CSci 4271W
Development of Secure Software Systems
Day 4: Auditing and Threat Modeling 1

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Outline

Code auditing

Integer overflow discussion

Threat modeling

Auditing is...

- Reading code to find security bugs
- Threat modeling comes first, tells you what kinds of bugs you're looking for
- Bug fixing comes next (might be someone else's job)

Tiers and triage

- You might not have time to do a complete job, so use auditing time strategically
- Which bugs are most likely, and easiest to find?
- Triage into definitely safe, definitively unsafe, hard to tell
  - "Hard to tell" might be improved, even if safe

Threat model and taint

- Vulnerability depends on what an attacker might control
- Another word for attacker-controlled is "tainted"
- Threat model is the best source of tainting information
  - Of course, can always be conservative

Where to look for problems

- If you can't read all the code carefully, search for indicators of common danger spots
  - For format strings, look for `printf`
  - For buffer overflows, look at buffers and copying functions

Ideal: proof

- Given enough time, for each dangerous spot, be able to convince someone:
  - Proof of safety: reasons why a bug could never happen, could turn into assertions
  - Proof of vulnerability: example of tainted input that causes a crash

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Overflow example

```
struct obj { short ident, x, y, z; long b; double c;};
struct obj *read_objs(int num_objs) {
    unsigned int size = num_objs*(unsigned)sizeof(obj);
    struct obj *objs = malloc(size);
    struct obj *p = objs;
    for (i = 0; i < num_objs; i++) {
        fread(p, sizeof(struct obj), 1, stdin);
        if (p->ident == 0x4442) return 0;
        /* ... */ p++; }
    return objs; }
```

Overflow example questions

1. What's a value of `num_objs` that would trigger an overflow?
   - Think back to 2021 on how multiplication overflows
2. Why is the `p->ident` check relevant to exploitability?

`http://www-users.cselabs.umn.edu/classes/Spring-2022/csci4271/slides/02/overflow-eg.c`

Integer input parsing

- Input is first parsed with `strtol`
  - As 64-bit signed integer; overflow clamped and ignored
- Then copied to signed int
  - Throw away top bits, reinterpret sign bit
- But any 32-bit int value can be produced by a program input

Loop bound

- Read loop is `for (int i = 0; i < num_objs; i++)`
- `num_objs` negative or zero will read nothing at all

Overflow in multiplication

- Struct size is 24 bytes, or 11000 (16+8) in binary
- `24*x == (x << 4) + (x << 3)`
- Top three bits fall off
- Interpreted as unsigned after multiplication, and by `malloc`

Vulnerability condition

- Overflow happens if we write more than we allocated
- Allocation won't fail on this 64-bit machine (4GB available)
- $24 \cdot \max(x, 0) > (24 \cdot x) \bmod 2^{32}$
- Safe if:
  - Count interpreted as negative
  - Overflow does not occur

Computing overflow values

- One approach: input must be bigger than $2^{32}/24$ to overflow
- No-calculator approach: pick numbers where multiplication is easy
  - Compare in decimal: $1001 \cdot 42 = 42042$

Outline

Why threat modeling?

- Think about and describe the security design of your system
- Enumerate possible threats
- Guide effort spent on combating threats
- Communicate to customers and other developers

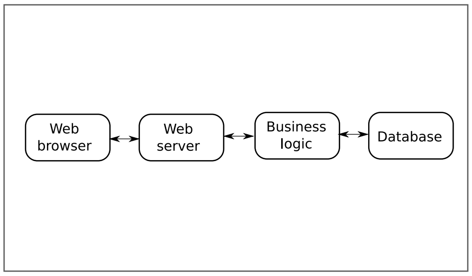
Why a structured approach?

- Goal is to avoid missing a threat
- Enumerate vectors for threats
- Enumerate kinds of threats per vector
- Convince readers of the model's completeness

Data-flow modeling

- Break down software into smaller modules
  - Modules drawn with rounded rectangles
  - More detail is better, within reason
- Show data flows among modules and external parties
  - Rectangles for external parties
  - Most data flows will be bi-directional

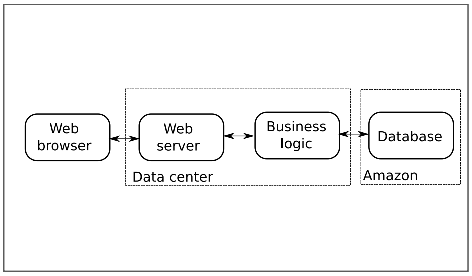
Data flow example



Trust boundaries

- A trust boundary groups components with the same privilege, which therefore trust each other
  - Drawn as labeled dotted box
  - Attacks usually don't originate within a trust group
- The boundary also corresponds to an *attack surface*

Trust boundaries example



Attacks come with data flows

- Principle: attacks propagate along data flows
- Therefore, enumerate flows to enumerate attacks
  - A more specific prompt, but does not eliminate the need for imagination
  - Other half is types of attacks, see next slide

STRIDE threat taxonomy

- Spoofing (vs authentication)
- Tampering (vs integrity)
- Repudiation (vs. non-repudiation)
- Information disclosure (vs. confidentiality)
- Denial of service (vs. availability)
- Elevation of privilege (vs. authortization)

What to do about threats

- Mitigate: add a defense, which may not be complete
- Eliminate: such as by removing functionality
- Transfer functionality: let someone else handle it
- Transfer risk: convince another to bear the cost
- Accept risk: decide that the risk (probability · loss) is sufficiently low

Spoofing threat examples

- Using someone else's account
- Making a program use the wrong file
- False address on network traffic

Tampering threat examples

- Modifying an important file
- Rearranging directory structure
- Changing contents of network packets

Repudiation threat examples

- Performing an important action without logging
- Destroying existing logs
- Add fake events to make real events hard to find or not credible

Info. disclosure threat examples

- Eavesdropping on network traffic
- Reading sensitive files
- Learning sensitive information from meta-data

DoS threat examples

- Flood network link with bogus traffic
- Make a server use up available memory
- Make many well-formed but non-productive interactions

Elevation of privilege threat examples

- Cause data to be interpreted as code
- Change process to run as root/administrator
- Convince privileged process to run attacker's code