Obfuscation Techniques

REVERSE ENGINEERING

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Obfuscation Techniques

- Aims at hardening the process of reverse engineering
  - Increases level of experience required
  - Increases cost (time, money)
  - Imposes the need for specific tools, techniques and procedures

- Applications (some):
  - **License protected software**: to prevent the generation of arbitrary licenses or subversion of the program code
  - **Proprietary software**: prevent the recovery of a design pattern or algorithm (IP protection)
  - **Malware**: to prevent recovery of the actions, prevent detection, Social Engineer users

Obfuscation Techniques

Static vs Dynamic

- Static obfuscation frequently transforms code before execution
  - Maybe before compilation, or during compilation
  - Countering static analysis
  - An obfuscated program is complex to analyze
- Dynamic obfuscation transforms code during execution
  - Countering Dynamic Analysis
  - The obfuscated program may change its behavior, expand or include further code

Obfuscation Techniques

Main Categories (Balachandran, TIFS 2013)

- Layout Obfuscation
- Design Obfuscation
- Data Obfuscation
- Control Obfuscation

- Also: Content Type Obfuscation

Content Type Obfuscation

- Dissimulate one file type as another file type or as raw data
  - Exploring how the file is processed
  - Exploring how users interact with it
  - Exploring how researchers and automatic tools process a file

- Purposes (some):
  - Marketing, branding and usability
  - Exploit users through social engineering
  - Increase the cost required for a reverse engineering task
  - Carry a malicious payload while escaping manual analysis
  - Carry a malicious payload bypassing automatic filtering

Content Type Obfuscation

Marketing, Branding and Usability

- Aims to make a filetype more usable, or to make the brand present to the user
  - Benning and common usage

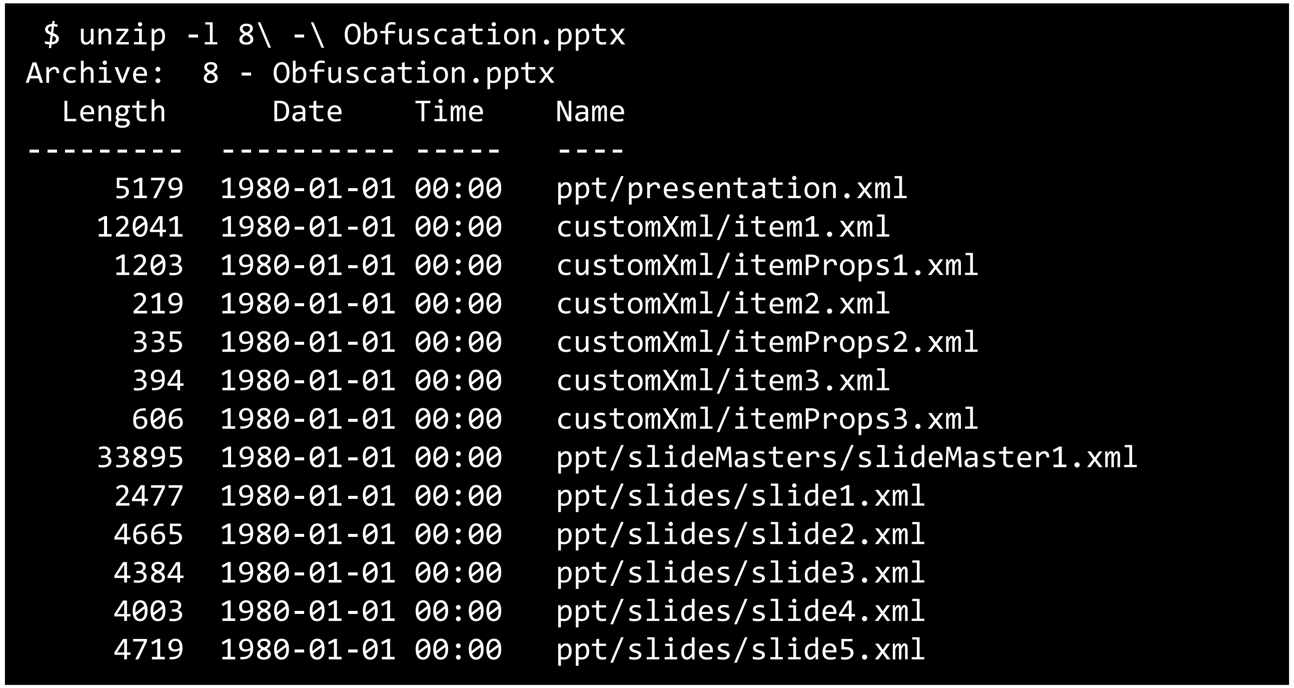
- **Approach**: file has one specific type, but uses another file extension
  - Environment has a configuration stating how to handle such file extension
  - Explores the fact that an Environment uses fixed string to know how to open file

- **Impact**: File explorers will present a content based on the file extension, not based on the content

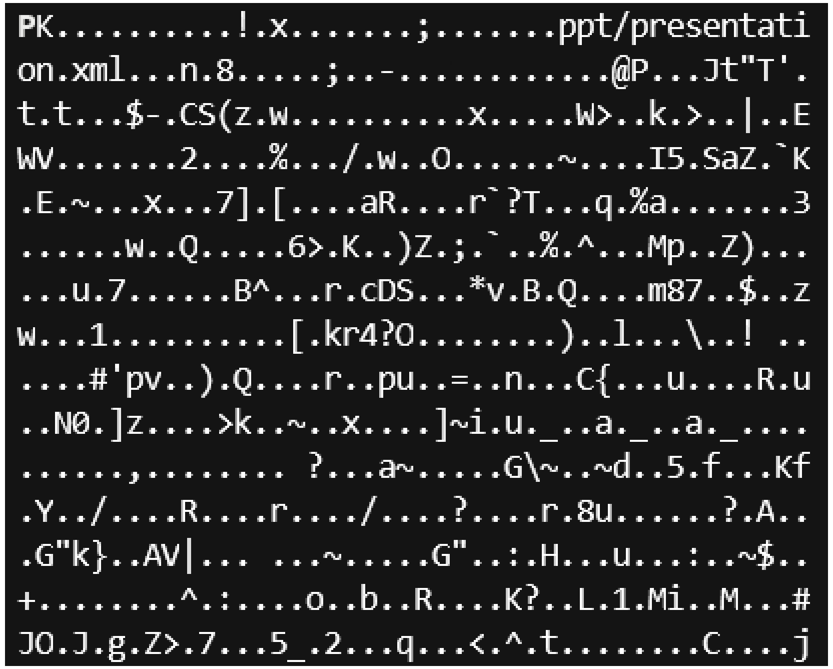
Content Type Obfuscation

Marketing, Branding and Usability

- For a PPTX file
  - File reports a zip file and magic is PK
  - DOCX and XLSX are similar



```
 $ unzip -l 8\ -\ Obfuscation.pptx
Archive:  8 - Obfuscation.pptx
  Length      Date    Time    Name
---------  ---------- -----   ----
     5179  1980-01-01 00:00   ppt/presentation.xml
    12041  1980-01-01 00:00   customXml/item1.xml
     1203  1980-01-01 00:00   customXml/itemProps1.xml
      219  1980-01-01 00:00   customXml/item2.xml
      335  1980-01-01 00:00   customXml/itemProps2.xml
      394  1980-01-01 00:00   customXml/item3.xml
      606  1980-01-01 00:00   customXml/itemProps3.xml
    33895  1980-01-01 00:00   ppt/slideMasters/slideMaster1.xml
     2477  1980-01-01 00:00   ppt/slides/slide1.xml
     4665  1980-01-01 00:00   ppt/slides/slide2.xml
     4384  1980-01-01 00:00   ppt/slides/slide3.xml
     4003  1980-01-01 00:00   ppt/slides/slide4.xml
     4719  1980-01-01 00:00   ppt/slides/slide5.xml
```



```
PK..........!.x.......;.......ppt/presentati
on.xml...n.8.....;..-............@P...Jt"T'.
t.t...$-.CS(z.w..........x.....W>..k.>..|..E
WV.......2....%.../.w..O......~....I5.SaZ.`K
.E.~...x...7].[....aR....r`?T...q.%a.......3
......w..Q.....6>.K..)Z.;.`..%.^...Mp..Z)...
...u.7......B^...r.cDS...*v.B.Q....m87..$..z
w...1..........[.kr4?O........)..l...\..! ..
....#'pv..).Q....r..pu..=..n...C{...u....R.u
..N0.]z....>k..~..x....]~i.u._..a._..a._....
......,........ ?...a~.....G\~..~d..5.f...Kf
.Y../....R....r..../....?....r.8u......?.A..
.G"k}..AV|... ...~.....G"..:.H...u...:..~$..
+........^.:....o..b..R....K?..L.1.Mi..M...#
JO.J.g.Z>.7...5_.2...q...<.^.t........C....j
```

Content Type Obfuscation

Explore users through social engineering

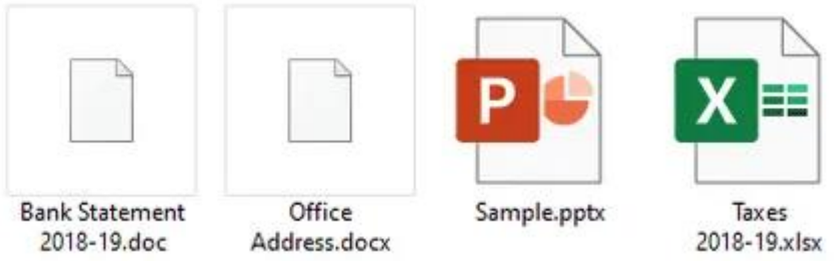
- Aims to confuse users about the purpose of a file
  - Malicious and common in phishing campaigns and malware

- Approach: file has a filename and presentation that confuses users
  - Mail client or explorer presents a safe file with known extension
  - But… icon is stored in the file metadata, and file has two extensions (file.txt.exe)

- Impact: User thinks that a file is not malicious (e.g, it's a word document), while in reality, it executes a malicious code

Content Type Obfuscation

Explore users through social engineering



- Windows hides extension of known file types
  - **`Sample.pptx`** becomes only **`Sample`**

- Executable files may have an embedded icon
  - Freely defined by the developer
  - Explorer will show that icon

- A file named **`Sample.pptx.exe`** will be shown as **`Sample.pptx`**
  - Users recognize the extension and may think the file is safe

- In a RE task, a file may have bogus extensions

Content Type Obfuscation

Increase the cost required for a reverse engineering task

- Aims to disguise/manipulate files so that a RE task skips the file, or processes the file incorrectly

- Approaches:
  - Hides content in file without extension, without headers or with modified headers
  - Mangles content to make it less human friendly
  - Polyglots

- Impact: Reversing or Forensics Analyst will not process the file, or will not process the file with the correct approach/tools
  - May prevent the researcher from recovering the original file

Content Type Obfuscation

Magic Headers

- Besides extensions, most files can be recognized by a magic value in the file start/end
  - Manipulating headers can lead to incorrect detection and maybe processing

- Some magic values:
  - Office Documents: `D0 CF 11 E0`
  - ELF: `7F E L F`
  - JPG: `FF D8`
  - PNG: `89 P N G 0D 0A 1A 0A`
  - Java class: `CA FE BA BE`

Content Type Obfuscation

Magic Headers

- Headers are important to maintain compatibility with third party software

- Headers may be irrelevant for custom software
  - Software has the filetype hard coded

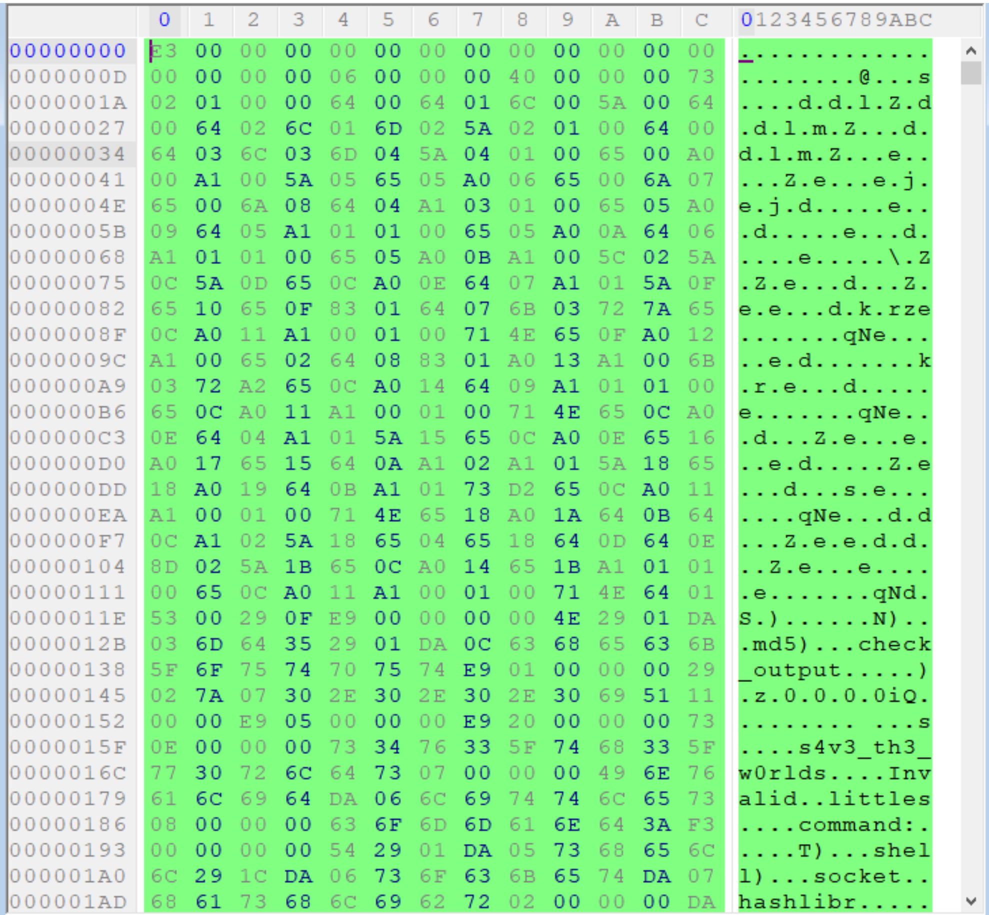
Content Type Obfuscation

Magic Headers

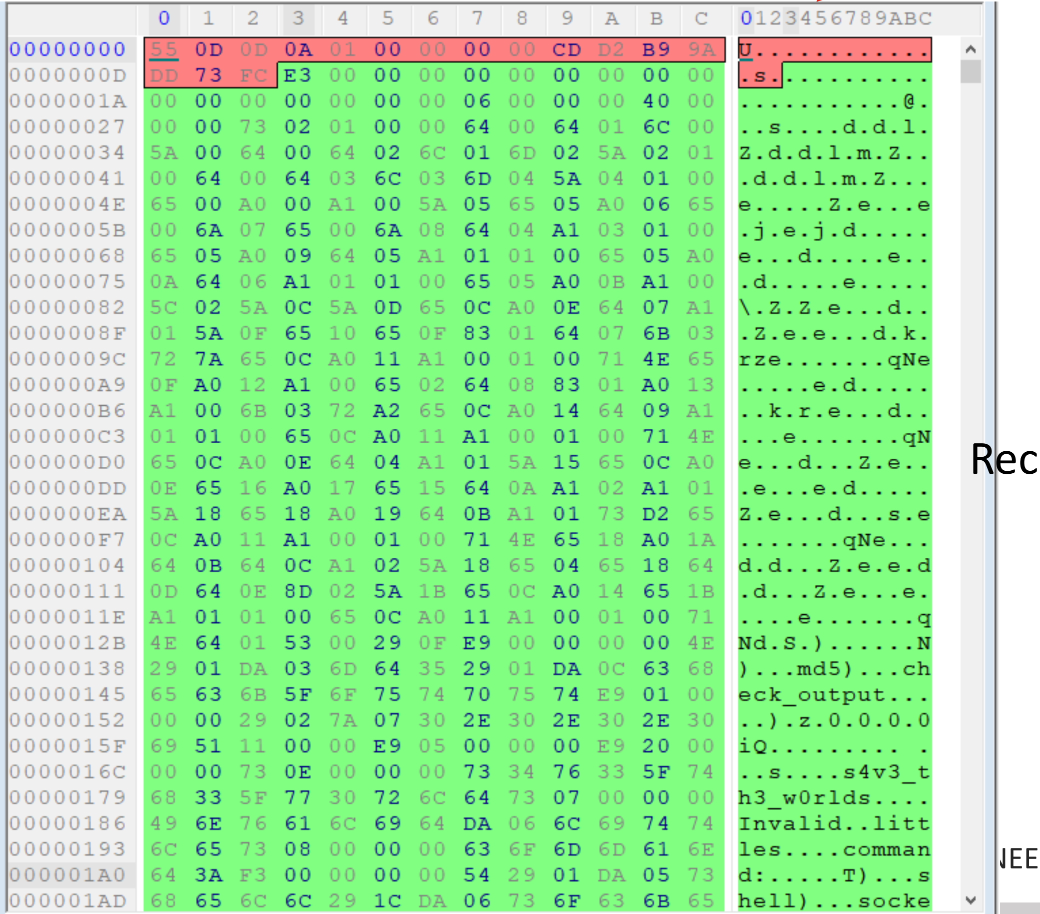
- `PyInstaller` allows converting Python code to an executable
  - It packs the pyc files into a container. Container is extracted on runtime and compiled python code is executed
  - Headers are omitted from pyc files. If header is added, extracted file executes as a standard pyc file

Added header

Extracted



```
          0  1  2  3  4  5  6  7  8  9  A  B  C   0123456789ABC
00000000  E3 00 00 00 00 00 00 00 00 00 00 00 00  .............
0000000D  00 00 00 00 06 00 00 00 40 00 00 00 73  ........@...s
0000001A  02 01 00 00 64 00 64 01 6C 00 5A 00 64  ....d.d.l.Z.d
00000027  00 64 02 6C 01 6D 02 5A 02 01 00 64 00  .d.l.m.Z...d.
00000034  64 03 6C 03 6D 04 5A 04 01 00 65 00 A0  d.l.m.Z...e..
00000041  00 A1 00 5A 05 65 05 A0 06 65 00 6A 07  ...Z.e...e.j.
0000004E  65 00 6A 08 64 04 A1 03 01 00 65 05 A0  e.j.d.....e..
0000005B  09 64 05 A1 01 01 00 65 05 A0 0A 64 06  .d.....e...d.
00000068  A1 01 01 00 65 05 A0 0B A1 00 5C 02 5A  ....e.....\.Z
00000075  0C 5A 0D 65 0C A0 0E 64 07 A1 01 5A 0F  .Z.e...d...Z.
00000082  65 10 65 0F 83 01 64 07 6B 03 72 7A 65  e.e...d.k.rze
0000008F  0C A0 11 A1 00 01 00 71 4E 65 0F A0 12  .......qNe...
0000009C  A1 00 65 02 64 08 83 01 A0 13 A1 00 6B  ..e.d.......k
000000A9  03 72 A2 65 0C A0 14 64 09 A1 01 01 00  .r.e...d.....
000000B6  65 0C A0 11 A1 00 01 00 71 4E 65 0C A0  e.......qNe..
000000C3  0E 64 04 A1 01 5A 15 65 0C A0 0E 65 16  .d...Z.e...e.
000000D0  A0 17 65 15 64 0A A1 02 A1 01 5A 18 65  ..e.d.....Z.e
000000DD  18 A0 19 64 0B A1 01 73 D2 65 0C A0 11  ...d...s.e...
000000EA  A1 00 01 00 71 4E 65 18 A0 1A 64 0B 64  ....qNe...d.d
000000F7  0C A1 02 5A 18 65 04 65 18 64 0D 64 0E  ...Z.e.e.d.d.
00000104  8D 02 5A 1B 65 0C A0 14 65 1B A1 01 01  ..Z.e...e....
00000111  00 65 0C A0 11 A1 00 01 00 71 4E 64 01  .e.......qNd.
0000011E  53 00 29 0F E9 00 00 00 00 4E 29 01 DA  S.)......N)..
0000012B  03 6D 64 35 29 01 DA 0C 63 68 65 63 6B  .md5)...check
00000138  5F 6F 75 74 70 75 74 E9 01 00 00 00 29  _output.....)
00000145  02 7A 07 30 2E 30 2E 30 2E 30 69 51 11  .z.0.0.0.0iQ.
00000152  00 00 E9 05 00 00 00 E9 20 00 00 00 73  ........ ...s
0000015F  0E 00 00 00 73 34 76 33 5F 74 68 33 5F  ....s4v3_th3_
0000016C  77 30 72 6C 64 73 07 00 00 00 49 6E 76  w0rlds....Inv
00000179  61 6C 69 64 DA 06 6C 69 74 74 6C 65 73  alid..littles
00000186  08 00 00 00 63 6F 6D 6D 61 6E 64 3A F3  ....command:.
00000193  00 00 00 00 54 29 01 DA 05 73 68 65 6C  ....T)...shel
000001A0  6C 29 1C DA 06 73 6F 63 6B 65 74 DA 07  l)...socket..
000001AD  68 61 73 68 6C 69 62 72 02 00 00 00 DA  hashlibr.....
```



```
          0  1  2  3  4  5  6  7  8  9  A  B  C   0123456789ABC
00000000  55 0D 0D 0A 01 00 00 00 00 CD D2 B9 9A  U............
0000000D  DD 73 FC E3 00 00 00 00 00 00 00 00 00  .s...........
0000001A  00 00 00 00 00 00 00 06 00 00 00 40 00  ...........@.
00000027  00 00 73 02 01 00 00 64 00 64 01 6C 00  ..s....d.d.l.
00000034  5A 00 64 00 64 02 6C 01 6D 02 5A 02 01  Z.d.d.l.m.Z..
00000041  00 64 00 64 03 6C 03 6D 04 5A 04 01 00  .d.d.l.m.Z...
0000004E  65 00 A0 00 A1 00 5A 05 65 05 A0 06 65  e.....Z.e...e
0000005B  00 6A 07 65 00 6A 08 64 04 A1 03 01 00  .j.e.j.d.....
00000068  65 05 A0 09 64 05 A1 01 01 00 65 05 A0  e...d.....e..
00000075  0A 64 06 A1 01 01 00 65 05 A0 0B A1 00  .d.....e.....
00000082  5C 02 5A 0C 5A 0D 65 0C A0 0E 64 07 A1  \.Z.Z.e...d..
0000008F  01 5A 0F 65 10 65 0F 83 01 64 07 6B 03  .Z.e.e...d.k.
0000009C  72 7A 65 0C A0 11 A1 00 01 00 71 4E 65  rze.......qNe
000000A9  0F A0 12 A1 00 65 02 64 08 83 01 A0 13  .....e.d.....
000000B6  A1 00 6B 03 72 A2 65 0C A0 14 64 09 A1  ..k.r.e...d..
000000C3  01 01 00 65 0C A0 11 A1 00 01 00 71 4E  ...e.......qN
000000D0  65 0C A0 0E 64 04 A1 01 5A 15 65 0C A0  e...d...Z.e..
000000DD  0E 65 16 A0 17 65 15 64 0A A1 02 A1 01  .e...e.d.....
000000EA  5A 18 65 18 A0 19 64 0B A1 01 73 D2 65  Z.e...d...s.e
000000F7  0C A0 11 A1 00 01 00 71 4E 65 18 A0 1A  .......qNe...
00000104  64 0B 64 0C A1 02 5A 18 65 04 65 18 64  d.d...Z.e.e.d
00000111  0D 64 0E 8D 02 5A 1B 65 0C A0 14 65 1B  .d...Z.e...e.
0000011E  A1 01 01 00 65 0C A0 11 A1 00 01 00 71  ....e.......q
0000012B  4E 64 01 53 00 29 0F E9 00 00 00 00 4E  Nd.S.)......N
00000138  29 01 DA 03 6D 64 35 29 01 DA 0C 63 68  )...md5)...ch
00000145  65 63 6B 5F 6F 75 74 70 75 74 E9 01 00  eck_output...
00000152  00 00 29 02 7A 07 30 2E 30 2E 30 2E 30  ..).z.0.0.0.0
0000015F  69 51 11 00 00 E9 05 00 00 00 E9 20 00  iQ........ .
0000016C  00 00 73 0E 00 00 00 73 34 76 33 5F 74  ..s....s4v3_t
00000179  68 33 5F 77 30 72 6C 64 73 07 00 00 00  h3_w0rlds....
00000186  49 6E 76 61 6C 69 64 DA 06 6C 69 74 74  Invalid..litt
00000193  6C 65 73 08 00 00 00 63 6F 6D 6D 61 6E  les....comman
000001A0  64 3A F3 00 00 00 00 54 29 01 DA 05 73  d:.....T)...s
000001AD  68 65 6C 6C 29 1C DA 06 73 6F 63 6B 65  hell)...socke
```

Reconstructed

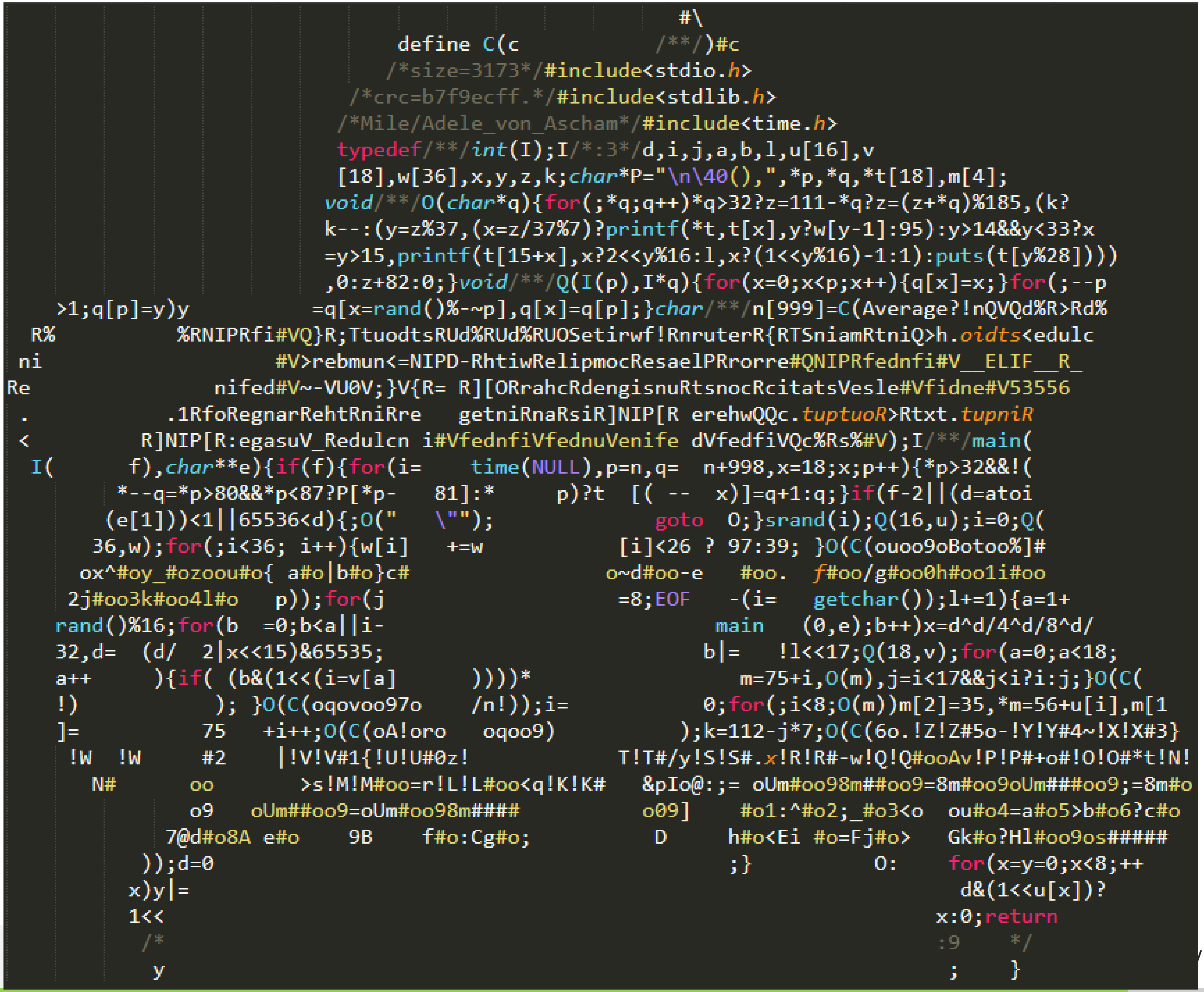
Code Obfuscation

Layout Obfuscation

- Aims at hiding how the **<u>source code</u>** is structured
  - As source code (or symbols) can present enough information to help reversing a program

- Applied to the source code, and focused on situations where source can be obtained
  - Javascript, HTML, CSS, Java

- Methods:
  - Deleting comments
  - Remove debugging information
  - Renaming classes, methods and variables
  - Removing spaces
  - Stripping a binary



```
                                                       #\
                                define C(c           /**/)#c
                               /*size=3173*/#include<stdio.h>
                            /*crc=b7f9ecff.*/#include<stdlib.h>
                           /*Mile/Adele_von_Ascham*/#include<time.h>
                           typedef/**/int(I);I/*:3*/d,i,j,a,b,l,u[16],v
                           [18],w[36],x,y,z,k;char*P="\n\40(),",*p,*q,*t[18],m[4];
                          void/**/O(char*q){for(;*q;q++)*q>32?z=111-*q?z=(z+*q)%185,(k?
                          k--:(y=z%37,(x=z/37%7)?printf(*t,t[x],y?w[y-1]:95):y>14&&y<33?x
                          =y>15,printf(t[15+x],x?2<<y%16:l,x?(1<<y%16)-1:1):puts(t[y%28]))
                          ,0:z+82:0;}void/**/Q(I(p),I*q){for(x=0;x<p;x++){q[x]=x;}for(;--p
    >1;q[p]=y)y          =q[x=rand()%-~p],q[x]=q[p];}char/**/n[999]=C(Average?!nQVQd%R>Rd%
  R%          %RNIPRfi#VQ}R;TtuodtsRUd%RUd%RUOSetirwf!RnruterR{RTSniamRtniQ>h.oidts<edulc
 ni                   #V>rebmun<=NIPD-RhtiwRelipmocResaelPRrorre#QNIPRfednfi#V__ELIF__R_
Re               nifed#V~-VU0V;}V{R= R][ORrahcRdengisnuRtsnocRcitatsVesle#Vfidne#V53556
 .           .1RfoRegnarRehtRniRre   getniRnaRsiR]NIP[R erehwQQc.tuptuoR>Rtxt.tupniR
 <         R]NIP[R:egasuV_Redulcn i#VfednfiVfednuVenife dVfedfiVQc%Rs%#V);I/**/main(
  I(      f),char**e){if(f){for(i=    time(NULL),p=n,q=  n+998,x=18;x;p++){*p>32&&!(
         *--q=*p>80&&*p<87?P[*p-   81]:*     p)?t  [( --  x)]=q+1:q;}if(f-2||(d=atoi
        (e[1]))<1||65536<d){;O("   \"");             goto  O;}srand(i);Q(16,u);i=0;Q(
       36,w);for(;i<36; i++){w[i]   +=w           [i]<26 ? 97:39; }O(C(ouoo9oBotoo%]#
      ox^#oy_#ozoou#o{ a#o|b#o}c#                o~d#oo-e   #oo.  f#oo/g#oo0h#oo1i#oo
     2j#oo3k#oo4l#o   p));for(j                   =8;EOF   -(i=   getchar());l+=1){a=1+
    rand()%16;for(b  =0;b<a||i-                           main   (0,e);b++)x=d^d/4^d/8^d/
    32,d=  (d/  2|x<<15)&65535;                          b|=   !l<<17;Q(18,v);for(a=0;a<18;
    a++     ){if( (b&(1<<(i=v[a]      ))))*                 m=75+i,O(m),j=i<17&&j<i?i:j;}O(C(
    !)           ); }O(C(oqovoo97o    /n!));i=           0;for(;i<8;O(m))m[2]=35,*m=56+u[i],m[1
    ]=          75   +i++;O(C(oA!oro   oqoo9)          );k=112-j*7;O(C(6o.!Z!Z#5o-!Y!Y#4~!X!X#3}
     !W  !W     #2    |!V!V#1{!U!U#0z!            T!T#/y!S!S#.x!R!R#-w!Q!Q#ooAv!P!P#+o#!O!O#*t!N!
       N#      oo       >s!M!M#oo=r!L!L#oo<q!K!K#   &pIo@:;= oUm#oo98m##oo9=8m#oo9oUm###oo9;=8m#o
               o9   oUm##oo9=oUm#oo98m####          o09]    #o1:^#o2;_#o3<o  ou#o4=a#o5>b#o6?c#o
             7@d#o8A e#o    9B    f#o:Cg#o;          D     h#o<Ei #o=Fj#o>   Gk#o?Hl#oo9os#####
           ));d=0                                          ;}          O:    for(x=y=0;x<8;++
          x)y|=                                                               d&(1<<u[x])?
          1<<                                                               x:0;return
           /*                                                               :9    */
            y                                                                ;     }
```

Code Obfuscation

Design Obfuscation

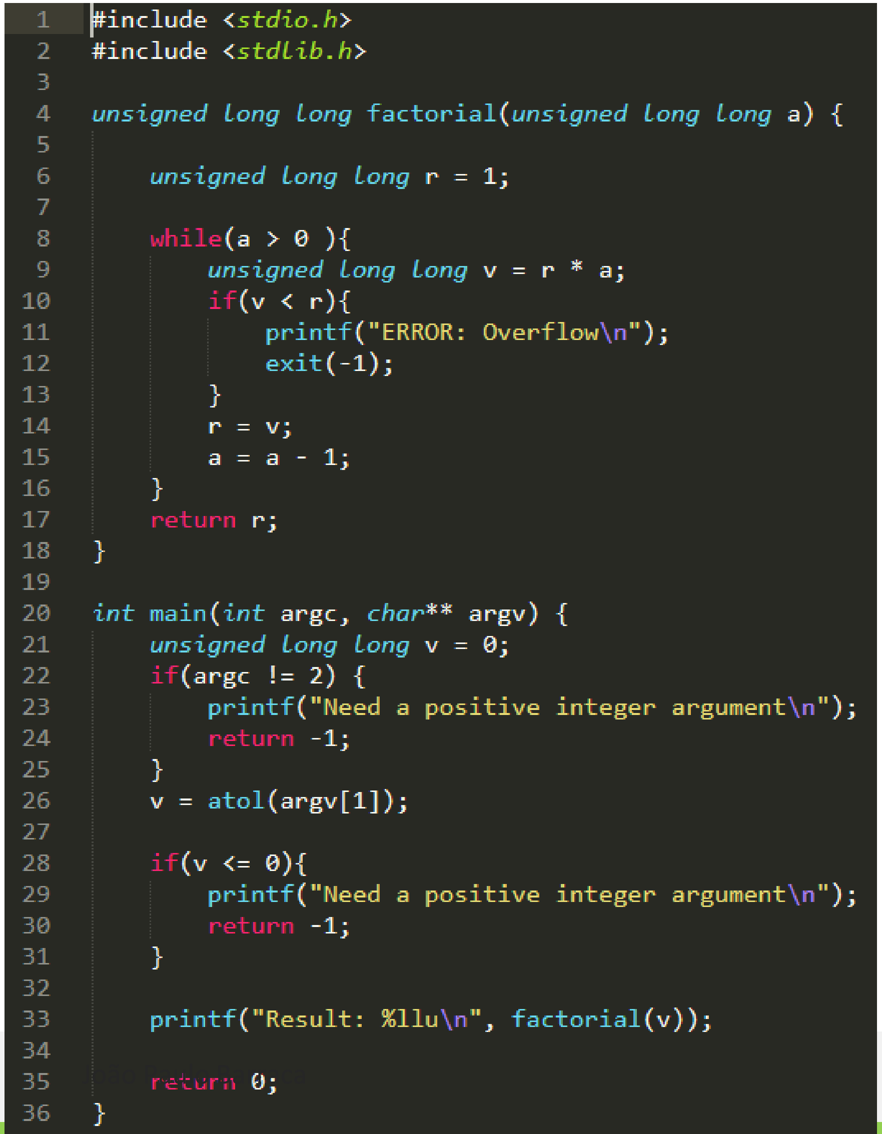
- Aims at making the design nonobvious, more difficult to recover
  - Usually done by a tool before compilation or during compilation
  - GCC can do this automatically by inlining functions (`-O3 –finline -funroll-loops`)

- Methods:
  - Merging and splitting methods
  - Merging and splitting classes
  - Splitting binary code, while inserting dummy instructions
  - Splitting loops and conditions, maybe interleaved with dummy code
  - Inlining functions
  - Dead Code

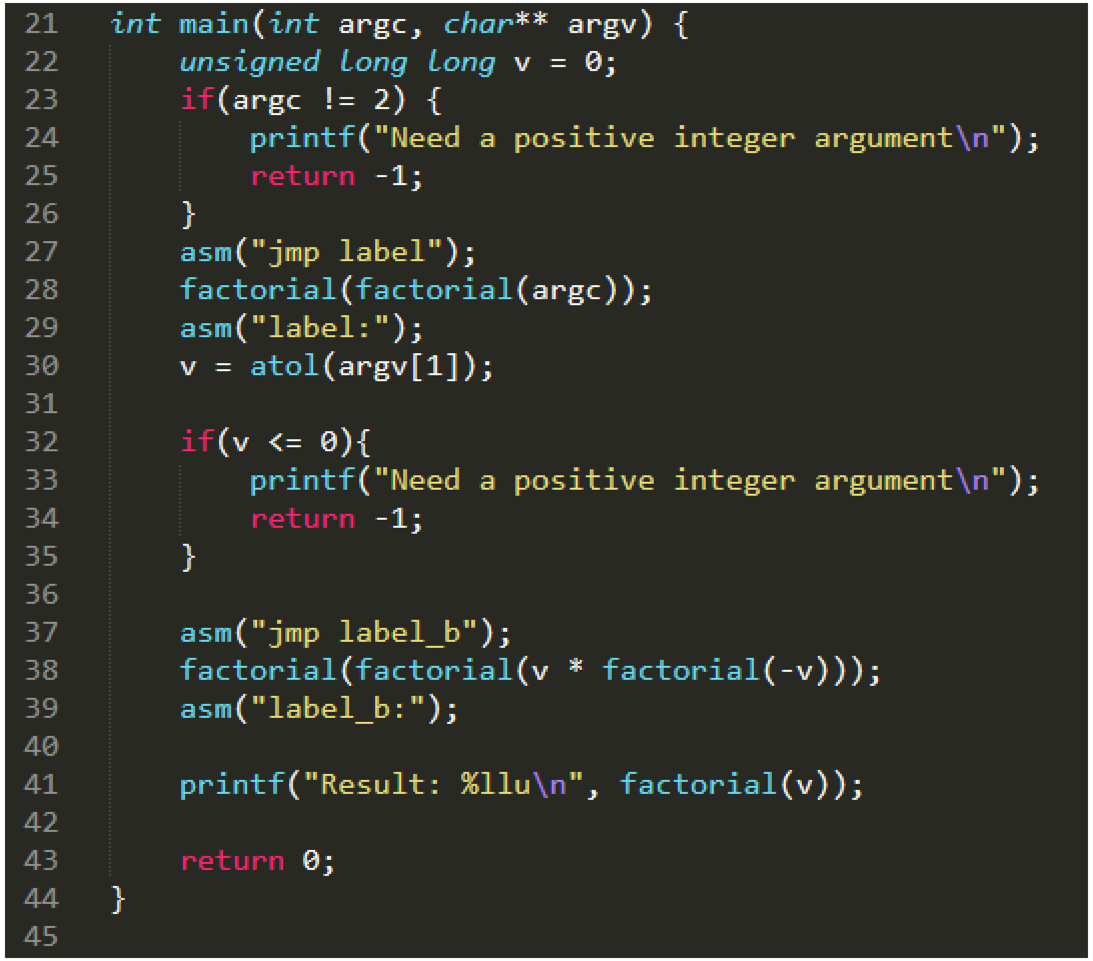
Code Obfuscation

Design Obfuscation – Breaking Code

Code inserted, but never executed.
JMP before dummy code effectively only splits code



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

unsigned long long factorial(unsigned long long a) {

    unsigned long long r = 1;

    while(a > 0 ){
        unsigned long long v = r * a;
        if(v < r){
            printf("ERROR: Overflow\n");
            exit(-1);
        }
        r = v;
        a = a - 1;
    }
    return r;
}

int main(int argc, char** argv) {
    unsigned long long v = 0;
    if(argc != 2) {
        printf("Need a positive integer argument\n");
        return -1;
    }
    v = atol(argv[1]);

    if(v <= 0){
        printf("Need a positive integer argument\n");
        return -1;
    }

    printf("Result: %llu\n", factorial(v));

    return 0;
}
```

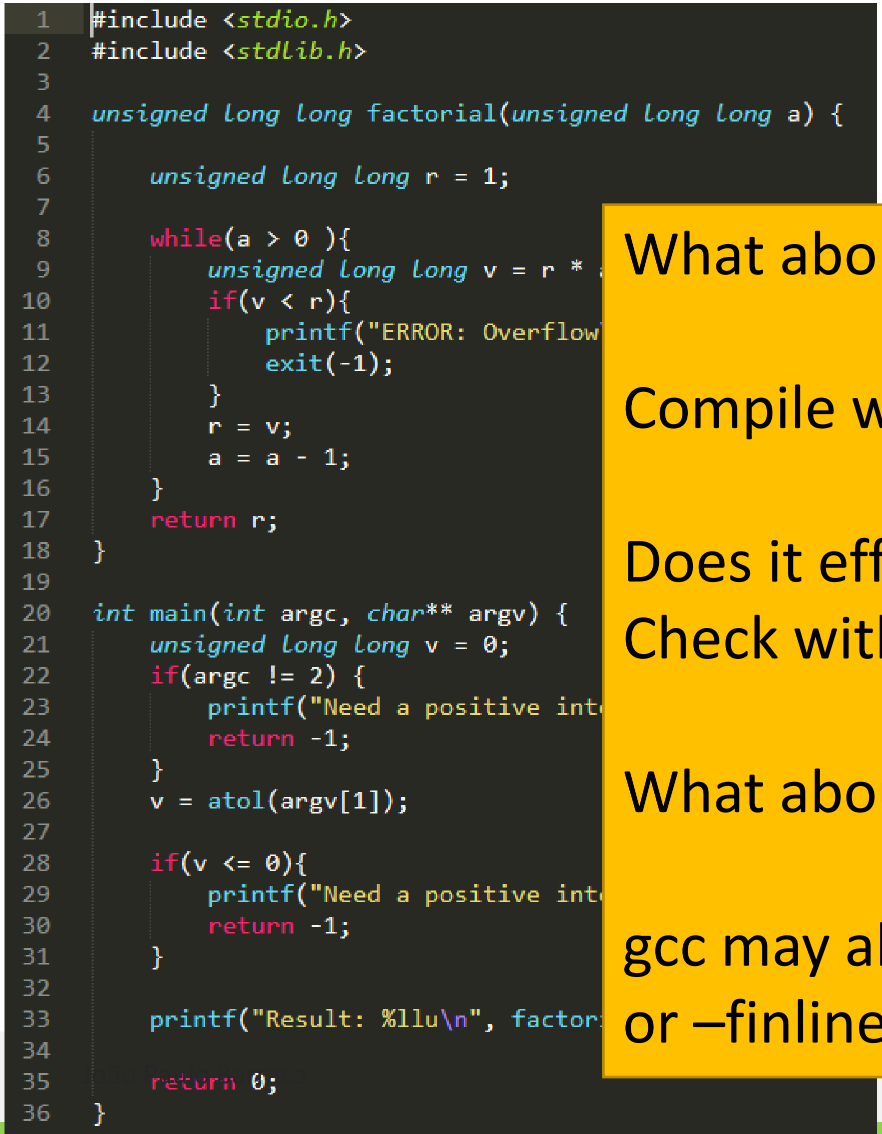


```c
int main(int argc, char** argv) {
    unsigned long long v = 0;
    if(argc != 2) {
        printf("Need a positive integer argument\n");
        return -1;
    }
    asm("jmp label");
    factorial(factorial(argc));
    asm("label:");
    v = atol(argv[1]);

    if(v <= 0){
        printf("Need a positive integer argument\n");
        return -1;
    }

    asm("jmp label_b");
    factorial(factorial(v * factorial(-v)));
    asm("label_b:");

    printf("Result: %llu\n", factorial(v));

    return 0;
}

```

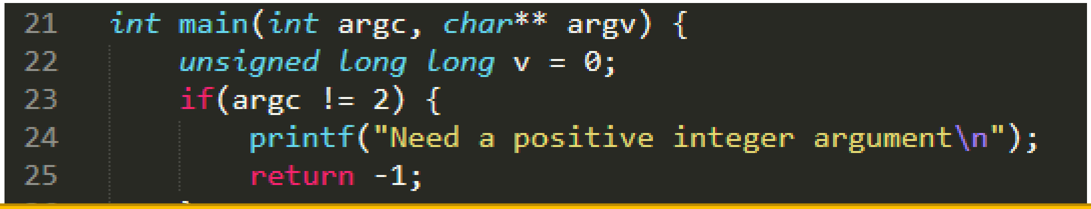
Code Obfuscation

Design Obfuscation – Breaking Code

Code inserted, but never executed.
JMP before dummy code effectively only splits code



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

unsigned long long factorial(unsigned long long a) {

    unsigned long long r = 1;

    while(a > 0 ){
        unsigned long long v = r *
        if(v < r){
            printf("ERROR: Overflow
            exit(-1);
        }
        r = v;
        a = a - 1;
    }
    return r;
}

int main(int argc, char** argv) {
    unsigned long long v = 0;
    if(argc != 2) {
        printf("Need a positive int
        return -1;
    }
    v = atol(argv[1]);

    if(v <= 0){
        printf("Need a positive int
        return -1;
    }

    printf("Result: %llu\n", factor

    return 0;
}
```



```
int main(int argc, char** argv) {
    unsigned long long v = 0;
    if(argc != 2) {
        printf("Need a positive integer argument\n");
        return -1;
```

What about the output binary?

Compile with gcc -O0 -o factorial-split factorial-split.c

Does it effect static or dynamic analysis?
Check with objdump -d and ghidra

What about if instead of jmp you use jz or jnz?

gcc may also inline functions (the opposite) when using –O3 or –finline-functions

Code Obfuscation

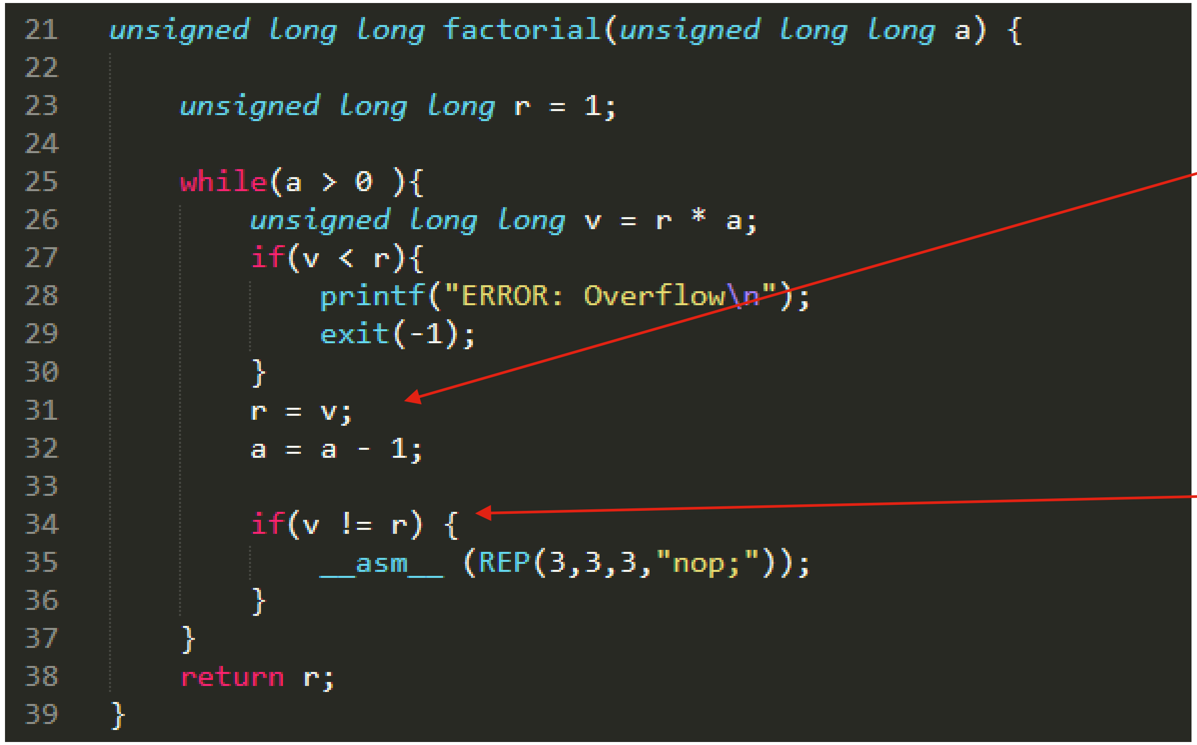
Design Obfuscation – Dead Code

- Aims at inserting dummy code to confuse the analysis
  - Code may follow some pattern (previous example), or be random
  - Code may lock the analysis tool if recursive disassembly is used
  - Decompilation to Pseudo C will surely be affected

- Dead code can be added after compilation
  - May contain fingerprinting information by making binaries unique

Code Obfuscation

Design Obfuscation – Dead Code



```c
unsigned long long factorial(unsigned long long a) {

    unsigned long long r = 1;

    while(a > 0 ){
        unsigned long long v = r * a;
        if(v < r){
            printf("ERROR: Overflow\n");
            exit(-1);
        }
        r = v;
        a = a - 1;

        if(v != r) {
            __asm__ (REP(3,3,3,"nop;"));
        }
    }
    return r;
}
```

`r=v`, therefore, **`if(v!=r)`** will be always false. Compiler will not easily discard this code.

`__asm__....` Instruction will insert 333 NOPs (which will not be executed)

This is a placeholder that can be used later for post processing by editing the binary directly

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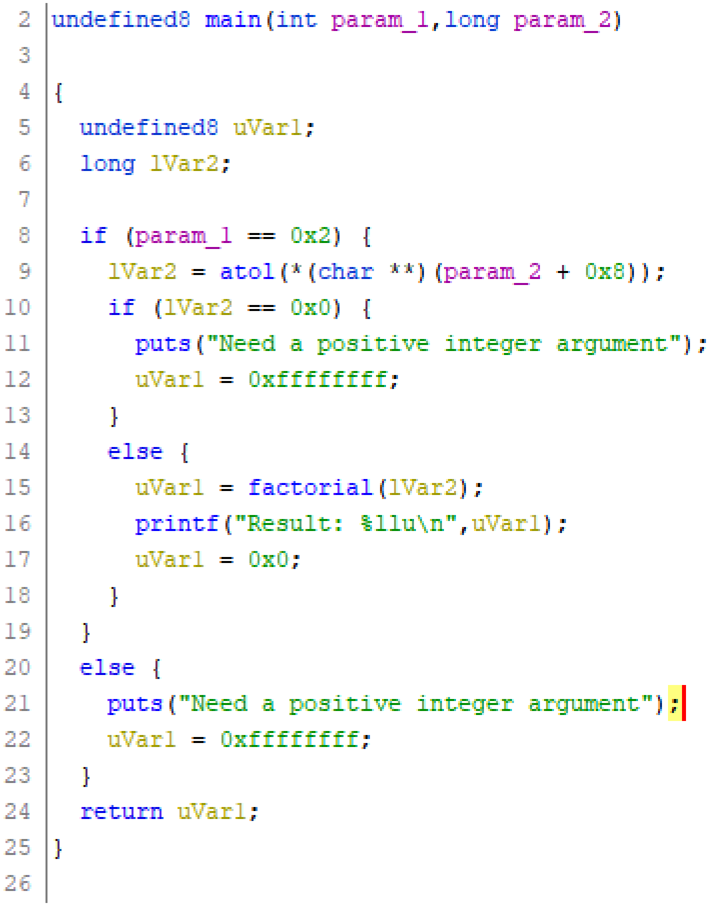
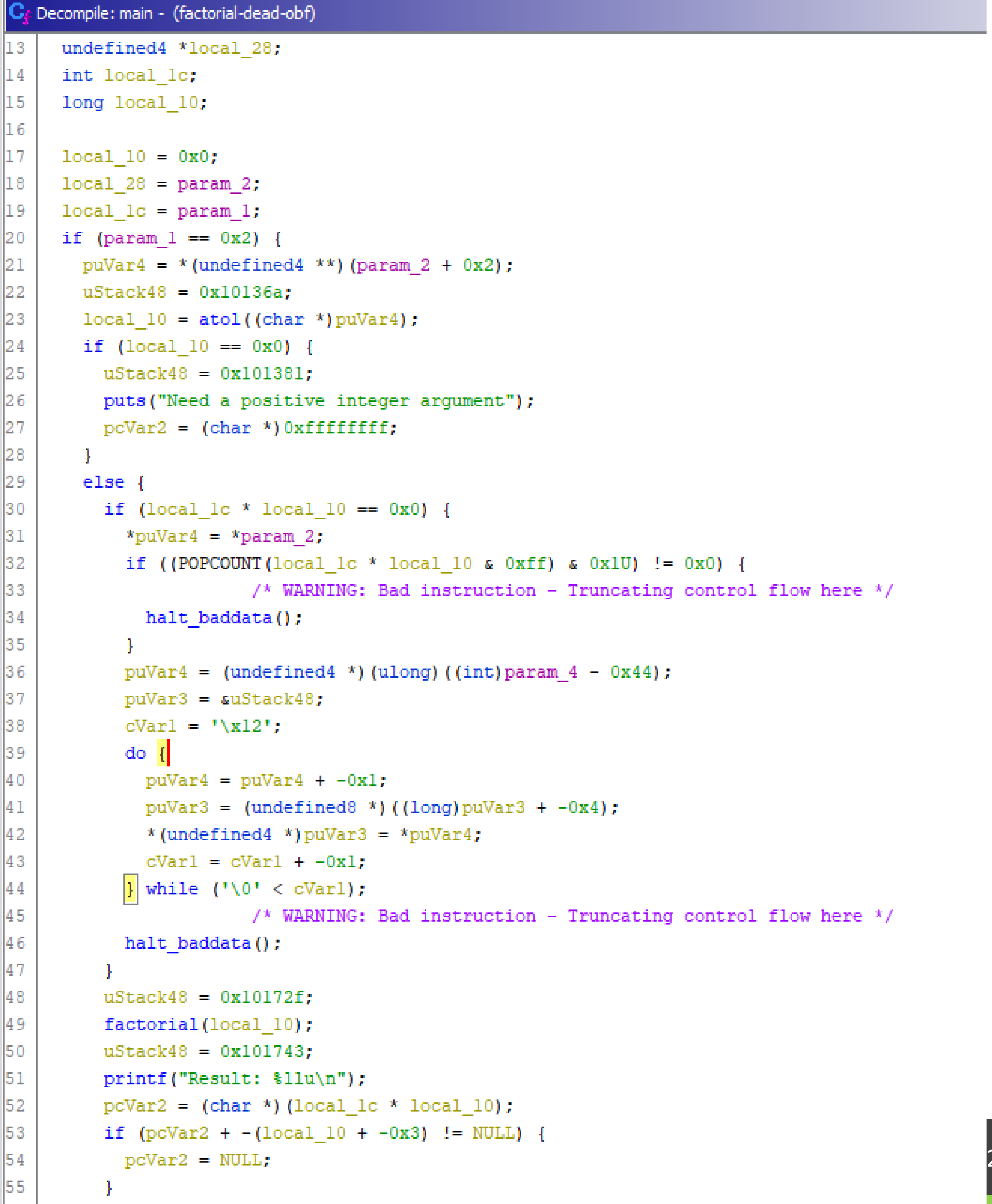


```
undefined8 main(int param_1,long param_2)

{
  undefined8 uVar1;
  long lVar2;

  if (param_1 == 0x2) {
    lVar2 = atol(*(char **)(param_2 + 0x8));
    if (lVar2 == 0x0) {
      puts("Need a positive integer argument");
      uVar1 = 0xffffffff;
    }
    else {
      uVar1 = factorial(lVar2);
      printf("Result: %llu\n",uVar1);
      uVar1 = 0x0;
    }
  }
  else {
    puts("Need a positive integer argument");
    uVar1 = 0xffffffff;
  }
  return uVar1;
}
```



```
  undefined4 *local_28;
  int local_1c;
  long local_10;

  local_10 = 0x0;
  local_28 = param_2;
  local_1c = param_1;
  if (param_1 == 0x2) {
    puVar4 = *(undefined4 **)(param_2 + 0x2);
    uStack48 = 0x10136a;
    local_10 = atol((char *)puVar4);
    if (local_10 == 0x0) {
      uStack48 = 0x101381;
      puts("Need a positive integer argument");
      pcVar2 = (char *)0xffffffff;
    }
    else {
      if (local_1c * local_10 == 0x0) {
        *puVar4 = *param_2;
        if ((POPCOUNT(local_1c * local_10 & 0xff) & 0x1U) != 0x0) {
                    /* WARNING: Bad instruction - Truncating control flow here */
          halt_baddata();
        }
        puVar4 = (undefined4 *)(ulong)((int)param_4 - 0x44);
        puVar3 = &uStack48;
        cVar1 = '\x12';
        do {
          puVar4 = puVar4 + -0x1;
          puVar3 = (undefined8 *)((long)puVar3 + -0x4);
          *(undefined4 *)puVar3 = *puVar4;
          cVar1 = cVar1 + -0x1;
        } while ('\0' < cVar1);
                    /* WARNING: Bad instruction - Truncating control flow here */
        halt_baddata();
      }
      uStack48 = 0x10172f;
      factorial(local_10);
      uStack48 = 0x101743;
      printf("Result: %llu\n");
      pcVar2 = (char *)(local_1c * local_10);
      if (pcVar2 + -(local_10 + -0x3) != NULL) {
        pcVar2 = NULL;
      }
```

Code Obfuscation

Data Obfuscation

- Encrypts, or otherwise encodes data contents
  - Contents are decrypted in real time, as the program is executed
  - Static analysis, or fingerprint matching may fail to correctly recover useful information
  - Frequent tactic to evade filters

- Why?
  - Strings frequently carry semantic information, that may help analysis
  - E.g. Str="Please input your AES key": we will know that this a key, and know the algorithm

Code Obfuscation

Data Obfuscation - how

- Split the string in parts
  - May be combined with two conditions or loops to validate both parts individually

- Erase strings right after use

- Common XOR is frequently found as it requires no dependencies and is fast
  - More recent malware will use RC4 or even AES for this purpose
  - Decryption key can also be encrypted, and some key may be obtained dynamically
    - E.g. from a hardware token as a form of licensing enforcement

- Create a custom encoding based on a complex state machine
  - May use flow information, voiding the decoding of strings if the execution order it changed

Code Obfuscation

Control Obfuscation – Opaque Predicates

- Introduces dummy control structures, with little impact to execution
  - Impact is only from a performance point of view (additional branch)
  - However, analysis tools will interpret the control structures and create complex CFGs

- Makes use of Opaque Predicates: predicates for which the programmer already knows the result.
  - E.g. **`if ( 1 > 0) or v=r; if(v==r)`**

Code Obfuscation

Control Obfuscation – Opaque Predicates

- Opaque predicates can be more complex

- Manipulate pointers, linked lists, use computation processes

- Result of a predicate can be dynamic, and related to execution state
  - Dynamic analysis may change execution sequence, therefore the predicate result and invalidate the execution
  - Similar to TPMs, where keys are provided at a valid situation
  - Predicate can use dynamic data, received from external services

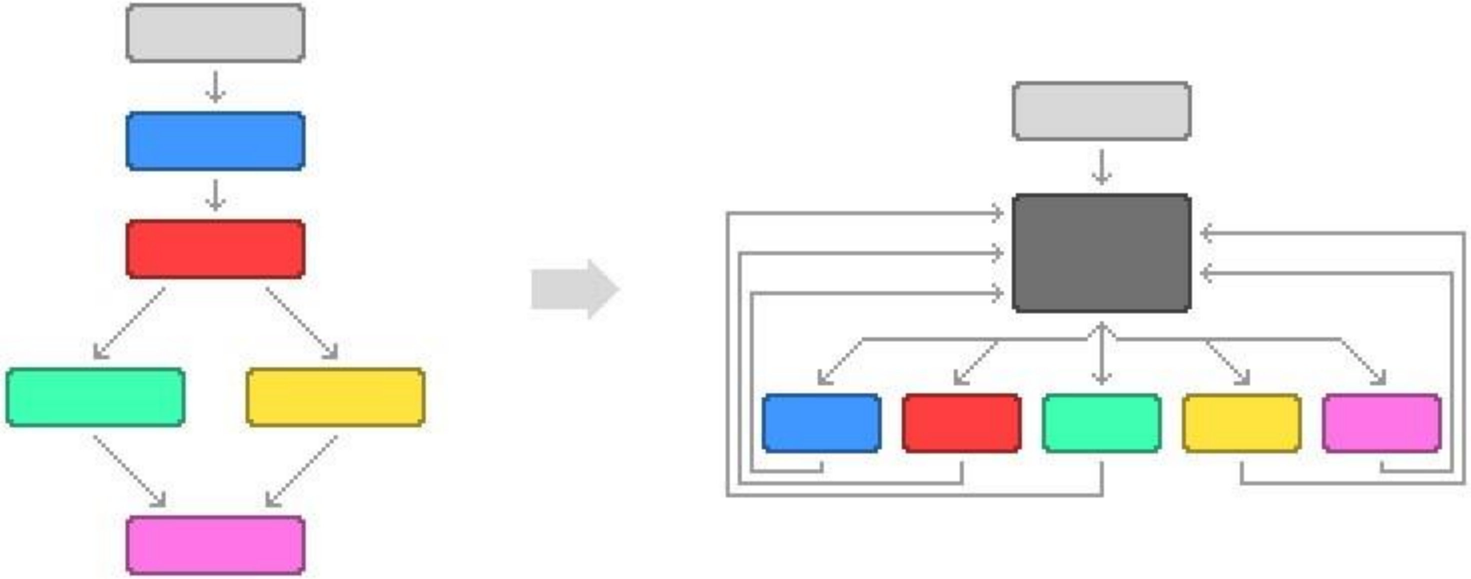
- Concurrency can be used to create predicates
  - If two threads are executing with some relation, one can update data, that the other uses to construct a predicate
  - Timing information can also be used, to further increase the complexity (information not available statically)

Code Obfuscation

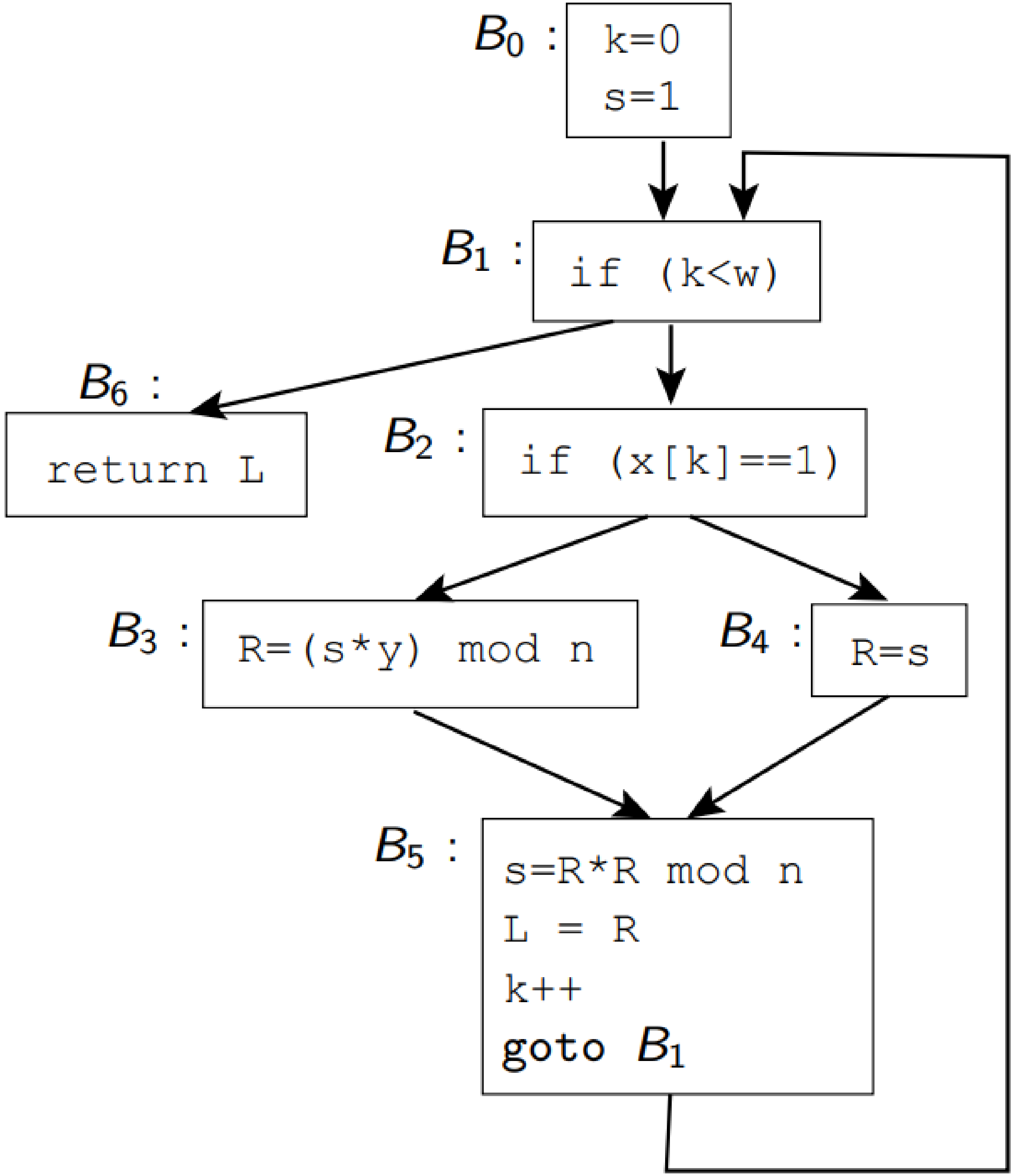
Control Obfuscation – Control Flow Flattening

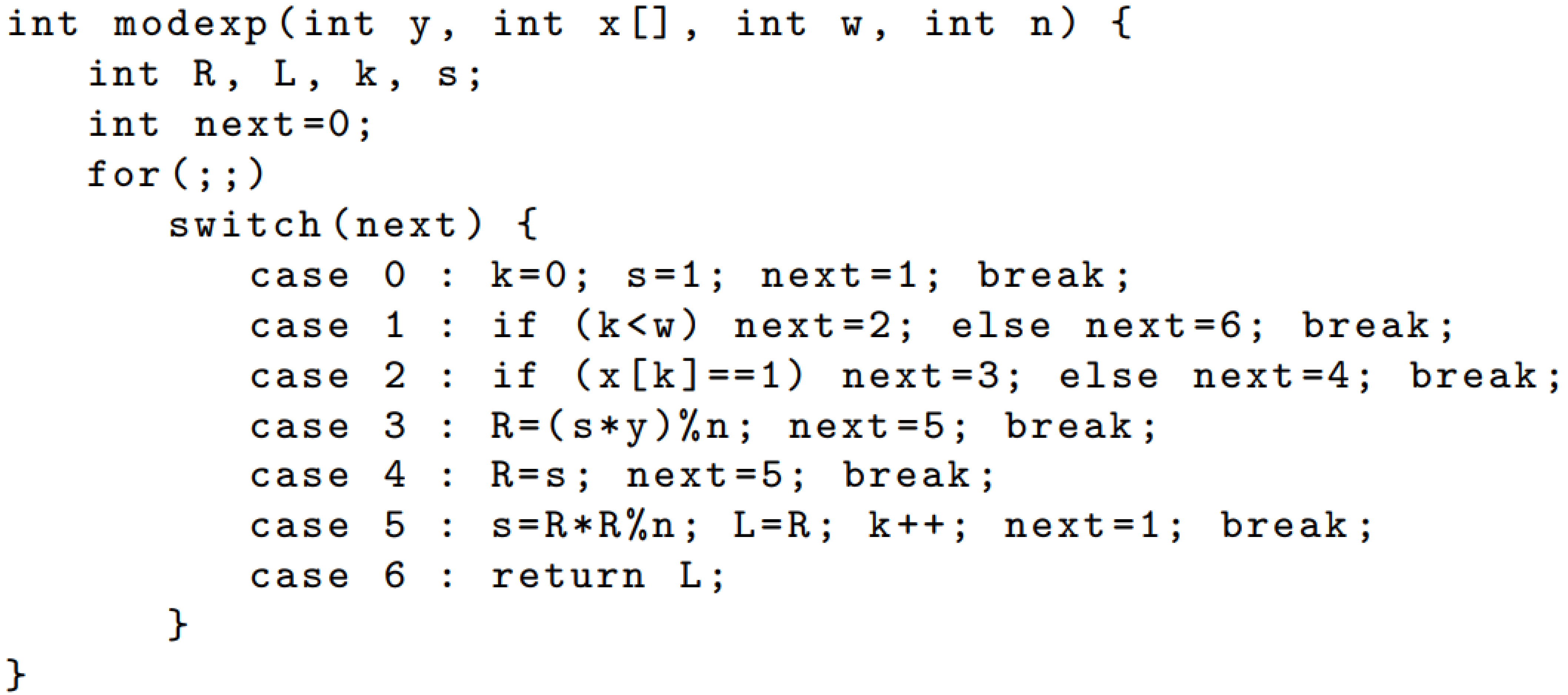
- Removes control flow structures from program
  - Converts the program to a gigantic Switch, where each condition is a case
  - Program runs on an infinite loop around the switch

- Program becomes ~4 times slower, and 2 times larger



```
int modexp(int y,int x[],
           int w,int n) {
   int R, L;
   int k = 0;
   int s = 1;
   while (k < w) {
      if (x[k] == 1)
         R = (s*y) % n;
      else
         R = s;
      s = R*R % n;
      L = R;
      k++;
   }
   return L;
}
```





```
int modexp(int y, int x[], int w, int n) {
    int R, L, k, s;
    int next=0;
    for(;;)
        switch(next) {
            case 0 : k=0; s=1; next=1; break;
            case 1 : if (k<w) next=2; else next=6; break;
            case 2 : if (x[k]==1) next=3; else next=4; break;
            case 3 : R=(s*y)%n; next=5; break;
            case 4 : R=s; next=5; break;
            case 5 : s=R*R%n; L=R; k++; next=1; break;
            case 6 : return L;
        }
}
```

Code Obfuscation

Self Decompressing Binaries

- Binaries can be compressed into a blob (and even encrypted)
  - Stub will process the blob and jump into it

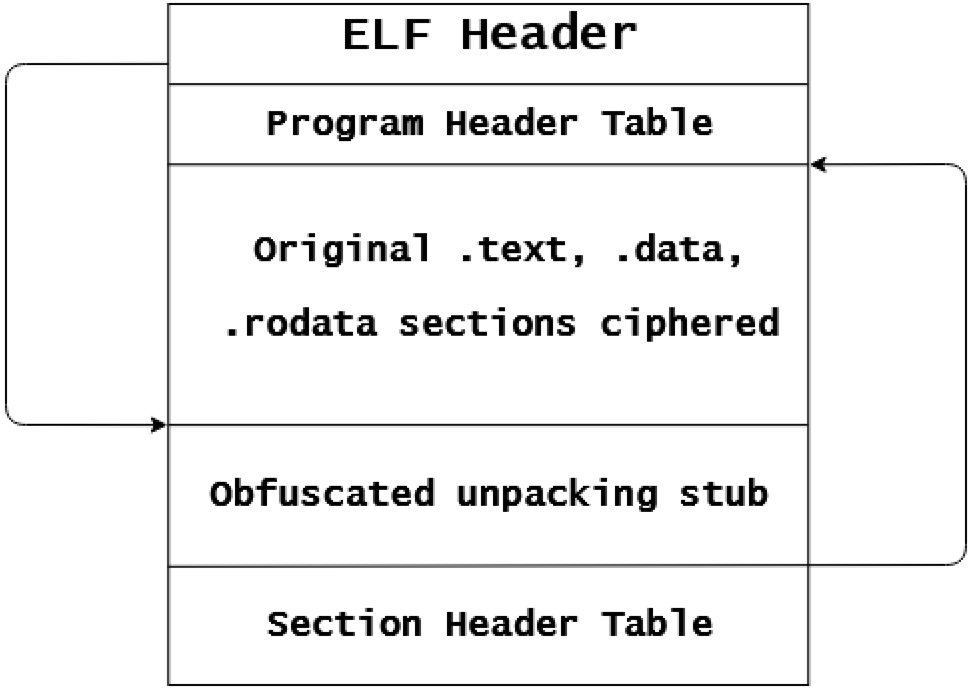
- Static analysis will be able to analyze the stub, which can be obfuscated
  - Stub provides a valid signature for scanners, but variations can exist

- Actual file is never available to analysis by static scanners
  - Is available at runtime, as file must be available for execution
  - Generic packers (upx) will pack the entire ELF, which is mapped at runtime
    - Easier to extract as file is recreated and mapped
  - Crafted packers will require more effort

- Generic approach uses a debugger or Qiling to dump the uncompressed file
  - For an overview, check: https://kernemporium.github.io/posts/unpacking/

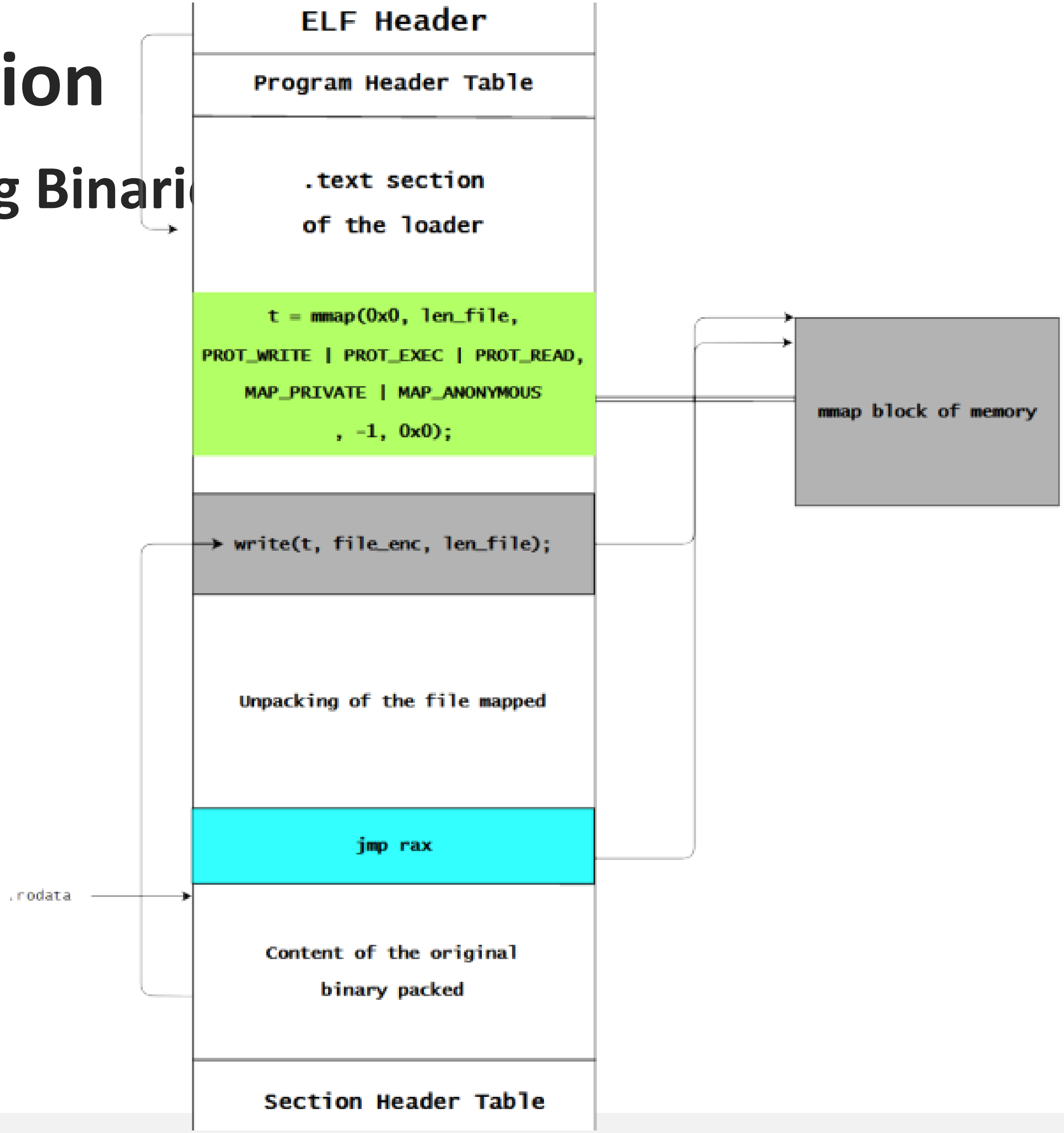
Code Obfuscation

Self Decompressing Binaries



Code Obfuscation

Self Decompressing Binari


ELF Header
Program Header Table
.text section
of the loader
t = mmap(0x0, len_file,
PROT_WRITE | PROT_EXEC | PROT_READ,
MAP_PRIVATE | MAP_ANONYMOUS
, -1, 0x0);
mmap block of memory
write(t, file_enc, len_file);
Unpacking of the file mapped
jmp rax
.rodata
Content of the original
binary packed
Section Header Table