CSc 466/566

Computer Security

12 : Malware

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Outline

Introduction

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Outline

Insider Attacks

- A <mark>backdoor</mark> is a hidden command inserted by the developer.
- Backdoors can be inserted
  1. for debugging
  2. to bypass security checks in an emergency
- <mark>War Games</mark>:
  - Trailer: http://www.youtube.com/watch?v=tAcEzhQ7oqA
  - Mr. Potatohead: http://www.youtube.com/watch?v=mNiiBrEHBWA

Malicious Backdoors

- A programmer may insert a <mark>malicious backdoor</mark> to gain access later.
- A <mark>deliberate vulnerability</mark> (buffer overflow, etc.) can be inserted, allowing the programmer easy access.

Logic Bombs

- A programmer inserts an action that will happen when a certain condition is true:

```
if (Bob is not on the payroll anymore)
    crash_system();
```

- A logic bomb can be combined with a backdoor that allows the programmer to disable it:

```
boolean disabled=false;

if (today=="April 1" && not disabled)
    delete_all_backups();

void backdoor() {
    disabled = true;
}
```

Fannie Mae Logic Bomb

Source: http://www.wired.com/threatlevel/2009/01/fannie/
Unix engineer Rajendrasinh Babubha Makwana, 35, was indicted Tuesday in federal court in Maryland on a single count of computer sabotage for allegedly writing and planting the malicious code on Oct. 24, the day he was fired from his job. The malware had been set to detonate at 9:00 a.m. on Jan. 31, but was instead discovered by another engineer five days after it was planted, according to court records.
On the afternoon of Oct. 24, he was told he was being fired because of a scripting error hed made earlier in the month, but he was allowed to work through the end of the day.

Fannie Mae Logic Bomb. . .

Five days later, another Unix engineer at the data center discovered the malicious code hidden inside a legitimate script that ran automatically every morning at 9:00 a.m. Had it not been found, the FBI says the code would have executed a series of other scripts designed to block the companys monitoring system, disable access to the server on which it was running, then systematically wipe out all 4,000 Fannie Mae servers, overwriting all their data with zeroes. "This would also destroy the backup software of the servers making the restoration of data more difficult because new operating systems would have to be installed on all servers before any restoration could begin," wrote Nye.

Fannie Mae Logic Bomb. . .

As a final measure, the logic bomb would have powered off the servers.
The trigger code was hidden at the end of the legitimate program, separated by a page of blank lines. Logs showed that Makwana had logged onto the server on which the logic bomb was created in his final hours on the job.

Fannie Mae Logic Bomb. . .

Source:

http://www.thetechherald.com/articles/Fannie-Mae-logic-bomb-creator-found-guilty/11557

Facts in the case prove that Fannie Mae had strong logging processes. The initial affidavit says Makwana was singled out as the person who wrote the malicious script because logs revealed his username was the last to access the system where the logic bomb was located. In addition, he was the last to access the malicious file itself, and IP address assignment was used to show he did all of this from his company laptop.

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Defending Against Insider Attacks

- **No single points of failure** — administrators shouldn't be allowed to access important systems alone.
- **Code walk-throughs** — can the programmer explain the logic bomb?
- **Use software engineering tools**.
- **Use least privilege principle** — no one should have more privileges than they need to do their job.
- **Physically secure systems**.
- **Monitor employee behavior** — watch out for disgruntled administrators.
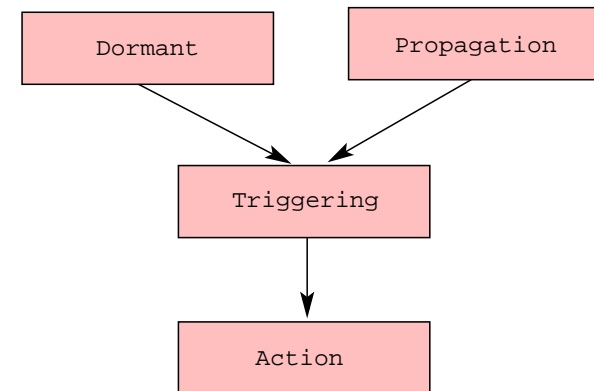- **Limit new software installations**.

Outline

Computer Viruses

- Viruses
  1. are **self-replicating**;
  2. attach themselves to other files;
 3. requires user assistance to to replicate.

Computer Viruses: Phases

Computer Viruses: Phases...

- Dormant — lay low, avoid detection.
- Propagation — infect new files and systems.
- Triggering — decide to move to action phase
- Action — execute malicious actions, the payload.

Virus Types

- Program/File virus:
  - Attaches to: program object code.
  - Run when: program executes.
  - Propagates by: program sharing.
- Doocument/Macro virus:
  - Attaches to: document (.doc,.pdf,...).
  - Run when: document is opened.
  - Propagates by: emailing documents.
- Boot sector virus:
  - Attaches to: hard drive boot sector.
  - Run when: computer boots.
  - Propagates by: sharing floppy disks.

Computer Viruses: Propagation
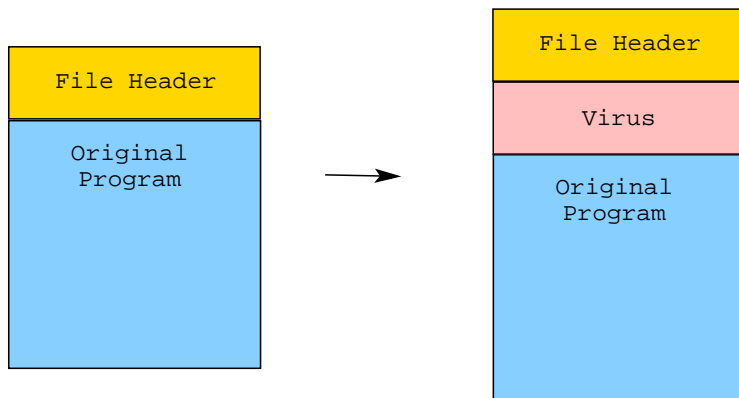
Example: Jerusalem

- Target: DOS executables.
- Trigger: Friday the 13th.
- Payload: Deletes files.
- Propagation: Memory resident, infects executed programs.
- http://www.youtube.com/watch?v=u3k-8kJ54sg

Example: Melissa

- Target: MS Word Macro virus.
- Trigger: User opens document.
- Payload/Propagation: Emails infected documents to 50 contacts.
- http://www.youtube.com/watch?v=hu-rhzOgExg

Example: Elk Cloner

- Target: Apple II boot sector.
- Payload: Prints poem every 50th time the program is rebooted.

  Elk Cloner: The program with a personality
  It will get on all your disks
  It will infiltrate your chips
  Yes, it's Cloner!
  It will stick to you like glue
  It will modify RAM too
  Send in the Cloner!

Example: Elk Cloner. . .

Source: http://en.wikipedia.org/wiki/Elk_Cloner
Elk Cloner was created in 1981 by Rich Skrenta, a 15-year-old high school student. Skrenta was already distrusted by his friends because, in sharing computer games and software, he would often alter the floppy disks to shut down or display taunting on-screen messages. Because his friends no longer trusted his disks, Skrenta thought of methods to alter floppy disks without physically touching them.
During a winter break [] Skrenta discovered how to launch the messages automatically on his Apple II computer. He developed what is now known as a boot sector virus, and began circulating it in early 1982 among high school friends and a local computer club.

Example: Sality

- Target: Windows executable files.
- Propagation: Infects other local executable files.
- Obscures its entry point.
- Downloads and executes other malware.
- Creates peer-to-peer botnet.
- Disables security software.
- Injects itself into running processes to make sure it remains on the computer.

Virus Defenses

- **Signatures**: Regular expressions over the virus code used to detect if files have been infected.
- Checking can be done
  1. periodically over the entire filesystem;
 2. whenever a new file is downloaded.

Virus Countermeasures

- Viruses need to protect themselves against detection.
- This means hiding any distringuishing features, making it hard to construct signatures.
- By **encrypting** its payload, the virus hides its distinguishing features.
- Encryption is often no more than xor with a constant.

Virus Countermeasures: Encryption

- By **encrypting** its payload, the virus hides its distinguishing features.
- The decryption routine itself, however, can be used to create a signature!

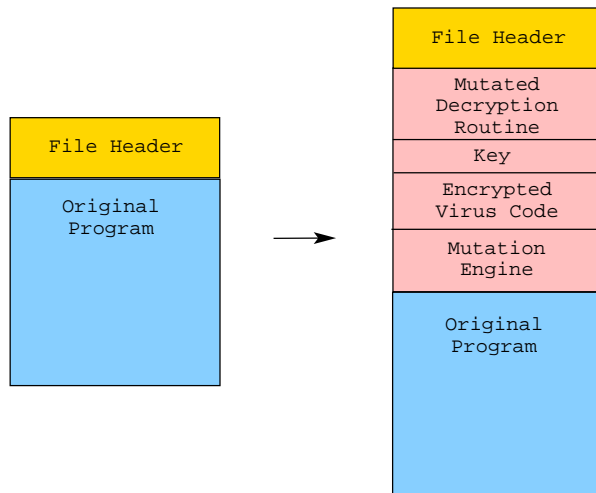# Computer Countermeasures: Encryption...
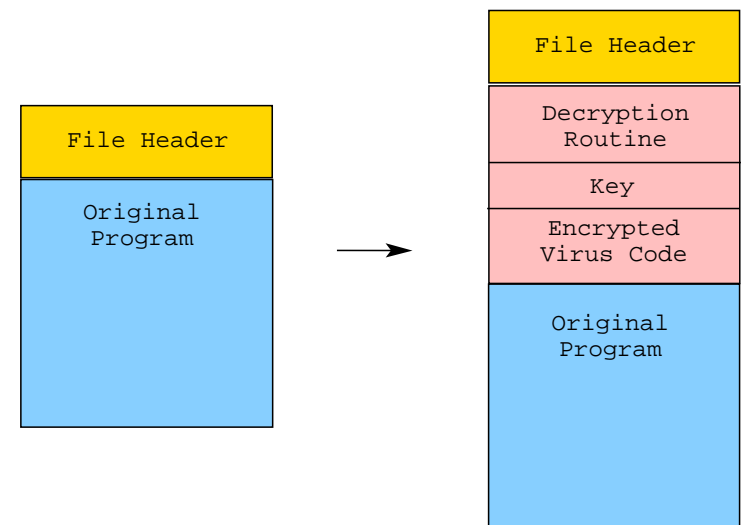
Virus Countermeasures: Polymorphism

- Each variant is encrypted with a different key.

Virus Countermeasures: Metamorphism

- To prevent easy creation of signatures for the decryption routine, metamorphic viruses will mutate the decryptor, for each infection.
- The virus contains a mutation engine which can modify the decryption code while maintaining its semantics.

Computer Countermeasures: Metamorphism. . .

File Header
Original Program

$\longrightarrow$

File Header
Mutated Decryption Routine
Key
Encrypted Virus Code
Mutation Engine
Original Program

Virus Countermeasures: Metamorphism. . .

- To counter metamorphism, virus detectors can run the virus in an emulator.
- The emulator gathers a trace of the execution.
- A virus signature is then constructed over the trace.
- This makes it easier to ignore garbage instructions the mutation engine may have inserted.

Outline

Trojan Horses

- A trojan horse is a program that appears to perform a useful task, but, in addition, performs a malicous task.
- Example:
  - Useful task: A better `ls`.
  - Malicious task: Exfiltrate company secrets.

Trojan Horses

Trojan Horses: The AIDS Trojan

- When the boot count reaches 90, AIDS encrypts the names of all files.
- The user is asked to *renew the license*.
- To recover the files the user needs to send $189 to a P.O. box in Panama.

Trojan Horses: The AIDS Trojan

Source: http://en.wikipedia.org/wiki/AIDS_(trojan_horse)

The AIDS software end user license agreement:

If you install [this] on a microcomputer... then under terms of this license you agree to pay PC Cyborg Corporation in full for the cost of leasing these programs... In the case of your breach of this license agreement, PC Cyborg reserves the right to take legal action necessary to recover any outstanding debts payable to PC Cyborg Corporation and to use program mechanisms to ensure termination of your use... These program mechanisms will adversely affect other program applications... You are hereby advised of the most serious consequences of your failure to abide by the terms of this license agreement; your conscience may haunt you for the rest of your life... and your [PC] will stop functioning normally... You are strictly prohibited from sharing [this product] with others...

Outline

Worms

- A computer virus:
    - adds itself to other programs;
    - cannot run independently;
    - needs help from a human to spread.
- A worm propagates fully working versions of itself to other machines without
    - attaching itself to other programs;
    - human assistance.
- Worms carry malicious payloads, such as
    - installing backdoors;
    - deleting files, . . .

Worm tasks

- Worm tasks:
    1. infect a victim machine by exploiting a vulnerability (buffer overflow) in a network service exported by the machine;
    2. spread by infecting other computers reachable from the victim machine;
    3. ensure survival when the victim machine is rebooted.

Worm Propagation

Vulnerable network service

Initial infection

Failed infections

Failed re−infection
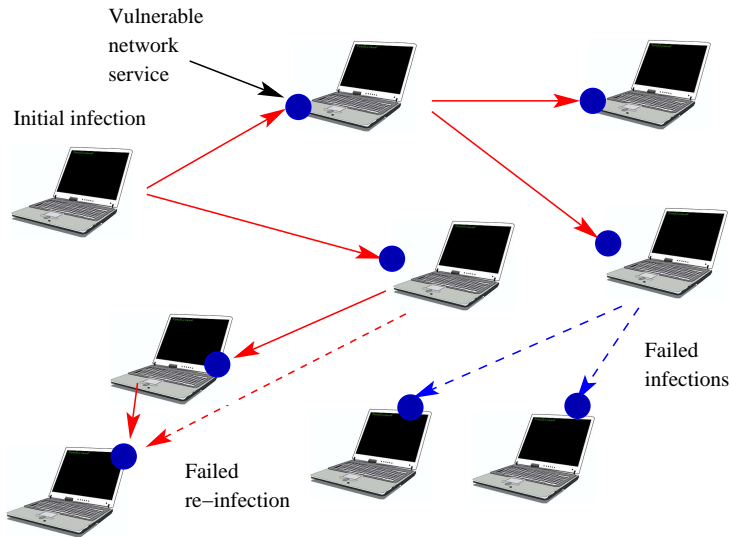
Worm Propagation Rate

- N — total number of vulnerable hosts.
- $I(t)$ — number of infected hosts at time t.
- $S(t)$ — number of susceptible hosts at time t. A host is susceptible if it's vulnerable but not infected yet.
- β — infection rate, constant describing the speed of propagation.

$$
\begin{aligned}
I(0) &= 1 \\
S(0) &= N - 1 \\
I(t+1) &= I(t) + \beta \cdot I(t) \cdot S(t) \\
S(t+1) &= N - I(t+1)
\end{aligned}
$$

Worm Propagation Rate. . .

$$
\begin{aligned}
I(0) &= 1 \\
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S(t+1) &= N - I(t+1)
\end{aligned}
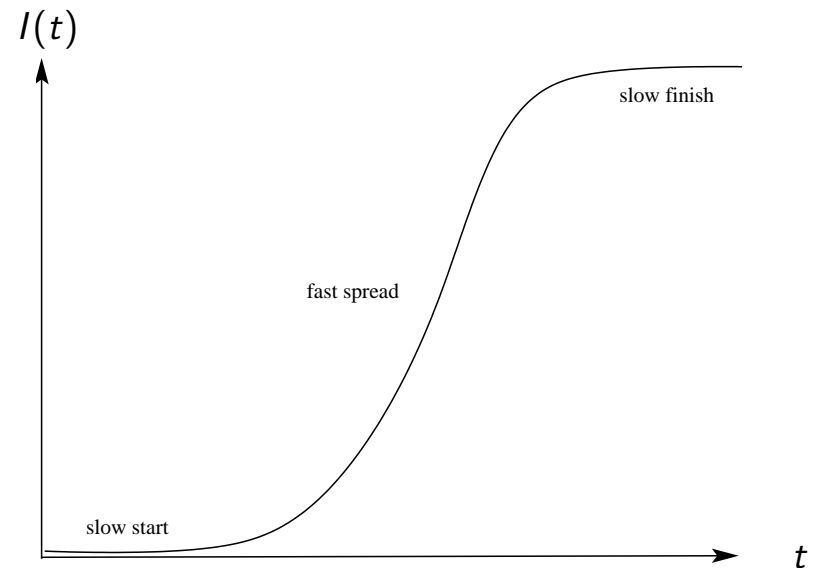$$

- The number of new infections is $I(t+1) - I(t)$:

$$
\begin{aligned}
I(t+1) - I(t) &= (I(t) + \beta \cdot I(t) \cdot S(t)) - I(t) \\
&= \beta \cdot I(t) \cdot S(t)
\end{aligned}
$$

- The number of new infections is proportional to the current number of infected hosts and to the number of susceptible hosts.

Three Phaseds of Worm Propagation

$I(t)$

slow finish

fast spread

slow start

t

The Morris Worm

- Attacked BSD Unix derivative systems on the internet on 2 November 1988.
- Specifically targeted SUNs and VAXes.
- Computer Virus TV News Report 1988:
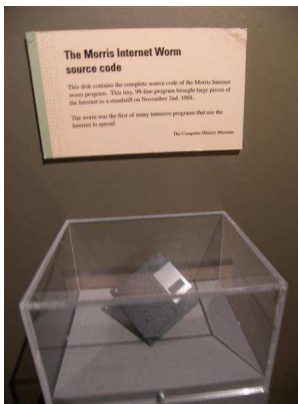 http://www.youtube.com/watch?v=G2i_6j55bS0

Robert Morris

- Cornell graduate student.
- Convicted under the Computer Fraud and Abuse Act: 3 years probation, 400 hours community service, $10,050.
- Tenured Professor at MIT.
- Son of Robert Morris, coauthor of UNIX, former chief scientist at the National Computer Security Center.

The Worm

- Disk containing the source code for the Morris Worm held at the Boston Museum of Science.
- Source: http://en.wikipedia.org/wiki/Morris_worm.

Which Vulnerabilities to Exploit?

- SUN: sendmail
- VAX: finger
- Remote execution system using rsh or rexec.

Exploting weak passwords

- Accounts with obvious passwords
- Accounts with passwords in a 432 word dictionary
- Accounts with passwords in `/usr/dict/words`
- Accounts which trusted other machines via the `.rhosts` mechanism

Which machines to spread to?

- SUNs and VAXes
- Machines in `/etc/hosts.equiv`
- Machines in `.rhosts`
- Machines in `.forward` files
- Network gateways from routing tables
- Machines at the far end of point-to-point interfaces
- Machines at randomly guessed addresses on networks of first hop gateways

What the Worm did not do. . .

- Did not
    - gain or attack root
    - destroy or attempt to destroy data
    - differentiate among networks

sendmail Exploit

- Worm exploited the "debug" function
- Debug includes the ability to send a mail message with a program as the recipient
- The recieving program runs with input from the body of the message

fingerd Exploit

- `fingerd` used `gets` for input
- `gets` takes input to a buffer without bounds checking
- buffer overflow allows for the creation of a fake stack frame, causing code to execute when the function returns

rexec Exploit

- `rexec` requires username and plaintext password that are passed over the network.
- The worm used pairs of usernames and passwords that it found to be correct on the local host.
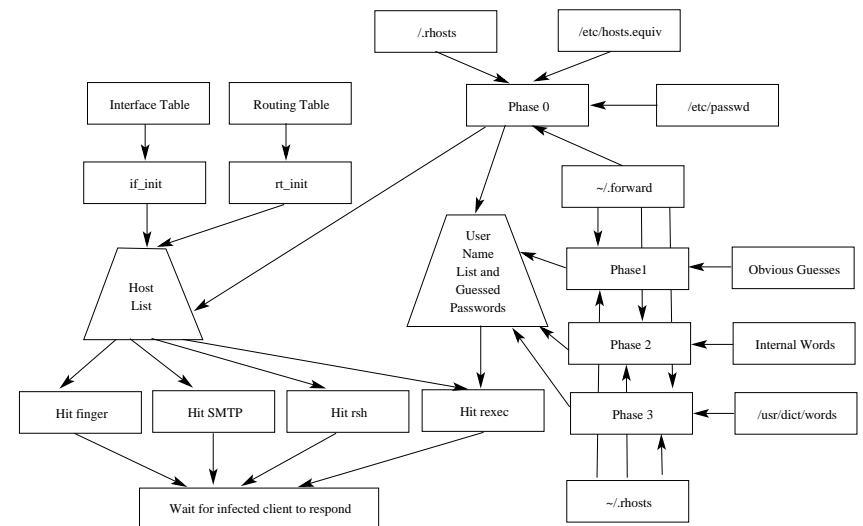- `/etc/passwd` facilitated this search.

rsh Exploit

- `/etc/hosts.equiv` contains a list of trusted hosts
- `.rhosts` contains a list of trusted hosts on a per-user basis
- `rsh` trusts the machine rather than any property of the user

How to Evade Detection?

- Covering tracks:
  - Erased argument list.
  - Deleted executing binary.
  - Used resource limit functions to prevent core dump.

Evading Detection...

- Camouflage:
  - Compiled under the name sh
  - Forked every 3 minutes
    - parent exits, child continues
  - Obscured constant strings by xor'ing each character with the constant 81

Code Red

- Code Red (original)
  - Released 7/13/2001
  - Exploited a buffer overflow in Microsoft Internet Information Server (Web Server)
  - Launched 99 threads to attack random IP addresses
  - 100th thread defaced the web server itself
- Problems with Code Red
  - Random number generator had a fixed seed
  - All copies of worm, on all infected hosts, attacked the same sequence of random IP addresses
  - Linear Spread

Code Red I

- Released 7/19/2001
- Fixed the random number generator seed problem
- Attacked www.whitehouse.gov
- Spread very rapidly
- Compromised all vulnerable MS IIS servers on the net
- Random Constant Spread (RCS) model

Code Red II

- Released 8/4/2001
- Unrelated to Code Red I
- A comment in the worm identified it as "Code Red II"
- Attacked MS IIS on Windows 2000
- Caused MS IIS on Windows NT to crash
- Installed root-access back door
- Introduced Localized Scanning strategy

What needs to be done?

1. Find vulnerabilities to exploit.
2. Write code to
   1. generate machines to attack;
   2. exploit vulnerability;
   3. check if host is already infected;
   4. install/execute the payload;
   5. make the worm survive reboots.
3. Launch the worm on initial victims.

Writing Better Worms

- Hit-List Scanning
- Permutation Scanning
- Warhol Worms (Hit-List + Permutation Scanning)
- Topological Worms
- Flash Worms
- Stealth Worms

Hit-List Scanning

- Worms need to "get off the ground" quickly
- Do preparatory work before releasing the worm:
  - Collect IP addresses of vulnerable servers
  - Create a hit-list with them
- The worm starts with the full hit-list
- Partition the hit-list in half each time a host is infected
- Divide-and-Conquer approach
- Once hit-list is exhausted, do random attacks

Permutation Scanning

- Would like to avoid attacking already-attacked hosts
- But, we can't tell ahead of time which hosts have already been attacked
- However, we can predict what other worms are doing
- How to stay out of the way of other worms:
  - All worms start with the same random permutation of address
  - Each worm starts at a different spot in the list
  - If you find an already-compromised host, then jump to a new random spot in the list

Warhol Worms

- Warhol Worms: "Everyone has their 15 minutes of fame"
  - Hit-List + Permutation Scanning
  - Attacks most vulnerable hosts on the net within 15-60 minutes

Topological Scanning

- Alternative to Hit-List
- Use information on the compromised host to find more targets
- Examples:
  - List of peers on peer-sharing systems
  - URLs on web servers
  - `www.yahoo.com` $\rightarrow$ `mail.yahoo.com`, `games.yahoo.com`, ...

Flash Worms: Cyber-Warfare

- Infect most vulnerable servers within 10s of seconds
- Works like hit-lists
- Scan the entire Internet for vulnerable machines prior to launching attack
- Scanning could be done in 2 hours with an OC-12 connection
- 12.6 million web servers = 48 MB list
- Divide and Conquer

Stealth Worms

- Spread slowly rather than quickly
- Infect without being detected
- Use unsuspecting clients to spread the attack

Detecting Worms

- Establish a Cyber Center for Disease Control (CDC)
  - Identify Outbreaks
  - Analyze Pathogens
  - Fight Infections
  - Anticipate new vectors
  - Devise detectors for new vectors
  - Resist future attacks

Outline

Readings and References

- Chapter 4 in *Introduction to Computer Security*, by Goodrich and Tamassia.

Acknowledgments

Additional material and exercises have also been collected from these sources:

1. Igor Crk and Scott Baker, *620—Fall 2003—Basic Cryptography*.