UFR IM²AG
UNIVERSITÉ Grenoble Alpes

Grenoble INP Ensimag

Software security, secure programming

About Code Obfuscation

Master M2 Cybersecurity

Academic Year 2021 - 2022

Code Obfuscation

$\rightarrow$ Protecting a code against **reverse-engineering** techniques allowing to **inspect and/or tamper** a software (man at the end attacks !)

Code Obfuscation

→ Protecting a code against **reverse-engineering** techniques allowing to **inspect and/or tamper** a software (man at the end attacks !)

Typical applications domains:

- intellectual property of some algorithms
- data confidentiality
- white-box cryptography
- digital rights managements (DRM)
- ...
- and malware implementation !

Code Obfuscation

→ Protecting a code against **reverse-engineering** techniques allowing to **inspect and/or tamper** a software (man at the end attacks !)

Typical applications domains:

- intellectual property of some algorithms
- data confidentiality
- white-box cryptography
- digital rights managements (DRM)
- ...
- and malware implementation !

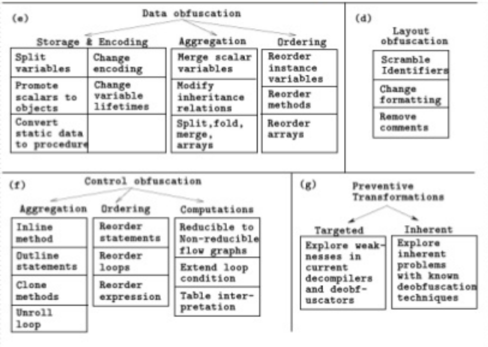
obfuscation may target various reverse-engineering approaches

- from source code vs from binary code
- manual vs tool-assisted
- static (i.e., code inspection) vs dymanic (i.e., code execution) techniques
- etc

⇒ a large spectrum of obfuscation techniques ...

Some examples of code obfuscation techniques

Kinds of obfuscation for each target information



Outline

Basic transformations

Examples of Data Obfuscation

Examples of Code Obfuscation

Some other obfuscation techniques

Example: source-level obfuscation against manual RE (1/3)

Example:From Stunnix

- Actual code:
- function foo(arg1)
- {
-   var myVar1 = "some string"; //first comment
-   var intVar = 24 * 3600; //second comment
-   /* here is
- a long
- multi-line comment blah */
-   document. write("vars are:" + myVar1 + " " + intVar + " " + arg1) ;
- } ;

- Obfuscated code:
- function z001c775808(z3833986e2c) { var z0d8bd8ba25= "\x73\x6f\x6d\x65\x20\x73\x74\x72\x69\x6e\x67"; var z0ed9bcbcc2= (0x90b+785-0xc04)* (0x1136+6437-0x1c4b); document. write("\x76\x61\x72\x73\x20\x61\x72\x65\x3a"+ z0d8bd8ba25+ "\x20"+ z0ed9bcbcc2+ "\x20"+ z3833986e2c);};

Example: source-level obfuscation against manual RE (2/3)

Step by step examination

- The Stunnix obfuscator targets at obfuscating only the layout of the JavaScript code
- As the obfuscator parses the code, it removes spaces, comments and new line feeds
- While doing so, as it encounters user defined names, it replaces them with some random string
- It replaces print strings with their hexadecimal values
- It replaces integer values with complex equations

Example: source-level obfuscation against manual RE (3/3)

- In the sample code that was obfuscated, the following can be observed
- User defined variables:
  - foo replaced with z001c775808
  - arg1 replaced with z3833986e2c
  - myvar1 replaced with z0d8bd8ba25
  - intvar replaced with z0ed9bcbcc2
- Integers:
  - 20 replaced with (0x90b+785-0xc04)
  - 3600 replaced with (0x1136+6437-0x1c4b)
- Print strings:
  - “vars are” replaced with \x76\x61\x72\x73\x20\x61\x72\x65\x3a
  - Space replaced with \x20

Example: source-level obfuscation against manual RE (3/3)

- In the sample code that was obfuscated, the following can be observed
- User defined variables:
  - foo replaced with z001c775808
  - arg1 replaced with z3833986e2c
  - myvar1 replaced with z0d8bd8ba25
  - intvar replaced with z0ed9bcbcc2
- Integers:
  - 20 replaced with (0x90b+785-0xc04)
  - 3600 replaced with (0x1136+6437-0x1c4b)
- Print strings:
  - "vars are" replaced with \x76\x61\x72\x73\x20\x61\x72\x65\x3a
  - Space replaced with \x20

Outline

Data re-encoding

Replace variables by complex expressions, e.g.,

```
int a = arg1;
int b = arg2;
int x = a*b;
printf("x=%i\n",x);
```

replaced by

```
a = 1789355803 * arg1 + 1391591831;
b = 1789355803 * arg2 + 1391591831;
x = ((3537017619 * (a * b) - 3670706997 * a) -
                        3670706997 * b) + 3171898074;
printf("x=%i\n", -757949677 * x - 3670706997);
```

Data re-encoding

Replace variables by complex expressions, e.g.,

```
int a = arg1;
int b = arg2;
int x = a*b;
printf("x=%i\n",x);
```

replaced by

```
a = 1789355803 * arg1 + 1391591831;
b = 1789355803 * arg2 + 1391591831;
x = ((3537017619 * (a * b) - 3670706997 * a) -
                        3670706997 * b) + 3171898074;
printf("x=%i\n", -757949677 * x - 3670706997);
```

Replace standart arithmetic operations by more complex ones,e.g.,

$$z = x + y + w$$

replaced by:

```
    z = (((x ^ y) + ((x & y) << 1)) | w) +
        (((x ^ y) + ((x & y) << 1)) & w)
```

Data re-encoding

Replace variables by complex expressions, e.g.,

```
int a = arg1;
int b = arg2;
int x = a*b;
printf("x=%i\n",x);
```

replaced by

```
a = 1789355803 * arg1 + 1391591831;
b = 1789355803 * arg2 + 1391591831;
x = ((3537017619 * (a * b) - 3670706997 * a) -
                        3670706997 * b) + 3171898074;
printf("x=%i\n", -757949677 * x - 3670706997);
```

Replace standart arithmetic operations by more complex ones,e.g.,

$$z = x + y + w$$

replaced by:

```
z = (((x ^ y) + ((x & y) << 1)) | w) +
    (((x ^ y) + ((x & y) << 1)) & w)
```

⇒ obfuscate the data operations performed in the code

Data split, fold or merge

- Split some variables of type T_1 into sets of variables of type T_2, e.g.:

  ```
  int a
  ```
  split into
  ```
  struct {char a1; char a2; char a3 ; char a4} a
  ```

- Merge some variables of type T_1, T_2 into a variables of type T, e.g.:

  ```
  int a ; char b
  ```
  merged into
  ```
  long ab
  ```

- Fold or Flatten arrays into higer/lower dimensionnal arrays

- Convert static data into `procedural` data ("table look-up", see next slide)

→ needs **alias computations** and **encoding/decoding** functions

Converting Static Data to Procedural Data

```
main() {
   String S1,S2,S3,S4;
   S1 = "AAA";
   S2 = "BAAA";
   S3 = "CCB";
   S4 = "CCB";
}
```

$\Downarrow \mathcal{T}$

```
main() {
   String S1,S2,S3,S4,S5;
   S1 = G(1);
   S2 = G(2);
   S3 = G(3);
   S4 = G(5);
   if (P^F) S5 = G(9);
}
```

$\xRightarrow{\mathcal{T}}$

```
static String G (int n) {
   int i=0;
   int k;
   char[] S = new char[20];
   while (true) {
      L1:  if (n==1) {S[i++]='A'; k=0; goto L6};
      L2:  if (n==2) {S[i++]='B'; k=-2; goto L6};
      L3:  if (n==3) {S[i++]='C'; goto L9};
      L4:  if (n==4) {S[i++]='X'; goto L9};
      L5:  if (n==5) {S[i++]='C'; goto L11};
           if (n>12) goto L1;
      L6:  if (k++<=2) {S[i++]='A'; goto L6}
           else goto L8;
      L8:  return String.valueOf(S);
      L9:  S[i++]='C'; goto L10;
      L10: S[i++]='B'; goto L8;
      L11: S[i++]='C'; goto L12;
      L12: goto L10;
   }
}
```

Outline

- Basic transformations
- Examples of Data Obfuscation
- Examples of Code Obfuscation
- Some other obfuscation techniques

Opaque predicates

Tramsform the control-flow graph (CFG) by inserting spurious conditions (evaluating always to **true**)
The condition is given as complex predicate, those value is hard to predict at compile-time, i.e.:

- not removed by the optimizer
- not detected by static code analyser

[1] `http://tigress.cs.arizona.edu/transformPage/docs/addOpaque/index.html`

Opaque predicates

Tramsform the control-flow graph (CFG) by inserting spurious conditions (evaluating always to **true**)
The condition is given as complex predicate, those value is hard to predict at compile-time, i.e.:

- not removed by the optimizer
- not detected by static code analyser

Some applications[1]

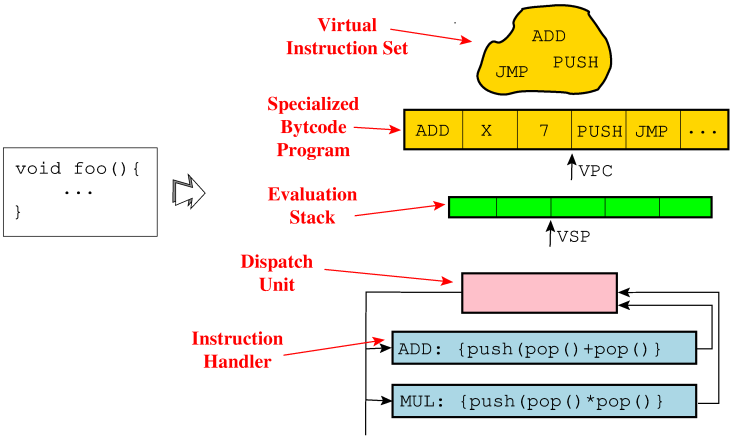
- if expr=false then
  call to random existing function
- if expr=false then
  call to non-existing function
- if expr=true then
  existing statement
  else
  buggified version of the statement

[1] http://tigress.cs.arizona.edu/transformPage/docs/addOpaque/index.html

Virtualization

Turns a function into a interpreter by:

- generating a dedicated (bytecode) instruction set
- a bytecode array, a virtual program counter (VPC) and a virtual stack pointer (VSP)
- a dispatch unit, and the bytecode instruction handlers



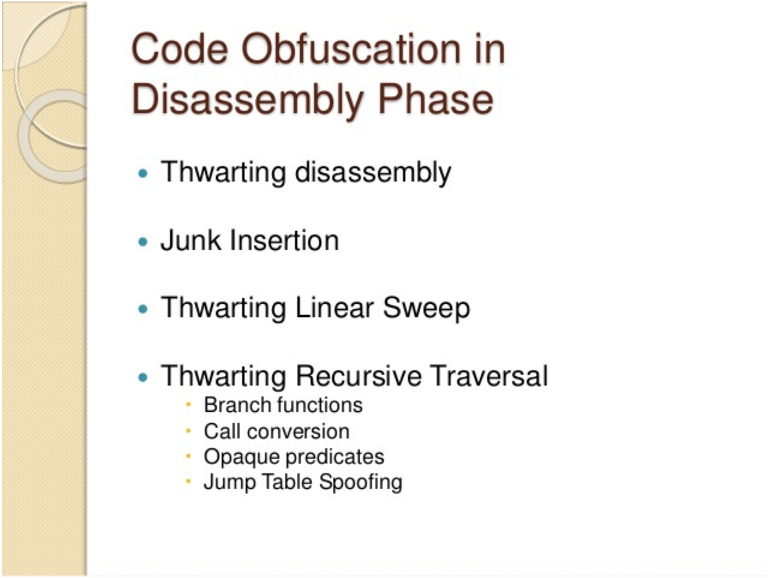
Outline

Basic transformations

Examples of Data Obfuscation

Examples of Code Obfuscation

Some other obfuscation techniques


Code Obfuscation in Disassembly Phase
Thwarting disassembly
Junk Insertion
Thwarting Linear Sweep
Thwarting Recursive Traversal
Branch functions
Call conversion
Opaque predicates
Jump Table Spoofing

Anti-Dynamic analysis

Prevent a program to be analyzed under a debugger, an emulator, a virtual machine . . .

- use process control primitives to prevent debugging
  e.g., `ptrace` on Linux,
- try to access regular peripherals (network, printer, filesystem, etc.)
- monitor the execution time
- etc.

Rk: (highly) used by malwares . . . !

Conclusion

Many other transformations proposed so far . . .

Expected properties of an obfuscator

- correctness: should preserve the code semantics
- resilience: should prevent (basic/advanced ?) reverse-engineering
- cost: should not “explode” the code complexity (time, memory, etc.)

Conclusion

Many other transformations proposed so far . . .

Expected properties of an obfuscator

- correctness: should preserve the code semantics
- resilience: should prevent (basic/advanced ?) reverse-engineering
- cost: should not "explode" the code complexity (time, memory, etc.)

However . . .

- no chance to build an universal obfuscator
  (i.e., able to obfuscate **any** input program)
- de-obfuscation tools are guided by existing obfuscation techniques . . .
  (keep your obfusactor **secret** !)

Conclusion

Many other transformations proposed so far . . .

Expected properties of an obfuscator

- correctness: should preserve the code semantics
- resilience: should prevent (basic/advanced ?) reverse-engineering
- cost: should not “explode” the code complexity (time, memory, etc.)

However . . .

- no chance to build an universal obfuscator
  (i.e., able to obfuscate **any** input program)
- de-obfuscation tools are guided by existing obfuscation techniques . . .
  (keep your obfusactor **secret** !)

Credits

- `https://fr.slideshare.net/bijondesai/code-obfuscation`
- `https://fr.slideshare.net/amolkamble16121/code-obfuscation-40283580`
- Christian Collberg web page: `http://tigress.cs.arizona.edu/index.html`