Fingerprinting and Cracking Java Obfuscated Code

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A total of 36 slides

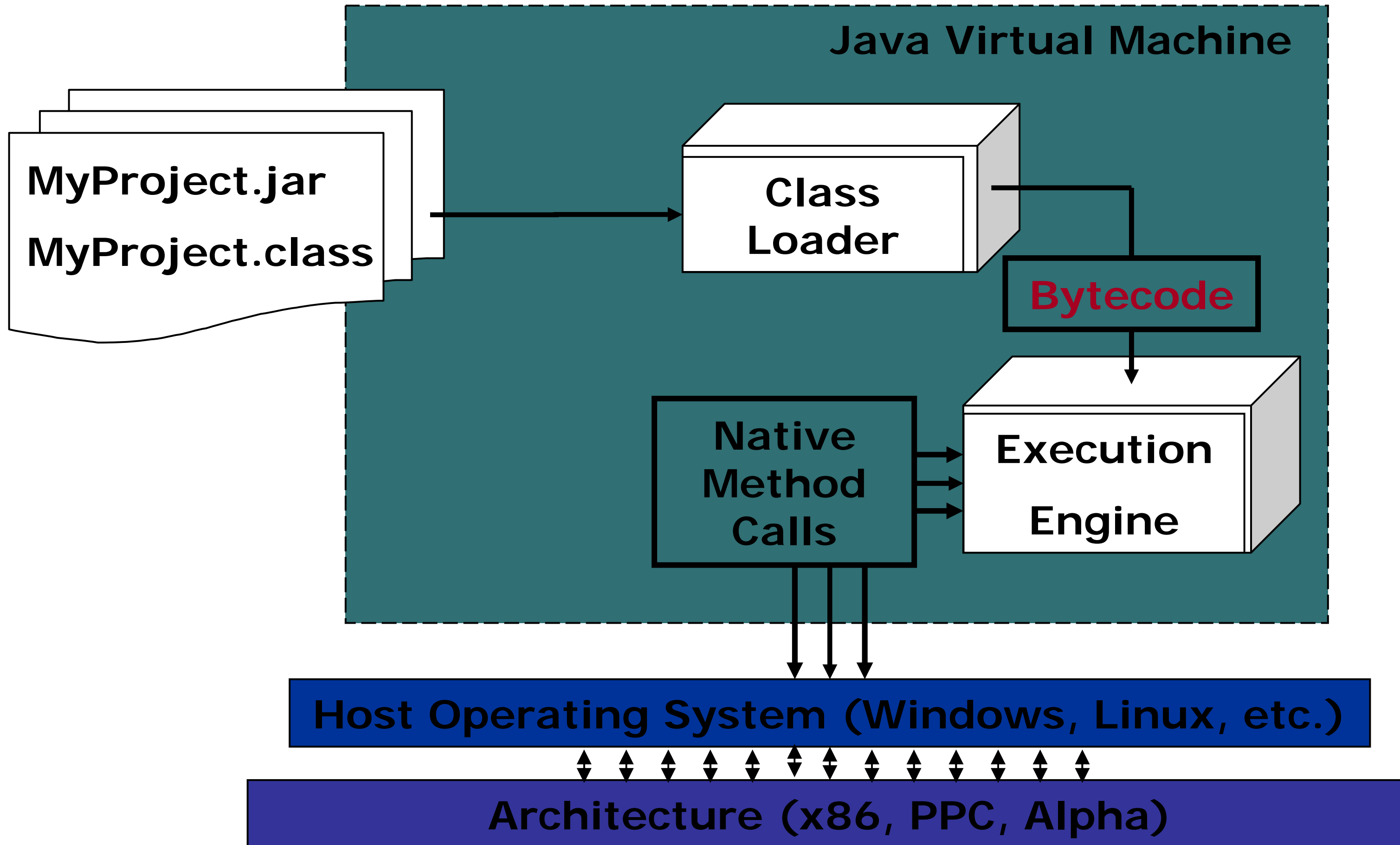
Brief Outline

1. Background
2. Motivation
3. Methodology
4. Fingerprinting Tool
5. Examples
6. Conclusions

1. Background

- Java Bytecode Operations
- Language Security Mechanisms
- Disassembling HelloWorld.java
- From Bytecode to Source
- What Popular Obfuscators Offer?

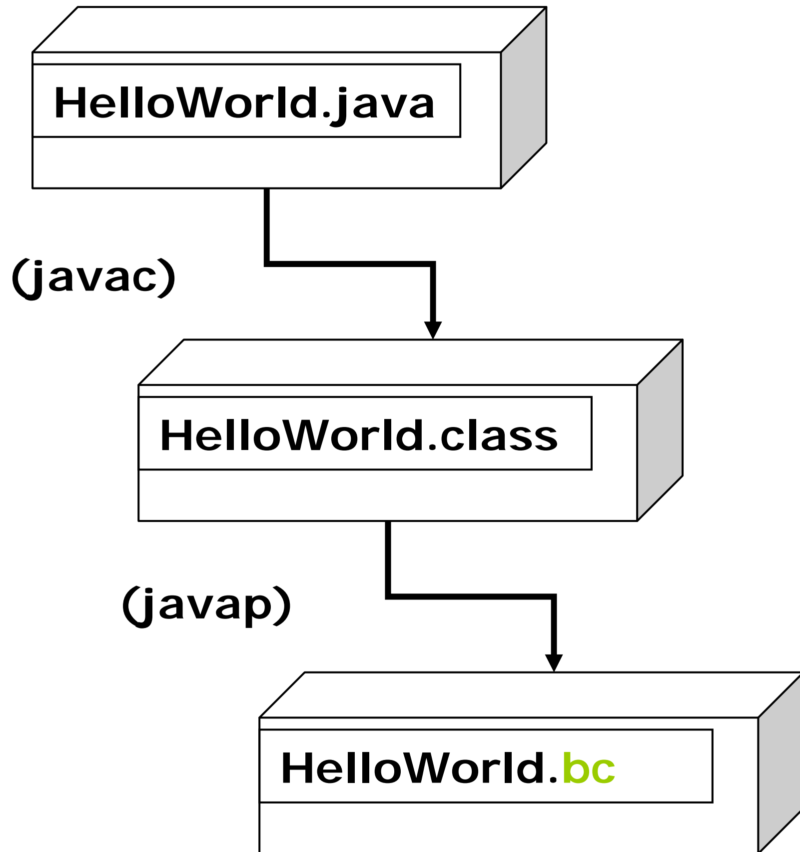
1.1 Java Bytecode



1.2 Language Security Mechanisms

- Type, memory and control flow checks
  - Instruction sets of the virtual machine [1]
    - Object creation
      - Privilege escalation [2]
    - Function calls
    - Exception handling
  - Verification (format, type, other violations) [3]
    - Security vulnerabilities lsd-pl.net [4]

1.3 HelloWorld in Bytecode




```
>more src\HelloWorld.java
public class HelloWorld {
        public static void main(String[] args) {
                System.out.println("Hello World");
        }
}
```

```
SourceFile☺
☼HelloWorld.java♀
♂
♀
←♀
∟
↑☺
♀Hello World
▲♀
▼
```

```
  Code:
   0:   aload_0
   1:   invokespecial   #1; //Method java/lang/Object.
   4:   return

public static void main(java.lang.String[]);
  Code:
   0:   getstatic       #2; //Field java/lang/System.o
   3:   ldc     #3; //String Hello World\n
   5:   invokevirtual   #4; //Method java/io/PrintStre
ing;)V
   8:   return
```

1.4 Bytecode to Source

- Java is Platform Independent Code
  - Simplifies reversing compared to C/C++
- Popular Java Decompilers [5]

Tool	License	Update
DJ Decompiler	Free to try	2007
JAD	Free for noncommercial use	2006
JODE	GNU Public License	2004
Mocha	Free	2001

- Particular obfuscators are written with the operations of java Decompilers in mind [6]

1.5 What do obfuscators offer?

- Operations:
  - Less Human Readable Code
  - Remove Debug Information
  - Alter the Control Flow
  - “Encrypt” Constants
  - Restructure Simple Logic
  - Inject Unnecessary Code
- Usability:
  - Used for applications that are delivered to the user
  - Generally, used in J2SE Applets, Installed Applications, etc.
  - Generally, not used in Java Enterprise Environments

2. Motivation

- Basic Obfuscation Techniques
- Reverse Engineering Particulars
- Who is Using Obfuscators?

2.1 Basic Obfuscation Techniques

"Obfuscation is possible for the same reasons that decompiling is possible" [7]

- Renaming of objects and methods
  - a.class, b.class, a.c(5), etc.
- Extending classes
  - public class a extends d {
- Removing line numbers
- Encoding String Values
- Variable Splitting Techniques
  - boolean z becomes int x=1; if (x < 0)

2.2 Reverse Engineering Particulars

- Obtain Application Code
- Extract/Review Class Files
- Quickly Establish:
  - Renamed files
  - Missing debug info
  - Unnecessary code present
  - Potential code optimization

2.3 Who is Using Obfuscators?

- Let us have a quick browse…

3. Methodology

- A Taxonomy of obfuscating transforms
- String and constant representation
- Uniformity across the code base
- Kirchoff’s principle reversed
- Obfuscation encryption levels

3.1 Taxonomy of Obfuscating Transforms

Data Obfuscation	Layout Obfuscation	Control Obfuscation	Preventive Obfuscation
Split Variables	Scramble Identifiers	Clone Methods	Exploit Weaknesses in Current Decompilers and Deobfuscators
Promote Scalars to Objects	Change formatting	Reorder Statements and Loops	Explore inherent problems with known deobfuscation techniques
Inheritance Relations	Remove Comments, Line Numbers	Reducible to Non-reducible Flow Graphs	
Change Encoding	Remove Debug Information	Extend Loop conditions	
Split, Fold, Merge Arrays		Outline Statements	
Reorder Instance Variables			

Source: [8]

3.2 String and Constant Representation

- The Perfect Entry Point!

- Identifying Strings while Reversing:
  - Yields Architecture
  - Yields Design Patterns
  - Hard-coded Constants

```
1  private static final
2    String password =
3      "ThisIsMyPassword";
4  ...
5  if(args[0].equals(password))
6    System.out.
7      println("Password Correct!");
8  ...
9  =======================================
10 if(args[0].equals(z[2]))
11             System.out.println(z[1]);
12 ...
13 String as[] = new String[4];
14     as;
15     as[0] = "q@DX\027NSS\013%SSXY";
```

3.3 Uniformity Across the Code Base

- Typically, obfuscation is uniform across the code base
- Understanding how UI and IO operations are obfuscated is key to cracking
- Design patterns and used structures (e.g. Vectors, Lists, FILOs) are also key
- Generally, obfuscators do not offer more than a handful of options for a transform

3.4 Kirchoff's Principle Reversed

- Obfuscation aims to make the code harder to interpret
- The equivalent of a known plaintext attack in a cryptosystem
- Becomes a known code attack for an obfuscator
- Using the obfuscator as a black box, assess the level of leet it offers

3.5 Obfuscation Encryption Levels

- Non-existent
  - Difficult to implement
  - Of little benefit: The bytecode has to run!
- No public/private crypto offered
  - Can it be implemented?
- String encryption uses XOR type operations
  - CPU and memory usage factors

4. Fingerprinting Tool

- Calibration Check
- Developing elucidate
- List of Available Flags
- Target Deliverables of elucidate

4.1 Calibration Check

- Depending on the obfuscation transform we intend to identify
- Attempt to generate generic definitions within a test class
- Objective: Capture the obfuscator’s fingerprint

```
1  package elucidate;
2
3  public class PasswordCheck {
4    private static final String password = "ThisIsMyPassword";
5
6    private static final String check =
7        "\000\001\002\003\004\005\006\007\008\009\010\011\012" +
8        "\013\014\015\016\017\018\019\020\021\022\023\024\025" +
9        "\000\001\002\003\004\005\006\007\008\009\010\011\012" +
10       "\013\014\015\016\017\018\019\020\021\022\023\024\025";
11
12   public static void main(String[] args) {
13     if(args.length != 1) {
14       System.out.println(check);
15       System.exit(1);
16     }
17     if(args[0].equals(password)) {
18       System.out.println("Password Correct!");
19     }
20     else {
21       System.out.println("Password Error");
22     }
23
24   }
25 }
```

4.2 Developing elucidate

- Build Calibration Classes for Particular Obfuscation Transforms
- Obtain Fingerprints for Particular Obfuscators
- Check the Generality and Overlap with other Obfuscators of that Fingerprint
- Include Results in elucidate

4.3 List of available flags

- >**perl elucidate.pl -h**

- Elucidate v0.1 - Java Obfuscator Fingerprinting/Cracking Tool
- Usage: elucidate.pl [-options *]

- -h : Print this usage message
- -v : Verbose option
- -o : Print supported obfuscators
- -t : Test current java environment
- **-f file : Specify class file to identify**
- **-j jar file : Specify jar file to identify**
- -d directory : Specify directory to identify

- Examples:

- elucidate.pl -f MyClass.class
- elucidate.pl -d MyJar.jar

4.4 Target Deliverables of elucidate

- Given a jar file, or class files
- Identify which obfuscator has been used
- Recover known Strings within the file

- Give an estimate of the complexity
- Provide a map, as a tool of the application

5. Examples

- Examine the following commercial tools:
  - Zelix KlassMaster (4.5.0)
  - JShrink (2.3.7)
  - RetroGuard (2.2.0)

5.1 Zelix KlassMaster 4.5.0 (1/4)

- String literals three levels: Normal, Aggressive and Flow Obfuscate.
- PasswordCheck.class through javap:

```
 6 :    ldc   #8; //String ,bw:)   q`i   qv,=   \"
14 :    ldc   #6; //String (km:N}?ps&,
22 :    ldc   #3; //String ,oa(-↓#w<.♀o}i?...
30 :    ldc   #9; //String ,bw:)!!q`i←♫qk;
```

5.1 Zelix KlassMaster 4.5.0 (2/4)

- Output in Unicode format
- Special characters such as \n \b …
- Unicode octal (\777)
- Unicode hexadecimal (\FFFF)

5.1 Zelix KlassMaster 4.5.0 (3/4)

- Uses XOR operation with five keys:
- 124, 3, 4, 73, 94
- -Original: ,bw:)‼q`i↔‼qv,"
- ->Decoded: Password Correct!

```
•    64:  tableswitch{ //0 to 3
•                        0: 96;
•                        1: 101;
•                        2: 105;
•                        3: 109;
•                        default: 114 }
•      96:bipush         124
•      98:goto           116
•      101:              iconst_3
•      102:              goto       116
•      105:              iconst_4
•      106:              goto       116
•      109:              bipush     73
•      111:              goto       116
•      114:              bipush     94
•      116:              ixor
•      117:              i2c
```

5.1 Zelix KlassMaster 4.5.0 (4/4)

- String literals: Normal, Aggressive and Flow Obfuscate.
- The algorithm used for all three appears to be identical.
- Yet, the keys used, change at every obfuscation attempt.

5.2 JShrink 2.3.7 (1/4)

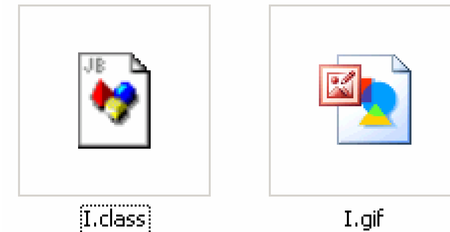
- Creates a new package, with a single class
- Replaces String code with:

```
23:  bipush  62
25:  invokestatic    #48; //Method
  I/I.I:(I)Ljava/lang/String;
28:  invokevirtual   #7; //Method
  java/lang/String.equals:(Ljava/lang/Object;)Z
```

- Equivalent to: `( I.I.I( 79 ) );`

5.2 JShrink 2.3.7 (2/4)

- Contents of package I include a file called I.gif
- However, this file is not an image file:




```
Untitled - Notepad
File  Edit  Format  View  Help
00000000h: 00 00 6F 53 6F 6E 6D 6C 6B 6A 69 68 6F 57 6F 56 ; ..oSonmlkjihoWoV
00000010h: 67 66 65 64 63 62 61 60 6E 57 6E 56 7F 7E 7D 7C ; gfedcba`nWnV□~}|
00000020h: 7B 7A 6F 6E 6D 6C 6B 6A 69 68 6F 57 6F 56 67 66 ; {zonmlkjihoWoVgf
00000030h: 65 64 63 62 61 60 6E 57 6E 56 7F 7E 7D 7C 7B 7A ; edcba`nWnV□~}|{z
00000040h: 7F 3B 07 06 1C 26 1C 22 16 3F 0E 1C 1C 18 00 1D ; □;...&.".?......
00000050h: 0B 7E 3F 0E 1C 1C 18 00 1D 0B 4F 2C 00 1D 1D 0A ; .~?.......O,....
00000060h: 0C 1B 4E 61 3F 0E 1C 1C 18 00 1D 0B 4F 2A 1D 1D ; ..Na?.......O*..
00000070h: 00                                              ; .
```

- As a file is being accessed, a decompiler can be used to view I.class

5.2 JShrink 2.3.7 (3/4)

```
1.  public class I {
2.    …
3.    public static synchronized final String I(int int1){
4.      int int2 = int1 & 0xFF;
5.      if( close[int2] != int1 ) {
6.        String String3;
7.        close[int2] = int1;
8.        if( int1 < 0 ) {
9.          int1 = int1 & 0xFFFF;
10.         String3 = new String( SDQU, int1, SDQU[int1 - 0x1] & 0xFF ).intern();
11.         append[int2] = String3;
12.       }
13.       return append[int2];
14.     }
15. …
16. static {
17.       try {
18.         Object Object1 = new I().getClass().getResourceAsStream( "" + 'I' + '.' + 'g'
    + 'i' + 'f' );
```

5.2 JShrink 2.3.7 (4/4)

- Creates an invalid gif file storing the encrypted Strings
- Uses a separate class and method to perform decryption
- Replaces Strings with: I.I(int) e.g. I.I(97)
- Does not alter Strings declared as static and final
- Introduces exceptions if the wrong int is passed as argument

5.3 RetroGuard 2.2.0

- Does offer String encryption
- Goes to show that some obfuscators simply don’t use this approach
- The creators of RetroGuard quote: “obfuscation is not encryption”

6. Conclusions

- Static obfuscation is at a primitive level
- Encrypted Strings are an excellent entry point into understanding the application
- Identifying the crypto used:
  - yields the obfuscator tool used
  - yields what changes to expect in snippets

6. Final Conclusions

- Propose polymorphic obfuscation
  - Developers map out critical elements
    - Understanding of what an obfuscator can do
  - Obfuscator changes behaviour depending on file
    - UI treated differently to say, protocol implementation
  - Algorithms vary according to key file
    - In how many ways can you write a for/while loop?

Questions

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