Lec 19: Obfuscation

CS492E: Introduction to Software Security

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Motivation

Can we make it difficult to reverse engineer binaries?

Obfuscation

The deliberate act of creating source or machine code that is difficult for humans to understand.

- Wikipedia

Why Obfuscate Binary Code?

- Digital Rights Management (DRM) or Copy Protection
  - Example: you have a secret algorithm in your software product, and you don't want to reveal it
- What about malicious uses?

Ultimate Copy Protection?

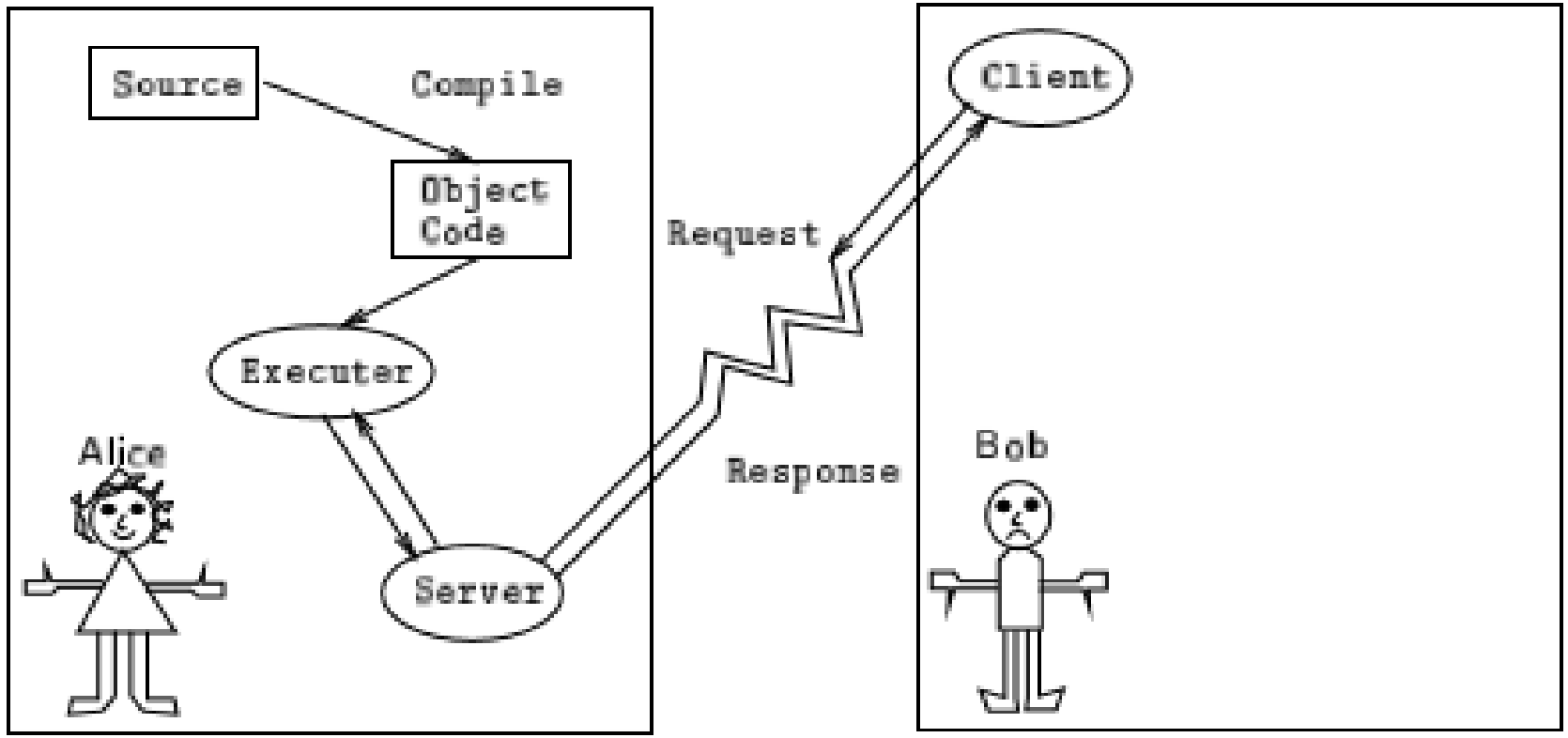


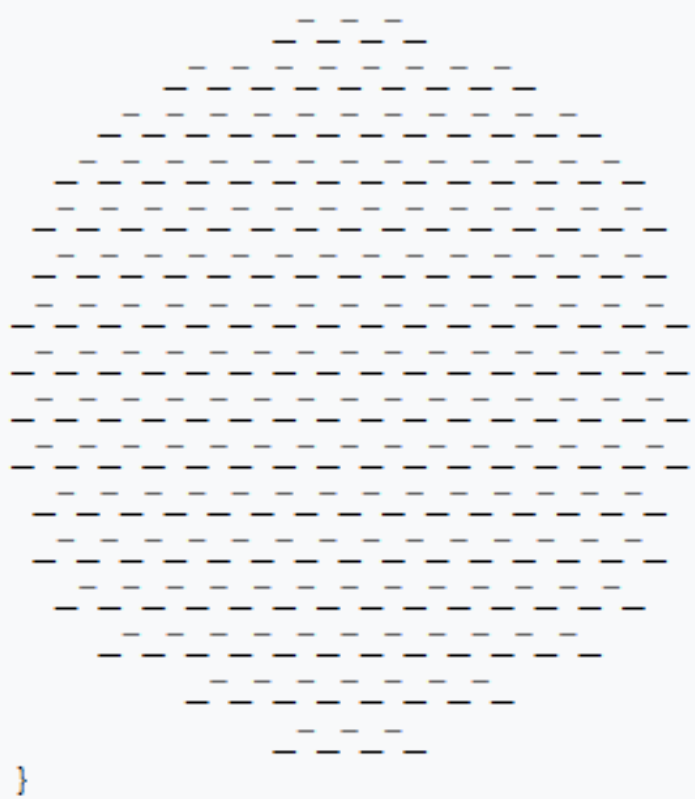
Figure from “A Taxonomy of Obfuscating Transformations”, Tech Report, University of Auckland, 1997

Why Not Obfuscate All the Time?

- Performance overhead
- Hard to debug / maintain

Traditional Obfuscation (Source Level)

```
#define _ -F<00||--F-OO--;
int F=00,OO=00;main(){F_OO();printf("%1.3f\n",4.*-F/OO/OO);}F_OO()
{
```



```
}
```


Image take from https://en.wikipedia.org/wiki/International_Obfuscated_C_Code_Contest

Traditional Obfuscation (Source Level)

```
#include   /*recall-the#    /-good--old-#    /IOCCC-days!#    */<unistd.h>
 typedef  unsigned/*int*/  short U;U(main)  [32768],n,r[8];  __attribute__((
# define  R(x)       A(r[  7-(n       >>x&  7)],       (n>>  x>>3       )%8)
#define   C(x)       (U*)  ((/*             ||O|             -dpd
*/char*)  main       *(x)  )/*|             |CC|             ||*/
# define  A(v,       i)(i  ?i<2             ?C(v             ):i#
-4?v+=2,  C(i-       6?v-  2:v+       *C(v  -2))       :C(v  -=2)       :&v)
/*lian*/  constructor))U(  x)(){for(;;*r+=  2,*r+=!n?_exit(  write(2,"Illeg"
"al ins"   "truction ;-"    "(#n",24)),0:    n>>8==001?(      signed char
```

```
)n*2   :548==n>>    6&&usleep     /**/(10
)+n%  64==   4?0*  write  (r[7   /**/],C(
*C(*  r)),   *C(*  r+2)   )+4:  /**/ n>>9
==63   &&--r[7-n/   64%8]?n%+  /**/  64*-
2:0,         n>>6  ==47   ?*R( 0):n>>12==1?
*R(0  )=*R   (+6)  :n>>  12==+       14?*
R(0)   -=*R(2*3)    :0)n=*C(*        r);}
```

Binary Obfuscation

Fun Fact

Oftentimes, hand-written assembly code is already difficult to reverse ☺

Recursive vs. Linear-Sweep Disassembly

```
1  mov eax, [ebx]
2  call 100
3  .dword 0x42424242
4  mov edi, [eax]
5  test edi, edi
6  jne 1
7  pop eax
```

```
1  mov eax, [ebx]
2  call 104
3  inc edx
4  inc edx
5  inc edx
6  inc edx
7  mov edi, [eax]
8  test edi, edi
9  jne 1
10 pop eax
```

Disassembly Coverage?

(a) Correctly disassembled instructions.

Why Linear Sweep Works Well?

Self-Repairing Disassembly

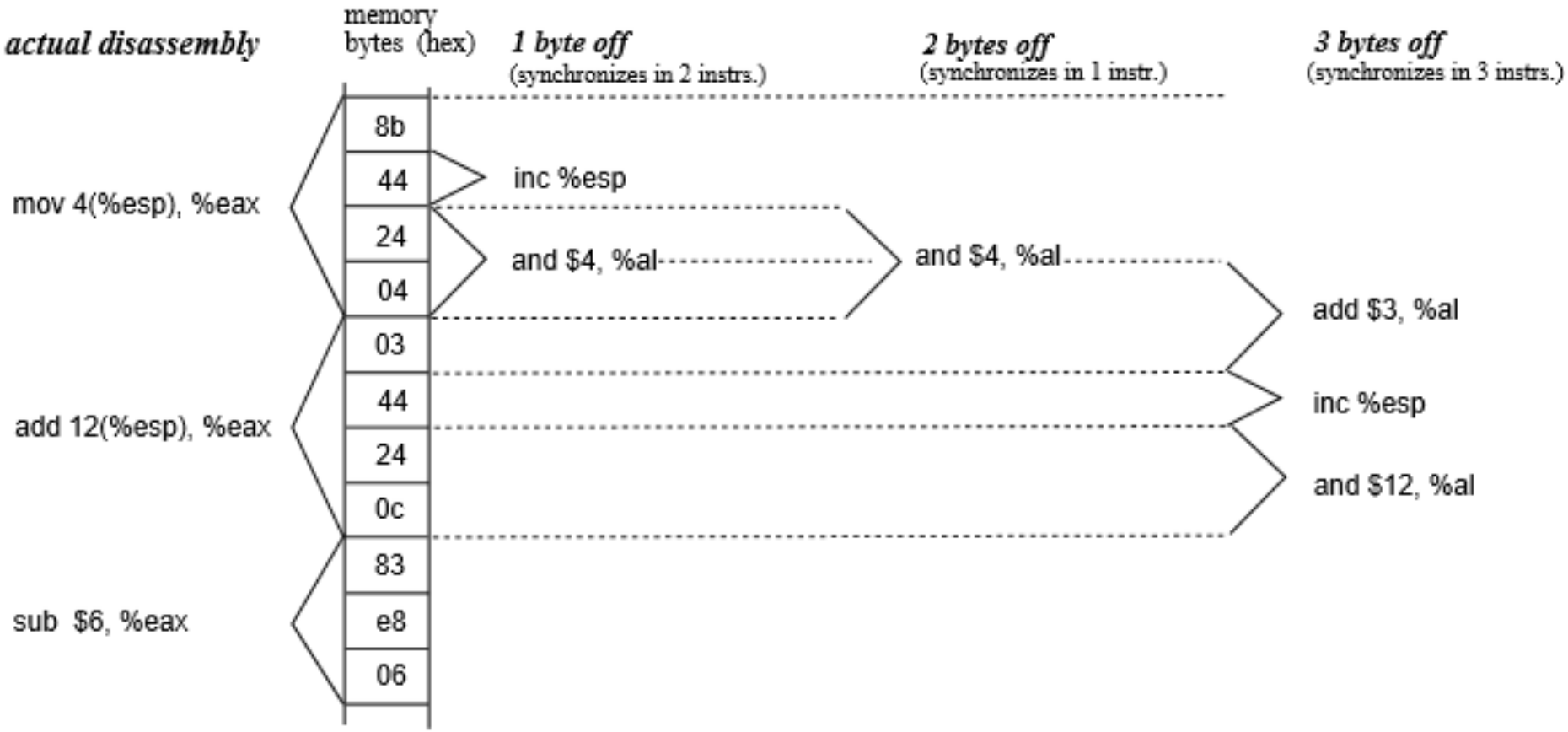


Image taken from “Obfuscation of Executable Code to Improve Resistance to Static Disassembly”, CCS 2003

Example

```
_start:
push ebx
xor ebx, ebx
je L0
.byte 0x11
L0:
pop ebx
ret
```

Example: Linear Sweep

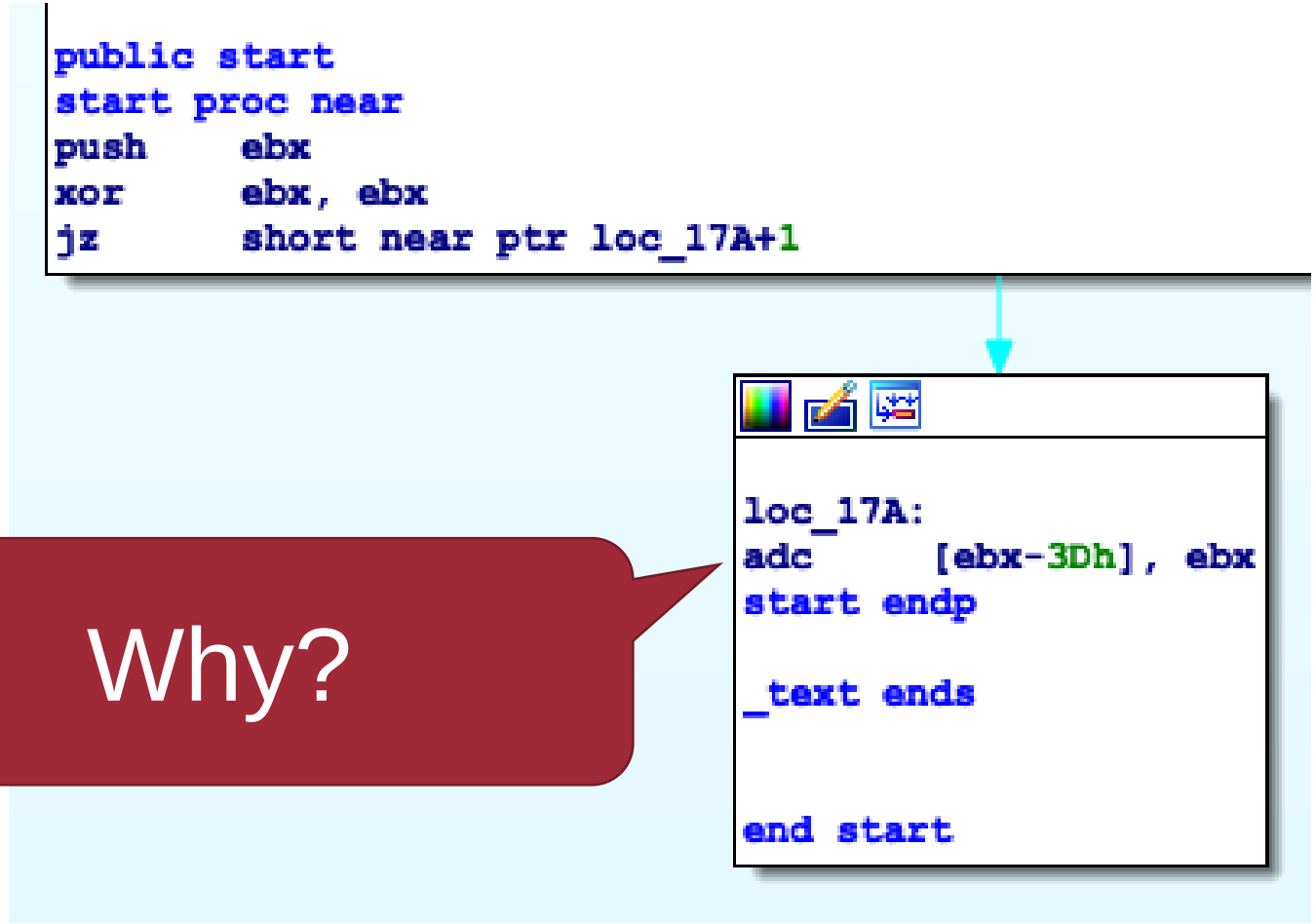
```
_start:
push ebx
xor ebx, ebx
je L0
.byte 0x11
L0:
pop ebx
ret
```

 # Output from OBJDUMP

```
00000175 <.text>:
 175: 53          push   ebx
 176: 31 db       xor    ebx,ebx
 178: 74 01       je     0x17b
 17a: 11 5b c3    adc    DWORD PTR [ebx-0x3d],ebx
```

Example: Recursive Descent

```
_start:
push ebx
xor ebx, ebx
je L0
.byte 0x11
L0:
pop ebx
ret
```



Disassembler Assumption

A sequence of bytes can only be represented in a single way

Obfuscation (1): Opaque Predicate

A variable in a program is ***opaque*** when it always has a fixed value, which is known a priori to the obfuscator, but is difficult to users (or deobfuscators) to deduce its value.

Opaque Predicates

```
int a = 5, b = 6;
int x = a + b;
if (b > 5) { ... /* dummy code */ }
if (rand() % 5 < a) { ... /* dummy code */ }
...
```

Collatz Conjecture (in 1937)

$$f(n) = \begin{cases} n/2 & \text{if } n \equiv 0 \pmod 2 \\ 3n+1 & \text{if } n \equiv 1 \pmod 2. \end{cases}$$

If we apply this function iteratively, we will always see 1 regardless of which positive integer is chosen initially.

Until now, we haven't found any counter example, but we also don't have any proof so far.

```
if ( collatz(i) == 1 ) { … }
```

Jump Table Spoofing

- Generalization of opaque predicates

- Convert a jump into an indirect jump through a jump table, where the index of the table is computed by an opaque expression that always evaluates to a single value

Obfuscation (2): Extended Loop

```
i = 1;
while (i < 100) {
  ...
  i++;
}
```

```
i = 1; j = 100;
while (i < 100
  && (j*j*(j+1)*(j+1) % 4 == 0)) {
  ...
  i++;
  j = j*i+3;
}
```

Obfuscation (3): Function Boundary Confusion

- `call` / `ret` instructions can be used for RIP-relative computations

- Difficult to decide whether a code block followed by `call` instruction is indeed a function entry or not

Knowing function boundaries is important for intra-procedural analyses or decompilation

Example Function

```
_start:
push ebx
xor ebx, ebx
call L0
L0:
pop ebx
add ebx, 0x6
push ebx
ret
pop ebx
ret
```

 # Output from OBJDUMP

```
00000175 <.text>:
 175: 53                push ebx
 176: 31 db             xor  ebx,ebx
 178: e8 00 00 00 00    call 0x17d
 17d: 5b                pop  ebx
 17e: 83 c3 06          add  ebx,0x6
 181: 53                push ebx
 182: c3                ret
 183: 5b                pop  ebx
 184: c3                ret
```

Confused Function Boundary

```
_start:
push ebx
xor ebx, ebx
call L0
L0:
pop ebx
add ebx, 0x6
push ebx
ret
pop ebx
ret
```

```
public start
start proc near
push    ebx
xor     ebx, ebx
call    $+5
pop     ebx
add     ebx, 6
push    ebx
retn
start endp ; sp-analysis failed
```

Conclusion

- Obfuscation is a way to protect software from reverse engineering.

- Finding a general way to de-obfuscate binaries is on-going research.

Questions?