Recognising C code in assembly

- Calling conventions

Recognising C code in assembly

- calling conventions describe the interface of called code:
  - parameters order
  - how parameters are passed (pushed on the stack, placed in registers, or a mix of both)
  - preserve registers for the caller:callee-saved registers or non-volatile registers
  - how prepararing and restoring stack tasks are divided between caller and callee

Recognising C code in assembly

- calling conventions are part of the application binary interface (ABI).
- different compilers, different calling conventions and different implementations of the conventions

Recognising C code in assembly

- Caller clean-up
  - cdecl
  - syscall
  - optlink
- Callee clean-up
  - stdcall
  - Microsoft fastcall
  - …
  - safecall

Recognising C code in assembly

- The malware and examples we will see during this talk are compiled with mingw gcc. It use cdecl
- Let's review this calling convention: cdecl

Recognising C code in assembly

- **cdecl**
  - stands for C declaration
  - originates from the C programming language
  - is used by many C compilers for the x86 architecture

Recognising C code in assembly

- **cdecl**
  - arguments are passed on the stack
  - integer values and memory addresses are returned in the EAX register
  - arguments are pushed on the stack in the right-to-left order (first argument is the last pushed on the stack)
  - GCC de facto standard
  - GCC v > 4.5 the stack must be aligned to a 16-byte boundary (`and esp, 0xfffffff0`)
  - caller clean-up stack

Recognising C code in assembly

- understanding cdlec and stack frame

```
1  int sum(int a,int b){
2      return a+b;
3  }
4
5  int main(){
6      return sum(1,2);
7  }
```

Recognising C code in assembly

- cdlec calling convention

Recognising C code in assembly

- cdlec calling convention

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Recognising C code in assembly

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Recognising C code in assembly

- cdlec calling convention

```c
int sum(int a,int b){
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}

int main(){
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}
```

```
[0x004014fd]> pdf
            ;-- _main:
┌ (fcn) main 36
│   int main (int argc, char **argv, char **envp);
│           ; var int32_t var_4h @ esp+0x4
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014fd      55              push ebp
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│           0x00401500      83e4f0          and esp, 0xfffffff0
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│           0x0040151a      e8d1ffffff      call sym._sum
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Recognising C code in assembly

- cdlec calling convention

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function prologue

Recognising C code in assembly

- cdlec calling convention

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function prologue

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16 byte stack alignment

function prologue

Recognising C code in assembly

- cdlec calling convention

Recognising C code in assembly

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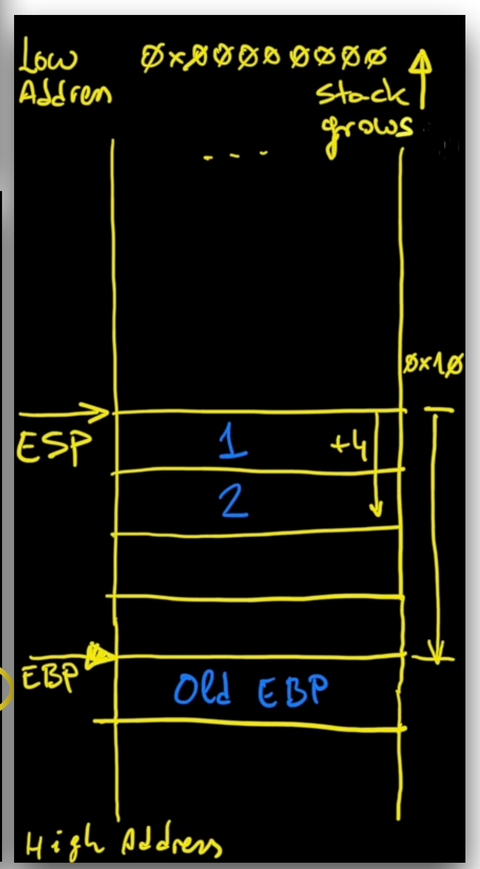

Recognising C code in assembly

- cdlec calling convention

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int main(){
    return sum(1,2);
}
```
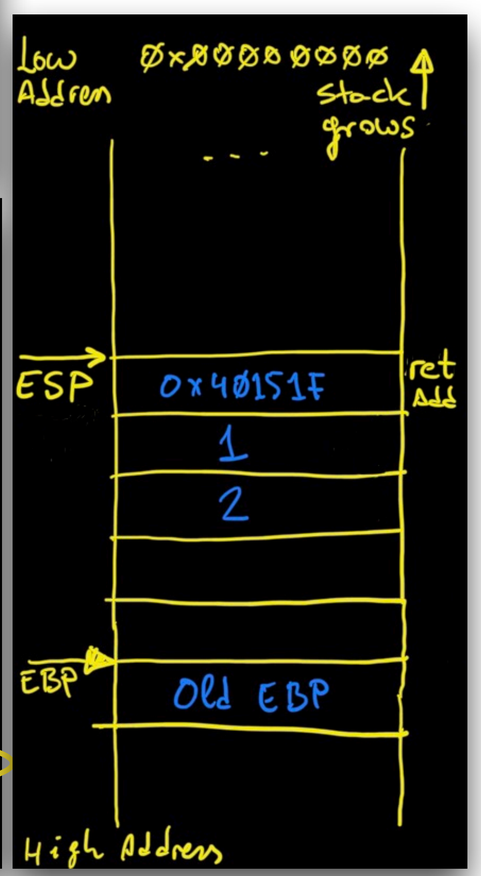

```
[0x004014fd]> pdf
            ;-- _main:
┌ (fcn) main 36
│   int main (int argc, char **argv, char **envp);
│           ; var int32_t var_4h @ esp+0x4
│           ; CALL XREF from entry0 @ 0x40135e
│           0x004014fd      55              push ebp
│           0x004014fe      89e5            mov ebp, esp
│           0x00401500      83e4f0          and esp, 0xfffffff0
│           0x00401503      83ec10          sub esp, 0x10
│           0x00401506      e8a5000000      call sym.___main
│           0x0040150b      c74424040200.   mov dword [var_4h], 2
│           0x00401513      c70424010000.   mov dword [esp], 1
│           0x0040151a      e8d1ffffff      call sym._sum
│           0x0040151f      c9              leave
└           0x00401520      c3              ret
```



Recognising C code in assembly

- cdlec calling convention

Recognising C code in assembly

- cdlec calling conventio

```c
int sum(int a,int b){
    return a+b;
}

int main(){
    return sum(1,2);
}
```

Recognising C code in assembly

- cdlec calling conventio

```
1  int sum(int a,int b){
2      return a+b;
3  }
4
5  int main(){
6      return sum(1,2);
7  }
```

Recognising C code in assembly

- cdlec calling conventio

```c
int sum(int a,int b){
    return a+b;
}

int main(){
    return sum(1,2);
}
```

```
[0x004014f0]> s sym._sum
[0x004014f0]> pdf
┌ (fcn) sym._sum 13
│   sym._sum (int32_t arg_8h, int32_t arg_ch);
│           ; arg int32_t arg_8h @ ebp+0x8
│           ; arg int32_t arg_ch @ ebp+0xc
│           ; CALL XREF from main @ 0x40151a
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      8b5508          mov edx, dword [arg_8h]
│           0x004014f6      8b450c          mov eax, dword [arg_ch]
│           0x004014f9      01d0            add eax, edx
│           0x004014fb      5d              pop ebp
└           0x004014fc      c3              ret
```

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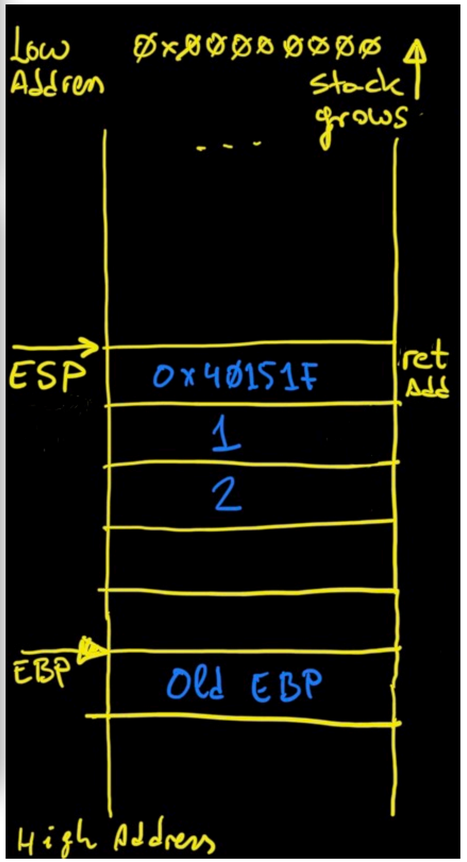

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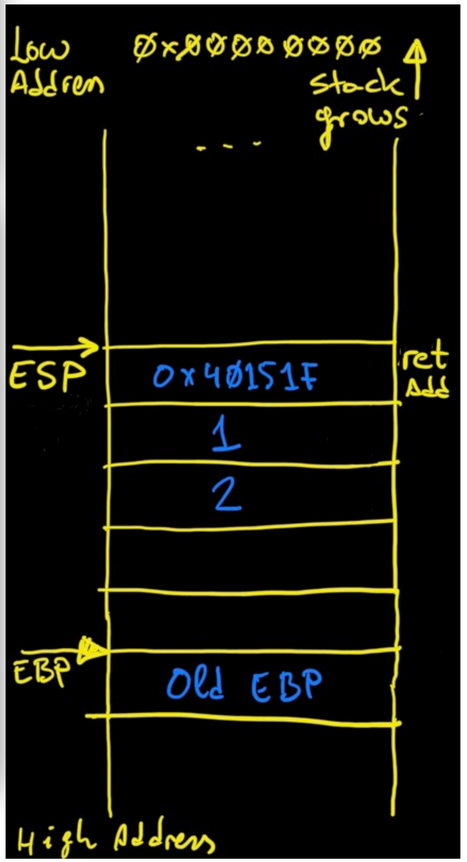

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│   sym._sum (int32_t arg_8h, int32_t arg_ch);
│     2 args; arg int32_t arg_8h @ ebp+0x8
│           ; arg int32_t arg_ch @ ebp+0xc
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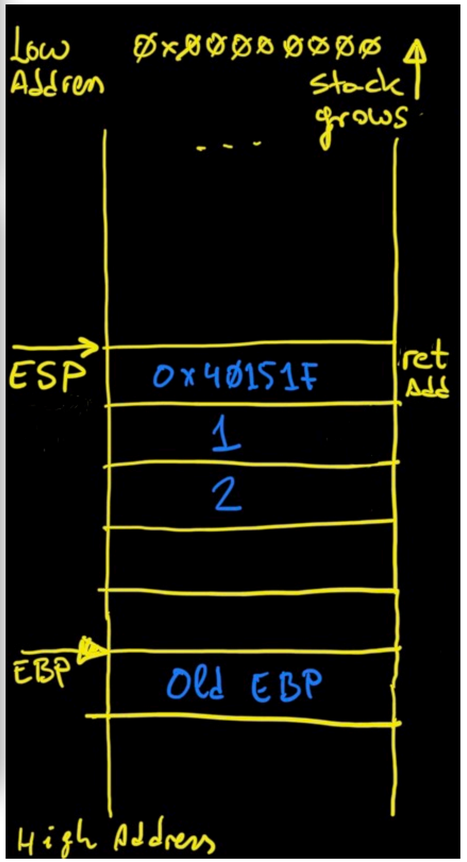

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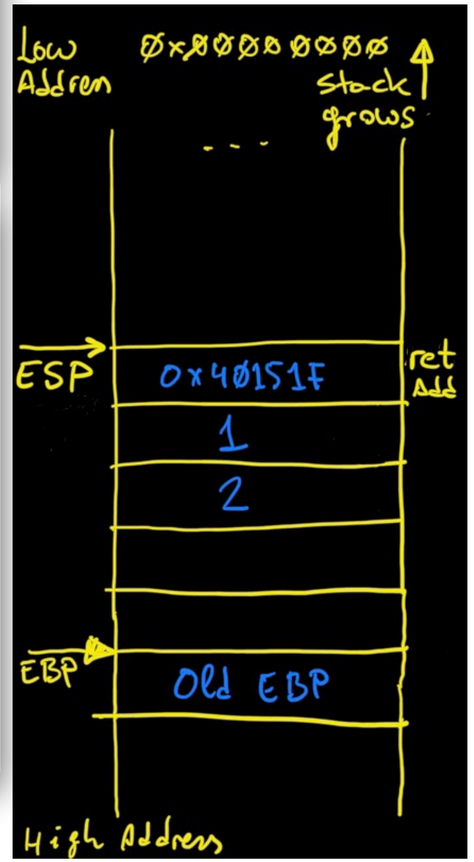
2 args

No local vars, registers will do the task



Recognising C code in assembly

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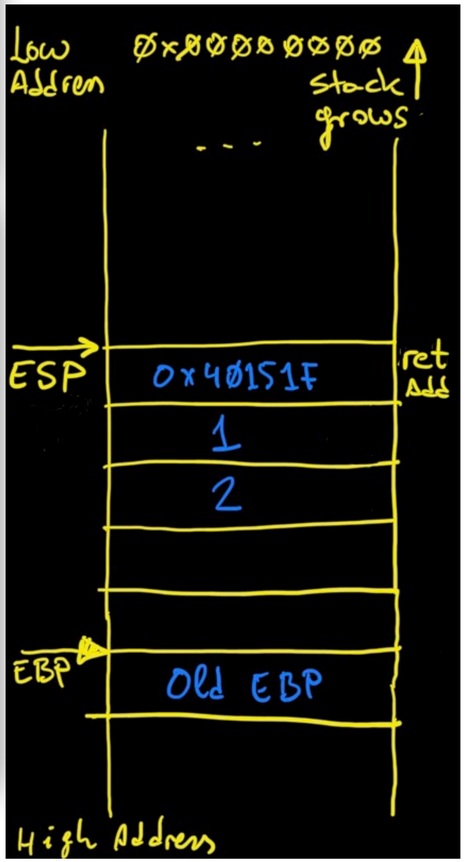

Recognising C code in assembly

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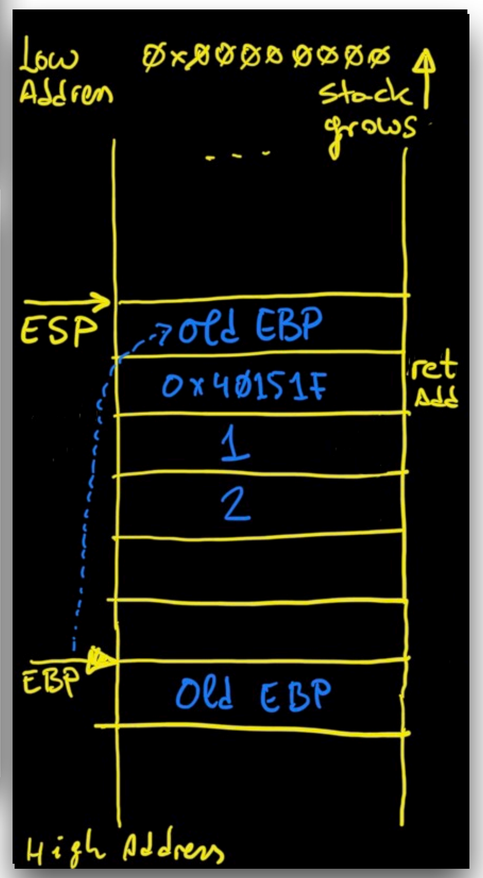

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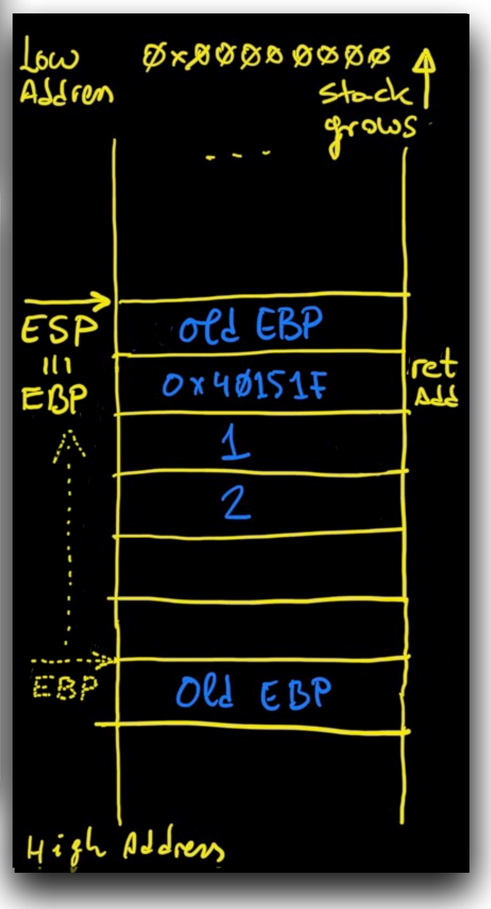

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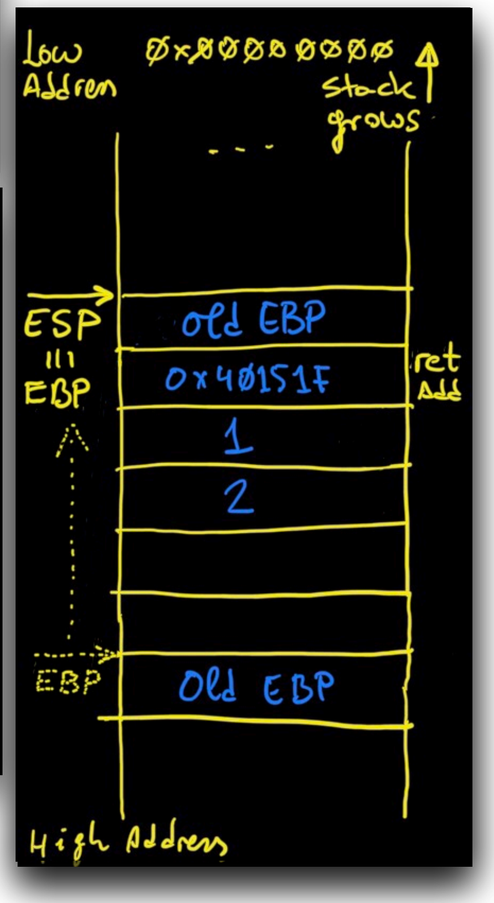

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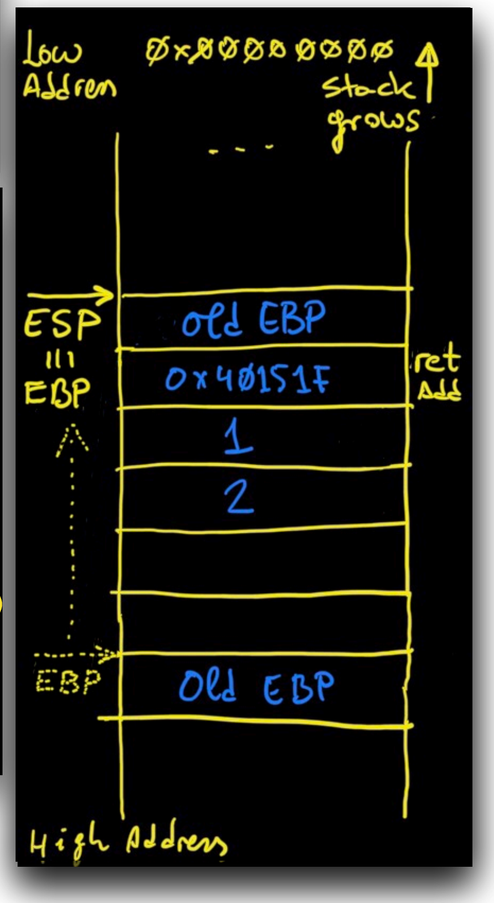

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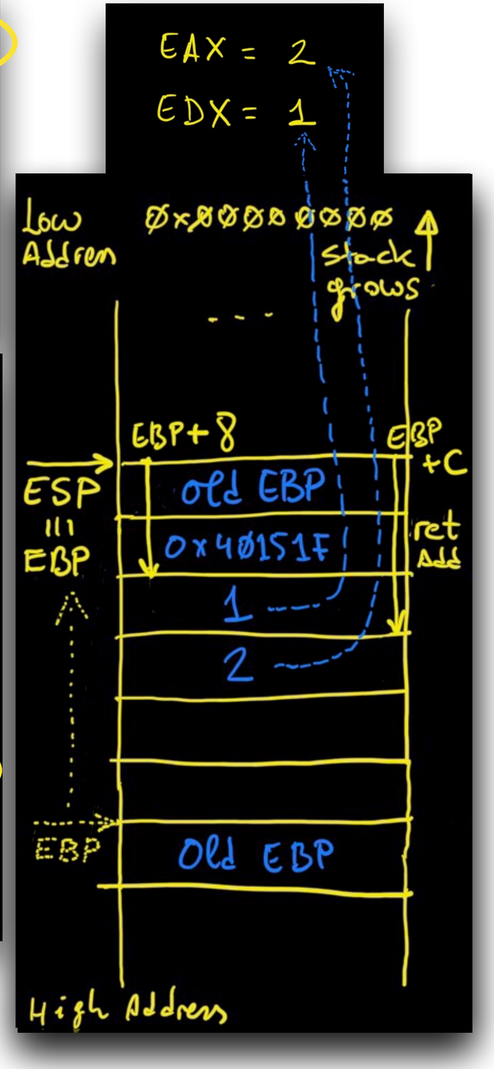

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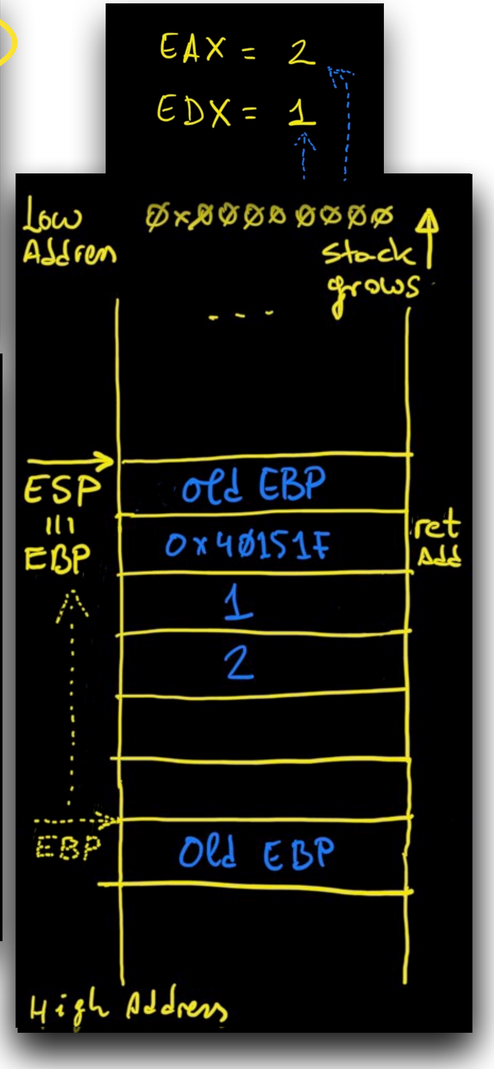

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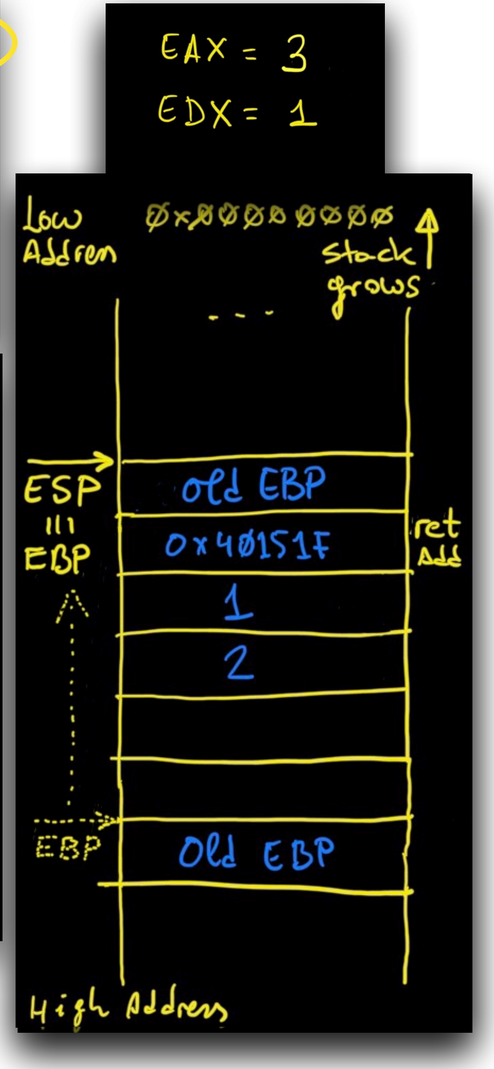

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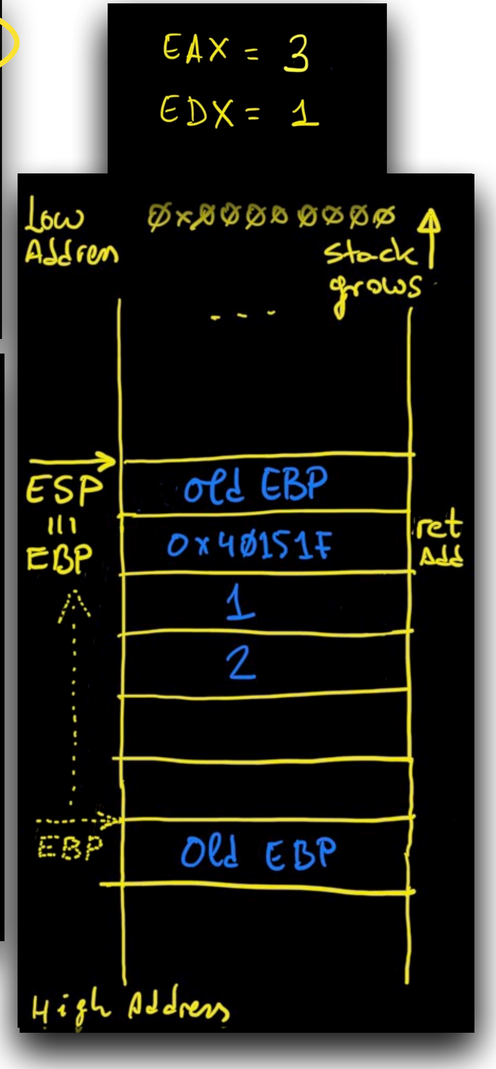

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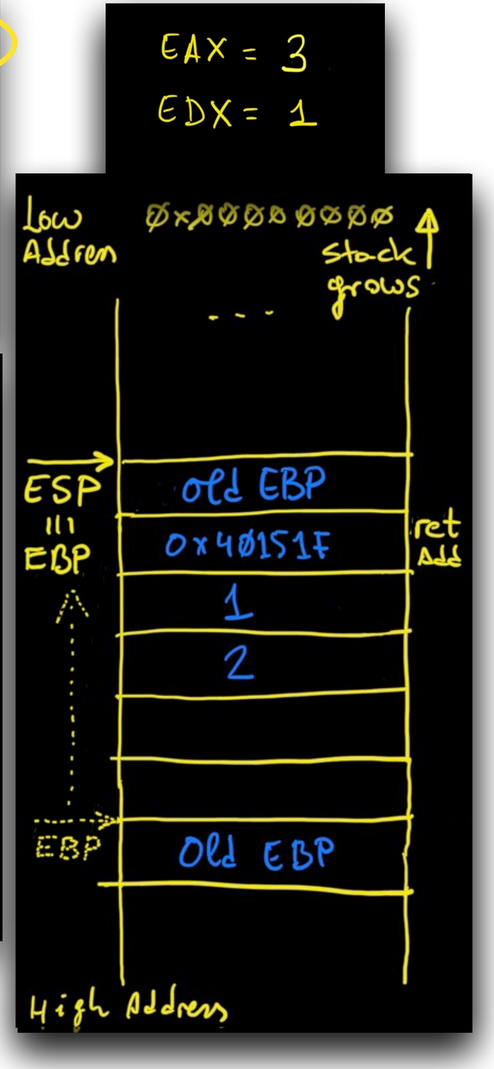
│           0x004014f9      01d0            add eax, edx
│           0x004014fb      5d              pop ebp
└           0x004014fc      c3              ret
```

2 args

No local vars, registers will do the task



Recognising C code in assembly

- cdlec calling conventio

```c
int sum(int a,int b){
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int main(){
    return sum(1,2);
}
```

```
[0x004014f0]> s sym._sum
[0x004014f0]> pdf
┌ (fcn) sym._sum 13
│   sym._sum (int32_t arg_8h, int32_t arg_ch);
│           ; arg int32_t arg_8h @ ebp+0x8
│           ; arg int32_t arg_ch @ ebp+0xc
│           ; CALL XREF from main @ 0x40151a
│           0x004014f0      55              push ebp
│           0x004014f1      89e5            mov ebp, esp
│           0x004014f3      8b5508          mov edx, dword [arg_8h]
│           0x004014f6      8b450c          mov eax, dword [arg_ch]
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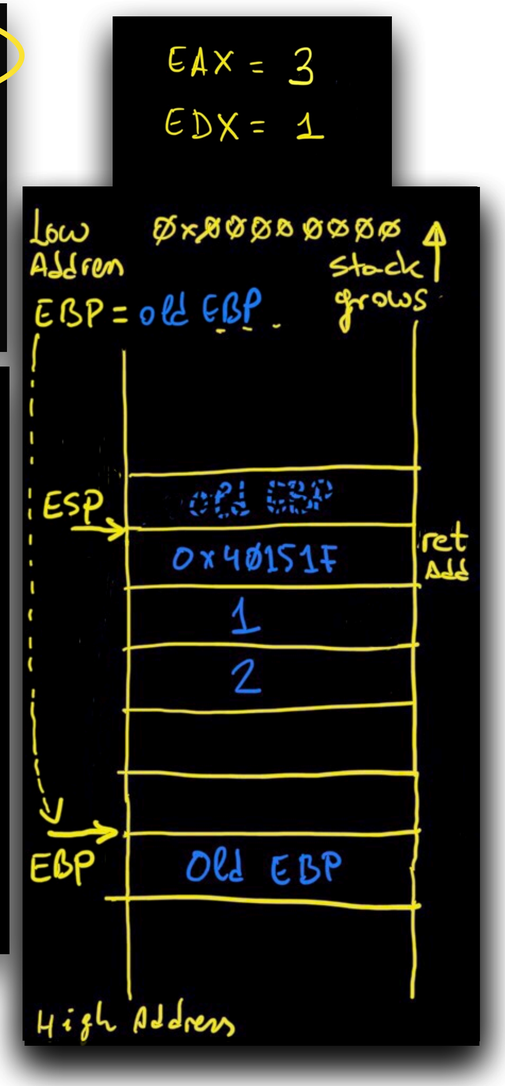

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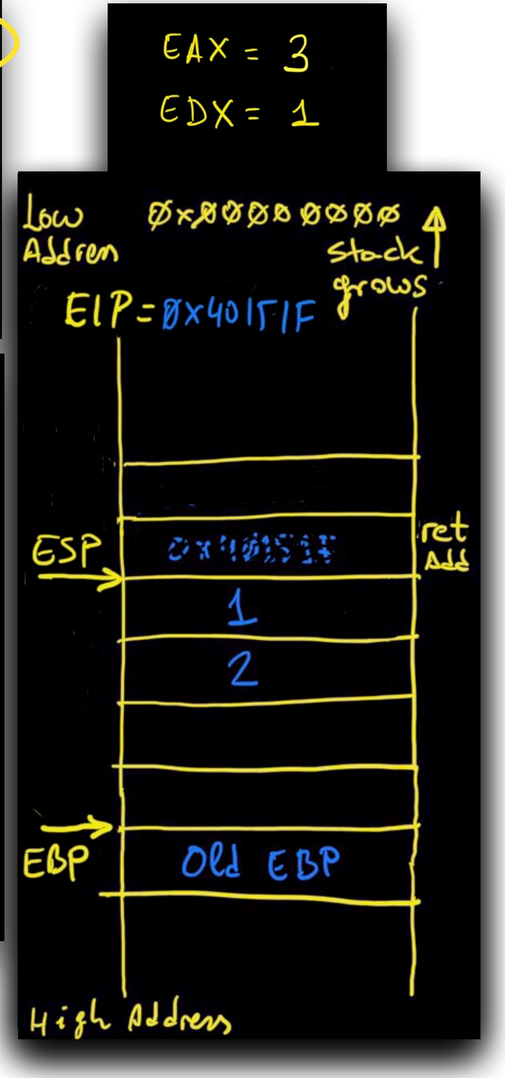

Recognising C code in assembly

- cdlec calling convention

Recognising C code in assembly

- cdlec calling conventio

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Recognising C code in assembly

- cdlec calling conventio

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function epilogue

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function epilogue

mov esp, ebp

pop ebp

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1  int sum(int a,int b){
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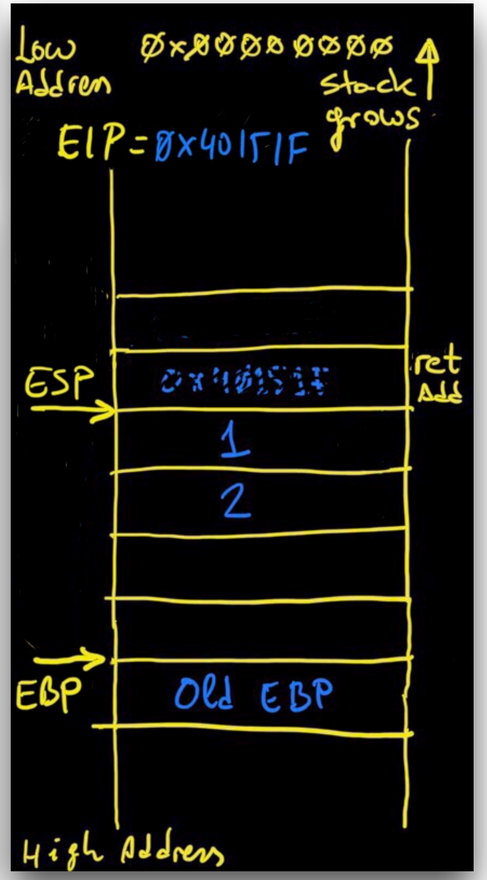

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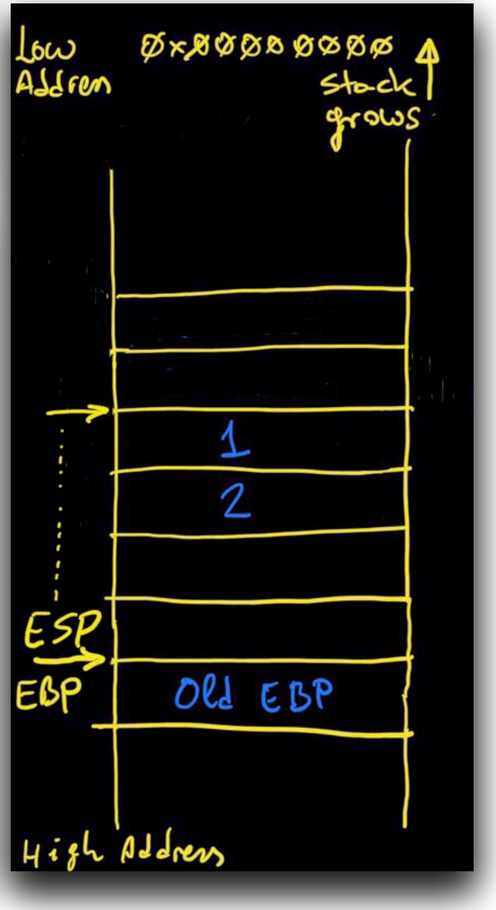

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mov esp, ebp

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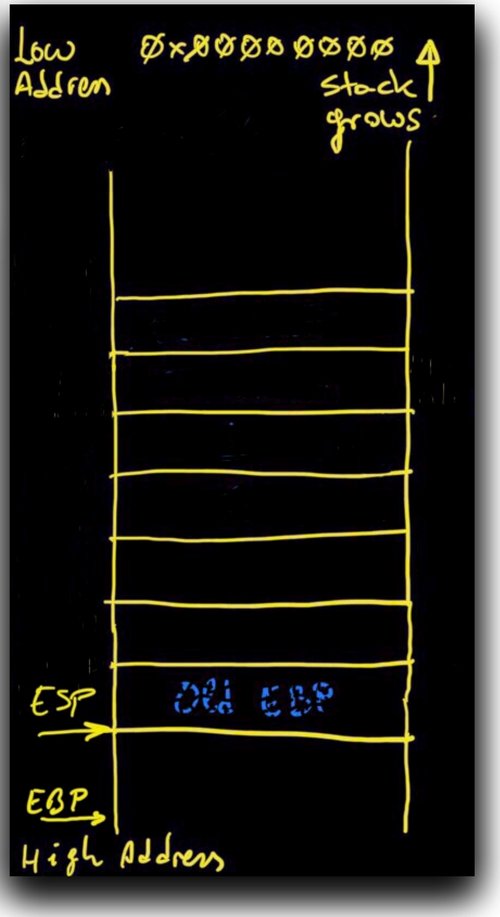


```
apasamar@INCIDE:arch$ i686-w64-mingw32-gcc c_code.c
apasamar@INCIDE:arch$ r2 -qc 'aaa;s main;pd 15' a.exe
            ; CALL XREF from entry0 @ 0x401381
            ;-- _main:
┌ 45: int main (int argc, char **argv, char **envp);
│           0x00401530      55              push ebp
│           0x00401531      89e5            mov ebp, esp
│           0x00401533      83e4f0          and esp, 0xfffffff0
│           0x00401536      83ec10          sub esp, 0x10
│           0x00401539      e8c2000000      call sym.___main
│           0x0040153e      c70424004040.   mov dword [esp], st
│
│           0x00401545      e872100000      call sym._puts
│           0x0040154a      c70424203040.   mov dword [esp], st
│           0x00401551      e866100000      call sym._puts
│           0x00401556      b800000000      mov eax, 0
│           0x0040155b      c9              leave
└           0x0040155c      c3              ret
            0x0040155d      90              nop
            0x0040155e      90              nop
            0x0040155f      90              nop
```

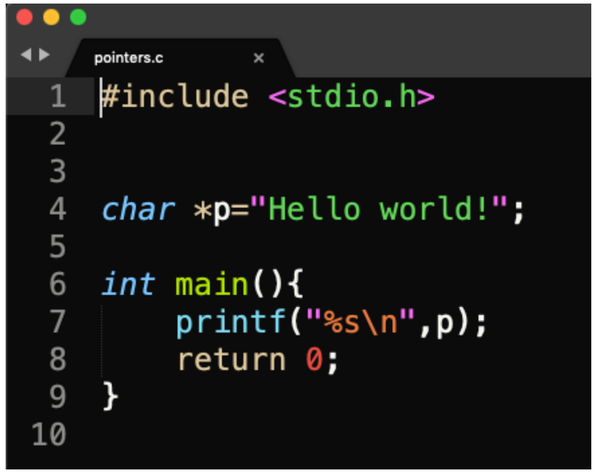
Disassembly of PE binaries

Disassembly of PE binaries

- Best way to do it is to code your own small programs and disassemble it
- To generate x86/64 w32 binaries in a Linux or OSX machine you can use cross compiling.
  - `mingw`
  - `wine`

PE in other OS?

C code



PE in other OS?

C code

pointers.c

```c
#include <stdio.h>


char *p="Hello world!";

int main(){
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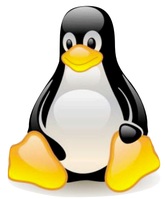

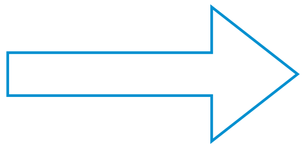

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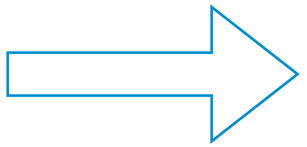

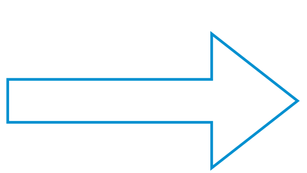

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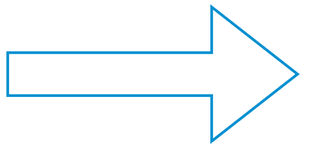

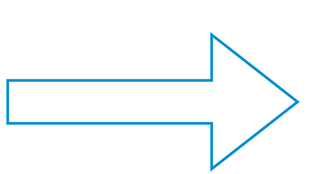

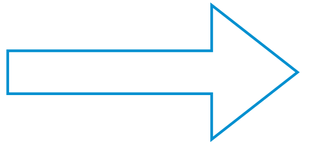

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Can I execute a PE File in MAC OS?

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Wine & Mingw32 Gcc

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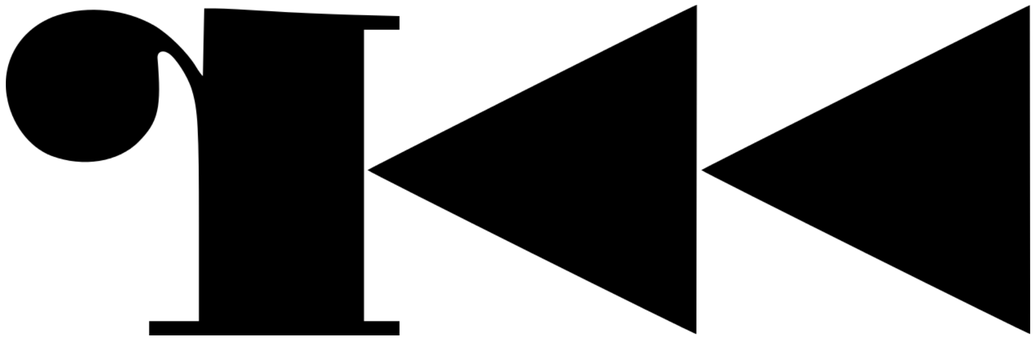
Also valid for Linux & Windows

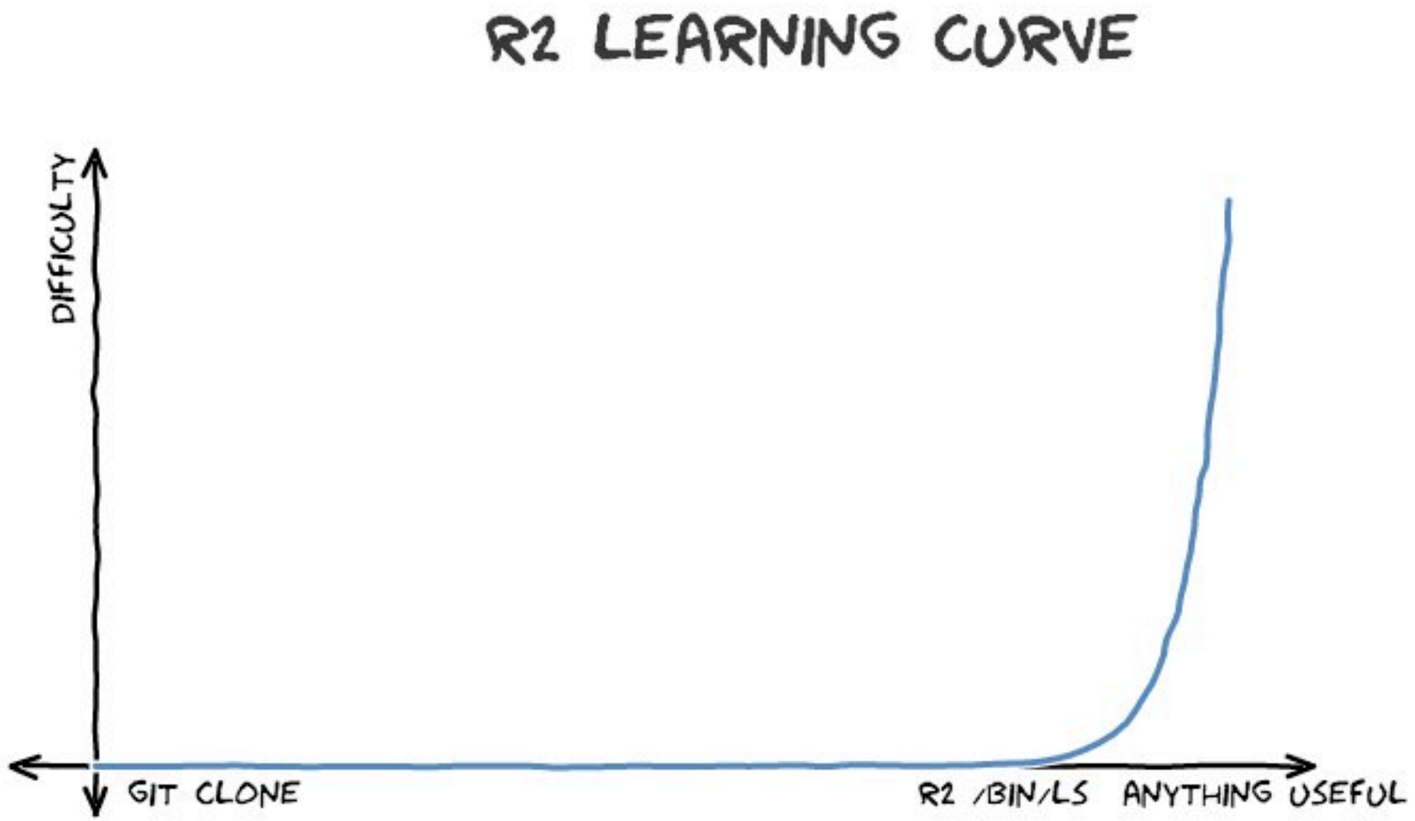
Disassembly of PE binaries

- How to dissambly PE binaries?
  - With a Disassembler !
    - objdump, IDA PRO, OllyDbg, Immunity Debugger, hopper, r2 (radare2)

Introduction to radare2



Introduction to radare2



What is radare2?

- Free Open Source reversing framework
- radare -> radare2 [r2] (rewriten in C), pancake @trufae
- Build from scratch. No third-party dependency
- Portable, scriptable, extendable and via plugins
- Release every six weeks
- Great community Telegram #radare , IRC
- r2con: annual conference in Barcelona (early Sept)

What can r2 do?

- Disassemble binaries (several archs and OS)
- Analyse code, data, refs, structures
- Debugging, tracing, exploiting
- Binary manipulation, code injection, patching, diffing
- Forensics: mount fs, detect partitions, data carving
- Extract information and metrics for binary classification
- Kernel analysis and debugging

has r2 support for …?

- **Operating Systems**
  - Windows (since XP), GNU/Linux, OS X, [Net|Free|Open]BSD, Android, iOS, OSX, QNX, Solaris, Haiku, Firefox OS.
- **Architectures**
  - i386, x86-64, ARM, MIPS, PowerPC, SPARC, RISC-V, SH, m68k, m680x, AVR, XAP, System Z, XCore, CR16, HPPA, ARC, Blackfin, Z80, H8/300, V810, V850, CRIS, XAP, PIC, LM32, 8051, 6502, i4004, i8080, Propeller, Tricore, CHIP-8, LH5801, T8200, GameBoy, SNES, SPC700, MSP430, Xtensa, NIOS II, Java, Dalvik, WebAssembly, MSIL, EBC, TMS320 (c54x, c55x, c55+, c66), Hexagon, Brainfuck, Malbolge, whitespace, DCPU16, LANAI, MCORE, mcs96, RSP, SuperH-4, VAX.
- **File Formats**
  - ELF, Mach-O, Fatmach-O, PE, PE+, MZ, COFF, OMF, TE, XBE, BIOS/UEFI, Dyldcache, DEX, ART, CGC, Java class, Android boot image, Plan9 executable, ZIMG, MBN/SBL bootloader, ELF coredump, MDMP (Windows minidump), WASM (WebAssembly binary), Commodore VICE emulator, QNX, Game Boy (Advance), Nintendo DS ROMs and Nintendo 3DS FIRMs, various filesystems.

r2 -> TL;DR

- RUNS everywhere
- SUPPORTS everything

Some r2 references

- Official radare2 book. https://radare.gitbooks.io/radare2book/
- Introducing radare2 for humans, Arnau Gàmez. https://www.youtube.com/watch?v=ARH1S8ygDnk
- #HITB2019AMS D1T3 - Overcoming Fear: Reversing With Radare2 - Arnau Gàmez. https://www.youtube.com/watch?v=317dNavABKo
- Quick tutorial radare2 and first crackme [ENG], Daniel Sc4. https://www.youtube.com/watch?v=avASgrsJ23M
- Radare2 - An Introduction with a simple CrackMe, Anto Joseph. https://www.youtube.com/watch?v=8dXhrOEGHTY

Why I use r2?

- IDA Pro licence is expensive, not for everyone
- I love *terminal/shell/CLI*
- I like text input/output control
- I like to script
- r2pipe is great for scripting
- It's a great open source project
- It's written in *pure* **C**
- Barcelona r2con rocks !

How do I install r2?

- Go to the repo and clone it using git
  - $ git clone https://github.com/radareorg/radare2.git
- Go to r2 created directory
  - $ cd radare2
- And install or update it
    - $ sys/install.sh #pull last version from git

```
[Imports]
nth vaddr      bind type lib          name
-----------------------------------------
1   0x004201f4 NONE FUNC KERNEL32.dll AddAtomA
2   0x004201f8 NONE FUNC KERNEL32.dll CloseHandle
3   0x004201fc NONE FUNC KERNEL32.dll CreateEventA
4   0x00420200 NONE FUNC KERNEL32.dll CreateMutexA
5   0x00420204 NONE FUNC KERNEL32.dll CreateSemaphoreA
6   0x00420208 NONE FUNC KERNEL32.dll DeleteCriticalSection
7   0x0042020c NONE FUNC KERNEL32.dll DuplicateHandle
8   0x00420210 NONE FUNC KERNEL32.dll EnterCriticalSection
9   0x00420214 NONE FUNC KERNEL32.dll ExitProcess
10  0x00420218 NONE FUNC KERNEL32.dll FindAtomA
11  0x0042021c NONE FUNC KERNEL32.dll GetAtomNameA
12  0x00420220 NONE FUNC KERNEL32.dll GetCommandLineA
13  0x00420224 NONE FUNC KERNEL32.dll GetCurrentProcess
14  0x00420228 NONE FUNC KERNEL32.dll GetCurrentThread
15  0x0042022c NONE FUNC KERNEL32.dll GetCurrentThreadId
16  0x00420230 NONE FUNC KERNEL32.dll GetHandleInformation
17  0x00420234 NONE FUNC KERNEL32.dll GetLastError
18  0x00420238 NONE FUNC KERNEL32.dll GetModuleFileNameA
19  0x0042023c NONE FUNC KERNEL32.dll GetModuleHandleA
20  0x00420240 NONE FUNC KERNEL32.dll GetProcAddress
21  0x00420244 NONE FUNC KERNEL32.dll GetProcessAffinityMask
```

Windows API

Windows API

- The **Windows API**, informally **WinAPI**, is Microsoft's core set of application programming interfaces (APIs) available in the Microsoft Windows operating systems.

Windows API

- **important windows functions commonly used by malware … some examples**
  - connect
  - CreateFile
  - CreateProcess
  - CreateRemoteThread
  - gethostname
  - gethostbyname
  - GetKeyState
  - GetProccAddress

Windows API

- **important windows functions commonly used by malware … some examples**

- connect
- CreateFile
- CreateProcess
- CreateRemoteThread
- gethostname
- gethostbyname
- GetKeyState
- GetProccAddress

These (and others) API functions are not BAD, they are simply commonly used by Malware

Malware Protection Methods

Malware protection methods

- **We need to pay attention and identify different kind of malware behaviours and typical malware protection methods/techniques …**

Malware protection methods

- **malware behaviour**
  - downloaders
  - launchers
  - backdoors
  - stealers
  - keyloggers

Malware protection methods

- **persistence mechanisms**
  - windows registry
  - Trojanized system binaries
  - dll load-order hijacking

Malware protection methods

- **data encoding**
  - simple ciphers
    - Ceasar cipher, XOR, ROT, …
  - common cryptographic algorithms
    - AES, RC4, …
  - encoders
    - Base64, custom, …

DEMOS

r2 intro

DEMO

```
apasamar@INCIDE:r2-intro$ r2 hello_world/hello_world.exe
[0x004014c0]> iq
arch x86
bits 32
os windows
endian little
minopsz 1
maxopsz 16
pcalign 0
```

Compiling and linking

DEMO

```
apasamar@INCIDE:hello_world$ cat hello_world.c
#include <stdio.h>

int main(){
        printf("Hello World\n");
        return 0;
}
apasamar@INCIDE:hello_world$ i686-w64-mingw32-gcc hello_world.c
apasamar@INCIDE:hello_world$ ls
a.exe           hello_world.c
apasamar@INCIDE:hello_world$
```

Assembly Language

DEMO

```
apasamar@INCIDE:hello_world$ i686-w64-mingw32-gcc --save-temps -masm=intel hello_world.c
apasamar@INCIDE:hello_world$ tail -10  hello_world.s
        and     esp, -16
        sub     esp, 16
        call    ___main
        mov     DWORD PTR [esp], OFFSET FLAT:LC0
        call    _puts
        mov     eax, 0
        leave
        ret
        .ident  "GCC: (GNU) 9.2.0"
        .def    _puts;  .scl    2;      .type   32;     .endef
apasamar@INCIDE:hello_world$
```

crackmes

DEMO

```
apasamar@INCIDE:crackmes$ cd IOLI-crackmes-pof/IOLI-crackme/bin-win32/
apasamar@INCIDE:bin-win32$ ls
crackme0x00.exe crackme0x02.exe crackme0x04.exe crackme0x06.exe crackme0x08.exe
crackme0x01.exe crackme0x03.exe crackme0x05.exe crackme0x07.exe crackme0x09.exe
apasamar@INCIDE:bin-win32$ r2 crackme0x00.exe
[0x00401260]> iq
arch x86
bits 32
os windows
endian little
minopsz 1
maxopsz 16
pcalign 0
```

http://pof.eslack.org/tmp/IOLI-crackme.tar.gz

malware

DEMO

```
apasamar@INCIDE:malware$ r2 maldev.bin
[0x004012d0]> aaa
[x] Analyze all flags starting with sym. and entry0 (aa)
[x] Analyze function calls (aac)
[x] Analyze len bytes of instructions for references (aar)
[x] Check for objc references
[x] Check for vtables
[x] Type matching analysis for all functions (aaft)
[x] Propagate noreturn information
[x] Use -AA or aaaa to perform additional experimental analysis.
[0x004012d0]> iz|head -n 10
[Strings]
nth paddr      vaddr      len size section type    string
―――――――――――――――――――――――――――――――――――――――――――――――――――――――――
0   0x000a0c00 0x004a2000 18  19   .rdata  ascii   libgcc_s_dw2-1.dll
1   0x000a0c13 0x004a2013 21  22   .rdata  ascii   __register_frame_info
2   0x000a0c29 0x004a2029 23  24   .rdata  ascii   __deregister_frame_info
3   0x000a0c48 0x004a2048 62  63   .rdata  ascii   =============================================================\n
4   0x000a0c88 0x004a2088 31  32   .rdata  ascii   [*] FOR RESEARCH PURPOSES ONLY\n
5   0x000a0ca8 0x004a20a8 46  47   .rdata  ascii   [*] SEE YOUTUBE CHANNEL FOR MORE INFORMATION:\n
6   0x000a0cd8 0x004a20d8 61  62   .rdata  ascii   [*] https://www.youtube.com/channel/UCo8vV94aQsuvPrkymFcl1Yg\n
[0x004012d0]>
```

https://github.com/stryker2k2/ghidra-reverse-maldev

Ghidra decompiler

- To write a decompiler is a very difficult task, but **NSA** did it quite well :)
- **Ghidra** is a free and open source reverse engineering tool developed by the National Security Agency (NSA).
  - https://www.nsa.gov/resources/everyone/ghidra/
- The **binaries were released at RSA Conference in March 2019**; the **sources were published one month later on GitHub.**
- and …

Ghidra in r2

- …the Ghidra decompiler is integrated into the radare2 project ;)
  - https://github.com/radareorg/r2ghidra-dec

Install the plugin

```
$ r2pm init
$ r2pm update
$ r2pm install r2ghidra-dec
```

Use ‘pdg’ to decompile

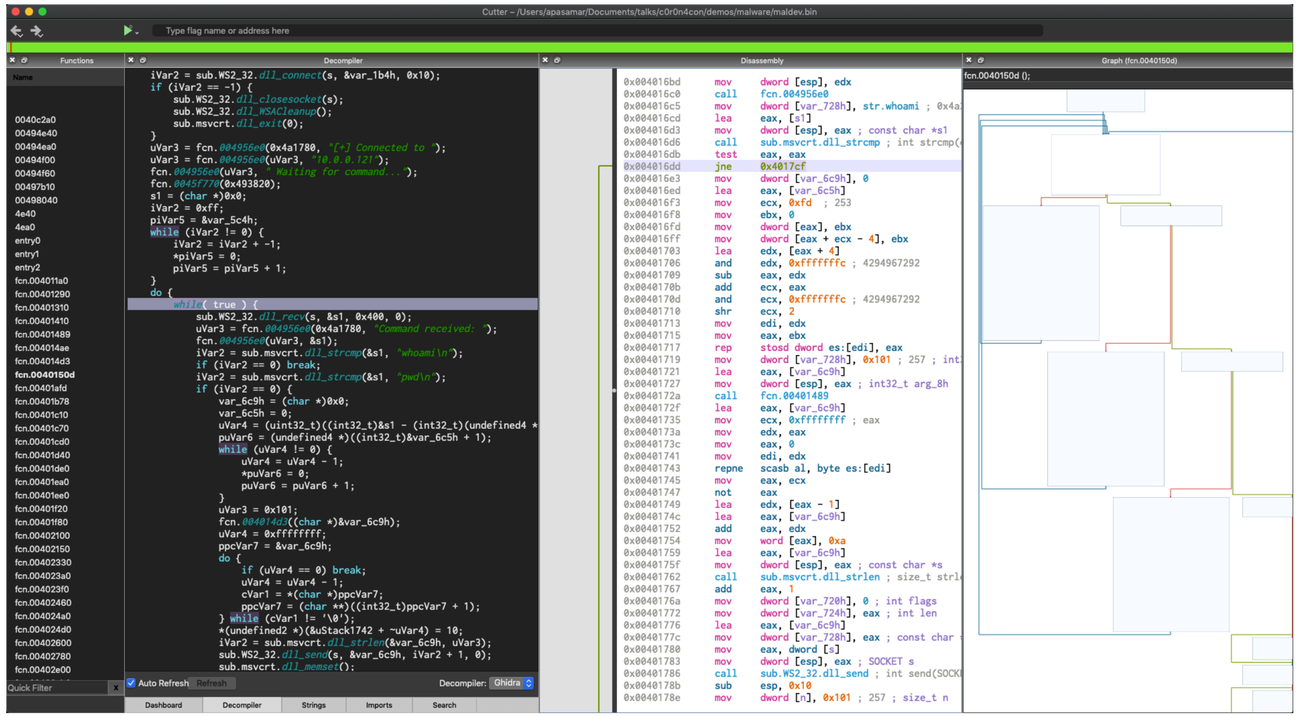
```
$ r2 /bin/ls
$ aaa
$ pdg
```

Maldev.exe decompiled with r2 ghidra-dec plugin

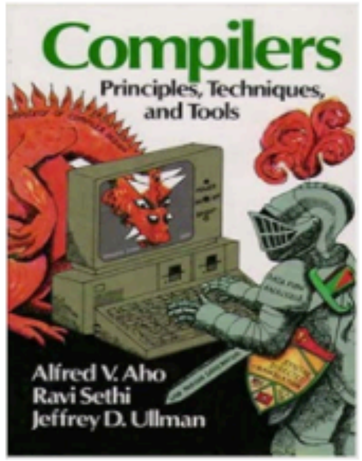
```
do {
    while( true ) {
        sub.WS2_32.dll_recv(s, &s1, 0x400, 0);
        uVar3 = fcn.004956e0(0x4a1780, "Command received: ");
        fcn.004956e0(uVar3, &s1);
        iVar2 = sub.msvcrt.dll_strcmp(&s1, "whoami\n");
        if (iVar2 == 0) break;
        iVar2 = sub.msvcrt.dll_strcmp(&s1, "pwd\n");
        if (iVar2 == 0) {
            var_6c9h = (char *)0x0;
            var_6c5h = 0;
            uVar4 = (uint32_t)((int32_t)&s1 - (int32_t)(undefined4 *)((int32_t)&var_6c5h + 1)) >> 2;
            puVar6 = (undefined4 *)((int32_t)&var_6c5h + 1);
            while (uVar4 != 0) {
                uVar4 = uVar4 - 1;
                *puVar6 = 0;
                puVar6 = puVar6 + 1;
            }
```

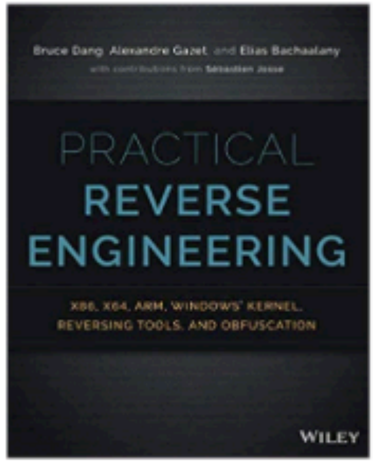
One more thing

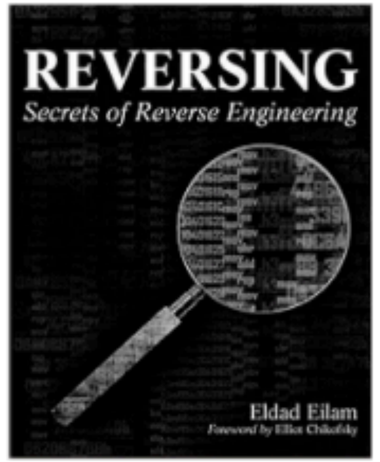
- Take a look a Cutter: free and open-source reverse engineering framework powered by **radare2**
  - https://github.com/radareorg/cutter

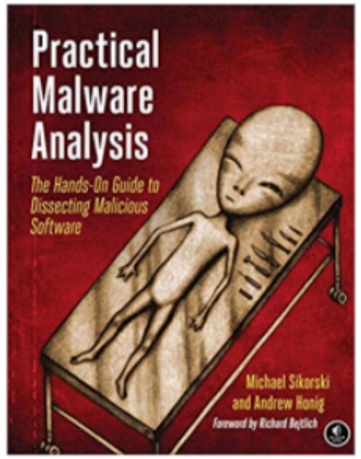


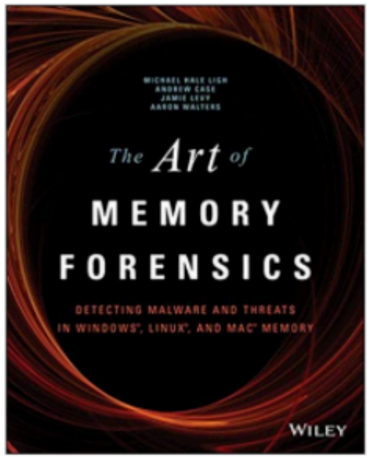
Bibliography

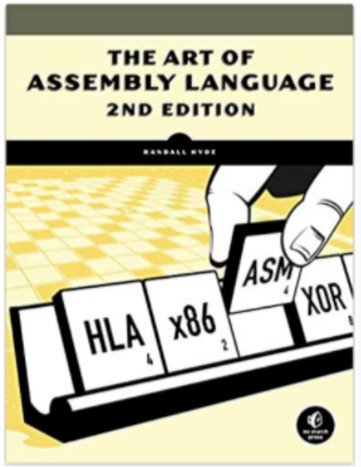


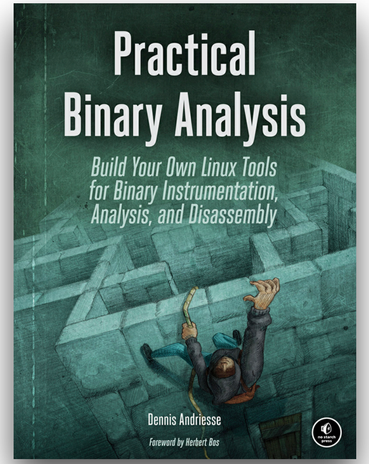












This talk is available for download?

Download it from my GitHub account:

https://github.com/apasamar/c0r0n4con_talk

and remember …

relax and enjoy the journey

The End

@apasamar
c0r0n4con
incide.es