CSC 405
Computer Security

Web Security

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(Derived from slides by Giovanni Vigna and Adam Doupe)

Web Security homework

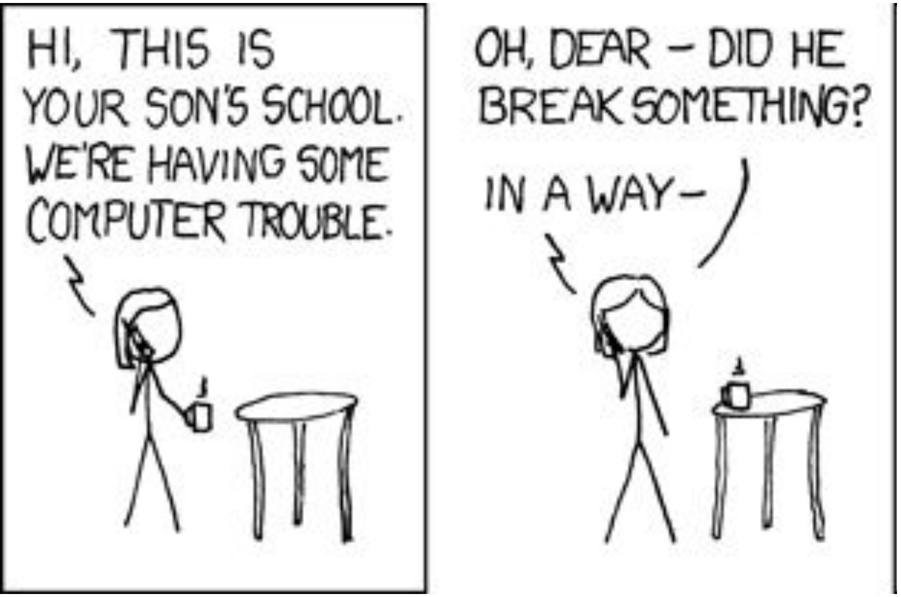
- Currently being setup & tested
- Three parts
  - 10 levels of web security issues
  - Two bonus parts
    - Pentest OpenMRS for a research project
    - Secret assignment!
  - The bonus parts are your last chance to recover if you didn't do well in previous assignments!
- 3 weeks to finish it
  - but **START EARLY**
  - this will help you do better in HackPack CTF on 4/12

Logistics

- No class next week (4/9)
  - but there will be an online class uploaded on mediasite
  - use the lecture time for solving web security levels before the CTF
- Hackpack CTF on **04/12**
  - This counts as your sixth and final homework
- Do not forget about the final exam on **04/16**
  - Same format as the midterm

HI, THIS IS YOUR SON'S SCHOOL. WE'RE HAVING SOME COMPUTER TROUBLE.

source: https://xkcd.com/327/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OH, DEAR – DID HE BREAK SOMETHING?
IN A WAY–

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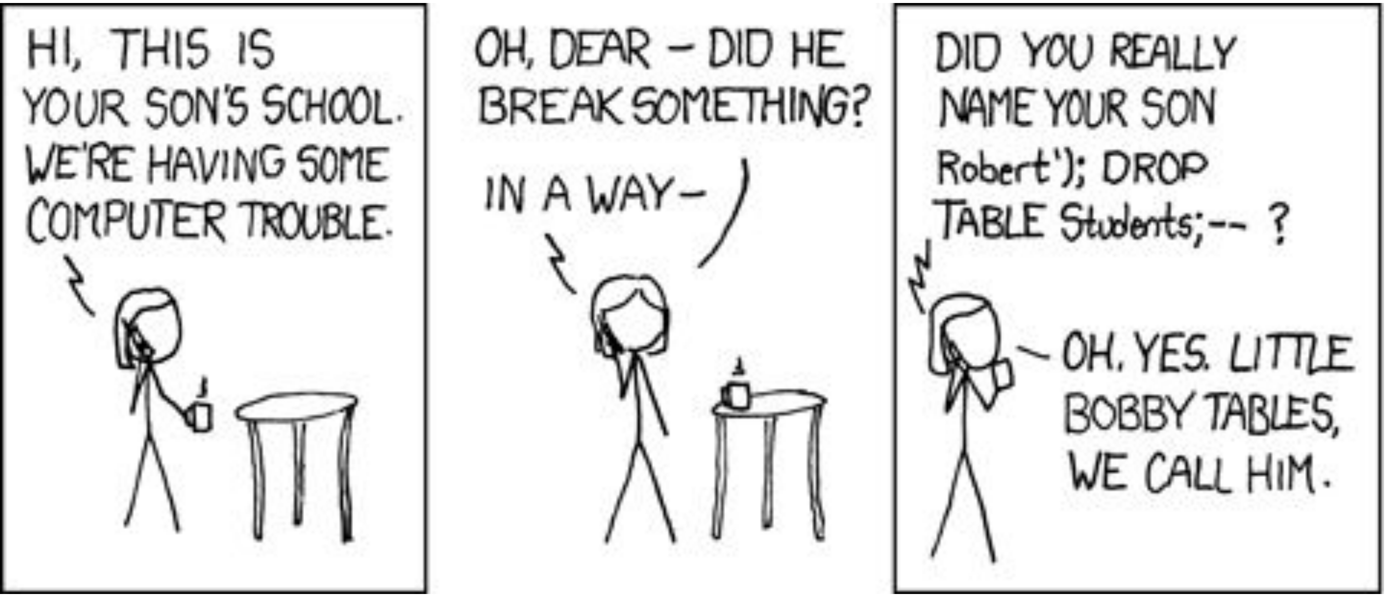
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DID YOU REALLY NAME YOUR SON Robert'); DROP TABLE Students;-- ?
OH. YES. LITTLE BOBBY TABLES, WE CALL HIM.

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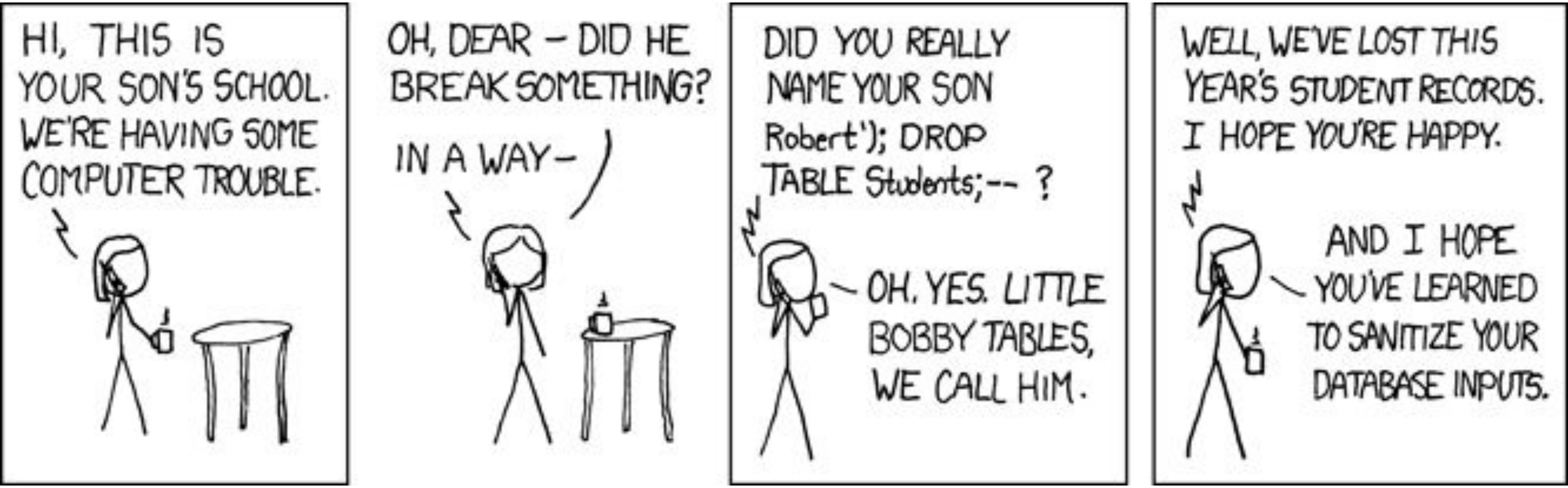
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OH, DEAR – DID HE BREAK SOMETHING?
IN A WAY–
DID YOU REALLY NAME YOUR SON Robert'); DROP TABLE Students;-- ?
OH. YES. LITTLE BOBBY TABLES, WE CALL HIM.
WELL, WE'VE LOST THIS YEAR'S STUDENT RECORDS. I HOPE YOU'RE HAPPY.
AND I HOPE YOU'VE LEARNED TO SANITIZE YOUR DATABASE INPUTS.

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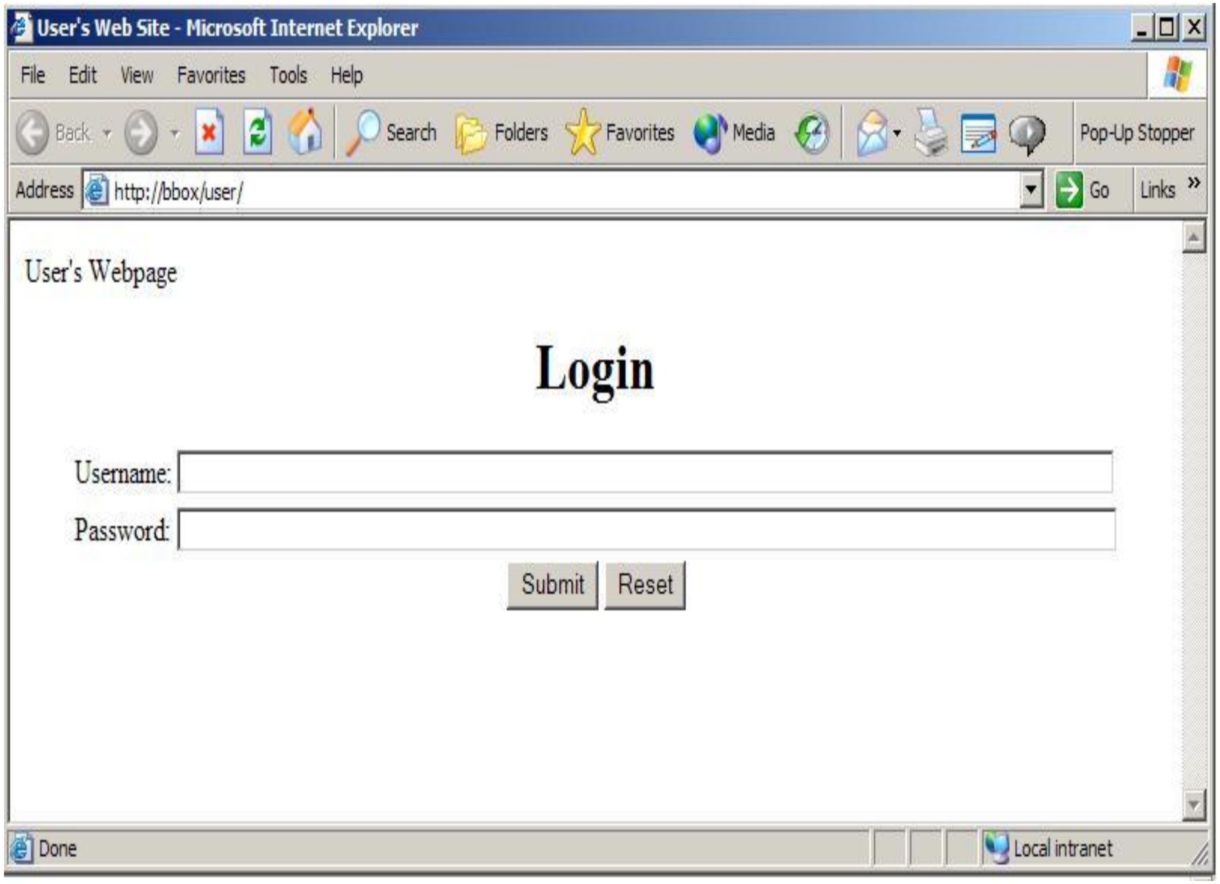
SQL Injection

- SQL injection might happen when queries are built using the parameters provided by the users
  - `$query = “select ssn from employees where name = ‘” + username + “’ ”`
- By using special characters such as ‘ (tick), -- (comment), + (add), @variable, @@variable (server internal variable), % (wildcard), it is possible to:
  - Modify queries in an unexpected way
  - Probe the database schema and find out about stored procedures
  - Run commands (e.g., using xp_commandshell in MS SQL Server)

An Example Web Page



User's Web Site - Microsoft Internet Explorer

Address http://bbox/user/

User's Webpage

Login

Username:

Password:

The Form

```
<form action="login.asp" method="post">
 <table>
   <tr><td>Username:</td>
     <td><input type="text" name="username"></td></tr>
   <tr><td>Password:</td>
     <td><input type=password name="password"></td></tr>
 </table>
 <input type="submit" value="Submit">
 <input type="reset" value="Reset">
</form>
```

The Login Script

```
… <% function Login( connection ) {
    var username = Request.form("username");
    var password = Request.form("password");
    var rso = Server.CreateObject("ADODB.Recordset");
    var sql = "select * from pubs.guest.sa_table \
                where username = ‘” + username + "‘ and \
                password = ‘" + password + "‘";
    rso.open(sql, connection); //perform query
    if (rso.EOF) //if record set empty, deny access
     { rso.close();
    %>  <center>ACCESS DENIED</center> <%
    } else  { //else grant access
    %>  <center>ACCESS GRANTED</center> <%
    // do stuff here ...
```

The ‘ or 1=1 -- Technique

- Given the SQL query string:

  ```
   "select * from pubs.guest.sa_table \
        where username = ‘” + username + "‘ and \
        password = ‘" + password + "‘";
  ```

- By providing the following username:

  ```
  ‘ or 1=1 --
  ```

- the user name (and any password) results in the string:

  ```
  select * from sa_table where username=‘’ or 1=1 --’ and
  password= ‘’
  ```

  – The conditional statement “`username=‘’ or 1=1 --`” is true whether or not username is equal to ‘’

  – The “--” makes sure that the rest of the SQL statement is interpreted as a comment and therefore `and password =‘’` is not evaluated

Injecting SQL Into Different Types of Queries

- SQL injection can modify any type of query such as
  - SELECT statements
    - `SELECT * FROM accounts WHERE user=‘${u}’ AND pass=‘${p}’`
  - INSERT statements
    - `INSERT INTO accounts (user, pass) VALUES(‘${u}’, ‘${p}’)`
      - Note that in this case one has to figure out how many values to insert
  - UPDATE statements
    - `UPDATE accounts SET pass=‘${np}’ WHERE user= ‘${u}’ AND pass=‘${p}’`
  - DELETE statements
    - `DELETE * FROM accounts WHERE user=‘${u}’`

Identifying SQL Injection

- A SQL injection vulnerability can be identified in different ways
  - Negative approach: special-meaning characters in the query will cause an error (for example: user=“ ’ ”)
  - Positive approach: provide an expression that would NOT cause an error (for example: “17+5” instead of “22”, or a string concatenation)

The UNION Operator

- The UNION operator is used to merge the results of two separate queries
- In a SQL injection attack this can be exploited to extract information from the database
- Original query:

  -
    ```
    SELECT id, name, price FROM products WHERE
    brand=‘${b}’
    ```
- Modified query passing ${b}=“foo’ UNION…”:

  -
    ```
    SELECT id, name, price FROM products WHERE brand=‘foo’
    UNION SELECT user, pass, NULL FROM accounts -- ‘
    ```
- In order for this attack to work the attacker has to know
  - The structure of the query (number of parameters and types have to be compatible: NULL can be used if the type is not known)
  - The name of the table and columns

Determining Number and Type of Query Parameters

- The number of columns in a query can be determined using progressively longer NULL columns until the correct query is returned
  - UNION SELECT NULL
  - UNION SELECT NULL, NULL
  - UNION SELECT NULL, NULL, NULL
- The type of columns can be determined using a similar technique
  - For example, to determine the column that has a string type one would execute:
    - UNION SELECT ‘foo’, NULL, NULL
    - UNION SELECT NULL, ‘foo’, NULL
    - UNION SELECT NULL, NULL, ‘foo’

Determining Table and Column Names

- To determine table and column names one has to rely on techniques that are database-specific
  - Oracle
    - By using the user_objects table one can extract information about the tables created for an application
    - By using the user_tab_column table one can extract the names of the columns associated with a table
  - MS-SQL
    - By using the sysobjects table one can extract information about the tables in the database
    - By using the syscolumns table one can extract the names of the columns associated with a table
  - MySQL
    - By using the information_schema one can extract information about the tables and columns

Second-Order SQL Injection

- In a second-order SQL injection, the code is injected into an application, but the SQL statement is invoked at a later point in time
  - e.g., Guestbook, statistics page, etc.
- Even if application escapes single quotes, second order SQL injection might be possible
  - Attacker sets user name to: `john’--`, application safely escapes value to `john’’--` (note the two single quotes)
  - At a later point, attacker changes password (and “sets” a new password for victim john):

```
update users set password=’hax’ where
database_handle(“username”)=‘john’--‘
```

register.php

```
<?php

session_start();

$sql = "insert into users (username, password) values ('" .
mysql_real_escape_string($_POST['name']) . "', '" .
mysql_real_escape_string($_POST['password']) . "');";

mysq_query($sql);

$user_id = mysql_insert_id();

$_SESSION['uid'] = $user_id;
```

change_password.php

```
<?php

session_start();
$new_password = $_POST['password'];
$res = mysql_query("select username, password from users where
id = '" . $_SESSION['uid'] . "';");
$row = mysql_fetch_assoc($result);

$query = "update users set password = '" .
mysql_real_escape_string($new_password) . "' where username = '"
.$row['username']."' and password = '".$row['password']."';";

mysql_query($query);
```

Blind SQL Injection

- A typical countermeasure is to prohibit the display of error messages: However, a web application may still be vulnerable to blind SQL injection
- Example: a news site
  - Press releases are accessed with pressRelease.jsp?id=5
  - A SQL query is created and sent to the database:
    - `select title, description FROM pressReleases where id=5;`
  - All error messages are filtered by the application

Blind SQL Injection

- How can we inject statements into the application and exploit it?
  - We do not receive feedback from the application so we can use a trial-and-error approach
  - First, we try to inject pressRelease.jsp?id=5 AND 1=1
  - The SQL query is created and sent to the database:
    - `select title, description FROM pressReleases where id=5 AND 1=1`
  - If there is a SQL injection vulnerability, the same press release should be returned
  - If input is validated, `id=5 AND 1=1` should be treated as the value

Blind SQL Injection

- When testing for vulnerability, we know 1=1 is always true
  - However, when we inject other statements, we do not have any information
  - What we know: If the same record is returned, the statement must have been true
  - For example, we can ask server if the current user is “h4x0r”:
    - `pressRelease.jsp?id=5 AND user_name()=‘h4x0r’`
  - By combining subqueries and functions, we can ask more complex questions (e.g., extract the name of a database table character by character)
    - `pressRelease.jsp?id=5 AND SUBSTRING(user_name(), 1, 1) < '?’`

SQL Injection Solutions

- Developers should never allow client-supplied data to modify SQL statements
- Stored procedures
  - Isolate applications from SQL
  - All SQL statements required by the application are stored procedures on the database server
- Prepared statements
  - Statements are compiled into SQL statements before user input is added

SQL Injection Solutions: Stored Procedures

- Original query:
  - String query = “SELECT title, description from pressReleases WHERE id= “+ request.getParameter(“id”);
  - Statement stat = dbConnection.createStatement();
  - ResultSet rs = stat.executeQuery(query);
- The first step to secure the code is to take the SQL statements out of the web application and **into the DB**
  - CREATE PROCEDURE getPressRelease @id integer AS SELECT title, description FROM pressReleases WHERE Id = @id

SQL Injection Solutions: Stored Procedures

- Now, in the application, instead of string-building SQL, a stored procedure is invoked. For example, in Java:

```
CallableStatements cs = dbConnection.prepareCall(
   “{call getPressRelease(?)}”);

cs.setInt(1,
   Integer.parseInt(request.getParameter(“id”)));
ResultSet rs = cs.executeQuery();
```

SQL Injection Solutions: Prepared Statements

- Prepared statements allow for the clear separation of what is to be considered data and what is to be considered code
- A query is performed in a two-step process:
  - First the query is parsed and the location of the parameters identified (this is the “preparation”)
  - Then the parameters are bound to their actual values
- In some cases, prepared statements can also improve the performance of a query

SQL Injection Solutions: Prepared Statements

```
$mysqli = new mysqli("localhost", "my_user", "my_pass", ”db");
$stmt =  $mysqli->stmt_init();
$stmt->prepare("SELECT District FROM City WHERE Name=?"));
$stmt->bind_param("s", $city);
/* type can be “s” = string, “i” = integer … */

$stmt->execute();
$stmt->bind_result($district);
$stmt->fetch();
printf("%s is in district %s\n", $city, $district);
$stmt->close();}
```