Security in Software Applications

Input Validation

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Input Validation

- Lack of input validation is the most commonly exploited vulnerability
- Many variants of attacks that exploit this
  - buffer overflows – "C(++) injection"
    - possibly via format string attacks and integer overflow attacks
  - Command injection
  - SQL injection
  - XSS (Cross site scripting) - "script injection"
  - …

Input Validation

- Buffer overflows
  - format string attacks
  - integer overflow
- Command injection
- SQL injection
- File name injection
- General remarks about input validation

Command Injection (CGI script)

- A CGI script might contain

  `cat thefile | mail clientaddress`

- An attack might enter email address

  `pippo@di.uniroma1.it | rm -rf`

- What happens then ?

  ```
  cat thefile | mail pippo@di.uniroma1.it |
  rm -rf/
  ```

- Can you think of countermeasures ?
  - validate input
  - reduce access rights of CGI script (*defense in depth*)
  - maybe we shouldn't use such a scripting languages for this?

Command Injection (C program)

Code that uses the system interpreter to print to a user-specified printer might include

```
char buf[1024];
snprintf(buf,"system lpr -P %s",printer_name,
          sizeof(buf)-1);
system(buf);
```

This can be attacked in the same way; entering

```
miro;xterm&
```

is less destructive and more interesting than

```
...;rm -fr /
```

Command Injection

- Vulnerability: many API calls and language constructs in many languages are affected, eg
  - **C/C++** `system(), execvp(), ShellExecute(), ..`
  - **Java** `Runtime.exec(), ...`
  - **Perl** `system, exec, open, `, /e, ...`
  - **Python** `exec, eval, input, execfile, ...`
  - **...**
- Countermeasures
  - validate *all* user input
    - *whitelist*, not blacklist
  - run with *minimal* privileges
    - doesn't prevent, but mitigates effects

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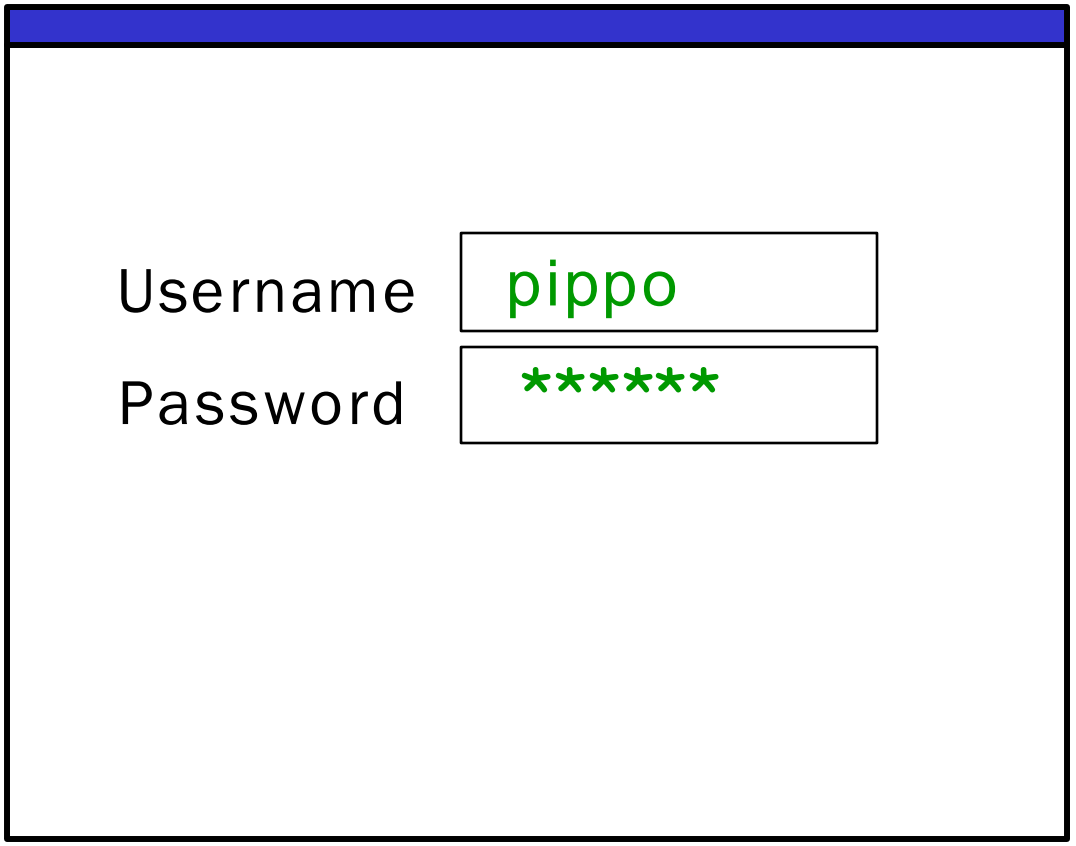
SQL injection



SQL injection

```
$result = mysql_query( “SELECT * FROM Accounts”.
      “WHERE Username = ’$username’”. “AND Password =
                        ’$password’;”);
          if (mysql_num_rows($result)>0)
                    $login = true;
```

SQL injection

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$result = mysql_query( "SELECT * FROM Accounts".
      "WHERE Username = '$username'". "AND Password =
                        '$password';");
          if (mysql_num_rows($result)>0)
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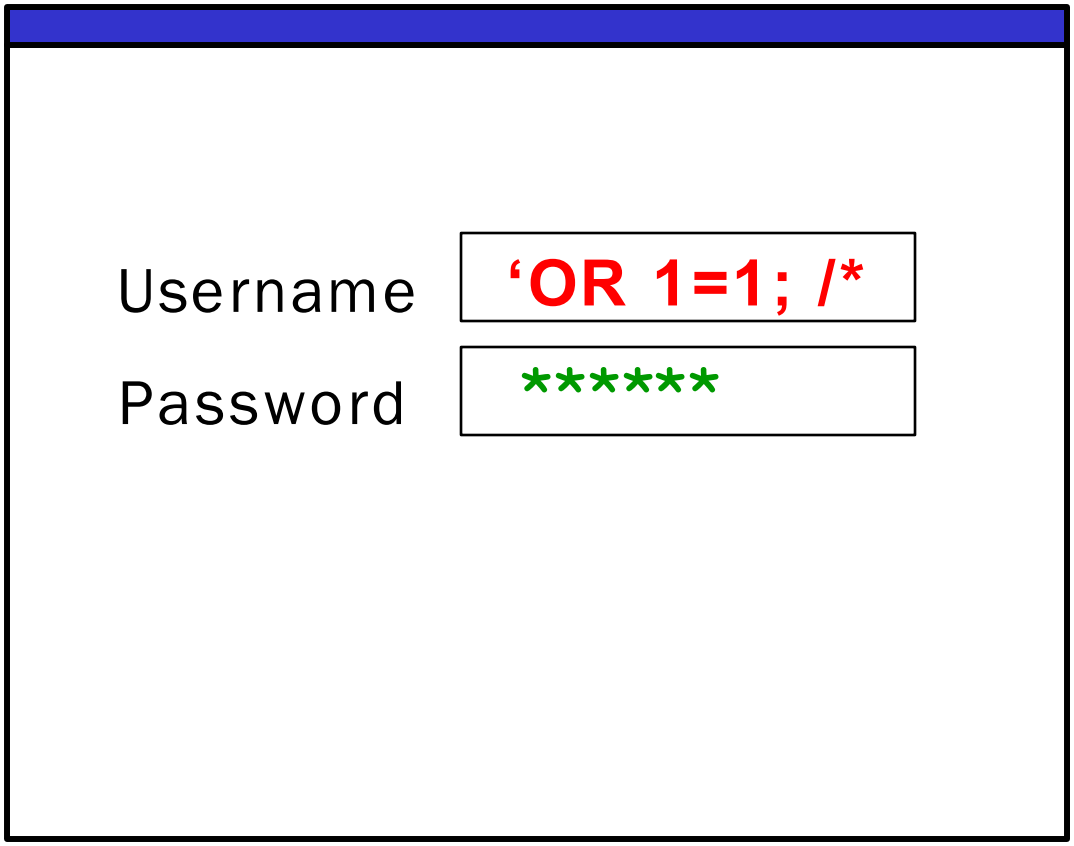
```

Resulting SQL Query:

```
SELECT * FROM Accounts WHERE Username = 'pippo' AND
Password = 'secret';
```

SQL injection



Resulting SQL Query

```
SELECT * FROM Accounts
WHERE Username = '' OR 1=1;/*'
AND Password = 'secret';
```

What does it mean?

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What does it mean?

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SELECT * FROM Accounts
WHERE Username = '' OR 1=1;
/*' AND Password = 'secret';
```

SQL Injection

- **Vulnerability:** any application in any programming language that connects to SQL database
  - if it uses dynamic SQL

- Note the common theme to many injection attacks: *contatenating strings*, some of them user input, and then interpreting, rendering, or executing the result

  is a **VERY BAD IDEA**

Avoiding SQL injection: Prepared Statement

Vulnerable:

```
String updateString = "SELECT * FROM Account WHERE
Username" + username + " AND Password = "
+ password;
stmt.executeUpdate(updateString);
```

Not Vulnerable:

```
PreparedStatement login =
con.preparedStatement("SELECT * FROM Account
        WHERE Username = ? AND Password = ?" );
login.setString(1, username);
login.setString(2, password);
login.executeUpdate();
```

Similar: Stored Procedures

Oracle PL/SQL:

```
CREATE PROCEDURE login
          (name VARCHAR(100), pwd VARCHAR(100)) AS
DECLARE @sql nvarchar(4000)
SELECT @sql =' SELECT * FROM Account WHERE username=' +
@name + 'AND password=' + @pwd
EXEC (@sql)
```

Called from Java with:

```
CallableStatement proc =
 connection.prepareCall("{call login(?, ?)}");
proc.setString(1, username);
proc.setString(2, password);
```

Avoiding SQL injection: Prepared Statement

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String updateString = "SELECT * FROM Account WHERE
Username" + username + " AND Password = "
+ password;
stmt.executeUpdate(updateString);
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PreparedStatement login =
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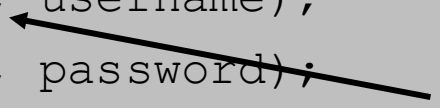


Some Observation

- Other issues – besides security - in discussions about prepared statements, stored procedures, bind variables, …
  - *efficiency*
  - *bandwidth* between web-app and database
  - *stored procedures* allow common fixed interface to several web-apps

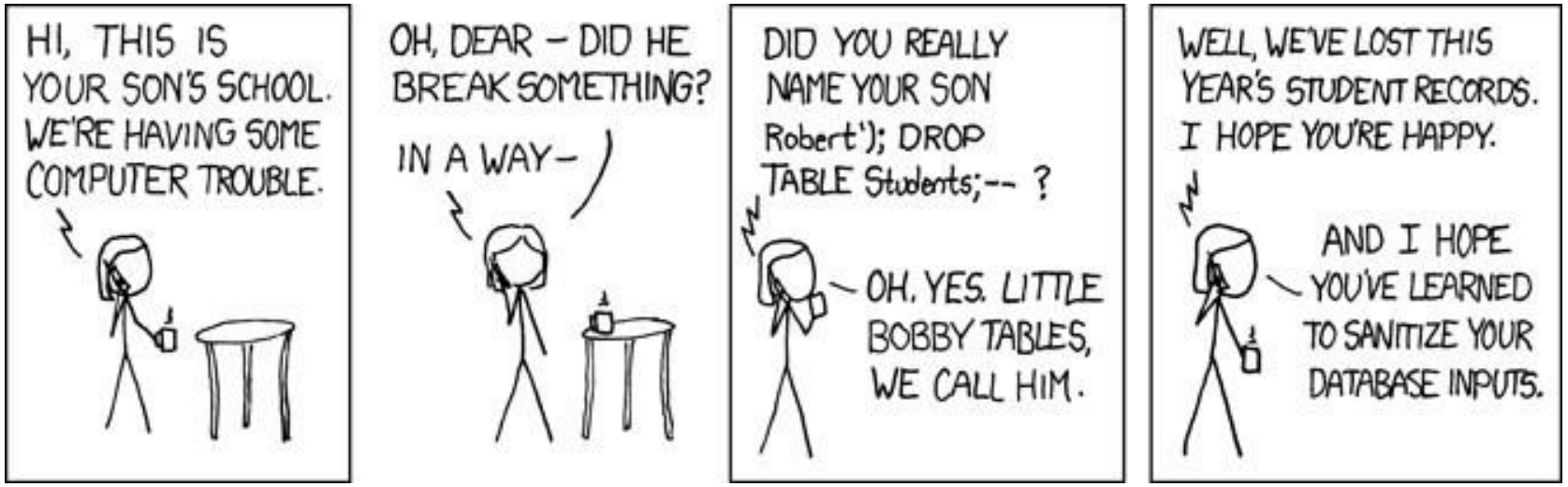
- Moral of the story: check the details for your configuration (language, database system) and your chosen solution!

- Open question: Why is SQL injection still a problem???
  - NB Top vulnerability in OWASP Top 10

Why doesn't everyone use parameterised queries???

Variation: Database Command Injection

- injecting *database command* with ;
- not manipulating SQL query with `
- *highly dependent on infrastructure*, e.g.
  - each database has its own commands
    - E.g. Microsoft SQL Server has `exec master.dbo.xp_cmdshell`
  - some configurations don't allow use of ;
    - E.g. Oracle database accessed via Java or PL/SQL



Variation: Function Call Injection

- Oracle SQL has > 1000 built-in functions that can be used inside stored procedures, eg **TRANSLATE**

```
TRANSLATE('acadaa', 'abcd', 'ABCD') = 'ACADAA'
```

- Arguments of such functions may be poisoned with other functions, e.g.

```
SELECT TRANSLATE('user input', 'abcd', 'ABCD') FROM ...
```

can become

```
SELECT TRANSLATE(''||
UTL_HTTP.REQUEST(http://.....)
||'', 'abcd', 'ABCD') FROM ...
```

`UTL_HTTP` does HTTP request directly from Oracle database, which is probably running *behind* the firewall...

Countermeasures to SQL injection

- input validation
- use prepared statements aka parameterised queries with bind variables
  - not string concatentation
  - or stored procedures, *if* these are safe
- use language/system level countermeasures
  - eg magic quotes in PHP
- apply principle of least privilige
  - ie. minimise rights of web application
- know what you're doing: find out the threats & countermeasures for your specific configuration, programming language, database system...

Input Validation

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File name injection

- user-supplied file name may be
  - existing file **../../../etc/passwd**
  - not really a file **/var/spool/lpr**
  - file the user can access in other ways

    /mnt/usbkey, **/tmp/file**
- this may break
  - *Confidentiality* (leaking information to the user)
  - *Integrity* (eg. of file or system)
  - *Availability* (eg. trying to open print device for reading)

File name injection

- File names constructed from user input – eg by string concatenation – are suspect too

  - Eg what is
    `"/usr/local/client-info/" ++ name`
    What if **`name`** is `../../../etc/passwd`?

- aka *directory traversal attack*
- validating file names is difficult: reuse existing code and/or use `chroot jail`

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Input Validation in general

- Input validations problems are *the* most common vulnerabilities
- Never *ever* trust any user input
  - Apart from generic risks dicussed so far (command, SQL, XSS, filenames,...), there will be additional input risks specific to an application
- Beware of *implicit assumptions* on user input
  - eg, that usernames only contain alphanumeric characters
- Think like an attacker!
  - think how you might abuse a system with weird input

Input Validation: **prevention**

- Find out about potential vulnerabilities:
  - use community resources to find out vulnerabilities of the system/language used
- avoid use of unsafe constructs, if possible

  make sure all input is validated at clear
- *choke-point*s in code when doing input

  validation:
  - use white-lists, not black-lists
    - unless you are 100% sure your black-list is complete
  - reuse existing input validation code known to be correct

Input Validation: **detection**

- *testing*

  test with inputs likely to cause problems

  - for buffer overflow, long inputs (*fuzzing*)
  - for SQL injection, inputs with fragments of SQL commands
  - …

  There are some tools that can help, eg webscarab for XSS

  Note: web-application returning a page with SQL error message is a bad sign…

- *tainting*
  - effectively typing, with runtime checking or static analysis (more precisely, data flow analysis)
    - eg SA_PRE(Tainted=SA_True) in PREfast
- code reviews, possibly using static analysis

19 Deadly sins of software security

[Howard, LeBlanc, Viega, 2005]

- buffer overruns
- format string problems
- integer overflows
- SQL injection
- command injection
- failing to handle errors
- XSS
- failing to protect network traffic
- use of magic URLs or hidden form fields
- improper use of TLS, SSL
- weak passwords
- failing to store & protect data securely
- information leakage
- improper file access
- trusting network name resolution
- race conditions
- unauthenticated key exchange
- weak random numbers
- poor usability

blue ones are input problems

Classification of Software Security Errors

1. Input Validation and Representation
2. API Abuse
3. Security Features
4. Time and State
5. Errors
6. Code Quality
7. Encapsulation

*. Environment

[Katrina Tsipenyuk, Brian Chess, Gary McGraw, Seven Pernicious Kingdoms: A Taxonomy of Software Security Errors]

One of the CVE Classifications