

# Automata and Formal Languages (9)

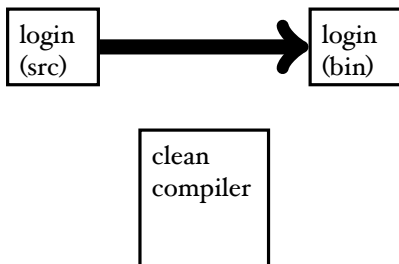
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Slides: KEATS (also home work is there)

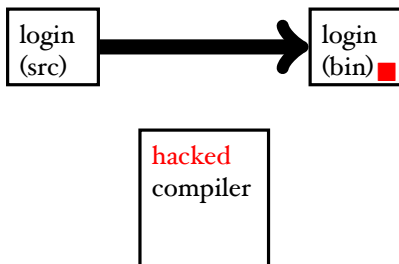
**Using a compiler,  
how can you mount the  
perfect attack against a system?**

# What is a **perfect** attack?

- 1 you can potentially completely take over a target system
- 2 your attack is (nearly) undetectable
- 3 the victim has (almost) no chance to recover

clean  
compiler





my compiler (src)



Scala

host language

my compiler (src)

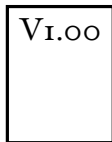


Scala



Scala

...



Scala

host language



my compiler (src)

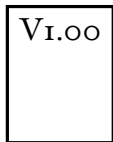


Scala

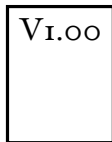


Scala

...

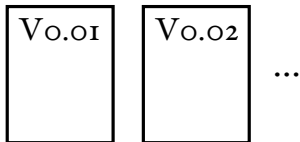


Scala



host language

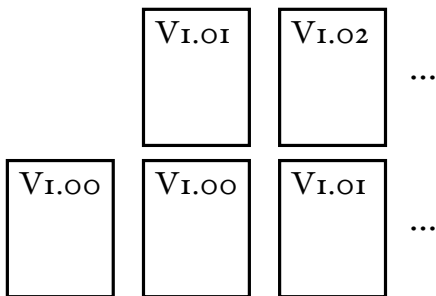
my compiler (src)



Scala

Scala

host language



Scala

no host language  
needed

# Hacking Compilers



Ken Thompson  
Turing Award, 1983

- Ken Thompson showed how to hide a Trojan Horse in a compiler **without** leaving any traces in the source code.
- No amount of source level verification will protect you from such Thompson-hacks.
- Therefore in safety-critical systems it is important to rely on only a very small TCB.

# Hacking Compilers



Ken Thompson  
Turing Award, 1983



- 1) *Assume you ship the compiler as binary and also with sources.*
- 2) *Make the compiler aware when it compiles itself.*
- 3) *Add the Trojan horse.*
- 4) *Compile.*
- 5) *Delete Trojan horse from the sources of the compiler.*
- 6) *Go on holiday for the rest of your life. ;o)*

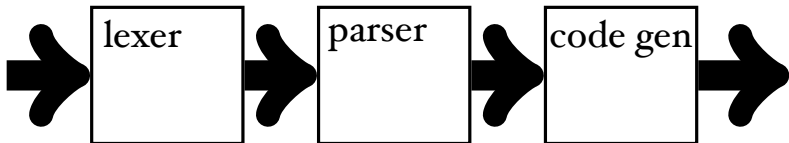
# Hacking Compilers



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# Our Compiler



lexer input: string

lexer output: sequence of tokens  
(white space and comments filtered out)

parser output: abstract syntax tree

code gen output: assembler byte code /  
assembler machine code

# For-Loops

for  $Id := AExp$  upto  $AExp$  do  
*Block*

```
for i := 2 upto 4 do {  
  write i  
}
```

# While-Language

*Stmt* → skip  
| *Id* := *AExp*  
| if *BExp* then *Block* else *Block*  
| while *BExp* do *Block*  
| write *Id*  
| read *Id*

*Stmts* → *Stmt* ; *Stmts*  
| *Stmt*

*Block* → {*Stmts*}  
| *Stmt*

*AExp* → ...

*BExp* → ...



# Interpreter

$\text{eval}(n, E)$	$\stackrel{\text{def}}{=} n$
$\text{eval}(x, E)$	$\stackrel{\text{def}}{=} E(x) \quad \text{lookup } x \text{ in } E$
$\text{eval}(a_1 + a_2, E)$	$\stackrel{\text{def}}{=} \text{eval}(a_1, E) + \text{eval}(a_2, E)$
$\text{eval}(a_1 - a_2, E)$	$\stackrel{\text{def}}{=} \text{eval}(a_1, E) - \text{eval}(a_2, E)$
$\text{eval}(a_1 * a_2, E)$	$\stackrel{\text{def}}{=} \text{eval}(a_1, E) * \text{eval}(a_2, E)$
$\text{eval}(a_1 = a_2, E)$	$\stackrel{\text{def}}{=} \text{eval}(a_1, E) = \text{eval}(a_2, E)$
$\text{eval}(a_1 \neq a_2, E)$	$\stackrel{\text{def}}{=} \neg(\text{eval}(a_1, E) = \text{eval}(a_2, E))$
$\text{eval}(a_1 < a_2, E)$	$\stackrel{\text{def}}{=} \text{eval}(a_1, E) < \text{eval}(a_2, E)$

# Interpreter (2)

$$\text{eval}(\text{skip}, E) \stackrel{\text{def}}{=} E$$

$$\text{eval}(x := a, E) \stackrel{\text{def}}{=} E(x \mapsto \text{eval}(a, E))$$

$$\begin{aligned} \text{eval}(\text{if } b \text{ then } cs_1 \text{ else } cs_2, E) &\stackrel{\text{def}}{=} \\ &\text{if } \text{eval}(b, E) \text{ then } \text{eval}(cs_1, E) \\ &\text{else } \text{eval}(cs_2, E) \end{aligned}$$

$$\begin{aligned} \text{eval}(\text{while } b \text{ do } cs, E) &\stackrel{\text{def}}{=} \\ &\text{if } \text{eval}(b, E) \\ &\text{then } \text{eval}(\text{while } b \text{ do } cs, \text{eval}(cs, E)) \\ &\text{else } E \end{aligned}$$

$$\text{eval}(\text{write } x, E) \stackrel{\text{def}}{=} \{ \text{println}(E(x)) ; E \}$$

# Compiling Writes

## write $x$

```
.method public static write(IV)      (library function)
  .limit locals 5
  .limit stack 5
  iload 0
  getstatic java/lang/System/out Ljava/io/PrintStream;
  swap
  invokevirtual java/io/PrintStream/println(IV)
  return
.end method
```

```
iload  $E(x)$ 
invokestatic write(IV)
```

```
.class public XXX.XXX  
.super java/lang/Object
```

```
.method public <init>()V  
  aload_0  
  invokevirtual java/lang/Object/<init>()V  
  return  
.end method
```

```
.method public static main([Ljava/lang/String;)V  
  .limit locals 200  
  .limit stack 200
```

(here comes the compiled code)

```
  return  
.end method
```