Some techniques of code obfuscation

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Objectives and Principles

- **Motivations**
  - Prevent reverse engineering
  - Protect secret data or operation
- **Target of transformations**
  - Data :
    - Constant Data
    - Variable Data
  - Code

Banescu, S., & Pretschner, A. (2018). A tutorial on software obfuscation. *Advances in Computers. Elsevier*.

Constant Data: Encode literals

Listing 1: Code before Encode Literals

```
1 int main(int ac, char* av[]) {
2   int a = 1;
3   // do stuff
4   return 0;
5 }
```

Listing 2: Code after Encode Literals

```
1 int main(int ac, char* av[]) {
2   double s = sin(atof(av[1]));
3   double c = cos(atof(av[1]));
4   int a = (int) (s * s + c * c);
5   // do stuff
6   return 0;
7 }
```

The adversary can think 'a' is variable as av[] is used in $\cos^2 + \sin^2$

Constant Data: White Box Cryptography

The constant is coded in Look Up Table (LUT)

Listing 4: 8-bit XOR with MSB of secret key

```
1 char xor(char input) {
2   return input ^ 0x53;
3 }
```

Listing 5: LUT-based 8-bit XOR

```
1  char lut[256] = {
2    0x53, 0x52, 0x51, ..., 0x5C,
3    0x43, 0x42, 0x41, ..., 0x4C,
4    0x73, 0x72, 0x71, ..., 0x7C,
5      |                      |
6    0xA3, 0xA2, 0xA1, ..., 0xAC
7  };
8
9  char xor(char input) {
10   return lut[input];
11 }
```

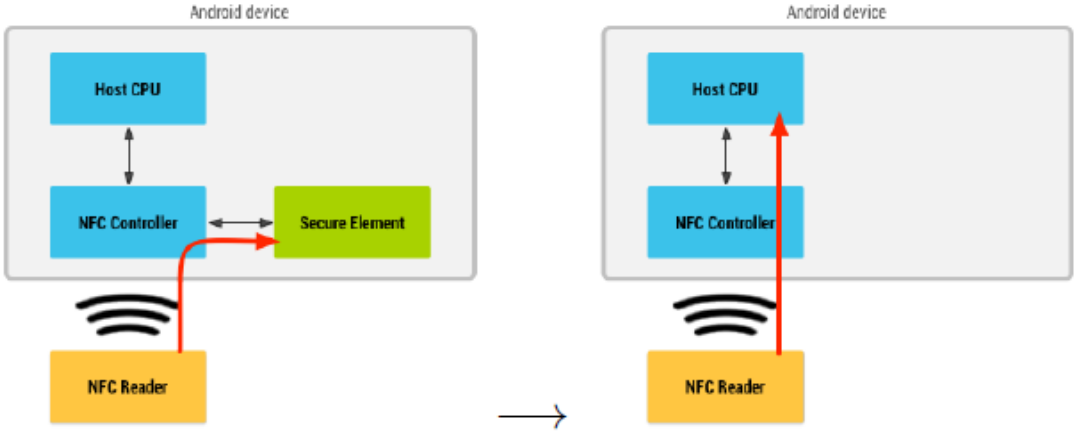
f(x) => LUT(f(x))

f ∘ g ∘ h (x) => LUT(f ∘ g ∘ h (x)) with K hidden

Constant K (as a cryptographic key)

Motivation for White Box in Crypto

- Host Card Emulation (HCE):



- DRM, software protection, mobile payment

Use case: AES as an asymmetric key crypto primitive

	Public key	**Private key**
RSA	(e, N)	(d, p, q)
WBC	Obfuscated program, which implements AES_k: ▶ in: 128-bit plaintext ▶ out: 128-bit ciphertext	k, 128-bit AES key

Variable Data: split or merge

SPLIT : 1 variable => N variables
MERGE : N variables => 1 variable

Listing 6: Split variable

```
1 char b1, b2, b3, b4; // i = b1,b2,b3,b4
2
3 int add(int a) {
4   return a + ((b1 << 8 + b2)
5                  << 8 + b3)
6                  << 8 + b4;
7 }
```

Listing 7: Merged variables

```
1 int i; // i = b1,b2,b3,b4
2 char add_b1(char a) {
3   return a + (i >> 24);
4 }
5 //...
6 char add_b4(char a) {
7   return a + (i & 0xff);
8 }
```

Code : Instruction substitution

Listing 20: Code before Encode Arithmetic

```
1 int main(int ac, char* av[]) {
2   int x = atoi(av[1]);
3   int y = atoi(av[2]);
4   int w = atoi(av[3]);
5   int z = x + y + w;
6   // do stuff
7   return 0;
8 }
```

Listing 21: Code after Encode Arithmetic

```
1 int main(int ac, char* av[]) {
2   int x = atoi(av[1]);
3   int y = atoi(av[2]);
4   int w = atoi(av[3]);
5   int z = (((x ^ y) + ((x & y) << 1)) | w) +
6           (((x ^ y) + ((x & y) << 1)) & w);
7   // do stuff
8   return 0;
9 }
```

Code: Garbage code

Listing 22: Code before inserting garbage code

```
1 int sum = 0;
2 for (i = 0; i < arr_len; i++)
3   sum += arr[i];
4 int average = sum / arr_len;
```

Listing 23: Code after inserting garbage code

```
1 int sum = 0;
2 int prod = 1;
3 for (i = 0; i < arr_len; i++) {
4   sum += arr[i];
5   prod *= arr[i];
6 }
7 int average = sqrt(prod);
8 average = sum / arr_len;
```

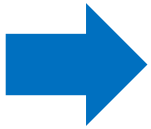
Code: Dead code

```
1   /* Original code */
2   Stmt1; ... Stmtn;
```

```
1   /* With dead code */
2   Stmt1; Stmt2; Stmt3; Stmt4;
3   if (opaque_is_always_true)
4     { /* Alive code */
5       Stmt5; ... Stmtn;
6     }
7   else
8     { /* Dead code */
9       Stmtn+1; ... Stmtm;
10    }
```

Code: flattening

```
int fct(int a, int b)
  int r=-1;
  if (a<b) {
    r=a;
  }
  else {
    if (a==b) {
      r=0;
    }
    else {
      r=b;
    }
  }
  return r;
}
```



```
int flt(int a, int b) {
  int r,x=0;
  while (1) switch (x) {
      case 0: r=-1; x = (a<b)?1:2; break;
      case 1: r=a;  x=5;           break;
      case 2:       x = (a==b)?3:4;break;
      case 3: r=0;  x=5;           break;
      case 4: r=b;  x=5;           break;
      case 5: return r;
  }
}
```

Code : Tiles Loops

```
1    /* Original loop */
2    for(i=0; i<N; ++i){
3       ...
4    }
```

```
1    /* Tiled loop */
2    /* split in blocks of size B */
3    for(j=0; j<N; j+=B)
4      for(i=j; i<min(N, j+B); ++i){
5         ...
6      }
```

Conclusions

- **Many more methods, Refer to:**

Banescu, S., & Pretschner, A. (2018). A tutorial on software obfuscation. *Advances in Computers. Elsevier*.

- **But they are all prone to attack**
- **They just slow down the attack process**
- **With a significant increase in complexity and time**