

Programming Securely I

Computer Security Lecture 4

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¹Based on original lecture notes by David Aspinall

Outline

Programming failures

Buffer overflows

Race conditions

Permissions and Access Control

Poor randomness

Confidentiality leaks

Building in security: design and guidelines

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Programming and Security

The relationship between programming and security may be viewed in at least a couple of ways.

Programming Security To develop code for security-specific functions such as encryption, digital signatures, firewalls, etc.

Programming Securely To develop code in a secure manner so that the code itself is not a vulnerability that can be exploited by an attacker.

In this lecture, we consider *Programming Securely*.

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- ▶ The **penetrate and patch** approach to fixing security problems in mass market systems is badly flawed, e.g.
 - ▶ patches often do not get applied
 - ▶ patches often fix only symptoms, not cause
 - ▶ patches cause version explosion, compatibility nightmare
- ▶ Much better to eliminate security bugs at outset

Vulnerabilities at CERT/CC

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- ▶ Recent statistics:

Year	2003	2004	2005	2006	2007	2008[Q1-3]
Vulnerabilities:	3784	3780	5990	8064	7236	6058

The no. 1 category of vulnerabilities (over 50% up to 2004, at least) is the **buffer overflow**.

Categories of programming failure

1. **buffer overflow (inadequate input validation)**
2. **race conditions**
3. **access control mistakes**
4. **poor randomness**
5. **confidentiality leaks**

The following slides review each category.

The single most important piece of advice for programming secure applications: **check your inputs!**

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A few overflow vulnerabilities

splitvt, syslog, mount/umount, sendmail, lpr, bind, gethostbyname(), modstat, cron, login, sendmail again, the query CGI script, newgrp, AutoSofts RTS inventory control system, host, talkd, getopt(), sendmail yet again, FreeBSD's crt0.c, WebSite 1.1, rlogin, term, ffbconfig, libX11, passwd yppasswd nispasswd, imapd, ipop3d, SuperProbe, lpd, xterm, eject, lpd again, host, mount, the NLS library, xlock, libXt and further X11R6 libraries, talkd, fdformat, eject, elm, cterm, ps, fbconfig, metamail, dtterm, df, an entire range of SGI programs, ps again, chkey, libX11, suidperl, libXt again, lquerylv, getopt() again, dtaction, at, libDtSvc, eeprom, lpr yet again, smbmount, xlock yet again, MH-6.83, NIS+, ordist, xlock again, ps again, bash, rdist, login/scheme, libX11 again, sendmail for Windows NT, wm, wwwcount, tgetent(), xdat, termcap, portmir, writesrv, rcp, opengroup, telnetd, rlogin, MSIE, eject, df, statd, at again, rlogin again, rsh, ping, traceroute, Cisco 7xx routers, xscreensaver, passwd, deliver, cidentd, Xserver, the Yapp conferencing server, ...

A few overflow vulnerabilities – continued

multiple problems in the Windows95/NT NTFTP client, the Windows War and Serv-U FTP daemon, the Linux dynamic linker, filter (part of elm-2.4), the IMail POP3 server for NT, pset, rpc.nisd, Samba server, ufsrestore, DCE secd, pine, dslip, Real Player, SLMail, socks5, CSM, Proxy, imapd (again), Outlook Express, Netscape Mail, mutt, MSIE, Lotus Notes, MSIE again, libauth, login, iwsh, permissions, unfsd, Minicom, nslookup, zpop, dig, WebCam32, smbclient, compress, elvis, lha, bash, jidentd, Tooltalk, ttdbserver, dbadmin, zgv, mountd, pcnfs, Novell Groupwise, mscreen, xterm, Xaw library, Cisco IOS, mutt again, ospf_monitor, sdtcm_convert, Netscape (all versions), mpg123, Xprt, klogd, catdoc, junkbuster, SerialPOP, and rdist

- ▶ It's frustrating that such a basic programming error can have such an enormous impact on software security, and doubly frustrating that it hasn't been eliminated yet.

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 - ▶ Standard C library functions like `strcpy()` **do not check bounds** when copying from source to destination. If the destination buffer is too small, the string will **overflow** and corrupt other data.
- ▶ Overflows can corrupt other pieces of the program data and cause security bugs, or even execution of arbitrary code...

Smashing the stack for fun and profit

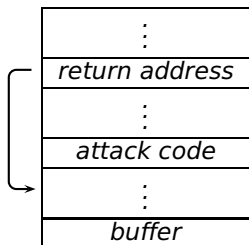
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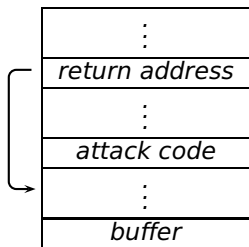
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- ▶ Similar attacks work on the heap.

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 - ▶ Execute Disable Bit (NX) now added to Intel and AMD CPUs
 - ▶ Needs operating system support
 - Added in Windows XP SP2, Linux 2.6.8

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- ▶ General approaches to fixing:
 - ▶ use locks in multi-threaded programming (**synchronized**)
 - ▶ reduce time-of-check, time-of-use (TOCTOU)

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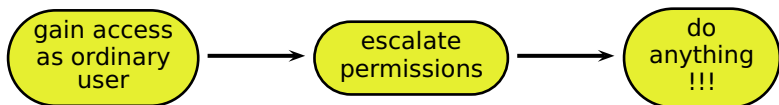
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Permissions vulnerabilities

- ▶ Many exploits have taken advantage of failure to follow the ***principle of least privilege***.
- ▶ Poor programming or inflexible OS permissions structures can lead to programs and users that are given more privileges than they need.
- ▶ Typical pattern of attacking a system is using **escalation of privilege**:



Managing permissions

- ▶ Two extreme views:
 1. Most machines are single-user or single-application so user-level access controls don't matter. Separation of users lies in application-level code and network security.
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The first view was originally argued by vendors such as Microsoft and the second view was typical of the military.

Nowadays, the second view is also being espoused by Microsoft (why?).

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- ▶ How do we get the true random seed? Without a dedicated random source, we must rely on non-deterministic external environmental data...

Environmental sources of randomness

- ▶ Good sources [RFC1750]: disk-head seek times, keystrokes, mouse movements, memory paging behaviour, network status, interrupt arrival times, random electrical noise (e.g. /dev/audio). Best use several, combined with a hash.

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- ▶ Bad sources: system clock, Ethernet addresses or hardware serial numbers, network arrival packet timing or anything else that can be predicted or influenced by an adversary.
- ▶ Linux's random kernel device uses an "entropy pool" and estimates the number of "true" random bits in the pool. Adding random data into pool recharges entropy; reading random bytes removes entropy. Strong random device `/dev/random` can return no more bits than are in the pool. Less secure device `/dev/urandom` returns unbounded amount of cryptographically strong numbers.

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 - ▶ Other defences beyond realm of software.

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4. **Open design** — the design should not be secret. Decouple protection mechanisms from protection keys; no security-by-obscurity.

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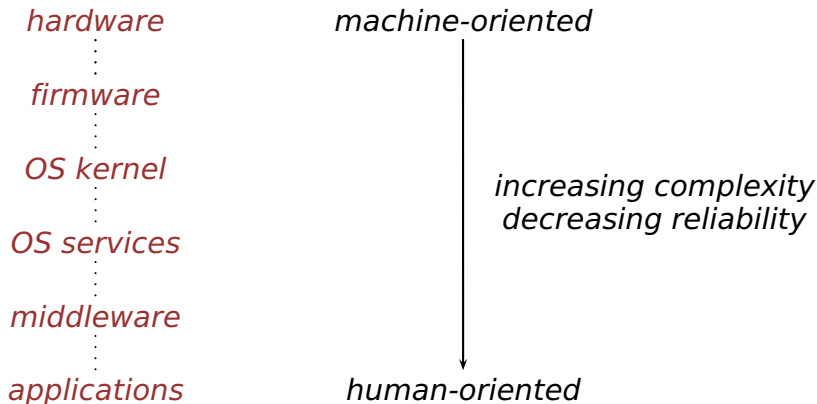
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Two further principles from physical security: **work factor** (comparison of cost of circumvention with the resources of an attacker) and **compromise recording** (make mechanisms tamper-evident).

Granularity of security provision

The hardware level has *fine grained* access controls. At higher levels, we implement increasingly user-oriented security policies. Reliability of each level depends on levels below, and increasingly complex implementations.



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3. **Use cryptography carefully.** Avoid predictable keys, small key spaces (choose cryptographic PRNGs and good seeds); be careful with key management (use secure locations, clear memory).
4. **Program defensively.** Beware data that comes from outside, and be aware of vulnerabilities introduced by relying on external programs. Try to minimise those vulnerabilities.

Some C coding guidelines (incomplete!)

- ▶ Check **all input arguments** for *validity*. Since C is not strongly typed, the validity of types should be checked. Semantical checks should also be performed: e.g., if input is an executable file, should check that the file is indeed executable and user has execute permission for file.

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- ▶ Take care with **root permissions**: beware of setuid programs, avoid setuid scripts, never open a file as root. If you need setuid root, give it up as soon as possible. Better to use ad-hoc user-names.

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- ▶ **Clear sensitive information.** Store sensitive data in mutable objects, then clear explicitly ASAP, to prevent heap-inspection attacks. Can't rely on java's garbage collection to do this.

References

-  Mark G. Graff and Kenneth R. van Wyk. *Secure Coding: Principles & Practices*. O'Reilly, 2003.
-  M. Howard and D. LeBlanc. *Writing Secure Code*. Microsoft Press, second edition, 2003.
-  John Viega and Gary McGraw. *Building Secure Software: How to Avoid Security Problems the Right Way*. Addison-Wesley, 2001.
-  John Viega and Matt Messier. *Secure Programming Cookbook for C and C++*. O'Reilly, 2003.
-  David Wheeler. *Secure Programming for Linux and Unix HOWTO*.
<http://www.dwheeler.com/secure-programs/>.

Recommended Reading

The short book Graff and van Wyk, or an equivalent, Chapters 1, 2, 5 of Wheeler.