Mind your Language(s)!
A discussion about languages and security

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LangSec Workshop @ IEEE SSP, 2014-05-18
ANSSI (French Network and Information Security Agency) has InfoSec (and no Intelligence) missions:

▶ detect and early react to cyber attacks
▶ prevent threats by supporting the development of trusted products and services
▶ provide reliable advice and support
▶ communicate on information security threats and the related means of protection

These missions concern:

▶ governmental entities
▶ companies
▶ the general public
Foreword

What this presentation is about

- the impact of the language on security properties is understudied
- it covers a broad spectrum of subjects

- since 2005, two studies: JavaSec and LaFoSec
- each time, our partners that did not at first share (or even understand) our concerns

- the following examples do not aim at criticising particular languages
- no language was harmed during our work\(^1\)

\(^1\)They were already like that when we began.
Outline

1 Illustrations

2 About assurance

3 Lessons learned
1 Illustrations
   - Encapsulation
     - Types, casts and overloading
     - Side effects
     - No comments
     - From source code to execution
Object encapsulation: a security mechanism?

Source (java/Introspect.java)

```java
import java.lang.reflect.*;
class Secret { private int x = 42; }
public class Introspect {
    public static void main (String[] args) {
        try {
            Secret o = new Secret();
            Class c = o.getClass();
            Field f = c.getDeclaredField("x");
            f.setAccessible(true);
            System.out.println("x =" + f.getInt(o));
        }
        catch (Exception e) {
            System.out.println(e);
        }
    }
}
```

- Some keyword may be confusing
- Even if possible, introspection can not easily be banned in practice
OCaml also has encapsulation mechanisms: modules

Source (ocaml/hsm.ml)

```ocaml
module type Crypto = sig val id:int end ;;

module C : Crypto =
struct
  let id=Random.self_init(); Random.int 8192
  let key=Random.self_init(); Random.int 8192
end ;;
```

It is a sealed box, where id is visible, but not key

C.id returns - : int = 2570

C.key returns Error: Unbound value C.key
Yet this encapsulation is not robust, since the box can be compared on a weighing scale

**Source (ocaml/hsmoracle.ml)**

```ocaml
let rec oracle o1 o2 =
  let o = (o1 + o2)/2 in
  let module O = struct let id=C.id let key=o end in
  if (module O: Crypto) >( module C: Crypto )
  then oracle o1 o
  else (if (module O: Crypto) <( module C: Crypto )
    then oracle o o2
    else o) ;;  

oracle 0 8192;;
```
1 Illustrations

- Encapsulation
- Types, casts and overloading
- Side effects
- No comments
- From source code to execution
How many value a boolean condition (e.g. $x=y$) can take?

Source (shell/login.sh)

```bash
#!/bin/bash
PIN=1234
echo -n "Please type your PIN code (4 digits): 
read -s PIN_TYPED; echo

if [ "$PIN" -ne "$PIN_TYPED" ]; then
    echo "Invalid PIN code."; exit 1
else
    echo "Authentication OK"; exit 0
fi
```
How many value a boolean condition (e.g. \( x=y \)) can take?

In shell, the following excerpt shows a third option should be treated. A bad PIN will be rejected, but "foo" will be accepted.
A recent vulnerability on GnuTLS may now sound familiar (March 2014, lwn.net)

But this bug is arguably much worse than Apple’s, as it has allowed crafted certificates to evade validation check for all versions of GnuTLS ever released since that project got started in late 2000.[...]
The check_if_ca function is supposed to return true (any non-zero value in C) or false (zero) depending on whether the issuer of the certificate is a certificate authority (CA). A true return should mean that the certificate passed muster and can be used further, but the bug meant that error returns were misinterpreted as certificate validations.
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The same flaw was pre-existant in OpenSSL… in 2008
Source (js/cast2.js)

```javascript
if ('0'==0) print("'0'==0");
else print("'0'<>0");
if (0=='0.0') print("0=='0.0'");
else print("0<>'0.0'");
if ('0'=='0.0') print("'0'=='0.0'");
else print("'0'<>'0.0'");
```
if ('0'==0) print("'0'==0");
else print("'0'<>0");
if (0=='0.0') print("0=='0.0'");
else print("0<>'0.0'");
if ('0'=='0.0') print("'0'=='0.0'");
else print("'0'<>'0.0'");

'0'==0, 0=='0.0' et '0'<>'0.0'
Source (js/cast2.js)

```javascript
if ('0'==0) print("'0'==0");
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if (0=='0.0') print("0=='0.0'");
else print("0<>'0.0'");
if ('0'=='0.0') print("'0'=='0.0'");
else print("'0'<>'0.0'");
```

'0'==0, 0==’0.0’ et ’0’<>’0.0’

Source (js/cast3.js)

```javascript
a=1; b=2; c='Foo';
print(a+b+c); print(c+a+b); print(c+(a+b));
```
Source (js/cast2.js)

```javascript
if ('0'==0) print("'0'==0");
else print("'0'<>0");
if (0=='0.0') print("0=='0.0'");
else print("0<>'0.0'");
if ('0'==0.0) print("'0'==0.0");
else print("'0'<>0.0");
```

'0'==0, 0==0.0 et '0'<>0.0

Source (js/cast3.js)

```javascript
a=1; b=2; c='Foo';
print(a+b+c); print(c+a+b); print(c+(a+b));
```

3Foo, Foo12 and Foo3
$x = "2d8"; print($x + 1); print("\n");

$x = "2d8"; print(++$x."\n"); print(++$x."\n"); print(++$x."\n");

if ("0xF9" == "249") { print("Equal\n"); } else { print("Different\n"); }
```php
$x = "2d8"; print($x+1); print("\n");

$x = "2d8"; print(++$x."\n"); print(++$x."\n"); print(++$x."\n");

if ("0xF9" == "249") { print("Equal\n"); } else { print("Different\n"); }
```

The first line produces 3 (an int)
The first line produces \texttt{3} (an int)

The second displays \texttt{2d9} (string), \texttt{2e0} (string) then \texttt{3} (float).
Source (php/castincr.php)

```
$x = "2d8"; print($x+1); print("\n");

$x = "2d8"; print(++$x."\n"); print(++$x."\n"); print(++$x."\n");

if ("0xF9" == "249") { print("Equal\n"); } else { print("Different\n"); }
```

The first line produces 3 (an int)

The second displays 2d9 (string), 2e0 (string) then 3 (float).

The third prints Equal
This may lead to security concerns

Source (php/hash.php)

```php
$s1 = 'QNKCDZO'; $h1 = md5($s1);
$s2 = '240610708'; $h2 = md5($s2);
$s3 = 'A169818202'; $h3 = md5($s3);
$s4 = 'aaaaaaaaaaaaaumdozb'; $h4 = md5($s4);
$s5 = 'badthingsrealmlavznik'; $h5 = sha1($s5);

if ($h1 == $h2) print("Collision\n");
if ($h2 == $h3) print("Collision\n");
if ($h3 == $h4) print("Collision\n");
if ($h4 == $h5) print("Collision\n");
```
This may lead to security concerns

Source (php/hash.php)

```php
$s1 = 'QNKCDZO'; $h1 = md5($s1);
$s2 = '240610708'; $h2 = md5($s2);
$s3 = 'A169818202'; $h3 = md5($s3);
$s4 = 'aaaaaaaaaaaaaumdozb'; $h4 = md5($s4);
$s5 = 'badthingsrealmlavznik'; $h5 = sha1($s5);

if ($h1==$h2) print("Collision\n");
if ($h2==$h3) print("Collision\n");
if ($h3==$h4) print("Collision\n");
if ($h4==$h5) print("Collision\n");
```

Collision is printed 4 times, but we did not break MD5 nor SHA1
1 Illustrations
  - Encapsulation
  - Types, casts and overloading
  - Side effects
    - No comments
    - From source code to execution
We all know this example and what happens with `abs(x++)`

### Source (c/strategy1-abs.c)
```c
#define abs(X) (X) >=0?( X):( -X)
```

What will the following code do?

### Source (c/strategy3.c)
```c
int zero(int x) { return 0; }
int main(void) { int x=0; x=zero(1/x); return 0; }
```
We all know this example and what happens with `abs(x++)`

Source (c/strategy1-abs.c)

```c
#define abs(X) (X) >=0?(X):(-X)
```

What will the following code do?

Source (c/strategy3.c)

```c
int zero(int x) { return 0; }
int main(void) { int x=0; x=zero(1/x); return 0; }
```

It depends on the optimisation level:

- `-O0`: Floating point exception (core dumped)
- `-O1`: normal termination
In OCAML, code is static and strings are mutable. What about strings appearing in code?

```ocaml
let check c =  
  if c then "OK" else "KO";;

let f=check false in  
  f.[0]<-’O’; f.[1]<-’K’;;

check true;;  
check false;;
```
In OCaml, code is static and strings are mutable. What about strings appearing in code?

Source (ocaml/mutable.ml)

```ocaml
let check c =  
  if c then "OK" else "KO";;

let f = check false in
  f.[0]<-’0’; f.[1]<-’K’;;

check true;;
check false;;
```

Both `check` calls return "OK"
In OCaml, code is static and strings are mutable. What about strings appearing in code?

Source (ocaml/mutable.ml)

```ocaml
let check c =  
  if c then "OK" else "KO";;

let f = check false in
  f.[0] <- 'O'; f.[1] <- 'K';;

check true;;
check false;;
```

Both `check` calls return "OK"

Such mutable shared strings may be used to determine control flow, or to escape characters (Char.escaped)
Python allows for comprehension lists, which is another syntax for a `map` application

```python
>>> l = [s+1 for s in [1, 2, 3]]
>>> l
[2, 3, 4]
```

Now, what is the value of `s`?
Python allows for comprehension lists, which is another syntax for a map application.

Source (python/listcomp.py)

```python
>>> l = [s+1 for s in [1,2,3]]
>>> l
[2, 3, 4]
```

Now, what is the value of \( s \)?

Unless you use Python 3, \( s \) is 3, whereas the \( s \) variable should have been local (bound).
1. Illustrations
   - Encapsulation
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No comments?

Syntax matter...

Source (c/comments2.c)

```c
#include <stdio.h>

int main(void) {

    // /!* DO NOT REMOVE COMMENTS IN NEXT BLOCK */!*
    /**************************************************************************************
        const char status[]="Safe";
    // /!* SET TO SAFE ONLY FOR TESTS */!*
    **************************************************************************************

    // /!* NEXT LINE REALLY IMPORTANT */!*
        const char status[]="Unsafe";
        printf("Status: %s\n",status);
}
```

- C trigrams
- UTF-8 characters / encoding allowed in JAVA
Outline

1 Illustrations
   ■ Encapsulation
   ■ Types, casts and overloading
   ■ Side effects
   ■ No comments
   ■ From source code to execution
This particular undefined behavior led to an optimisation, which is now known as CVE-2009-1897.
import java.io.*;
class Friend { } // Unlikely to be dangerous!
class Deserial {
    public static void main (String[] args)
        throws FileNotFoundException, IOException, 
            ClassNotFoundException {
        FileInputStream fis = new FileInputStream("friend");
        ObjectInputStream ois = new ObjectInputStream(fis);
        Friend f=(Friend)ois.readObject();
        System.out.println("Hello world");
    }
}
import java.io.*;
class Friend { } // Unlikely to be dangerous!
class Deserial {
    public static void main (String[] args)
        throws FileNotFoundException, IOException, ClassNotFoundException {
        FileInputStream fis = new FileInputStream("friend");
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        Friend f=(Friend)ois.readObject();
        System.out.println("Hello world");
    }
}
import java.io.*;
class Friend { } // Unlikely to be dangerous!
class Deserial {
    public static void main (String[] args)
        throws FileNotFoundException, IOException, ClassNotFoundException {
            FileInputStream fis = new FileInputStream("friend");
            ObjectInputStream ois = new ObjectInputStream(fis);
            Friend f=(Friend)ois.readObject();
            System.out.println("Hello world");
        }
}
Some concerns about memory management

When dealing with interpreted languages and Garbage collectors

- what `chmod -x` does?
- can the memory pages be marked as non-exeutable?
- how can we really enforce $W \land X$?
- what does a JIT compiler change?

- how can I be sure a data is not spread by a \textit{mark and copy} strategy?
- can I have guarantees on a key lifetime?
- can I zeroise it in some way?
Outline

1. Illustrations
2. About assurance
3. Lessons learned
The official JAVA specification about Object.clone()

The general intent is that, for any object $x$, the expression:

$x$.clone()!=$x$ will be true, and that the expression:

$x$.clone().getClass()== $x$.getClass() will be true, but these are not absolute requirements. While it is typically the case that:

$x$.clone().equals($x$) will be true, this is not an absolute requirement.

Serialisation specifications (writeObject and readObject functions) are also worth reading.
In “The C programming language (Second edition)”, by B. W. Kernighan & D. M. Ritchie

The direction of truncation for / and the sign of the result for % are machine-dependent for negative operands, as is the action taken on overflow or underflow.

How would you check that a compiler complies to this non-deterministic specification?
In “The C programming language (Second edition)”, by B. W. Kernighan & D. M. Ritchie

The direction of truncation for \(/\) and the sign of the result for \(\%\) are machine-dependent for negative operands, as is the action taken on overflow or underflow.

How would you check that a compiler complies to this non-deterministic specification?

Would your check reject a compiler changing its mind at each division, which would lead to \(1/-2==1/-2\) being false. This is an instance of the Refinement Paradox
Outline

1. Illustrations
2. About assurance
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Lessons learned

- Programming languages can impact software security
- There is room for improvement in them
- We could benefit from more research and tools

- Writing secure software requires a broad vision in many aspects of computer science
- Teaching should take more those aspects into account
Questions?

Thank you for your attention

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