CSCI 1800 Cybersecurity and International Relations

Security Through Software Engineering

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Outline

• Security modeling including access control
• Federal security regulations and standards
• Software vulnerability assessments
• Microsoft’s Security Development Lifecycle
• Introduction to Threat Analysis
Policy, Models and Trust

• To have secure systems, engineers need clear
  – Security goals
  – Effective implementation strategy

• A security policy puts constraints on actions that can taken by actors on objects in the system in order to achieve security goals.
Security Policy Components

- **Actors**
  - Individual or group agents interacting with a system.

- **Objects**
  - Informational/computational resources affected by policy.

- **Actions**
  - Possible modifications to objects, e.g. read, edit, copy, remove

- **Permissions**
  - Rules constraining actions that actors may take on objects.

- **Protections**
  - Features of policy, e.g. confidentiality, availability, anonymity.
Security Model

• A security model is an abstraction providing conceptual language to specify security policies.
  – E.g. Unclassified (U), Confidential (C), Secret (S), Top Secret (TS)
  – Special compartments for special compartmentalized information (SCI), such as human intelligence (HUMINT), satellite observations (GEOINT)
Two Models of Access Control

• **Discretionary access control**
  – Owner may specify permissions on files
  – A more relaxed form of control

• **Mandatory access control**
  – Administrator fixes permissions in advance.
  – More strict control

• **Rules have subjects** (parties requesting access) and **objects** (those things being accessed).
Bell-LaPadula (BLP) Access Control Model

• Applies to **confidentiality** – dates from the 1970s
• Object x and user u have security levels L(x) & L(u)
  – Examples of security levels: U, C, S, TS
• For users u and v, v has higher clearance than u if L(u) ≤ L(v). u can pass info to v but not vice versa.

• No “read up” (user can’t see more secure data)
  – User u can read x only if L(x) ≤ L(u)
• No “write down” (user can’t use more secure data)
  – User u can write to object x only if L(u) ≤ L(x).
BLP Access Control Model

BLP model weakness: only handles confidentiality
Ken Biba (‘77) Access Control Model

• Goal of Biba’s model is to maintain data integrity:
  – the accuracy and consistency of data over its life-cycle.

• Let $I(x)$ and $I(u)$ be the integrity of user $u$ & object $x$
  – The higher is $I(u)$ or $I(x)$, the more trustworthy or accurate the user $u$ or object $x$ is.

• Don’t corrupt data by reading from lower integrity level, don’t write to higher integrity level.
  • User $u$ can read object $x$ only if $I(u) \leq I(x)$.
  • User $u$ can write to object $x$ only if $I(x) \leq I(u)$.
Role-Based Access Control

- **Components:** users, roles, permissions, sessions
  - A role is a collection of users.
  - A session is an interaction for a period of time.
- **Role hierarchy** is defined, as in a corporation.
  - President IsA manager IsA employee
  - Higher role user inherits permissions of lower one
  - When is this not a good idea?
- **Role constraints** may be imposed
  - Example: avoid conflicts of interest.
USG Security Standards

  – Division A: system has a formal process for verification of security
  – Division B: mandatory access control
  – Division C: discretionary access control
  – Division D: minimal protection criteria
USG Security Standards

- **Common Criteria** for Information Technology Security Evaluation – an ISO standard
  - It subsumes the Orange Book
  - Defines key concepts related to security evaluations
  - Framework for documenting security goals
  - Not a certification vouching for product security.
Government Regulations & Standards

• Federal Information Processing Standards (FIPS 140-2)
  – Standards for designing/handling of cryptographic modules by US government organizations
  – Last updated in 2002

• Security levels:
  1. **No physical security**, can run modules on open machine
  2. **Some physical security**, e.g. tamper-evident coatings, some role-based authentication, trusted OS
  3. **Prevent physical tampering, identity-based authentication** instead of role-based authentication
  4. **Tighter physical security**, all keys and messages destroyed when unauthorized attempts to break security are made.
Government Regulations & Standards

- **HIPAA (1996)**
  - Sets privacy standards on patient records for healthcare providers and employers.

- **Family Educational Rights and Privacy Act (FERPA) (‘74)**
  - Requires protection of privacy of educational records in US.

- **Federal Information Security Management Act (FISMA)**
  - Revised in 2014 – provides government information security.
  - It requires federal agencies to implement processes and controls designed to ensure the confidentiality, integrity, and availability of system-related information.
  - Must follow FISMA and NIST standards, and legislative requirements, such as the Privacy Act of 1974.
Software Vulnerability Assessment

• The problem: software can be enormous
  – Mac OS X 10.4 has > 86 million lines of code!
  – Code can have both performance & security bugs

• “A vulnerability is a security exposure that results from a product weakness ... the product developer did not intend to introduce and should fix once it is discovered.”*

• How many errors per 1,000 lines of code (KLOC)?
  – Estimates vary from 5-50 defects per KLOC
  – Some open-source have bug density of .4 bugs/KLOC!†

* Microsoft definition

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Software Vulnerability Assessment

• Approaches to vulnerability assessment:
  – **Black-box analysis**
    • Penetration test (pentest) done without knowledge of innards.
    • Pentests look for security vulnerabilities
  – **White-box analysis**
    • Same but with full knowledge of hardware/software, network environment, etc.
Code Analysis for Privacy/Security

• Problem: Cybercrime is here to stay.
• Goal: **Find and remove privacy/security hazards.**
  – Static code analysis studies non-running programs.
    • This is white-box testing of non-running code. E.g.
  – Dynamic analysis examines running programs.
• Good analysis requires training and investment
  – Software engineers generally not educated on this.
  – Microsoft’s Security Development Lifecycle (SDL) represents a big step forward.
• Benefits: Improved security, privacy and reliability.
Components of Static Code Analysis*

• Data Flow Analysis
  – Based on analysis of basic blocks, sections of code in which control stays within a block during execution

• Control flow graph (CFG)
  – Shows all possible control paths

• Taint analysis
  – It identifies variables touched by users or “tainted”
  – Influence of tainted variables on the CFG and actions

* https://www.owasp.org/index.php/Static_Code_Analysis
Example of a Basic Block

1. $a = 0;
2. $b = 1;
3.
4. if ($a == $b)
5. { # start of block
6.   echo “a and b are the same”;
7. } # end of block
8. else
9. { # start of block
10. echo “a and b are different”;
11. } # end of block

Note: # starts a comment
Example of Data Flow Graph
Dynamic Code Analysis

• Good analysis explores all important paths
  – Requires good choice of test data
  – Incomplete testing can result in catastrophic failure
• “Fuzzing” can reveal hidden errors
• Malware may detect it is being run in a virtual environment and not activate
• Many tools exist for dynamic software analysis
Top Incidents in 2016 Verizon Report*

Incidents representing more than 90% of data breaches:
1. Insider and privilege misuse
2. Cyber-espionage – attacks by external actors hunting for data & trade secrets
3. Web application attacks
4. Crimeware – malware incidents, typically opportunistic and financially motivated in nature (e.g., banking Trojans, ransomware).
5. Point-of-sale (POS) Intrusions
6. Denial of service (DoS) Attacks
7. Payment card skimmers – tampering of ATMs and fuel terminals.
8. Physical theft and loss of data or IT-related assets.

Microsoft’s Security Development Lifecycle (SDL)

• Bill Gates inaugurated Microsoft’s Trustworthy Computing Initiative in 2002.
  – Success with major new corporate initiatives often requires support from top management.
• Every product that impacts privacy or may be used by children needs security analysis.
  – This means almost all hardware/software products
• Average cost of fixing a security bug was $300K!
• Microsoft code is now among the most secure!
Microsoft’s SDL

- Personnel must be trained.
- Security requirements, risk assessment needed
- Must do threat modeling (STRIDE) and reduce attack surface.
  - Spoofing, Tampering, Repudiation, Information Disclosure, Denial of service, Elevation of privilege.
- Implementation requires good tools to protect against attacks
- Must plan for post-release handling of errors
- Verification needed via dynamic analysis including fuzzing.
Modeling System Threats

- *Data flow analysis* preferable to *exploring assets or motivations of attackers*.
- Group components by *trust boundaries*
Information Security Attributes
The CIA Triad

- **Confidentiality**: Access to information is limited to those with proper authorization.

- **Integrity**: Maintaining the consistency, accuracy and trustworthiness of data during its life cycle.

- **Availability**: Reliable access is maintained to resources by authorized parties.
STRIDE Threats*

- **S** – Spoofing
- **T** – Tampering
- **R** – Repudiation
- **I** – Information Disclosure
- **D** – Denial of Access or Service
- **E** – Elevation of Privilege

* Microsoft’s mnemonic for types of software threats
STRIDE Explained

- **S** – pretending to be another person or thing
- **T** – modifying something one should not
- **R** – falsely claiming not to have taken an action
- **I** – exposing information to those unauthorized
- **D** – denying users access to a service
- **E** – acquiring access at an elevated level
## STRIDE Elaborated

<table>
<thead>
<tr>
<th>Threats</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spoofing</td>
<td>Authenticity</td>
</tr>
<tr>
<td>Tampering</td>
<td>Integrity</td>
</tr>
<tr>
<td>Repudiation</td>
<td>Non-Repudiation</td>
</tr>
<tr>
<td>Information Disclosure</td>
<td>Confidentiality</td>
</tr>
<tr>
<td>Denial of Service</td>
<td>Availability</td>
</tr>
<tr>
<td>Elevation of Privilege</td>
<td>Proper Authorization</td>
</tr>
</tbody>
</table>
Options to Address Threats (META)

• Mitigate a threat
  – Increase the work to exploit it
• Eliminate a threat
  – Usually requires elimination of features
• Transfer of a threat
  – Let some other system element cope with it
• Accept a threat
  – Risk acceptance may be less costly than other steps
Source Material

Is Open Source Software a Panacea?

• Software is available for modification under liberal copyright policy.
• Do many eyeballs on the code make it secure?
  – “… in reality that doesn’t happen” Cowan 2002.
• Russia believes it – avoids US software.
  – Putin orders Russian government to move to Open Source Software by 2015. (12/28/2010)
• Problems: No incentive to find bugs. Coders not trained to find them. It is hard!

Review

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- Federal security regulations and standards
- Software vulnerability assessments
- Microsoft’s Security Development Lifecycle
- Introduction to Threat Analysis