Learning security through insecurity

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Web application security

- **86%** of all websites have **at least one serious vulnerability** (Ø: 56 vuln.)*
- Web applications are ubiquitous: Almost everything on the web is not a static webpage, but generated dynamically; most are based on a database
  - But see also the trend for mobile devices: HTML5 instead of Apps (which are similar anyway regarding security, but not the topic here)
- Practically all web applications are insecure
  - E.g. XSSed.com: Web site with XSS vulnerabilities. These included (and regularly occur again!): Google, Microsoft, Facebook, NYTimes, Ebay, McAfee, PayPal…
- Therefore: Education in website security is sorely needed!
  - Also: 57% provide some security training → 40% fewer vulnerabilities, solved 59% faster; but 12% lower remediation rate*

*: WhiteHat Website Security Statistics Report 5/2013, https://www.whitehatsec.com/assets/WPstatsReport_052013.pdf

Part of the solution: more security education

- Security education is urgently needed – for all kinds of SW, but specifically for web applications because of their public attack surface
- Potential approaches:
  - Paper, book, lectures: Security problems and their solutions are described
    - Nice, but depends on attention & retention; lacks training in applying them
  - Penetration testing: Good for testers, but will help implementers little
- Proposed solution:

Interactive system where security problems are shown, can be tested, and remedies are also explained and can be tested too

Existing systems

- WebGoat: Insecure web application
  - J2EE and ASP.NET environments; Java Runtime + Tomcat + Web application
  - Black-box testing to exploit vulnerabilities
  - No corrected (=secure) version available
- HackThisSite: Numerous individual small web application
  - Penetration testing: Users must hack them
  - No source code of the applications; no corrected versions
  - Includes also modifying executables, steganography etc.
- Damn Vulnerable Web Application:
  - Live-CD or existing web server; source code accessible
  - Three security levels available (insecure, programmed-tried-but-failed, secure)
  - Few vulnerabilities, no education (explanations e.g. for secure version lacking)

Proposed solution: aims & characteristics (1)

- Independent vulnerabilities: No “real” application
  - Easier to understand because code is short and little external elements contained
  - But: Differs significantly from real applications
    - Finding problems is more difficult, not-programming them gets easier!
- Providing solutions: For education
  - Each vulnerability exists twice: Once vulnerable and once fixed
  - This includes explanations why this is a fix and what other approaches are possible
- Versatile: Many security problems shall be exemplified
  - No artificial restrictions
  - Problems for server, other servers, and end-users

Proposed solution: aims & characteristics (2)

- Simplicity: “Pure” vulnerabilities; no pre-knowledge required
  - Avoiding frameworks, template engines, complex stylesheets etc.
  - To focus the attention on the security issues and remove extraneous clutter
- No hacking: Penetration testing is no goal
  - Testing only to understand problem & test own code; no exploitation (remote shell etc.)
- Self-contained: No additional software needed
  - Must be trivial to use; download should be small; no public webserver
- Own webserver implementation: Required for some vulnerabilities
  - Allows running several webservers and reduces complexity
- One-time bonus: Students implemented the individual vulnerabilities

The SecuritySampleServer

- Implemented in Java, as this is the main teaching language (here)
  - Also widely use for web applications
- Webserver: Implemented in Java too
  - Uncommon for a webserver, but here acceptable
  - Supports GET/PUT, cookies, and server-side-includes: Simple (and insecure!)
  - Started on port 8080 (80 might already be used), and 8081…
- Each "application" embodies a single vulnerability and is called directly
  - Specific "path" element for each, where individual subpaths are possible
- No database included in general, individual applications use an in-memory SQL database

Anatomy of a lesson (1)

- Each lesson consists of several webpages and two applications
- Introductory page
  - General description of the problem
  - Shows a color-coded table of the "danger" from this vulnerability:
    - Exploitability: How easy it is to exploit the vulnerability
    - Prevalence: How common is this problem
    - Detectability: How easy it is to find out if a problem has such a vulnerability
    - Impact: What can happen when it is exploited
- Insecure code: The full code of the example application
  - General elements are placed in a base class → typ. 50-150 lines of code

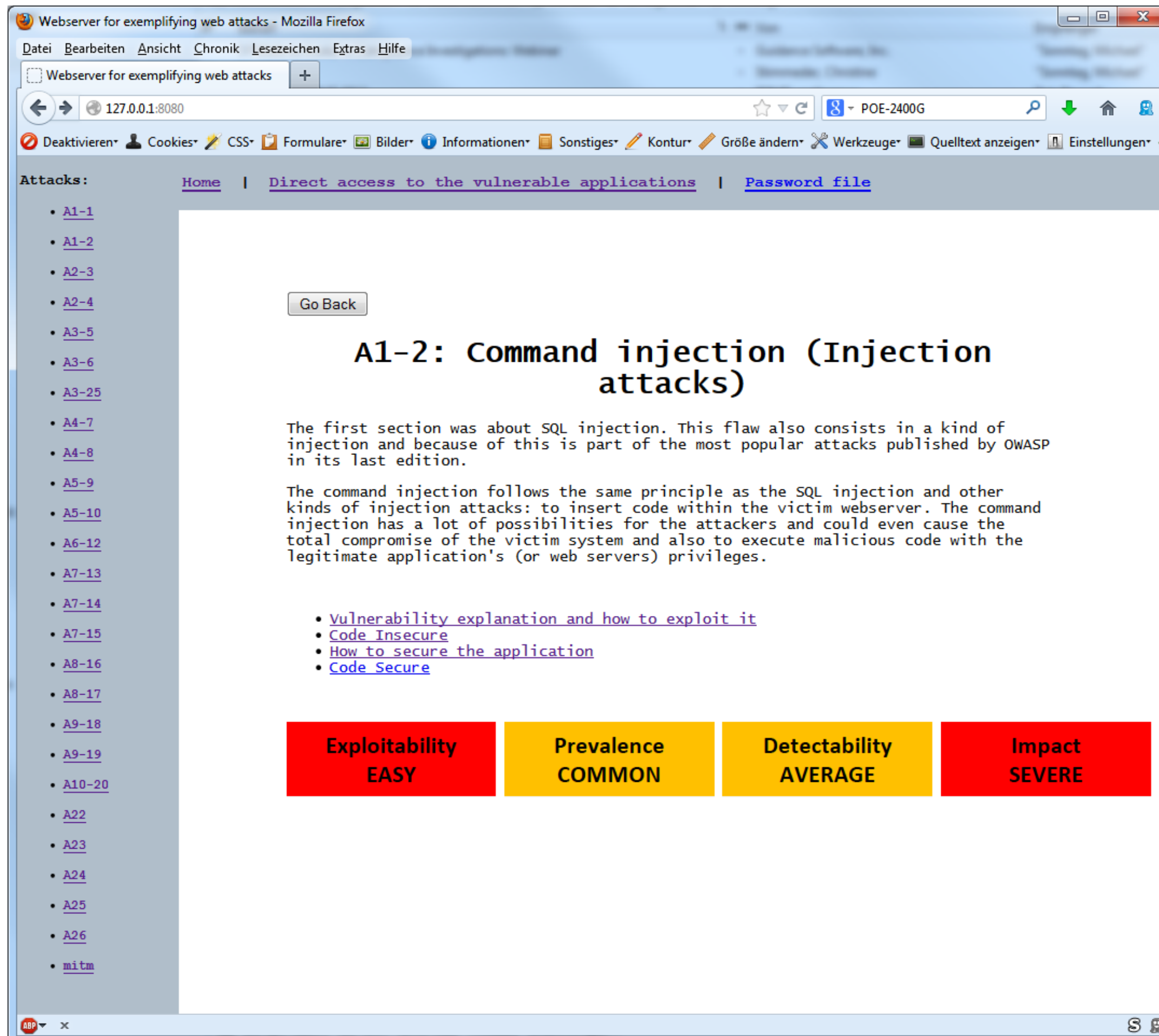
Anatomy of a lesson (2)

- Explanation of the vulnerability
  - Includes exploits and directions to try them (if possible direct links)
    - Can be tested manually, also with other parameters/data/…
  - Partially shows code and browser results
  - Database or other state: Reset link to restore the app to the initial version
- How to secure the application
  - Explanation how to prevent such an attack; what must be changed in the code
  - Links to same exploits as before, just not working any more
    - Own tests can be tried again too, obviously!
- Secure code: The code of the same application without the vulnerability

Restrictions and limitations

- Only “pure” vulnerabilities, but none specific to a language or a framework
  - Different languages might be included through a bridge
    - Especially interpreted languages, which learners could change directly
  - No buffer overflows (→ Java!): They are just explained
- Not available online: Too insecure
  - A secure tunnel to a cloned VM would be too complex/expensive
- Simplistic view because of independent vulnerabilities
  - Investigating code for them is different in reality; so less suited for educating testers
- No assessment: Learners can try out, but their activities are not logged
  - Formative self-assessment could be built into it

Example lesson: OS command injection (1)



Example lesson: OS command injection (2)

A1_2: OS command injection

Output of the Echo command:

value

http://127.0.0.1:8080/A1_2/insecure/CmdEchoApp/?param=value ** Try it in a new window **

But the attacker could try the following as input value:

param=value&netstat -an -p UDP

Or what is the same:

param=value%26netstat -an -p UDP

And the insecure application will answer with the private information:

A1_2: OS Command Injection - Windows Internet Explorer

http://127.0.0.1:8080/A1_2/insecure/CmdEchoApp/?param=value%26netstat -an -p UDP

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A1_2: OS Command Injection

A1_2: OS command injection

Output of the Echo command:

value

Conexiones activas

Proto Direcci¢n local Direcci¢n remota Estado

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Example lesson: OS command injection (3)

Go Back

A1.2: Code Secure

```
package simplewebserver.application.A1_2;

import java.io.IOException;
import java.io.OutputStream;

import simplewebserver.SimpleWebServer;

public class SecureCmdEchoApp extends CmdEchoApp {

    public SecureCmdEchoApp(final SimpleWebServer server) {
        super(server);
    }

    @Override
    public boolean handlesRequest(String host, String path) {
        return path.equalsIgnoreCase("/A1_2/secure/CmdEchoApp/");
    }

    @Override
    protected String[] getCmdLine(OutputStream responseStream, String cmd, String osName) throws IOEx
        // remove all non-alphanumeric characters except for some punctuation marks
        return super.getCmdLine(responseStream, cmd.replaceAll("[^A-Za-z0-9 _.-]", " "), osName);
    }
}
```

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Example lesson: OS command injection (4)

value

http://127.0.0.1:8080/A1_2/secure/CmdEchoApp/?param=value** Try it in a new window **

But when the attacker tries to "steal" some information, the program avoids this by filtering all illegal characters from the passed string (here extremely strict; only letters, numbers and _, - and . are allowed).

127.0.0.1:8080/A1_2/secure/CmdEchoApp/?param=value%26netstat -an -p UDP

Deaktivieren Cookies CSS Formulare Bilder Informationen

A1_2: OS command injection

Output of the Echo command:

value netstat -an -p UDP

Go back

The code changed is the function "getCmdLine":

```
@Override
protected String[] getCmdLine(OutputStream responseStream, String cmd, String osName) throws IOException {
    // remove all non-alphanumeric characters except for some punctuation marks
    return super.getCmdLine(responseStream, cmd.replaceAll("[^A-Za-z0-9 _.-]", " "), osName);
}
```

Apart from method used before, we have some others tips in order to prevent OS Command injection:

- We can also use Java library calls to avoid direct calls to operating system commands.
- Ideally only predefined and fixed commands are issued and the application merely selects from them based on user input.
- We can use a Sandbox. A Sandbox is a security mechanism in order to separate the programs in execution from the rest of our machine. With this method we

Conclusions

- Practical evaluation is planned for next summer term (=next course)
- Planned extensions:
  - Gathering statistics on usage locally (potentially anonymized upload)
    - Might be extended to scoring: Provide hints based on tries, show completed elements etc. → Towards a tutoring system
  - Bridge to PHP, for interpreted languages
  - Differential view on code: Comparing the insecure and the secure code
  - Adding a different educational approach: Secure version is not available initially
    - Students only receive explanations and must correct the code, which is then automatically tested by the system (examples shown + additional ones)

Link

- **The server can be downloaded under**

  http://www.fim.uni-linz.ac.at/Research/SecuritySampleServer/SecuritySampleServer.zip

- Running it:
  - Download and unpack to a local folder
  - Run Start.bat (or start.sh - depending on OS; requires a JRE!)
  - Open http://127.0.0.1:8080/ in your webbrowser

Thank you for your attention!

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