Applying obfuscation techniques to cipher programs using goal-oriented analysis

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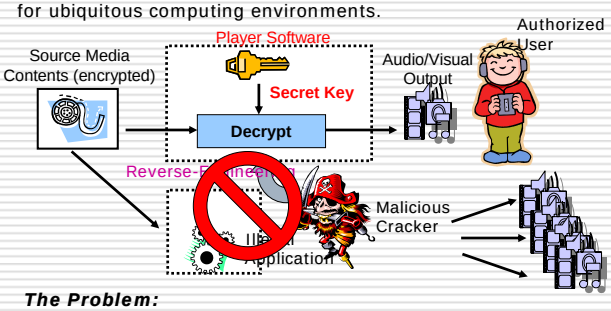
Background

Digital Rights Management (DRM) software (such as iTunes and Windows Media Player) became an important application for ubiquitous computing environments.



The Problem:
Protect the authorized software (esp. Secret Key) from the reverse-engineering by malicious crackers.

Program Obfuscation

A technique of inhibiting the reverse-engineering, transforming a program into an equivalent one that is difficult to understand.

```
int fact=1, upper=16
int  i;
for(i=1;i<=upper;i++){
  fact *= i;
}
printf("%d",fact);
```

Original program [Computing 16!]

obfuscate

```
int a[] = {1,50};
int i=1; LOOP:
if(i!=(a[1]-2)/3)){ a[0]
*= (++i); goto LOOP;
}printf("%d",a[0]);
```

Obfuscated program [Computing 16!]

Effects:

- The obfuscated program preserves the specification of the original program.
- Cracking the obfuscated program requires an expensive cost.

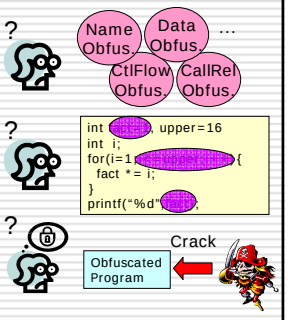
Existing Techniques:

- Name obfuscation
- Control flow obfuscation
- Data obfuscation (Type, Value, Structure)
- Operation obfuscation
- Inter module call relation obfuscation
- Overload induction obfuscation

Problem

There is no systematic method on how to apply obfuscation techniques appropriately.

- Which obfuscation technique should be used?
- Which part of the program should be obfuscated?
- How much effects of obfuscation can be expected?



These problems are caused because the conventional techniques do not count the purpose and target of the cracker.

Research Objective

Establish a goal-oriented analysis framework for proper use of the existing obfuscation techniques.

Key idea

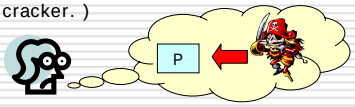
- Assume an imaginary cracker with his purpose and target (i.e., goal).
- Break down the goal into pieces, each of which an appropriate obfuscation is applied to.

Approach

Step1. Determine a capability of an imaginary cracker.
Step2. Identify a cracker's goal.
Step3. Conduct a goal-oriented analysis.
Step4. For every terminal sub-goal, select an obfuscation.
Step5. Apply the selected obfuscations to the program.

Step1. Determine an Imaginary Cracker.

Define a capability model of an imaginary cracker from three viewpoints: knowledge, observation, control (presuming a very skillful cracker.)



Knowledge : What does the cracker know beforehand?
- The cracker has full knowledge of the principles and external specification of a program.

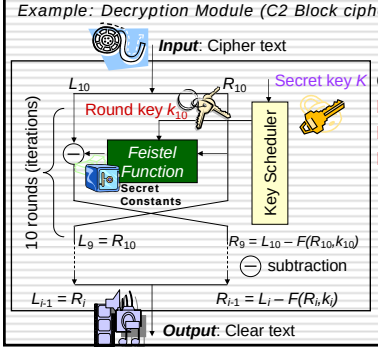
Observation : What can the cracker see in the program?
- The cracker owns a disassembled code of a program.
- The cracker can watch the program states and execution traces.

Control : What can the cracker do for the program?
- The cracker can execute the program with an arbitrary input.
- The cracker can modify the program in any desired way.

Step2. Identify Cracker's Goal

For the given program *P*, define specific goals, for which the cracker reverse-engineer *P*.

Example: Decryption Module (C2 Block cipher [1]*)*



Cracker's Goals (candiates)

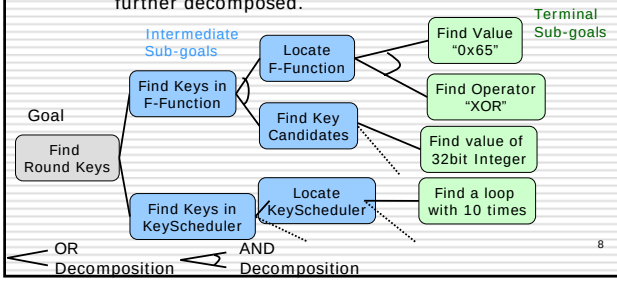
- ☐ **Find Round Keys**
- ☐ Find Secret Key
- ☐ Extract Secret Constants from Feistel Function

[1] 4C Entity, "Content protection for recordable media specification – Introduction and common cryptographic elements," rev. 1.0, 31 pp.1.0, Jan. 2003.

Step3. Conduct a Goal-Oriented Analysis

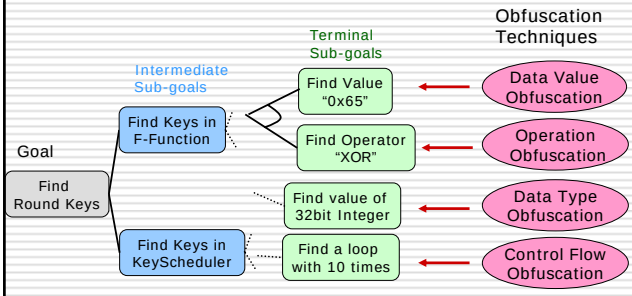
For each goal decided in Step2, decompose and refine the goal into more specific sub-goals.

- Make an AND-OR graph based on Cracker's Capability Model defined in Step1.
- Repeat the decomposition until no sub-goal can be further decomposed.



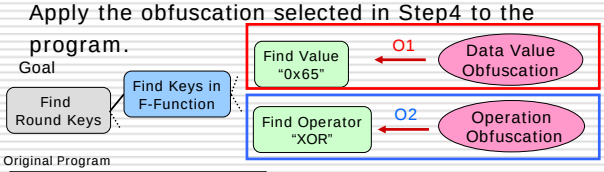
Step4. Select an appropriate obfuscation.

For each terminal sub-goal, select an appropriate obfuscation that can inhibit the sub-goal.



Step5. Apply Selected Obfuscations

Apply the obfuscation selected in Step4 to the program.



Original Program

```
public static int F(int data, int key) {
  :
  u = (byte)(v[0] ^ 0x65);
  :
}
```

O1: Data Value Obfuscation
Replace value "0x65" using homo-morphism f(x) = 2x+1

```
public static int F(int data, int key) {
  :
  int d = 203;
  :
  u = (byte)(v[0] ^ ((d-1)/2));
  :
}
```

```
public static int F(int data, int key) {
  :
  int d = 203;
  :
  u = (byte)(~v[0] & ((d-1)/2)) |
      (byte)((v[0] & ~((d-1)/2))
  :
}
```

O2: Operation Obfuscation
Replace XOR with NOT, AND, OR.

Case study

We have applied the proposed framework to a practical cipher program.

Target program

- A data decryption program using the C2 block cipher[1].
- Comprising 140 lines of Java code.

Cracker's Capability Model

Knowledge: Know C2 algorithm, but does not know keys.
Observation: Watch memory, stack and execution trace.
Control: Use all debugger operations, binary editor, disassembler, decompiler.

Goal

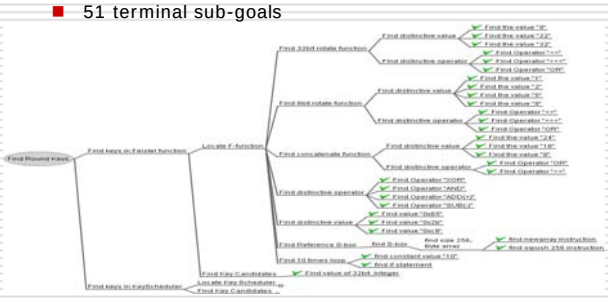
- Find the round key.

[1] 4C Entity, "Content protection for recordable media specification – Introduction and common cryptographic elements," rev. 1.0, 31 pp.1.0, Jan. 2003.

Result of Goal-Oriented Analysis

82 sub-goals have been identified.

- 31 intermediate sub-goals
- 51 terminal sub-goals



We confirmed all the terminal sub-goals can be inhibited by certain obfuscation techniques.

Summary

We have proposed a goal-oriented framework of applying the existing obfuscation techniques.

- Determine the capability model and goal of cracker.
- Using the goal-oriented analysis, decompose the goal into pieces, corresponding to an appropriate obfuscation.

Future Work

- Evaluate the proposed framework with other programs.
- Investigate optimal obfuscation.
  - Dependency analysis among sub-goals.
  - Dependency analysis among obfuscation techniques.

Thank you, That's ALL.