Industrial Approach: Obfuscating Transformations

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17/03/2006

Commercial Obfuscators:

- Semantic Designs: Thicket^{tm} obfuscators
  http://www.semanticdesigns.com/Products/Obfuscators/
- Zelix Klassmaster^{tm} obfuscator
  http://www.zelix.com/klassmaster/
- PreEmptive: DotObfuscator^{tm}
  http://www.preemptive.com/products/dotfuscator/
- Only for Java: at least 26 obfuscators
  http://dmoz.org/Computers/Programming/Languages/Java/Development_Tools/Obfuscators/

Outline

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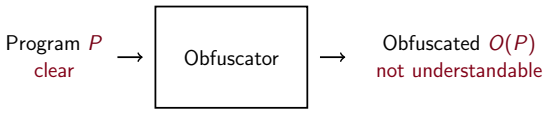
Objectives of Obfuscator



Objectives:

- Make automated analysis difficult
- Make code more complicated
- Make decompilation & reverse engineering difficult
- Make code not readable by human

Anatomy of Obfuscator (1)

How real obfuscator works?

1. Prepares program to be obfuscated
2. Makes a single transformation
3. Repeats **step 2** until task completed or constraints exceeded

Anatomy of Obfuscator (2)

The workflow of obfuscator:

- Parse input program
  - Makes a list of obfuscation candidates: classes, variables, methods
  - Constructs internal representation of the program (e.g. control flow and basic blocks)
  - Makes some appropriateness suggestions
- Main while loop (until constraints are exceeded or quality is achieved)
  - Choose next (by priority) element of the program to be obfuscated
  - Implement appropriate obfuscating transformation (from obfuscator library)
  - Update internal representation

Quality of Obfuscation

How good is obfuscation? Measures:

- Potency
  $\frac{\text{Complexity}(O(P))}{\text{Complexity}(P)}$
- Resilience (irreversibility)
  Weak, strong, one-way
- Cost
  Slowdown, increasing of code size and space requirements
- Stealth
  How similar are introduced obfuscated constructions to the rest of the code

Software Complexity Metrics

How do you define a program code complexity?

- Program length
  Number of operators and operands
- Data flow complexity
  Number of inter-block variable references
- Cyclomatic complexity
  Number of predicates in a function
- Nesting complexity
  Number of nesting level of conditionals in a program
- Data structure complexity
  Complexity of the static data structures in the program like variables, vectors, records
- OO Metrics
  Level of inheritance, coupling, number of methods triggered by another method, non-cohesiveness

Statistical Metrics

Measuring chaos:

- Distribution of opcodes (and any elements of program)
  - Rare elements contain iformation. Replace them by basic instructions
- Clustering (usage of variables, control flow commands)
  - Best of all: no clastering, uniform distribution
- Code patterns
  - Destroy long repeating patterns in program

Cost Analysis

What do we pay for security?

- Costs at creation time
  Obfuscation need time!
- Costs at transmition time (resulting size)
  Inlining library functions may increase size enormously!
- Cost at execution time
  Checking procedures, dummy code, inlining
- Cost by not using efficiency enhancing mechanisms
  Caching is rarely possible; losing module structure

Outline

Top Three Methods

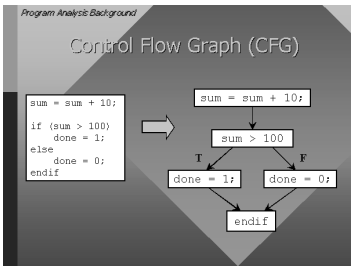
- Renaming variables/procedures/classes/methods
- Deleting comments and spaces (destroying layout)
- Inserting dead code

Data Obfuscation

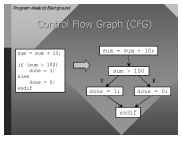
Any ideas for data obfuscation?

- Variable splitting
- Scalar/object conversion
- Static data to procedure
- Change variable lifetime
- Split/fold/merge arrays
- Change encoding
- Merge scalar variables

Control Flow (1)



Control Flow (2)



Compiler theory: program = control flow graph (CFG)

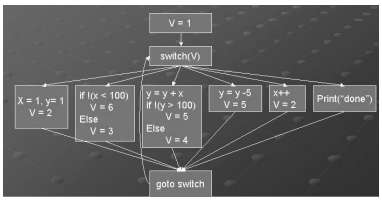
- Node = basic block = straight-line piece of code without any jumps or jump targets
- Directed edges = jumps in the control flow
- Every block: starts from jump target, ends by jump command

Control Flow: Basic Tricks

Any ideas for control flow obfuscation?

- Break basic blocks
- Inline methods
- Outline statements
- Unroll loops
- Reorder statements
- Reorder loops

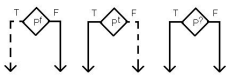
How to Destroy a Control Flow Graph?



1. Write down a list of all basic blocks
2. Split and merge some of them
3. Enumerate them
4. Replace all calls by indirect pointing
5. Write a single dispatcher to maintain all control flow

Opaque Predicates

How can we use IF operator for obfuscation?



Opaque predicates: every time the same value
Difficult to discover by automatical static analysis

Examples:

$$((q + q^2)\ mod\ 2)\ =\ 0$$

$$((q^4)\ mod\ 16)\ =\ 0 \text{ OR } ((q^4)\ mod\ 16)\ =\ 1$$

Functions Unifying

How can we make program procedures indistinguishable?

Idea:

- Merge all functions to one
- Call universal function with additional parameter

Difficulty: different signatures (input-output specifications)

Solution: unify signatures (in groups)

Even more transformations

Question: Can you invent more?

- Reuse identifiers
- Introduce misleading comments :-)
- Modify inheritance relations
- Convert static data to procedural data
- Store part of the program as a text and interpret it only during runtime
- Remove library calls
- Protection aginst specific decompiling tools

Current Techniques: Pro and Contra

Advantages:

- ✔ Easy to implement
- ✔ Universal
- ✔ Good against static analysis

Disadvantages:

- ✘ No guaranteed security
- ✘ Even no hope for that
- ✘ Weak against dynamic attacks

Summary

Main points:

- Obfuscator workflow: parse the program; apply transformations until the cost is exceeded
- Obfuscating transformations consist of layout, data and control tricks
- Hardness of deobfuscation is not proved

Course Conclusion

Why programming people like code obfuscation so much?

Programming: CONSTRUCTIVE process

Obfuscation: DESTRUCTIVE process

Reading List

C. Collberg, C. Thomborson, D. Low
A taxonomy of obfuscating transformations, 1997.
http://www.cs.arizona.edu/people/collberg/Research/Publications/CollbergThomborsonLow97a/A4.ps.

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A tentative approach to constructing tamper-resistant software, 1998.
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Obfuscation of executable code to improve resistance to static disassembly, 2003.
http://www.cs.arizona.edu/~linnc/research/CCS2003.pdf.

Thanks for attention. Questions?

Course Feedback

1. Comments/suggestions on contents:
   - Choice of topics? Ratio of theoretical/practical?
2. Comments/suggestions on presentation aspects:
   - Your opinion on slides? Black board explanation? Language mistakes?
3. Comments/suggestions on technical aspects:
   - Timetable of the course? Webpage? Room? Announcement?
4. Main advantage of the course (if any)?
   - Best lecture in your opinion?
5. Disatvantages. What and how can be improved?