6.857 Rivest
L18.1 4/13/09

Admin: Quizzes back on Wed
meet with TA's this week re project

Outline: Viruses

- ☐ Brief history of viruses
- ☐ Self-referential programs
- ☐ Halting Problem is undecidable
- ☐ Virus detection is undecidable
- ☐ Some practicalities of virus detection

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Virus History

1981: first virus: "Elk Cloner" Apple II; Floppy disk xmit.

1983: Term "virus" coined by Adleman & Cohen (1986 PhD thesis)

1988: Internet worm (≈60,000 hosts on Internet; 10% infected.)

- fingerd buffer overflow
- sendmail debug mode left on - left access to shell
- dictionary attacks on passwords
- "trusted hosts" vulnerability

1990's: 1M hosts on web in '92
First "polymorphic" viruses (Tequila & Amoeba)
Start of anti-virus industry (Symantec)
late 90's: 30M hosts on web ('98)

2001: Code Red infects 360,000 hosts in 14 hours
(out of 125M hosts on web in '01)
buffer overflow in M.S. indexing service

2003: Slammer: infected M.S. SQL servers
doubled # infected every 8.5 seconds!
infected ≥ 75,000 hosts
caused network congestion (severe)
376 byte UDP packet
random scanning of 32-bit IP addresses

Jan '09
625M

2006: 440M hosts on Internet (www.isc.org)

"Malware Theory"

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- We are used to programs that work on other programs:
  E.g. interpreters, optimizers, compilers, byte-code verifier, virus detector...

- We are now interested in programs that work on <u>themselves</u> ("self-referential") - they have access to their own source code.

- Can you write a program that <u>prints itself</u>? ("Quine")
  in C:

```
char *s="char *s=%c%s%c; main(){printf(s,34,s34);}";
main(){printf(s,34,s,34);}
```

Note: 34 is decimal code for double-quote char.

- We can modify above pgm to save text in a variable, rather than printing it.
  (Use "sprintf" in C; or modify s by substitution...)

Thus, we can have programs P of form:

P ≡ { s = <text for P>; ← modification of above

← other code, can operate on s, as if it were input. }

- For example, we can write a program P that applies a routine A to text of P:

$$P \equiv \begin{cases} s = \langle \text{text for } P \rangle \\ \text{define } A(x): \equiv \\ \\ A(s) \end{cases}$$

or (in high-level notation):

$$P \equiv A(P)$$

[running P is same as applying A to source code for P.]

(All this is called "Recursion Theorem" in theory of computation...)

- **Def:** The Halting Problem is: Given a program P that takes no inputs, decide if P halts, or loops forever when run.

- **Thm:** The Halting Problem is undecidable.
  (I.e. there is no program A that takes as input a description of a program P, and always halts & outputs correctly whether P halts or loops.)

$$P \longrightarrow \boxed{A} \longrightarrow \begin{cases} \text{true} & \text{if } P \text{ halts} \\ \text{false} & \text{if } P \text{ loops} \end{cases}$$

Proof: Assume such an A exists (& we have its code):

Let $P \equiv$ [if $A(P)$ then loop else halt

What does A do on P?

if $A(P)$ true then A says P halts $\Rightarrow$ A is wrong

if $A(P)$ false then A says P loops $\Rightarrow$ A is wrong

$\therefore$ A doesn't exist. ■

- More generally, <u>determining any nontrivial property of (output) behavior of a program is undecidable.</u>

(known as "Rice's Theorem")

Nontrivial means: $\exists$ program X that exhibits behavior

& $\exists$ program X' that doesn't exhibit behavior.

Behavior = output behavior; not things that depend on source code or number of steps taken

e.g. "uses printer" or "halts" or "prints two zeros in a row"

<u>Pf:</u> Same as before.

Assume A can decide if program has property.

Consider $P \equiv$ [<u>if</u> $A(P)$ <u>then</u> $X'()$ <u>else</u> $X()$]

A is wrong about P. ∎

- <u>Thm:</u> Virus detection is undecidable. (Cohen '87)

(Define virus to be a program that "spreads" (infects other programs).)

<u>Pf:</u> Same as for Rice's Theorem, etc.

Assume A can decide if input program is a virus.

Consider $P \equiv$ [<u>if</u> $A(P)$ <u>then</u> halt <u>else</u> spread()]

A is wrong on P.

(Contradiction, so A doesn't exist.)

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- Every virus scanner must make mistakes on some inputs, and/or fail to halt on some inputs.

- Even worse: (Chess & White)

What we have shown is

$$(\forall A)(\exists P)\ A \text{ is wrong about whether } P \text{ is a virus.}$$

But it is true that

$$(\exists P)(\forall P)\ A \text{ is wrong about whether } P \text{ is a virus}$$

P is polymorphic
P uses randomization
P spreads as a different form P'

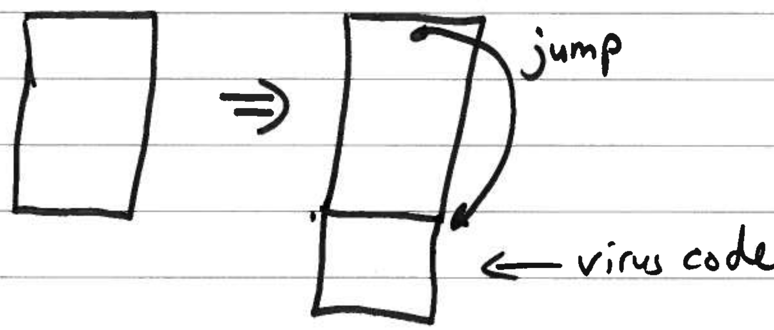
P = if $A(P)$ then halt else spread( )
↖ randomized

P' = if $A'(P)$ then halt else spread.
↖ random A/V scanner

∃ one member of family that defeats each A...

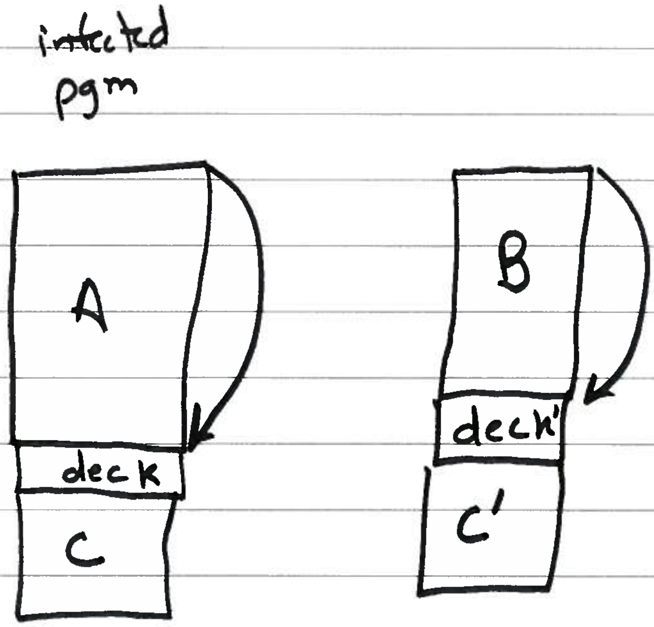
(Material from Corey Nachenberg slides "Virus/Antivirus Co-evolution")

1. simple virus: insert code at end for virus
   insert jump to beginning of virus code



2. A/V responses:
   "signatures": for each virus, find static pattern that occurs in virus code, but not in any common good code (e.g. μsoft word)
   build table of signatures
   scan files for signatures

3. virus writer response: polymorphic code
   "poly" = many
   "morphic" = shape
   virus code never looks the same



dec = decryption routine

Use encryption: when infected pgm A runs, it generates a <u>new key</u> K', so that ciphertext $C' = E(K', \text{virus})$ looks random. Only common part is small decryption routine.

④ A/V response:

scan for small decryption routine

⑤ Virus writer response:

change enc/dec algorithm when spreading; generate at random a new enc/dec pair.

∴ no static decryption routine!

(6) A/V response:
emulate code in "sandbox" until it decrypts itself, <u>then</u> run static signature check.
(Hard to know exactly when to stop, though...)

(7) Virus writer's response:

- randomly decrypt, or not
- don't decrypt at beginning of execution, but later
- "recompile" virus code in a way that preserves semantic equivalence, but destroys all "signatures"

(8) A/V response: this is getting really hard!