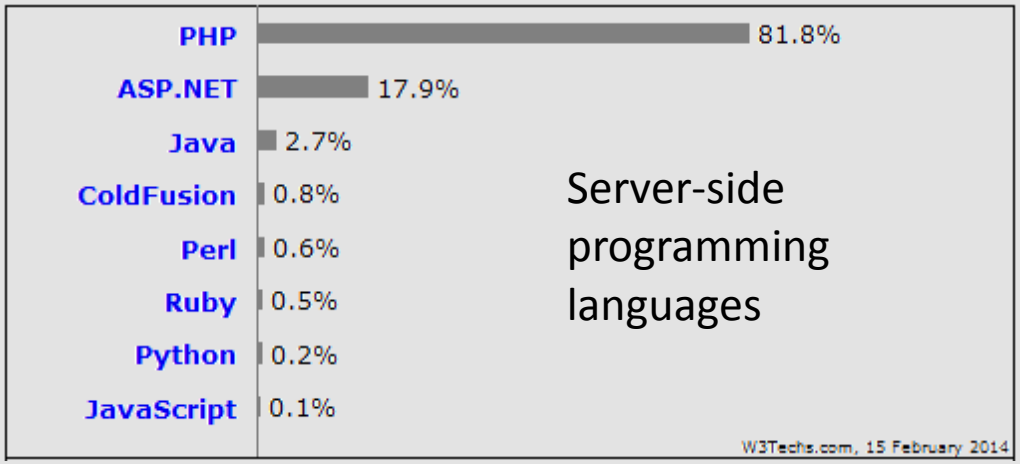
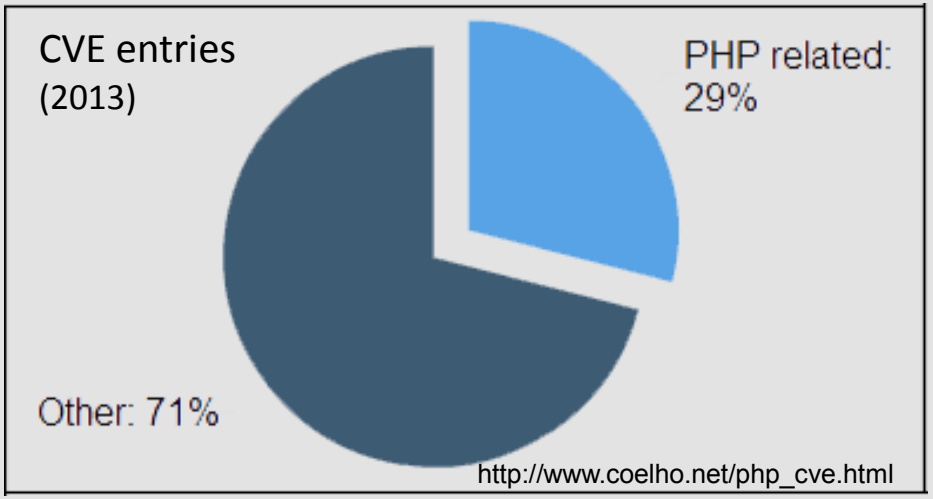
Simulation of Built-in PHP Features for Precise Static Code Analysis

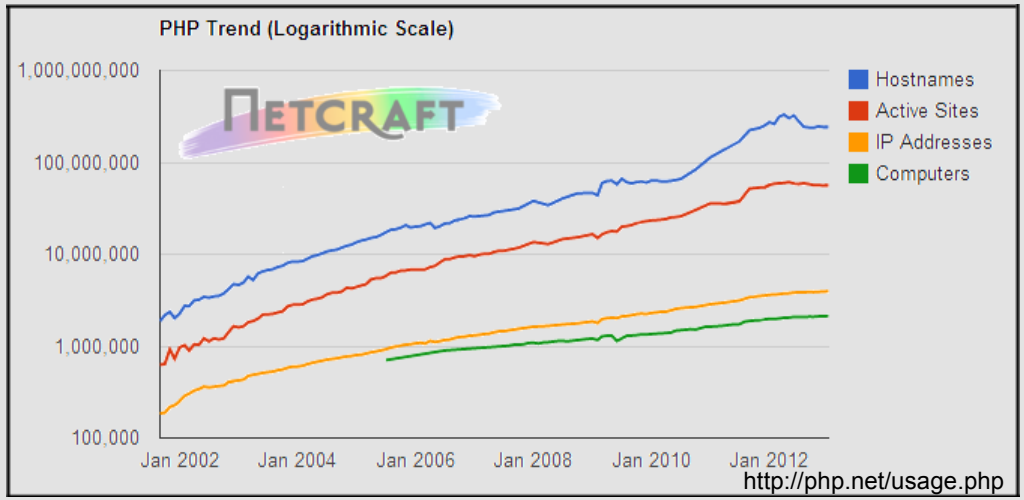
Johannes Dahse and Thorsten Holz
Ruhr-University Bochum

NDSS ’14, 23-26 February 2014, San Diego, CA, USA

php *is everywhere.*







Simulation of Built-in PHP Features for Precise Static Code Analysis

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HotCRP Conference Management Software

Target: Taint-style Vulnerabilities

- **SQL injection**

```
<?php
    $id = $_GET['id'];
    $sql = "SELECT data FROM users WHERE id = '$id' ";
    mysql_query($sql);
?>
```

- **Cross-Site Scripting**

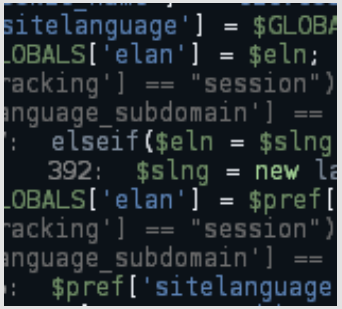
```
<?php
    $name = $_GET['name'];
    $html = "<h1>Hello $name</h1>";
    print($html);
?>
```

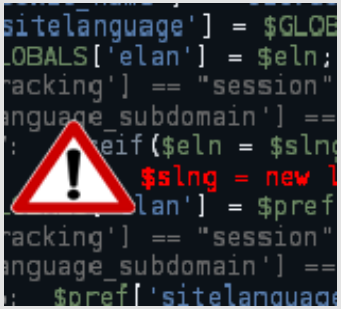
PHP Built-in Features

- 228+ Extensions
- 5700+ built-in functions
  - Sinks, sanitization, data flow
- 10+ *superglobal* variables
  - $GLOBALS, $_FILES, $_SERVER ...
- Settings
  - `magic_quotes_gpc`, `register_globals`

Our Approach

- Static Code Analysis for PHP applications
- Precise simulation of built-in features is the key
  - to detect taint-style vulnerabilities
  - *to accept your paper on your own*





2. Implementation

Source: http://rewalls.com

Precise Simulation

http://rub.de/index.php/payload

```
<?php
    $uri = trim($_SERVER['PHP_SELF']);
    $uri = urldecode($uri);
    $url = 'http://rub.de/' . htmlentities($uri);
    $html = “<a href='$url' >back</a>“;
    print($html);
?>
```

Precise Simulation

1. **taintable sources**
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   - ~~$_FILES[]['tmp_name']~~
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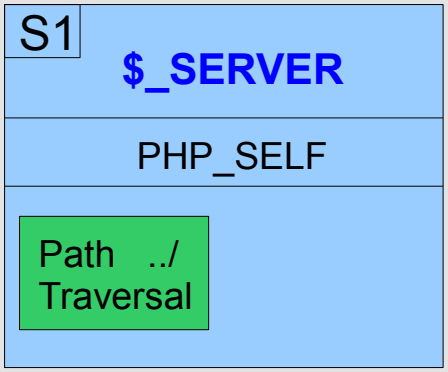

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   - Format string
   - Regular expressions

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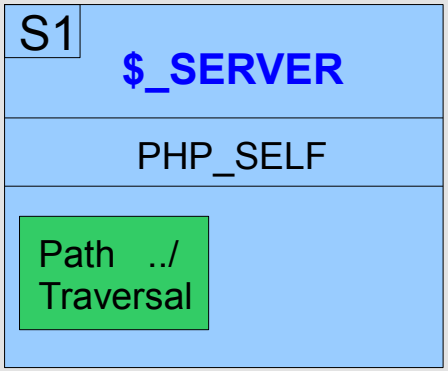

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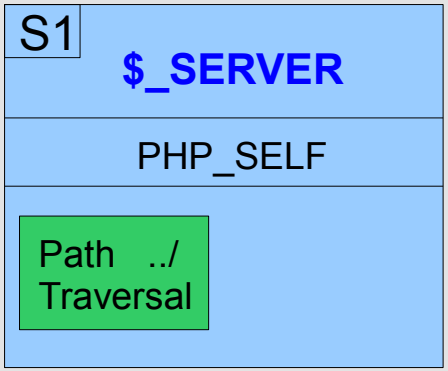

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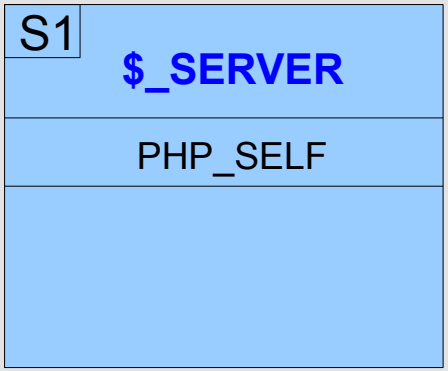

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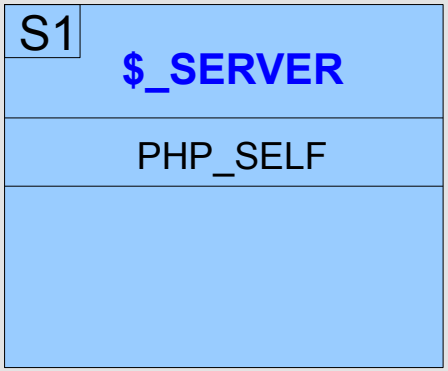

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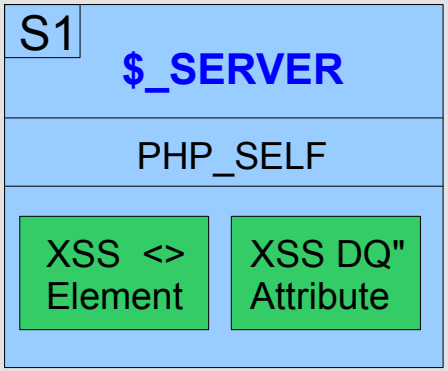

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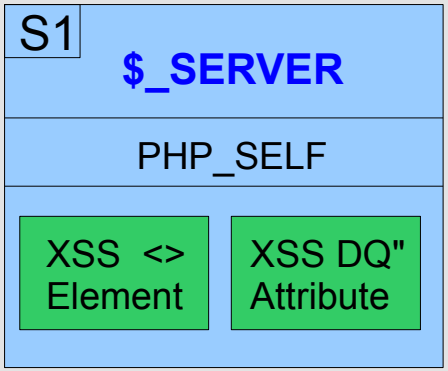
5. **sinks**
   - Parameter
   - Vulnerability type



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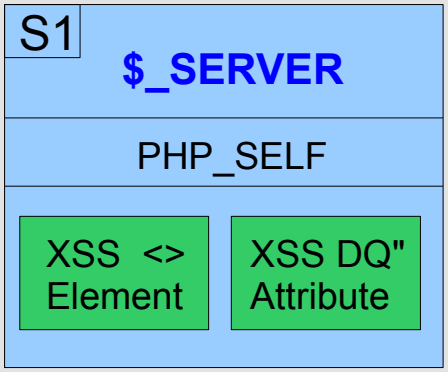

back

→ XSS Single-Quoted ' Attribute

Precise Simulation

1. **taintable sources**
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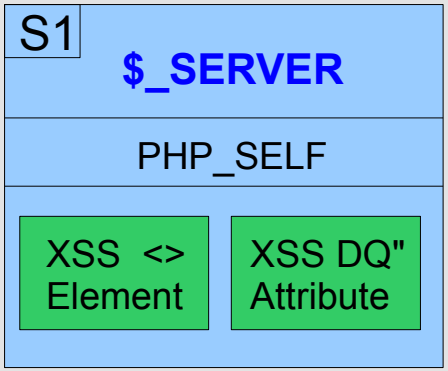

back

→ ' onclick='alert(document.cookie)

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- 952 built-in functions
- 20 vulnerability types
- 45 markup contexts

5. **sinks**
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   - Vulnerability type

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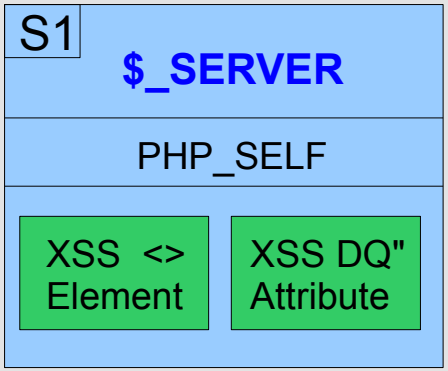

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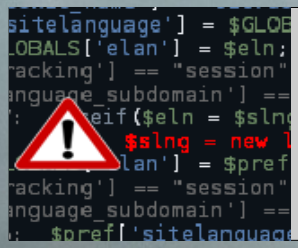
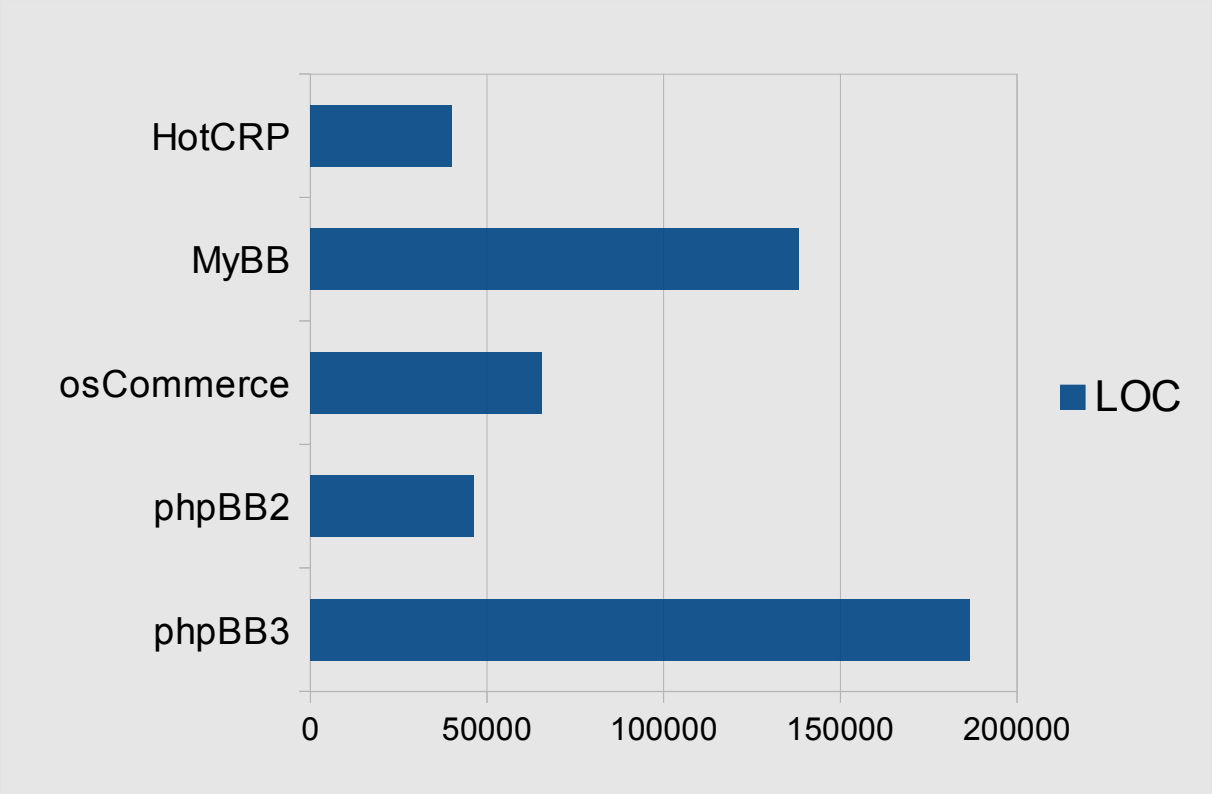


3. Evaluation

Source: http://rewalls.com

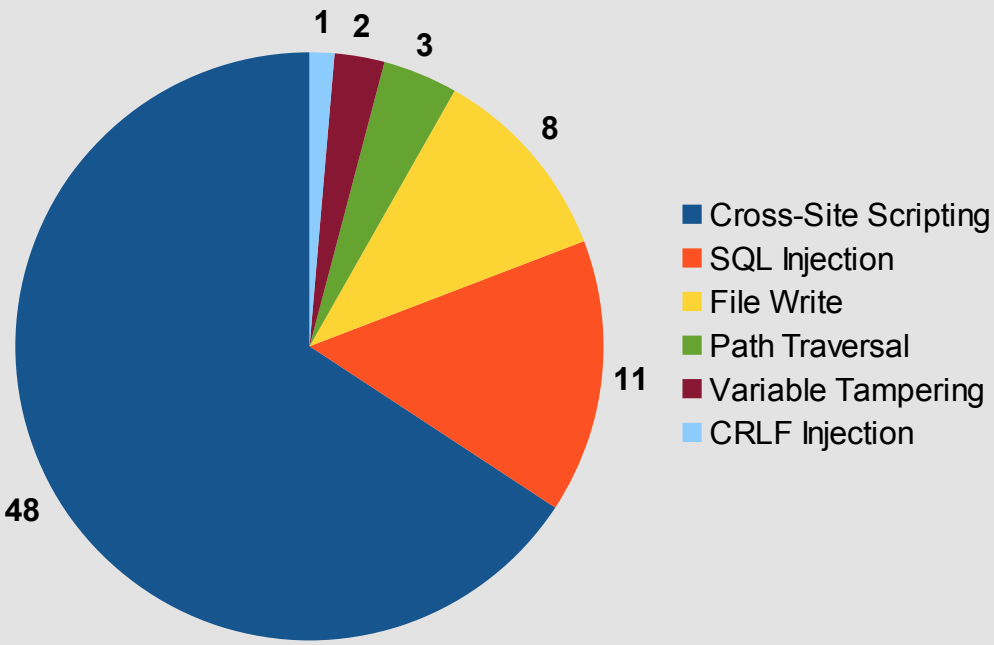
Software

- HotCRP 2.60
- MyBB 1.6.10
- OsCommerce 2.3.3
- phpBB2 2.0.23
- phpBB3 3.0.11



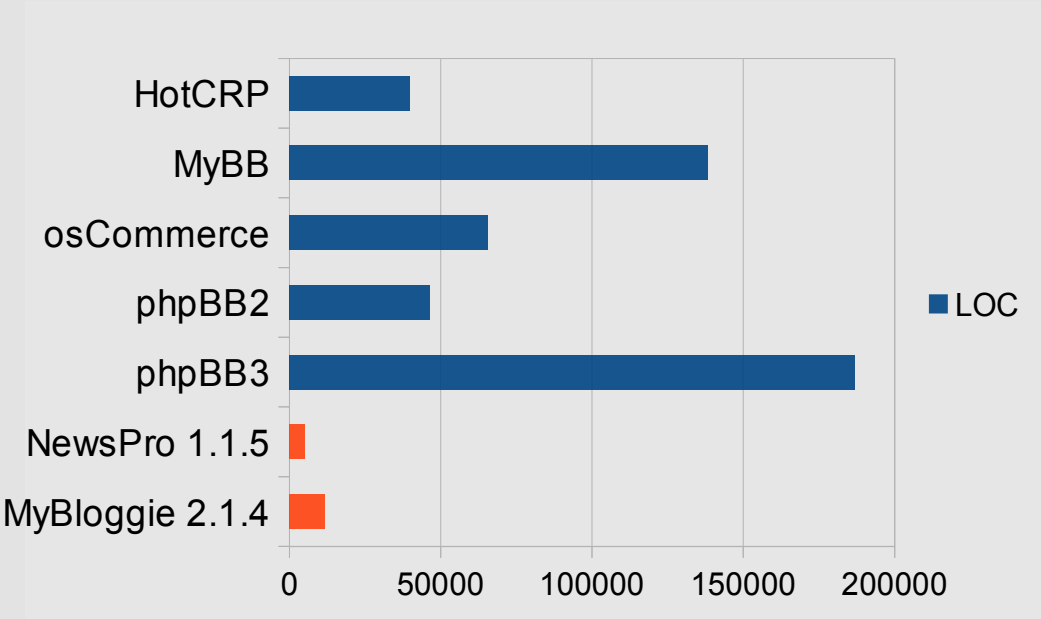
Vulnerability Detection

- 73 True Positives (72%)
- 29 False Positives (28%)
  - 19 FP in OsCommerce
  - Root cause: Path-sensitivity
- 10 False Negatives (24%)
  - 42 CVE entries
  - 8 FN in MyBB
  - Root cause: OOP



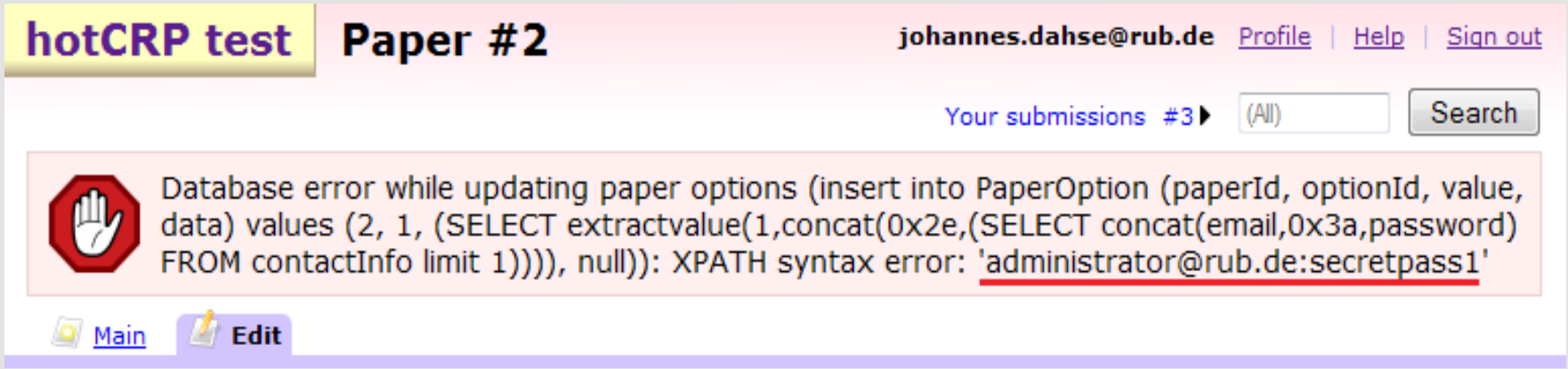
Software in Related Work

- Criteria
  - Available
  - Follow-up version exists
  - Patch-only
- Our results
  - 31 new vulnerabilities detected
  - 0 false positives
  - Precise simulation pays off



Vulnerability Example

- Blind SQL Injection in HotCRP 2.60
- Fixed in version 2.61
- HotCRP stores credentials in plaintext



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#1 Simulation of Built-in PHP Features for Precise Static Code Analysis

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+ ABSTRACT

The World Wide Web grew rapidly during the last decades and is used by millions of people every day for online shopping, banking, networking, and other activities. Many of [more]

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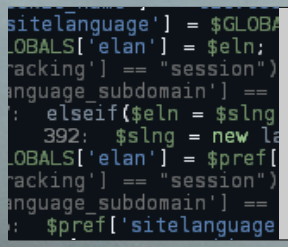


4. Conclusion

Source: http://rewalls.com

Conclusion

- New approach to PHP static code analysis
  - 20 vulnerability types, 45 markup contexts
  - 900+ built-in features simulated
- 73 new vulnerabilities, 28% false positives
  - Current vulnerabilities base on complex PHP features
  - Modeling these features precisely is crucial, missed by previous work
- Future work
  - Path-sensitivity
  - OOP

Questions ?

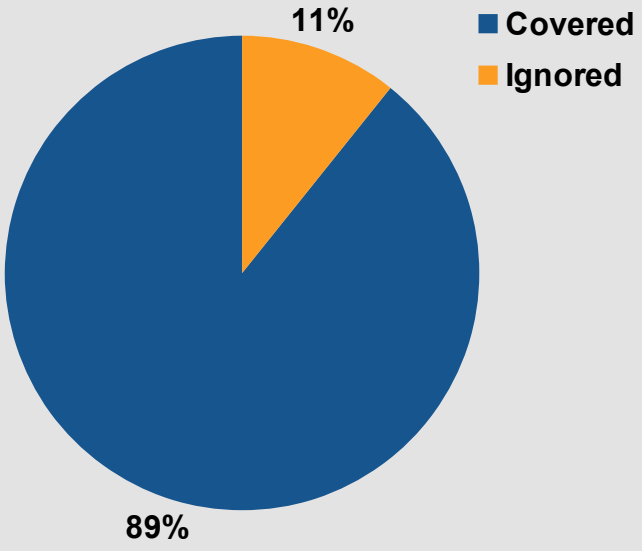
johannes.dahse@rub.de

Thank you!
Enjoy the conference.

Backup Slides

Built-in Function Coverage

- Every 13th line of code calls a built-in function
  - Static point of view
- 970 **unique** calls
  - 70% covered
- 37 651 **total** calls
  - 89% covered
- Remaining calls are less relevant
  - Do not influence our analysis results



Target: Taint-style Vulnerabilities

- **SQL injection**

```
<?php
    $id = mysql_real_escape_string($_GET['id']);
    $sql = "SELECT data FROM users WHERE id = $id ";
    mysql_query($sql);
?>
```

- **Cross-Site Scripting**

```
<?php
    $name = htmlentities($_GET['name']);
    $html = "<h1>Hello $name</h1>";
    print($html);
?>
```

Path-sensitive sanitization

```
1 function tep_output_string($string, $protected = false) {
2   if ($protected == true) {
3     return htmlspecialchars($string);
4   } else {
5     return $string;
6   }
7 }
```

Supported vulnerability types

1) Code Execution
2) Command Execution
3) Connect Injection
4) Cross-Site Scripting
5) Denial of Service
6) Env. Manipulation
7) File Inclusion
8) File Upload
9) File Write
10) HTTP Resp. Splitting
11) LDAP Injection
12) Open Redirect
13) Path Traversal
14) Reflection Injection
15) Session Fixation
16) SQL Injection
17) Unserialize
18) Variable Tampering
19) XML/XXE Injection
20) XPath Injection

Simulation of Built-in PHP Features
for Precise Static Code Analysis

TABLE I: Evaluation results for popular real-world applications.

Software	Files	LOC	TA	TBC	TBI	UBC	UBI	MP	ST	TP	FP	FN	CVE
HotCRP	72	39 938	19 420	5 171	289	170	51	293	55	7	4	0	0
MyBB	327	138 357	55 917	8 152	1 287	225	115	1 117	188	2	0	8	10
osCommerce	545	65 556	7 453	9 059	860	184	85	476	60	48	19	1	29
phpBB2	176	46 287	10 623	3 666	340	144	56	289	29	13	6	1	2
phpBB3	270	186 814	43 616	7 554	1 273	269	192	1 143	252	3	0	0	1
Total	1 390	476 952	137 029	33 602	4 049	676	294	3 318	584	73	29	10	42
Average	278	95 390	27 406	89%	11%	70%	30%	664	117	72%	28%	24%	8

TABLE II: Compared evaluation results for previously studied real-world applications.

						RIPS				Jovanovic et al.				Xie & Aiken	
						XSS		SQLi		XSS		SQLi		SQLi	
Software		Files	LOC	TB	UB	TP	FP	TP	FP	TP	FP	TP	FP	TP	FP
NewsPro	1.1.4	23	5 047	827	56	5	0	18	0	4	14	14	34	8	0
NewsPro	1.1.5	23	5 077	841	57	4	0	6	0	-	-	-	-	-	-
myBloggie	2.1.3b	91	11 487	1 218	122	15	0	26	3	13	3	31	11	16	0
myBloggie	2.1.4	92	11 772	1 235	124	13	0	8	0	-	-	-	-	-	-
Total		229	33 383	4121	134	37	0	58	3	17	17	45	45	24	0
Average		57	8 346	1030	90	100%	0%	95%	5%	50%	50%	50%	50%	100%	0%

SQL Injection in phpBB2

```
1  $style_name = urldecode($_GET['style']);
2  $install_to = urldecode($_GET['install_to']);
3  $template_name = $$install_to;
4  for($i = 0; $i < count($template_name); $i++) {
5    if($template_name[$i]['style_name'] == $style_name) {
6      while(list($key, $val) = each($template_name[$i])) {
7        $db_fields[] = $key;
8        $db_values[] = addslashes($val);
9      }
10   }
11 }
12 $sql = "INSERT INTO " . THEMES_TABLE . " (";
13 $sql .= implode(',', $db_fields);
14 $sql .= ") VALUES (";
15 $sql .= "'" . implode("','", $db_values) . "'";
16 $sql .= ")";
17 mysql_query($sql);
```

admin_styles.php?style=rips&install_to=_GET&0[style_name]=rips&0[template_name)VALUES('sqli','sqli')-- -]=1