

CSci 5271
Introduction to Computer Security
Day 7: Defensive programming and design,
part 1

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Outline

Saltzer & Schroeder's principles
More secure design principles
Software engineering for security
Announcements intermission
Secure use of the OS

Economy of mechanism

- Security mechanisms should be as simple as possible
- Good for all software, but security software needs special scrutiny

Fail-safe defaults

- When in doubt, don't give permission
- Whitelist, don't blacklist
- Obvious reason: if you must fail, fail safe
- More subtle reason: incentives

Complete mediation

- Every mode of access must be checked
 - Not just regular accesses: startup, maintenance, etc.
- Checks cannot be bypassed
 - E.g., web app must validate on server, not just client

Open design

- Security must not depend on the design being secret
- If anything is secret, a minimal key
 - Design is hard to keep secret anyway
 - Key must be easily changeable if revealed
 - Design cannot be easily changed

Open design: strong version

- "The design should not be secret"
- If the design is fixed, keeping it secret can't help attackers
- But an unscrutinized design is less likely to be secure

Separation of privilege

- Real world: two-person principle
- Direct implementation: separation of duty
- Multiple mechanisms can help if they are both required
 - Password and `wheel` group in Unix

Least privilege

- Programs and users should have the most limited set of powers needed to do their job
- Presupposes that privileges are suitably divisible
 - Contrast: Unix `root`

Least privilege: privilege separation

- Programs must also be divisible to avoid excess privilege
- Classic example: multi-process OpenSSH server
- N.B.: Separation of privilege \neq privilege separation

Least common mechanism

- Minimize the code that all users must depend on for security
- Related term: minimize the Trusted Computing Base (TCB)
- E.g.: prefer library to system call; microkernel OS

Psychological acceptability

- A system must be easy to use, if users are to apply it correctly
- Make the system's model similar to the user's mental model to minimize mistakes

Sometimes: work factor

- Cost of circumvention should match attacker and resource protected
- E.g., length of password
- But, many attacks are easy when you know the bug

Sometimes: compromise recording

- Recording a security failure can be almost as good as preventing it
- But, few things in software can't be erased by `root`

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Pop quiz

- What's the type of the return value of `getchar`?
- Why?

Separate the control plane

- Keep metadata and code separate from untrusted data
- Bad: format string vulnerability
- Bad: old telephone systems

Defense in depth

- Multiple levels of protection can be better than one
- Especially if none is perfect
- But, many weak security mechanisms don't add up

Canonicalize names

- Use unique representations of objects
- E.g. in paths, remove ., . . , extra slashes, symlinks
- E.g., use IP address instead of DNS name

Fail-safe / fail-stop

- If something goes wrong, behave in a way that's safe
- Often better to stop execution than continue in corrupted state
- E.g., better segfault than code injection

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Modularity

- Divide software into pieces with well-defined functionality
- Isolate security-critical code
 - Minimize TCB, facilitate privilege separation
 - Improve auditability

Minimize interfaces

- Hallmark of good modularity: clean interface
- Particularly difficult:
 - Safely implementing an interface for malicious users
 - Safely using an interface with a malicious implementation

Appropriate paranoia

- Many security problems come down to missing checks
- But, it isn't possible to check everything continuously
- How do you know when to check what?

Invariant

- A fact about the state of a program that should always be maintained
- Assumed in one place to guarantee in another
- Compare: proof by induction

Pre- and postconditions

- Invariants before and after execution of a function
- Precondition: should be true before call
- Postcondition: should be true after return

Dividing responsibility

- Program must ensure nothing unsafe happens
- Pre- and postconditions help divide that responsibility without gaps

When to check

- At least once before any unsafe operation
- If the check is fast
- If you know what to do when the check fails
- If you don't trust
 - your caller to obey a precondition
 - your callee to satisfy a postcondition
 - yourself to maintain an invariant

Sometimes you can't check

- Check that p points to a null-terminated string
- Check that fp is a valid function pointer
- Check that x was not chosen by an attacker

Error handling

- Every error must be handled
 - i.e, program must take an appropriate response action
- Errors can indicate bugs, precondition violations, or situations in the environment

Error codes

- Commonly, return value indicates error if any
- Bad: may overlap with regular result
- Bad: goes away if ignored

Exceptions

- Separate from data, triggers jump to handler
- Good: avoid need for manual copying, not dropped
- May support: automatic cleanup (finally)
- Bad: non-local control flow can be surprising

Testing and security

- "Testing shows the presence, not the absence of bugs" – Dijkstra
- Easy versions of some bugs can be found by targeted tests:
 - Buffer overflows: long strings
 - Integer overflows: large numbers
 - Format string vulnerabilities: %x

Fuzz testing

- Random testing can also sometimes reveal bugs
- Original 'fuzz' (Miller): `program </dev/urandom`
- Modern: small random changes to a benign input

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Note to early readers

- This is the section of the slides most likely to change in the final version
- If class has already happened, make sure you have the latest slides for announcements

Alternative Saltzer & Schroeder

- Not a replacement for reading the real thing, but:

 <http://emergentchaos.com/>

`the-security-principles-of-saltzer-and-schroeder`

- Security Principles of Saltzer and Schroeder, illustrated with scenes from Star Wars (Adam Shostack)

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Avoid special privileges

- Require users to have appropriate permissions
 - Rather than putting trust in programs
- Anti-pattern 1: setuid/setgid program
- Anti-pattern 2: privileged daemon
- But, sometimes unavoidable (e.g., email)

One slide on setuid/setgid

- Unix users and process have a user id number (UID) as well as one or more group IDs
- Normally, process has the IDs of the user who starts it
- A setuid program instead takes the UID of the program binary

Don't use shells or Tcl

- ... in security-sensitive applications
- String interpretation and re-parsing are very hard to do safely
- Eternal Unix code bug: path names with spaces

Prefer file descriptors

- Maintain references to files by keeping them open and using file descriptors, rather than by name
- References same contents despite file system changes
- Use `openat`, etc., variants to use FD instead of directory paths

Prefer absolute paths

- Use full paths (starting with /) for programs and files
- \$PATH under local user control
- Initial working directory under local user control
 - But FD-like, so can be used in place of `openat` if missing

Prefer fully trusted paths

- Each directory component in a path must be write protected
- Read-only file in read-only directory can be changed if a parent directory is modified

Don't separate check from use

- Avoid pattern of e.g., `access` then `open`
- Instead, just handle failure of `open`
 - You have to do this anyway
- Multiple references allow races
 - And `access` also has a history of bugs

Be careful with temporary files

- Create files exclusively with tight permissions and never reopen them
 - See detailed recommendations in Wheeler
- Not quite good enough: reopen and check matching device and inode
 - Fails with sufficiently patient attack

Give up privileges

- Using appropriate combinations of `set*id` functions
 - Alas, details differ between Unix variants
- Best: give up permanently
- Second best: give up temporarily
- Detailed recommendations: Setuid Demystified (USENIX'02)

Whitelist environment variables

- Can change the behavior of called program in unexpected ways
- Decide which ones are necessary
 - As few as possible
- Save these, remove any others

Next time

- 📖 Recommendations from the author of `qmail`
- 📖 A variety of isolation mechanisms