Virus Scanning as Model Checking

Mihai Christodorescu

mihai@cs.wisc.edu

University of Wisconsin, Madison

Overview

1. The Problem:
   - Virus writers are getting smarter!

2. Smart Virus Scanner
   - Model checking

3. Encouraging Results

4. Future Directions

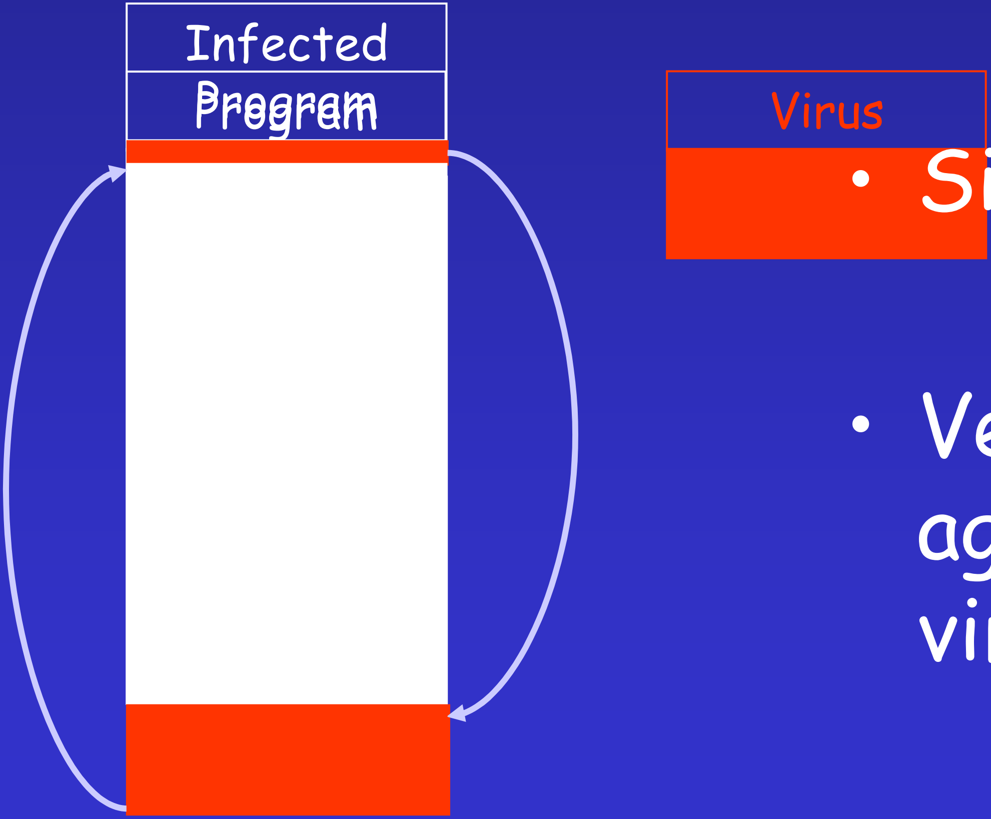
Why Another Virus Scanner?

- The Problem:
  - Viruses are becoming better at hiding themselves in binaries
  - Virus writers use complex techniques to obfuscate virus code in a host program
- Current commercial virus scanners are inadequate

Obfuscation: Vanilla Virus

- Simple obfuscation methods

=> Easy detection:

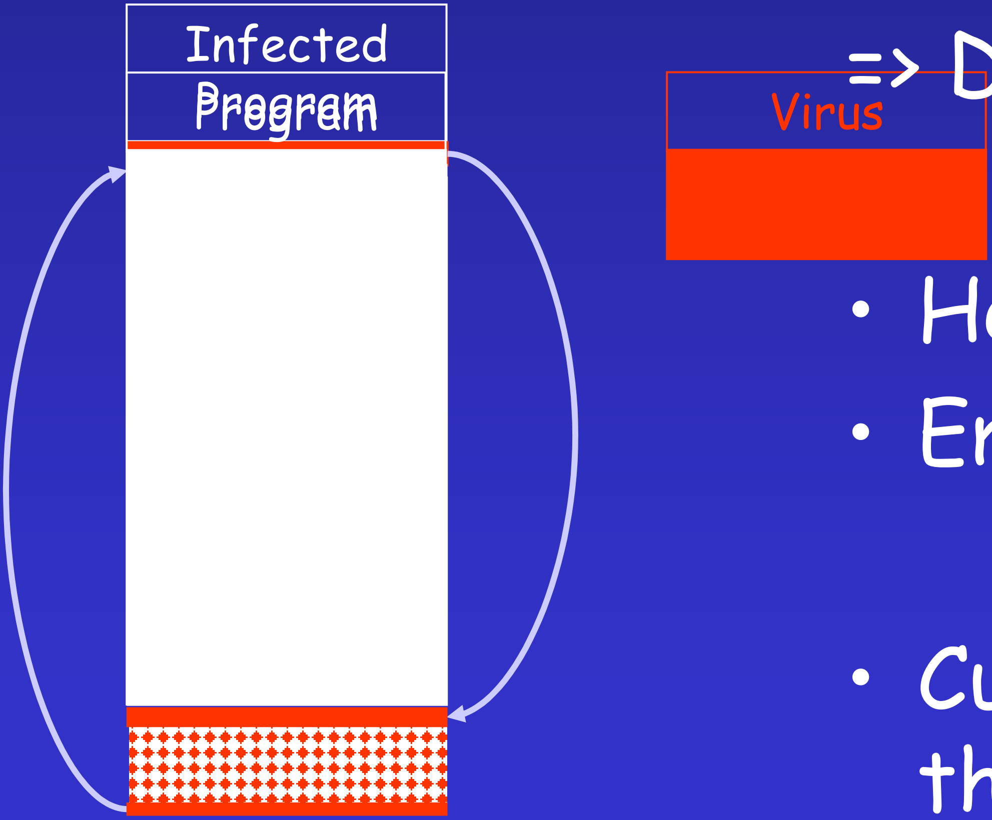


- Signature matching

- Very successful against first-gen viruses!

Obfuscation: Polymorphism

- Encrypted virus body + morphed decryption routine

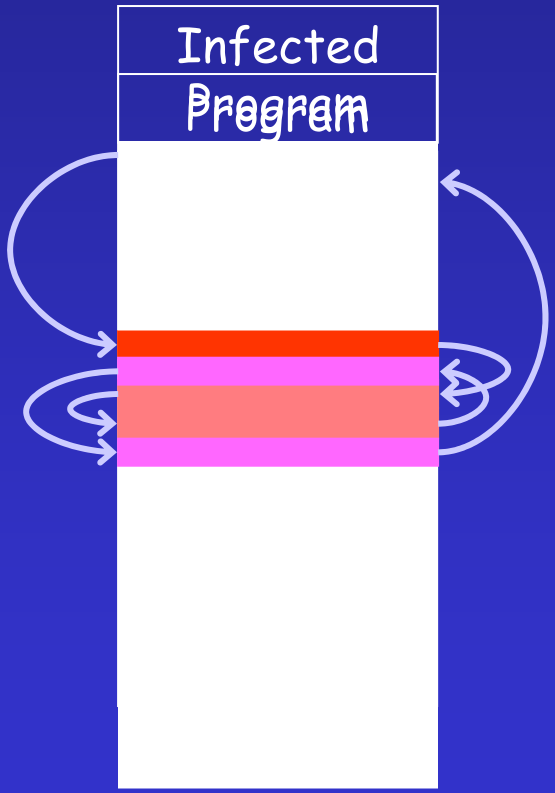


=> Detection methods:

- Heuristic detection
- Emulation
- Current state-of-the-art

Obfuscation: Metamorphism

- Metamorphic viruses:
  - Morph the whole virus body

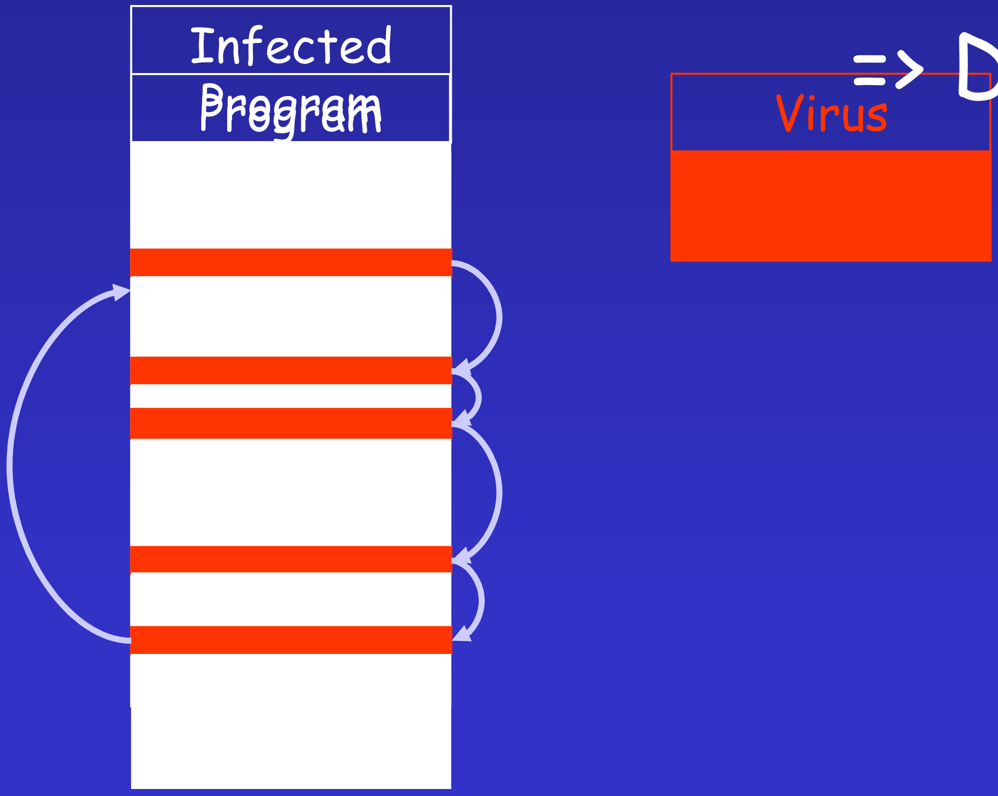


=> Detection methods

?

Obfuscation: Code Integration

- Integration of virus and program
  - e.g. Mistfall Virus Engine



=> Detection methods

?

Example

Virus Code

(from Chernobyl CIH 1.4):

```
Loop:
        pop     ecx
        jecxz   SFModMark
        mov     esi, ecx
        mov     eax, 0d601h
        pop     edx
        pop     ecx
        call    edi
        jmp     Loop
```

Morphed Virus Code

(from Chernobyl CIH 1.4):

```
Loop:
        pop     ecx

        jecxz   SFModMark


        mov     esi, ecx

        mov     eax, 0d601h
        pop     edx
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        call    edi



        jmp     Loop
```

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        pop     edx
        pop     ecx
        call    edi
        jmp     Loop
```

Morphed Virus Code

(from Chernobyl CIH 1.4):

```
Loop:
        pop     ecx
        nop
        jecxz   SFModMark
        xor     ebx, ebx
        beqz    N1
N1:     mov     esi, ecx
        nop
        mov     eax, 0d601h
        pop     edx
        pop     ecx
        nop
        call    edi
        xor     ebx, ebx
        beqz    N2
N2:     jmp     Loop
```

Example

Virus Code

(from Chernobyl CIH 1.4):

```
Loop:
        pop     ecx
        jecxz   SFModMark
        mov     esi, ecx
        mov     eax, 0d601h
        pop     edx
        pop     ecx
        call    edi
        jmp     Loop
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N1:     mov     esi, ecx
        nop
        mov     eax, 0d601h
        pop     edx
        pop     ecx
        nop
        call    edi
        xor     ebx, ebx
        beqz    N2
N2:     jmp     Loop
```

Example

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(from Chernobyl CIH 1.4):

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        pop     edx
        pop     ecx
        call    edi
        jmp     Loop
```

Morphed Virus Code

(from Chernobyl CIH 1.4):

```
Loop:
        pop     ecx
        nop

        call    edi
        xor     ebx, ebx
        beqz    N2
N2:     jmp     Loop

        nop
        mov     eax, 0d601h
        pop     edx
        pop     ecx
        nop

        jecxz   SFModMark
        xor     ebx, ebx
        beqz    N1
N1:     mov     esi, ecx
```

Example

Virus Code

(from Chernobyl CIH 1.4):

```
Loop:
          pop       ecx
          jecxz     SFModMark
          mov       esi, ecx
          mov       eax, 0d601h
          pop       edx
          pop       ecx
          call      edi
          jmp       Loop
```

Morphed Virus Code

(from Chernobyl CIH 1.4):

```
Loop:
          pop       ecx
          nop
          jmp L1
L3:       call      edi
          xor       ebx, ebx
          beqz      N2
N2:       jmp       Loop
          jmp L4
L2:       nop
          mov       eax, 0d601h
          pop       edx
          pop       ecx
          nop
          jmp L3
L1:       jecxz     SFModMark
          xor       ebx, ebx
          beqz      N1
N1:       mov       esi, ecx
          jmp L2
L4:
```

Example

Virus Code

(from Chernobyl CIH 1.4):

```
Loop:
          pop       ecx
          jecxz     SFModMark
          mov       esi, ecx
          mov       eax, 0d601h
          pop       edx
          pop       ecx
          call      edi
          jmp       Loop
```

Morphed Virus Code

(from Chernobyl CIH 1.4):

```
Loop:
          pop       ecx
          nop
          jmp L1
L3:       call      edi
          xor       ebx, ebx
          beqz      N2
N2:       jmp       Loop
          jmp L4
L2:       nop
          mov       eax, 0d601h
          pop       edx
          pop       ecx
          nop
          jmp L3
L1:       jecxz     SFModMark
          xor       ebx, ebx
          beqz      N1
N1:       mov       esi, ecx
          jmp L2
L4:
```

What to do?

- Better virus detection tool
  - Analyze the program structure (instead of signature matching)
  - More flexible

- Check whether viral properties are present in a given program
  - e.g.: "program writes to an executable file"
  - e.g.: "program monitors as executables are loaded into memory and changes them"
  - e.g.: "program behaves just like virus XYZ"

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☞ 2. Smart Virus Scanner
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Use Model Checking

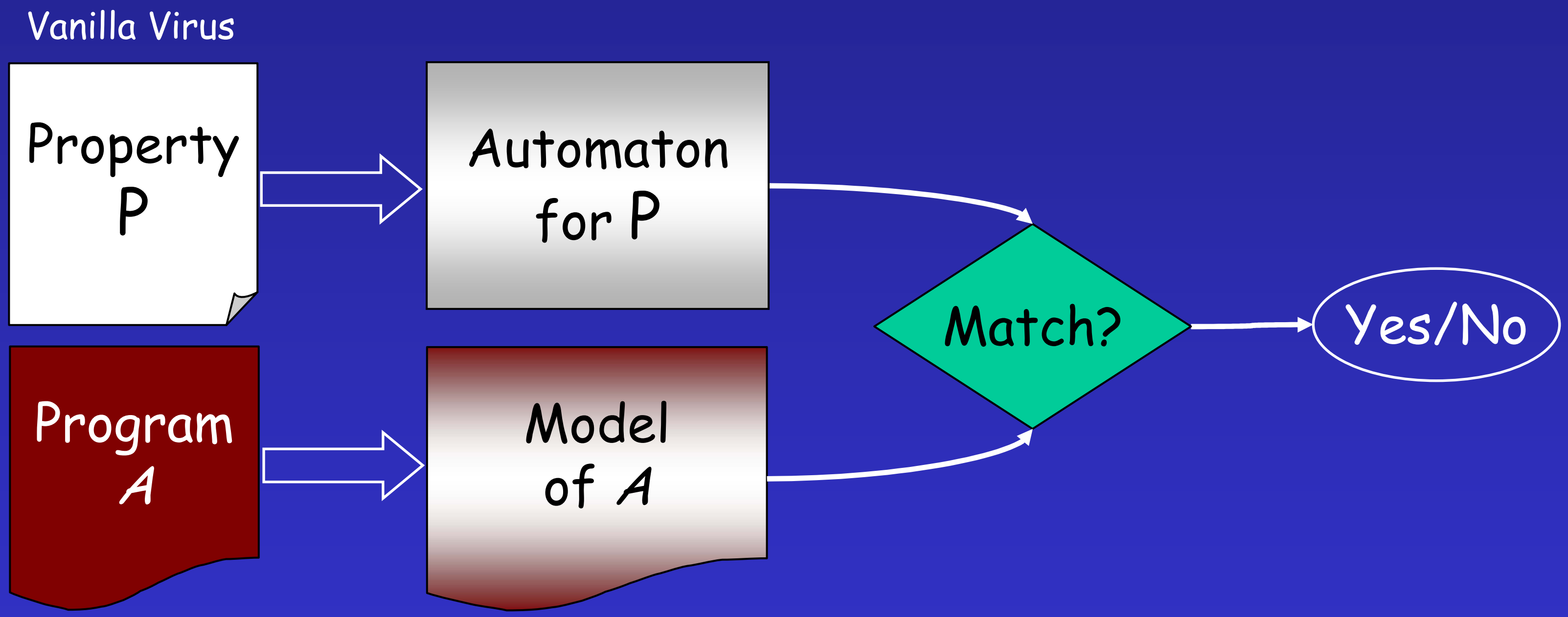
- Consider the vanilla virus code as a set of one or more properties
- Check that the program exhibits those properties
  - If YES => infected

Model Checking

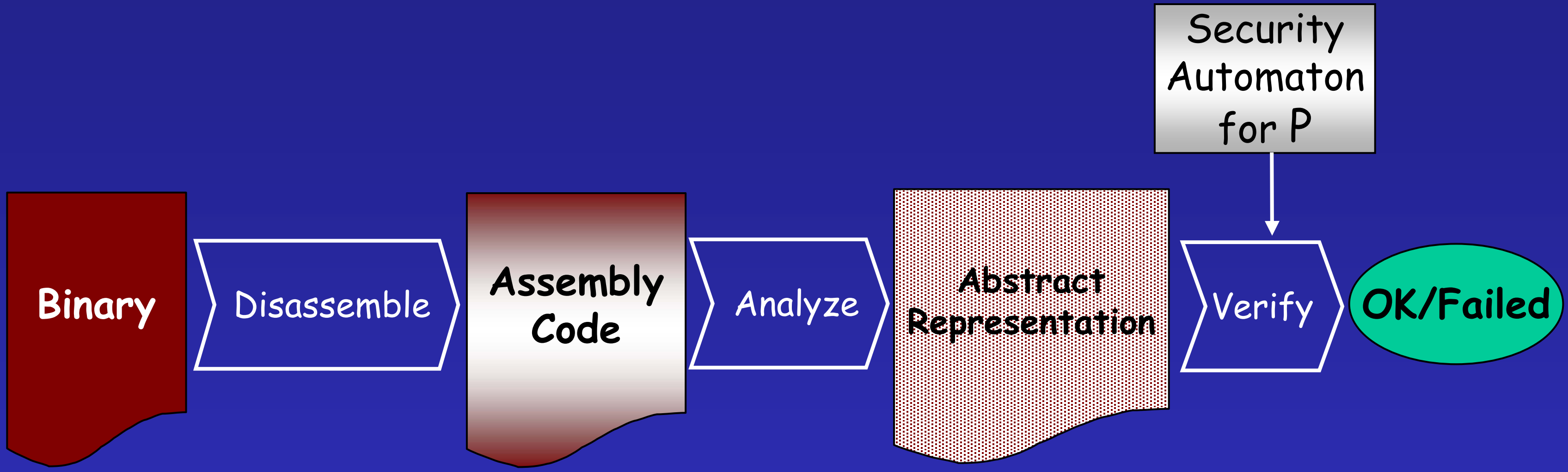
- Technique for checking program properties

1. Build automaton for the desired property
2. Extract program model
3. Compare the model against the automaton

Model Checking



Model Checking Binaries



IDA Pro

(+ SDK plugins)

Transducer

(on top of CodeSurfer static analysis engine)

Model Checker

Smart Virus Scanner

1. Build automaton from vanilla virus
   - Blueprint of virus behavior

2. Build a model of the program

3. Verify that model does <u>not</u> match the blueprint

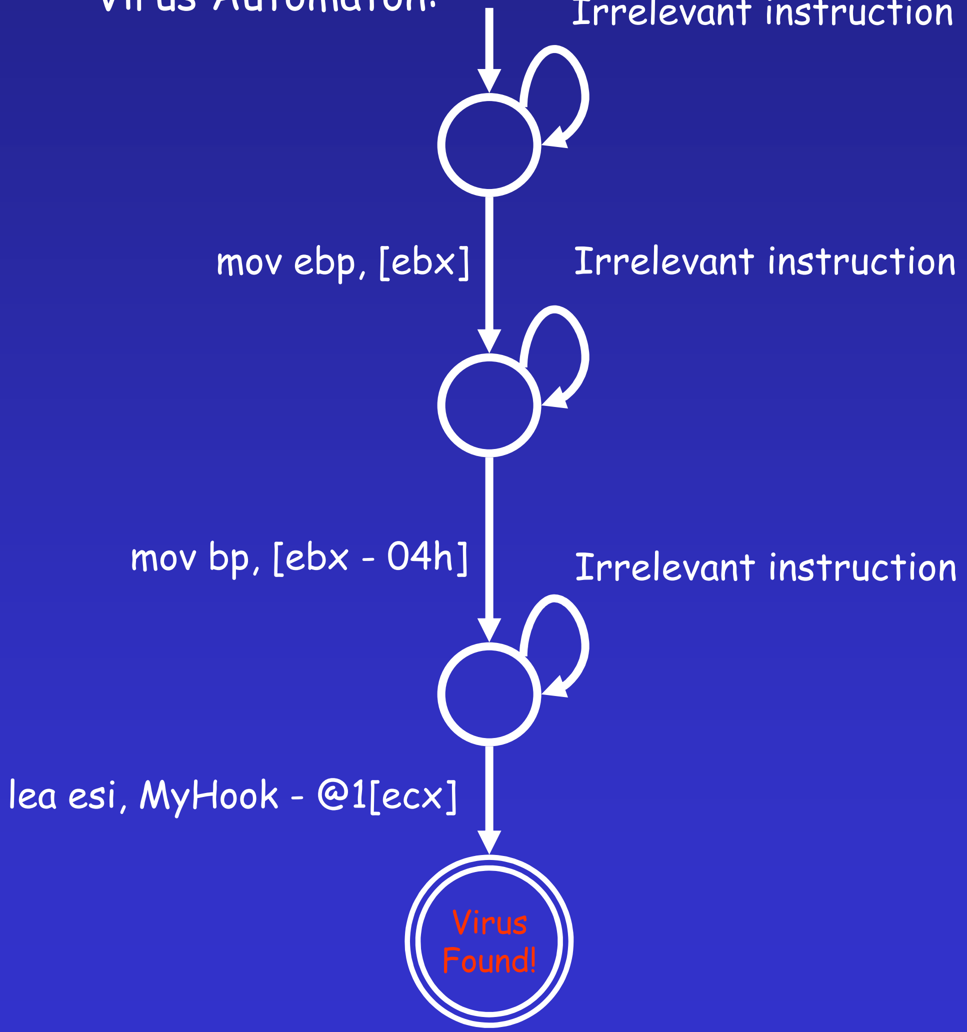
Smart Virus Scanner Example

Virus Code:

```
push    eax
sidt    [esp-02h]
pop     ebx
add     ebx, HookNo * 08h + 04h
cli
mov     ebp, [ebx]
mov     bp, [ebx-04h]
lea     esi, MyHook - @1[ecx]
push    esi
mov     [ebx-04h], si
shr     esi, 16
mov     [ebx+02h], si
pop     esi
```

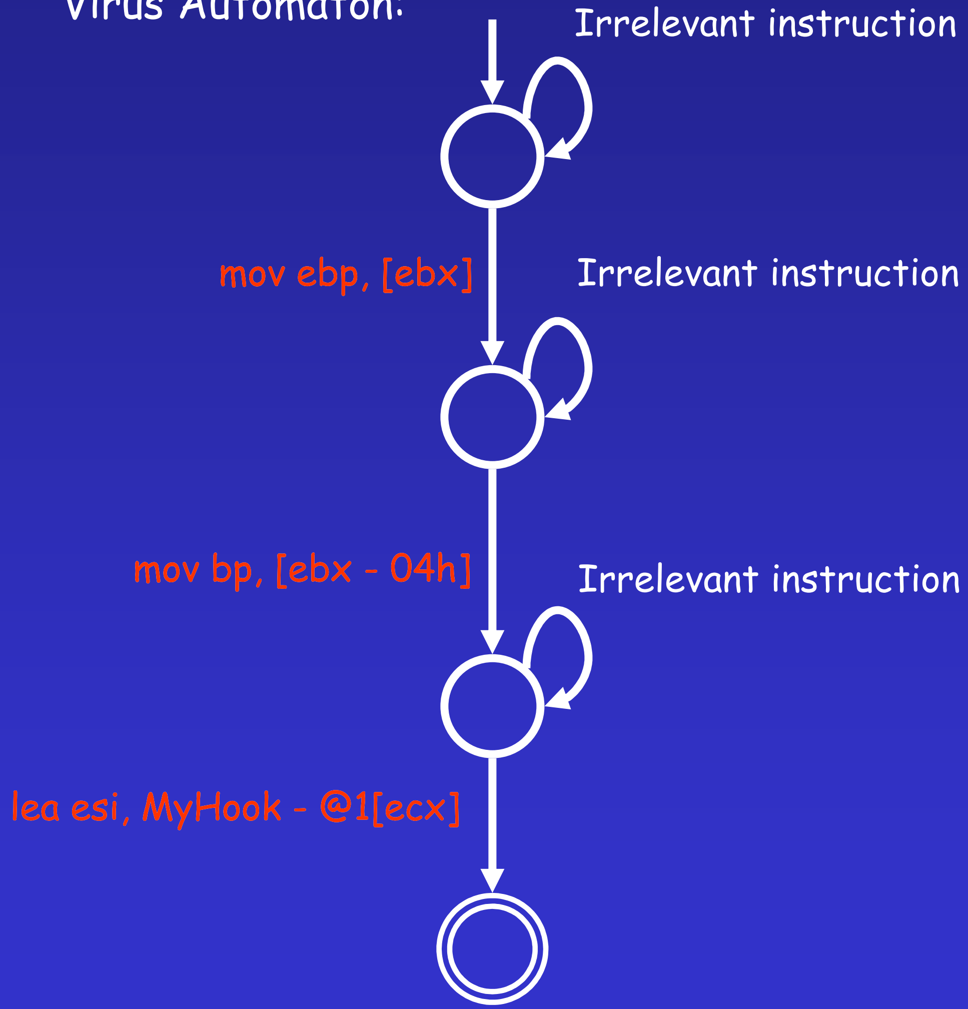
(from Chernobyl CIH 1.4 virus)

Virus Automaton:



Smart Virus Scanner Example

Virus Automaton:



Program to be checked:

```
            mov ebp, [ebx]
            nop
            mov bp, [ebx-04h]
            test ebx
            beqz next
next:       lea esi, MyHook - @1[ecx]
```

Smart Virus Scanner

- What are *irrelevant instructions*?
  - NOPs
  - Control flow instructions that do not change the control flow
    - e.g.: jumps/branches to the next instructions
  - Instructions that modify dead registers
  - Sequences of instructions that do not modify architectural state
    - e.g.:

```
add ebx, 1
sub ebx, 1
```

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Current Status

- We disassemble and analyze program structure
- We can detect viruses morphed in a simple manner
  - Irrelevant instructions = NOPs

Results

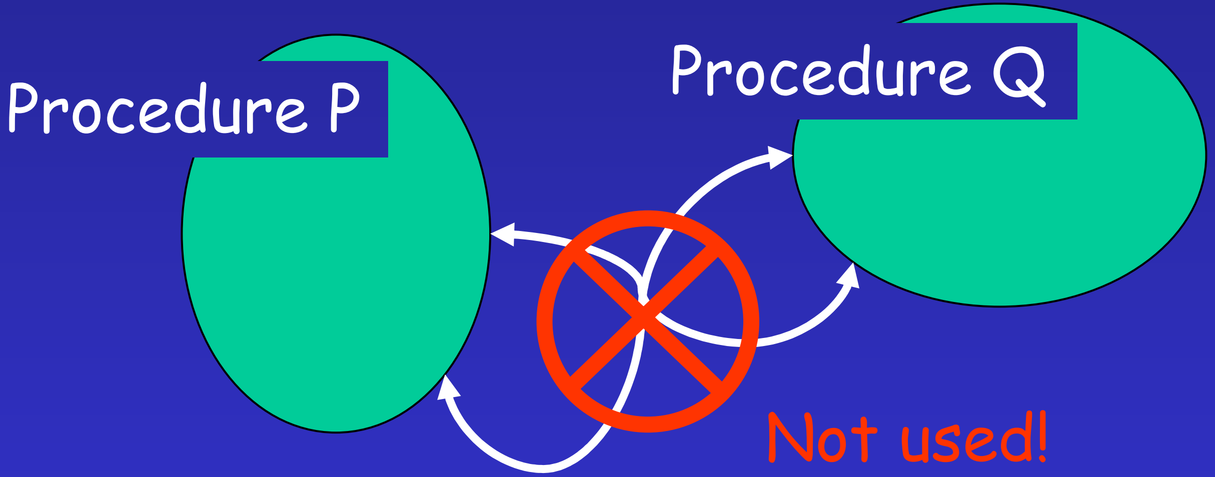
- Testing
  - Viruses used: Chernobyl, Hare
  - AntiVirus utilities
    - Command AntiVirus (F-Prot)
    - Norton AntiVirus (Symantec)

☹ Not surprising!
  - Norton and Command AV do not detect "NOP"-morphed viruses

☺ Our Smart Virus Scanner catches "NOP"-morphed viruses

Current Status

- Limitations:
  - Intra-procedural only



  - Cannot detect equivalent instruction sequences

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Future Work

- Main focus:
  - Improve detection of "irrelevant insn's"
- More (precise) information from static analysis
  - live range information
  - alias/points-to analysis
- Library of equivalent instructions sequences

Future Directions

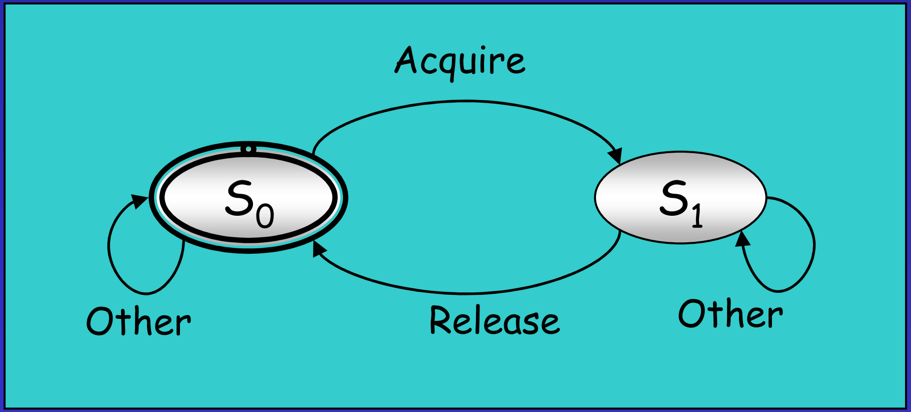
- Context-sensitive model checking
  - Recognize virus code spread across subroutines
- Automata with uninterpreted symbols
  - Recognize virus code with different register usage
- Virus scanning for component-based systems
  - Recognize virus code distributed across components
- Scan for multiple viruses at the same time

References

- Schneider, F.B. *Enforceable Security Policies.* TR99-1759, July 27, 1999.
- Dawson Engler, Benjamin Chelf, Andy Chou, and Seth Hallem. *Checking System Rules Using System Specific, Programmer-Written Compiler Extensions.* In Proceedings of the Fourth Symposium on Operating Systems Design and Implementation, San Diego, CA, October 2000. http://citeseer.nj.nec.com/engler00checking.html
- Péter Ször, and Peter Ferrie. *Hunting For Metamorphic.* In Proceedings of Virus Bulletin Conference, September 2001. Pp. 123 – 154. http://www.geocities.com/szorp/metamorp.pdf
- Zombie. *Zombie's Homepage.* http://z0mbie.host.sk

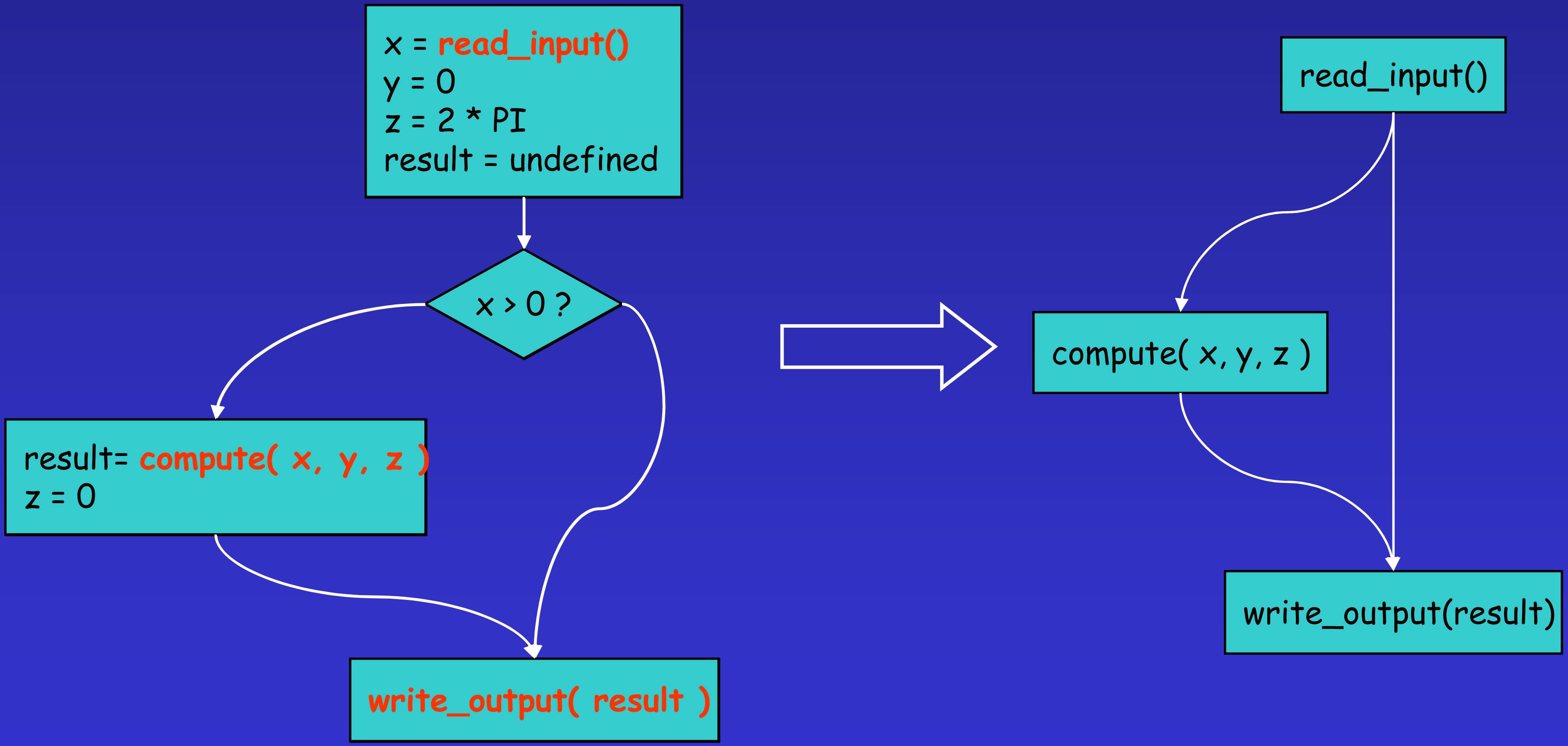
More Model Checking

- Security Automaton
  - For policy "Always release a resource after acquiring it."



Even More Model Checking

- Abstract Representation



x = read_input()
y = 0
z = 2 * PI
result = undefined
x > 0 ?
result= compute(x, y, z)
z = 0
write_output(result)
read_input()
compute(x, y, z)
write_output(result)