CSE 484 / CSE M 584: Web Security

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Announcements / Plan

• Monday (2/20): No class
• Wednesday (2/22): Zoom (no office hours)
• Friday (2/24): Guest Lecture: Alex Gantman (Qualcomm) (On Zoom)

1. Injection
2. Broken Authentication
3. Sensitive Data Exposure
4. XML External Entities (XXE)
5. Broken Access Control
6. Security Misconfiguration
7. Cross-Site Scripting (XSS)
8. Insecure Deserialization
9. Using Components with Known Vulnerabilities
10. Insufficient Logging and Monitoring
Cross-Site Scripting (XSS)
PHP: Hypertext Processor

• Server scripting language with C-like syntax
• Can intermingle static HTML and code

  <input value='?php echo $myvalue; ?>'>

• Can embed variables in double-quote strings

  $user = "world"; echo "Hello $user!";
  or  $user = "world"; echo "Hello" . $user . "!";

• Form data in global arrays $_GET, $_POST, ...
Echoing / “Reflecting” User Input

Classic error in server-side applications


search.php responds with
<html> <title>Search results</title> <body>You have searched for <?php echo $_GET['term'] ?>… </body>
Echoing / “Reflecting” User Input

naive.com/hello.php?name= User

Welcome, dear User

Welcome, dear

Cross-Site Scripting (XSS)

Access some web page


Forces victim’s browser to call hello.cgi on naive.com with this script as “name”

GET/steal.php?cookie=

Interpreted as JavaScript by victim’s browser; opens window and calls steal.cgi on evil.com


<HTML>Hello, dear
Welcome!</HTML>

evil.com

naive.com

Hello.php

Hello.php executed

victim’s browser
Basic Pattern for Reflected XSS

Injected script can manipulate website to show bogus information, leak sensitive data, cause user’s browser to attack other websites. This violates the “spirit” of the same origin policy!
Reflected XSS

• User is tricked into visiting an honest website
  – Phishing email, link in a banner ad
• Bug in website code causes it to echo to the user’s browser an arbitrary attack script
  – The origin of this script is now the website itself!
• Script can manipulate website contents (DOM) to show bogus information, request sensitive data, control form fields on this page and linked pages, cause user’s browser to attack other websites
  – This violates the “spirit” of the same origin policy
Stored XSS

1. Attack server injects malicious script.
2. Server victim stores the malicious script.
3. User victim requests content.
4. User victim receives malicious script and requests content.

Users view or download content.

Attack server

Server victim
Where Malicious Scripts Lurk

• User-created content
  – Social sites, blogs, forums, wikis

• When visitor loads the page, website displays the content and visitor’s browser executes the script
  – Many sites try to filter out scripts from user content, but this is difficult!
Preventing Cross-Site Scripting

• Any user input and client-side data must be preprocessed before it is used inside HTML
• Remove / encode HTML special characters
  – Use a good escaping library
    • OWASP ESAPI (Enterprise Security API)
    • Microsoft’s AntiXSS
  – In PHP, htmlspecialchars(string) will replace all special characters with their HTML codes
    • ‘ becomes &#039; “ becomes &quot; & becomes &amp;”
  – In ASP.NET, Server.HtmlEncode(string)
Evading Ad Hoc XSS Filters

• Preventing injection of scripts into HTML is hard! → Use standard APIs
  – Blocking “<” and “>” is not enough
  – Event handlers, stylesheets, encoded inputs (%3C), etc.
  – phpBB allowed simple HTML tags like <b>
    \[<b c="">" onmouseover="script" x="<b >">Hello</b>\]

• Beware of filter evasion tricks (XSS Cheat Sheet)
  – If filter allows quoting (of <script>, etc.), beware of malformed quoting:
    \[<IMG """"><SCRIPT>alert("XSS")</SCRIPT>"\]
  – Long UTF-8 encoding
  – Scripts are not only in <script>:
    \[<iframe src='https://bank.com/login’ onload='steal()'>\]
MySpace Worm (1)

- Users can post HTML on their MySpace pages
- MySpace does not allow scripts in users’ HTML
  - No `<script>`, `<body>`, `onclick`, `<a href=javascript://>`
- ... but does allow `<div>` tags for CSS.
  - `<div style="background:url(‘javascript:alert(1)’)">`
- But MySpace will strip out “javascript”
  - Use “java<NEWLINE>script” instead
- But MySpace will strip out quotes
  - Convert from decimal instead:
    `alert('double quote: ' + String.fromCharCode(34))`
MySpace Worm (2)

Resulting code:

```javascript
<script type="text/javascript">
// JavaScript code goes here
</script>
```

https://samy.pl/myspace.tech.html
MySpace Worm (3)

• “There were a few other complications and things to get around. This was not by any means a straight forward process, and none of this was meant to cause any damage or [make anyone angry]. This was in the interest of..interest. It was interesting and fun!”

• Started on “samy” MySpace page

• Everybody who visits an infected page, becomes infected and adds “samy” as a friend and hero

• 5 hours later “samy” has 1,005,831 friends
  – Was adding 1,000 friends per second at its peak

https://samy.pl/myspace/tech.html
Another Common Web App Vulnerability: SQL Injection
Typical Login Prompt
Typical Query Generation Code

```
$selecteduser = $_GET['user'];
$sql = "SELECT Username, Key FROM Key " .
    " WHERE Username='".$selecteduser."';
$rs = $db->executeQuery($sql);
```

What if ‘user’ is a malicious string that changes the meaning of the query?
User Input Becomes Part of Query

SELECT passwd
FROM USERS
WHERE uname IS ‘$user’
Normal Login

Web browser (Client) → Enter Username & Password → Web server → SELECT passwd FROM USERS WHERE uname IS ‘alice’ → DB
Malicious User Input
SQL Injection Attack

Web browser (Client) → Web server

Enter Username & Password

SELECT passwd
FROM USERS
WHERE uname IS ' '; DROP TABLE USERS; -- ';

DB

Eliminates all user accounts
Hi, this is your son’s school. We’re having some computer trouble.

Oh, dear — did he break something?

In a way—

Did you really name your son Robert’); DROP TABLE Students;--?

Oh, yes. Little Bobby Tables, we call him.

Well, we’ve lost this year’s student records. I hope you’re happy.

And I hope you’ve learned to sanitize your database inputs.

http://xkcd.com/327/
SQL Injection: Basic Idea

- This is an input validation vulnerability
  - Unsanitized user input in SQL query to back-end database changes the meaning of query
- Special case of command injection

1. Post malicious form
2. Unintended query
3. Receive data from DB
Authentication with Backend DB

set UserFound = execute(
    "SELECT * FROM UserTable WHERE
    username='" & form("user") & "' AND
    password='" & form("pwd") & "'");

User supplies username and password, this SQL query checks if user/password combination is in the database

If not UserFound.EOF
    Authentication correct
else Fail

Only true if the result of SQL query is not empty, i.e., user/pwd is in the database

(*) remember to hash passwords for real authentication scheme
Using SQL Injection to Log In

• User gives username: ’ OR 1=1 --

• Web server executes query

\[
\text{set UserFound=execute(}
\text{SELECT * FROM UserTable WHERE}
\text{username=’ ’ OR 1=1 -- … );}
\]

Always true! Everything after -- is ignored!

• Now all records match the query, so the result is not empty ⇒ correct “authentication”!
“Blind SQL Injection”
https://owasp.org/www-community/attacks/Blind_SQL_Injection

• SQL injection attack where attacker asks database series of true or false questions

• Used when
  – the database does not output data to the web page
  – the web shows generic error messages, but has not mitigated the code that is vulnerable to SQL injection.

• SQL Injection vulnerability more difficult to exploit, but not impossible.
Preventing SQL Injection

• Validate all inputs
  – Filter out any character that has special meaning
    • Apostrophes, semicolons, percent, hyphens, underscores, ...
    • Use escape characters to prevent special characters from becoming part of the query code
      – E.g.: escape(O’Connor) = O\’Connor
  – Check the data type (e.g., input must be an integer)

• Same issue as with XSS: is there anything accidentally not checked / escaped?
Prepared Statements

```java
PreparedStatement ps =
    db.prepareStatement("SELECT pizza, toppings, quantity, order_day "
                      + "FROM orders WHERE userid=? AND order_month=?");
ps.setInt(1, session.getCurrentUserId());
ps.setInt(2, Integer.parseInt(request.getParameter("month")));
ResultSet res = ps.executeQuery();
```

- **Bind variables**: placeholders guaranteed to be data (not code)
- Query is parsed without data parameters
- Bind variables are typed (int, string, ... )

http://java.sun.com/docs/books/tutorial/jdbc/basics/prepared.html
Core Issue: Data-As-Code

• XSS

• SQL Injection

• (Like buffer overflows)
Cross-Site Request Forgery (CSRF/XSRF)
Browser Sandbox Review

• Based on the same origin policy (SOP)
• Active content (scripts) can send anywhere!
  – For example, can submit a POST request
  – Some ports inaccessible -- e.g., SMTP (email)
• Can only read response from the same origin
  – ... but you can do a lot with just sending!
Cross-Site Request Forgery

• Users logs into bank.com, forgets to sign off
  – Session cookie remains in browser state
• User then visits a malicious website containing
  `<form name=BillPayForm
  action=http://bank.com/BillPay.php>
  <input name=recipient value=attacker> ...

  <script> document.BillPayForm.submit(); </script>

• Browser sends cookie, payment request fulfilled!
• **Lesson**: cookie authentication is not sufficient when side effects can happen
Cookies in Forged Requests

User credentials automatically sent by browser
Sending a Cross-Domain POST

```
<form method="POST" action=http://othersite.com/action >
...
</form>
<script>document.forms[0].submit()</script>
```

- Hidden iframe can do this in the background
- User visits a malicious page, browser submits form on behalf of user
  - Hijack any ongoing session (if no protection)
    - Netflix: change account settings, Gmail: steal contacts, Amazon: one-click purchase
  - Reprogram the user’s home router
  - Many other attacks possible
Impact

• Hijack any ongoing session (if no protection)
  – Netflix: change account settings, Gmail: steal contacts, Amazon: one-click purchase
• Reprogram the user’s home router
• Login to the attacker’s account
  – Why might an attacker want this?
XSRF True Story

Internet Explorer

www.cybervillians.com/news.html

Bernanke Really an Alien?

script

GET news.html

HTML and JS

HTML Form POSTs

StockBroker.com

ticker.stockbroker.com

Java

Hidden iframes submitted forms that...
- Changed user’s email notification settings
- Linked a new checking account
- Transferred out $5,000
- Unlinked the account
- Restored email notifications
XSRF (aka CSRF): Summary

1. establish session
2. visit server
3. receive malicious page
4. send forged request

Q: how long do you stay logged on to Gmail? Financial sites?
Broader View of XSRF

• Abuse of cross-site data export
  – SOP does not control data export
  – Malicious webpage can initiate requests from the user’s browser to an honest server
  – Server thinks requests are part of the established session between the browser and the server (automatically sends cookies)
XSRF Defenses

• Secret validation token

• Referer validation
Referer Validation

• **Lenient** referer checking – header is optional
• **Strict** referer checking – header is required

Referer:
http://www.facebook.com/home.php

Referer:
http://www.evil.com/attack.html

Referer:
Why Not Always Strict Checking?

• Why might the referer header be suppressed?
  – Stripped by the organization’s network filter
  – Stripped by the local machine
  – Stripped by the browser for HTTPS → HTTP transitions
  – User preference in browser
  – Buggy browser

• Web applications can’t afford to block these users

• Many web application frameworks include CSRF defenses today
Better Idea: Add Secret Token to Forms

• “Synchronizer Token Pattern”
• Include a secret challenge token as a hidden input in forms
  – Token often based on user’s session ID
  – Server must verify correctness of token before executing sensitive operations
• Why does this work?
  – **Same-origin policy:** attacker can’t read token out of legitimate forms loaded in user’s browser!
  – So: can’t create fake forms with correct token!

<input type=hidden value=23a3af01b>