Vejovis: Suggesting Fixes for JavaScript Faults

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Problem and Motivation

JavaScript in web applications has plenty of reliability issues

JS faults are not trivially fixed [ESEM'13]

issues [ESEM'13]

Problem and Motivation

JavaScript in web applications has plenty of reliability issues,

these JavaScript faults matter and these JavaScript faults are non-trivial to fix

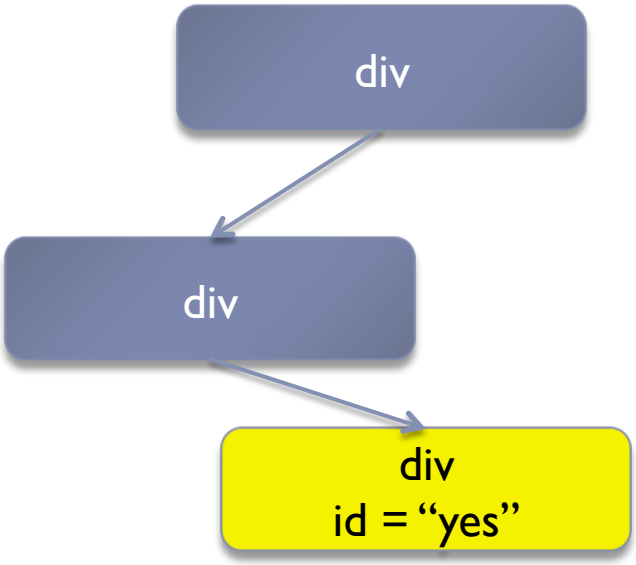
Faults in JavaScript Code

- Study of JS bug reports [ESEM'13]

- **Key Insight**: Most (65%) mistakes programmers make in JS propagate to ***parameters of DOM API method calls***
  - DOM API methods: getElementById, getElementsByTagName, jQuery's $(), etc.
  - We also found that such faults are the most impactful, and take the longest to fix

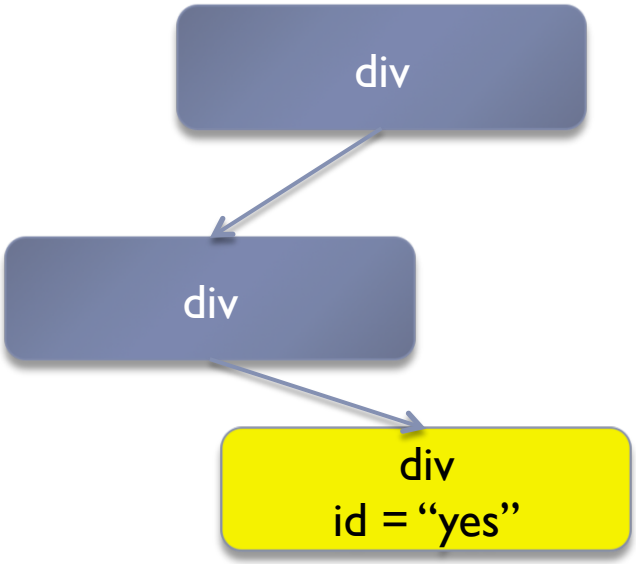
DOM-RELATED FAULTS

DOM-Related Fault Example




```
var x = "yes";
var elem = document.getElementById(x);
```

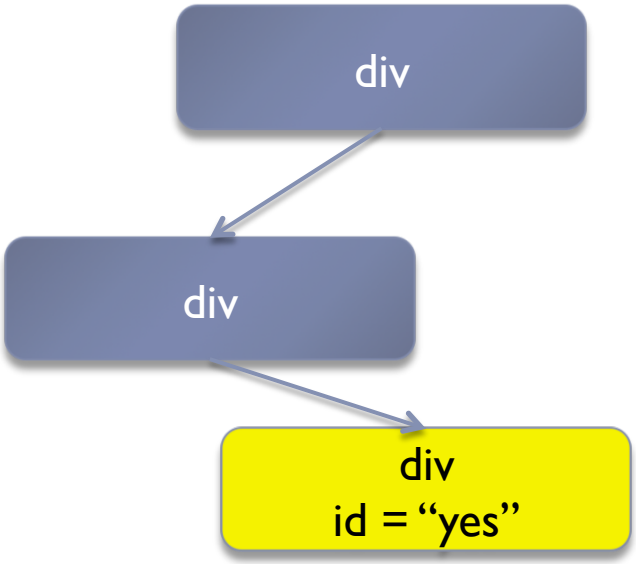
DOM-Related Fault Example



MISTAKE!

```
var x = "no";
var elem = document.getElementById(x);
```

DOM-Related Fault Example



MISTAKE!

```
var x = “no”;
var elem = document.getElementById(x);
```

ID parameter evaluates to “no”, which is not in the DOM

Goal

Facilitate the process of fixing DOM-related faults

Fault Model

- Suggest repairs for ***DOM-related faults***
- Only one mistake made

Common Developer Fixes

- Study of 190 *fixed* bug reports from 12 web apps

elem = getElementById(param)
elem.innerHTML = "…"

Common Developer Fixes

- Study of 190 *fixed* bug reports from 12 web apps

Modify the parameter

elem = getElementById(*new_param*)
elem.innerHTML = "…"

Ways Programmers Fix Faults

- Parameter Modification

Common Developer Fixes

- Study of 190 *fixed* bug reports from 12 web apps

```
elem = getElementById(param)
if (elem)
    elem.innerHTML = "…"
```

Check if null

Ways Programmers Fix Faults

- Parameter Modification
- DOM Element Validation

Common Developer Fixes

- Study of 190 *fixed* bug reports from 12 web apps

elem = querySelector(param)
elem.innerHTML = "…"

Modify the method

Ways Programmers Fix Faults

- Parameter Modification
- DOM Element Validation
- Method Modification

Common Developer Fixes

- Study of 190 *fixed* bug reports from 12 web apps

elem = getElementById(param)
elem.innerHTML = "…"

Ways Programmers Fix Faults

- Parameter Modification 27.2%
- DOM Element Validation 25.7%
- Method Modification 24.6%

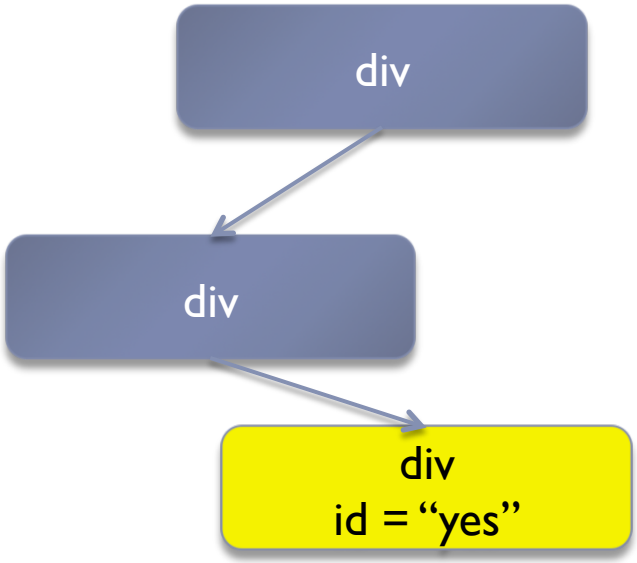
Structure in DOM Method Parameters

WRONG	RIGHT
`getElementById("no")`	`???`

Question: How do we know that we should replace "no" with "yes"

Answer: We need to infer programmer *intent*

- Very difficult to do in general, but…
- We have the DOM!



Structure in DOM Method Parameters

WRONG

```
getElementById("no")
```

RIGHT

```
getElementById("yes")
```

Question: How do we know that we should replace "no" with "yes"

Answer: We need to infer programmer *intent*

- Very difficult to do in general, but…
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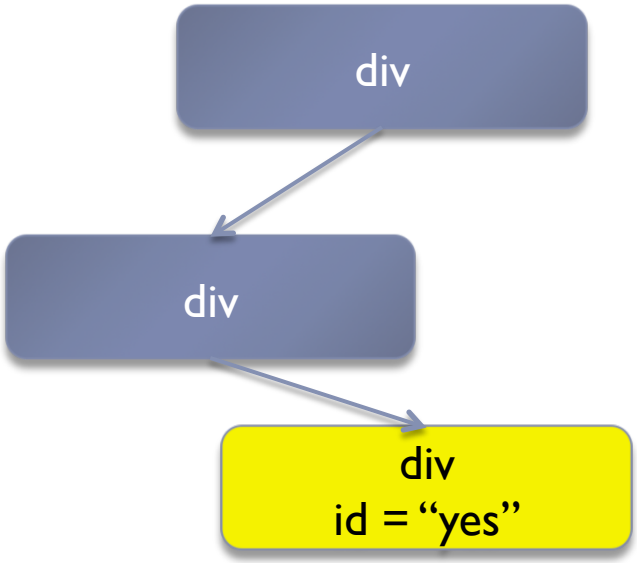
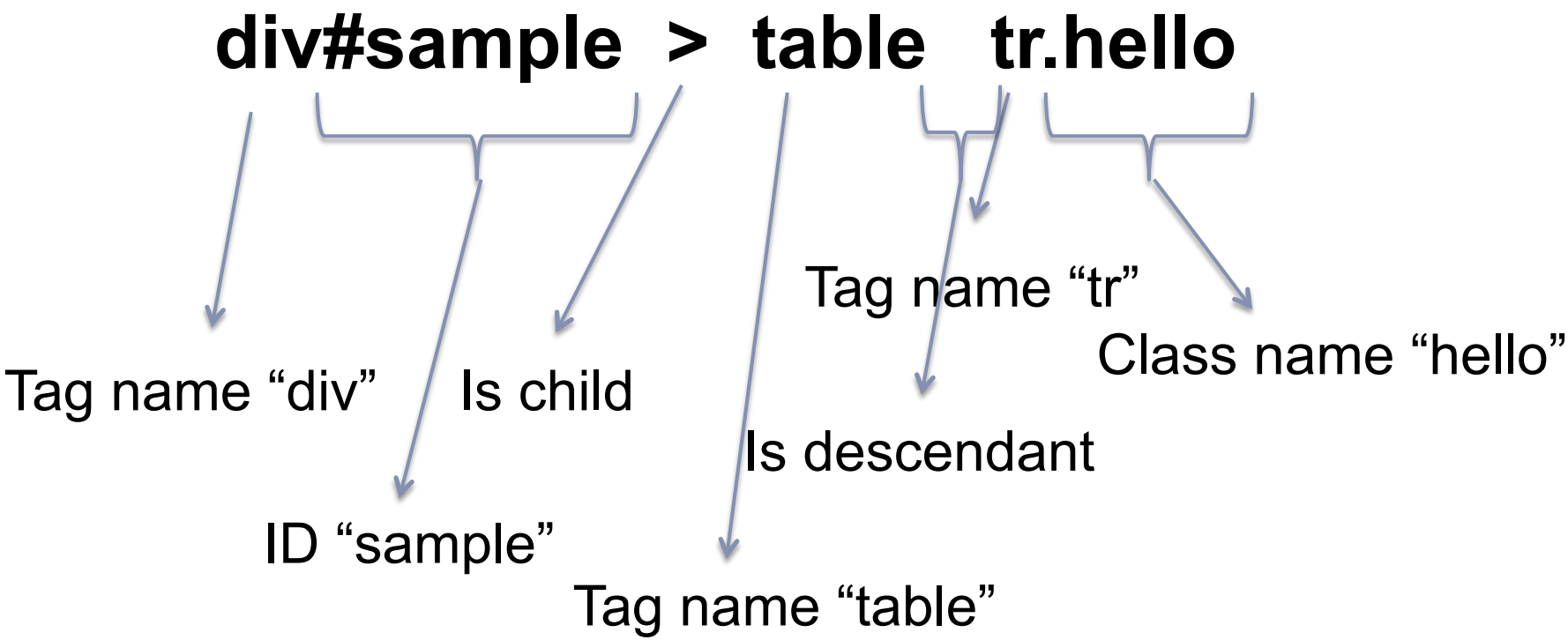
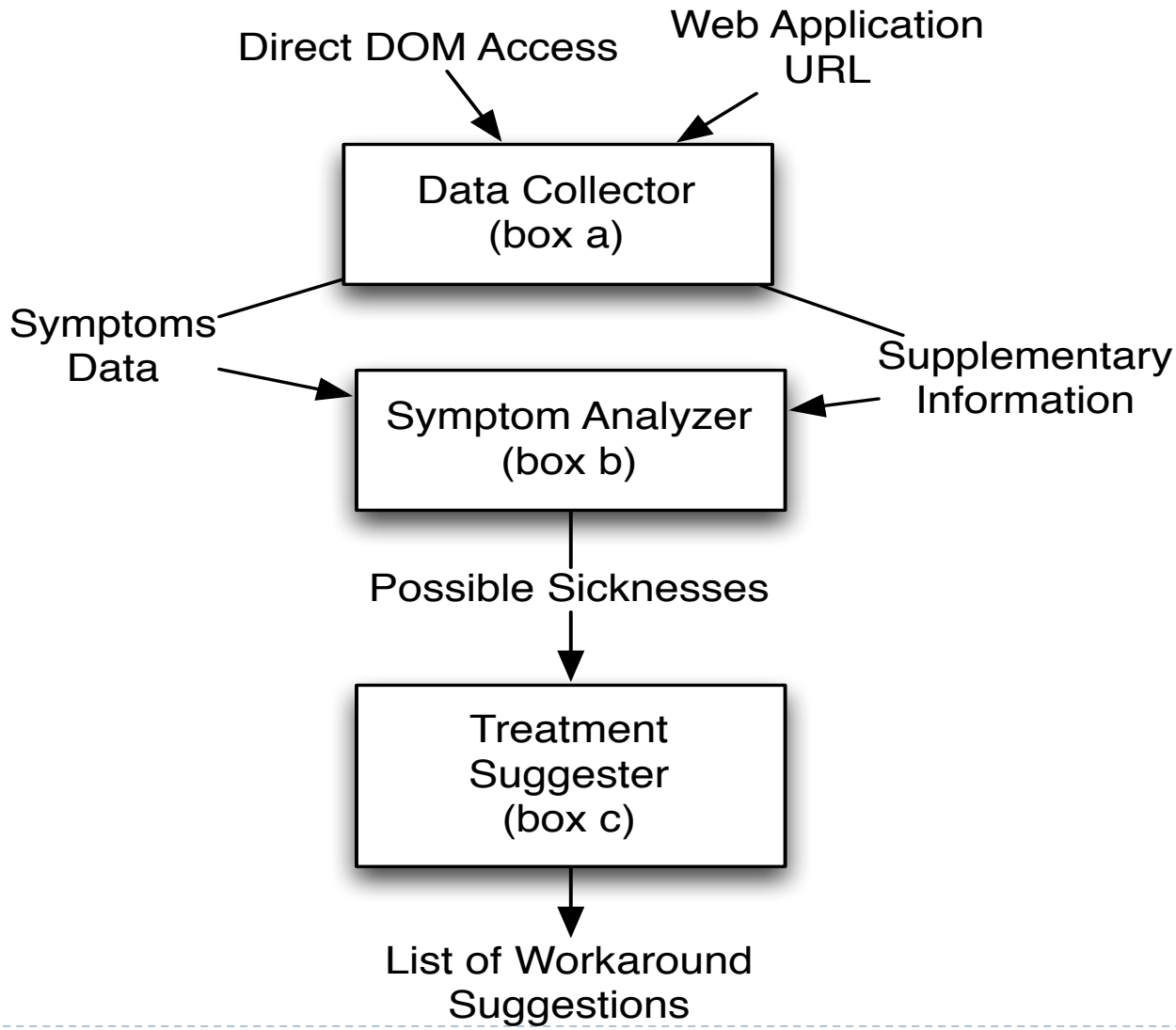


CSS Selectors



Input to querySelector(), $(), etc. to retrieve list of elements

Design


Direct DOM Access
Web Application URL
Data Collector (box a)
Symptoms Data
Supplementary Information
Symptom Analyzer (box b)
Possible Sicknesses
Treatment Suggester (box c)
List of Workaround Suggestions

Running Example

```
1 firstTag = “div”;
2 prefix = “pain-”;
3 suffix = “elem”;
4 level1 = firstTag + “#” + prefix + suffix;
5 level2 = “span.cls”;
6 e = $(level1 + “ “ + level2);
7 e[0].innerHTML = “new content”;
```

Access DOM element using CSS selector

Running Example

```
1 firstTag = “div”;
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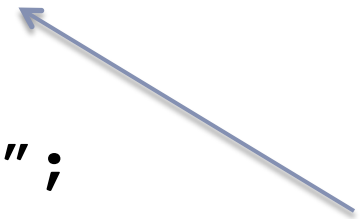
7 e[0].innerHTML = “new content”;
```



Lines to set up the CSS selector passed to $()

Running Example

```
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7 e[0].innerHTML = “new content”;
```

Constructed selector: div#pain-elem span.cls

Running Example

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1 firstTag = “div”;
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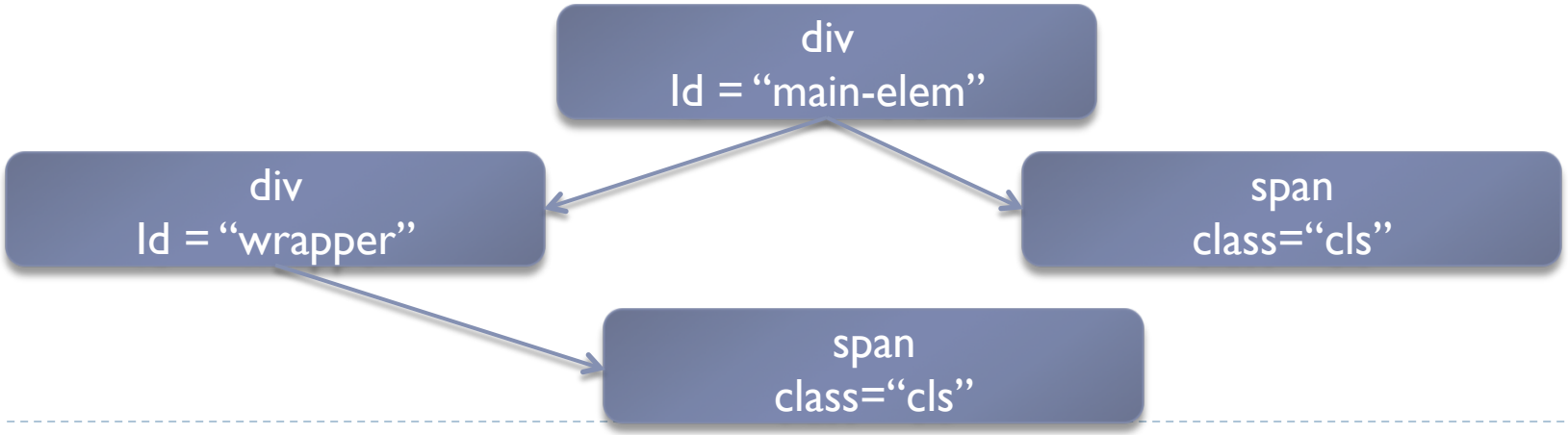
Constructed selector: div#pain-elem span.cls



Running Example

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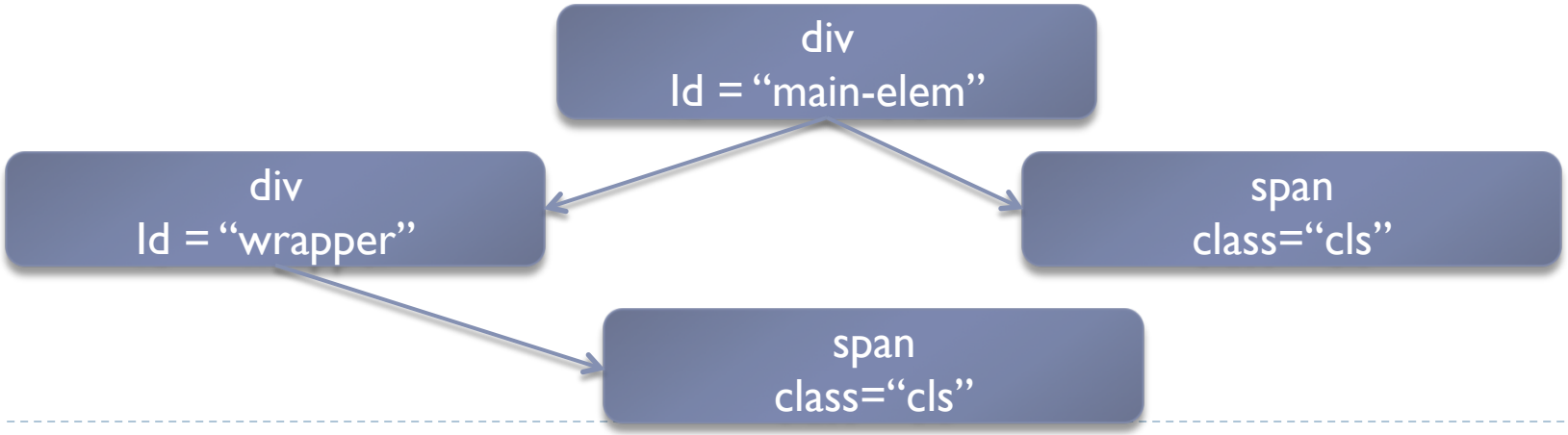
6 e = $(level1 + “ “ + level2);
7 e[0].innerHTML = “new content”;
```

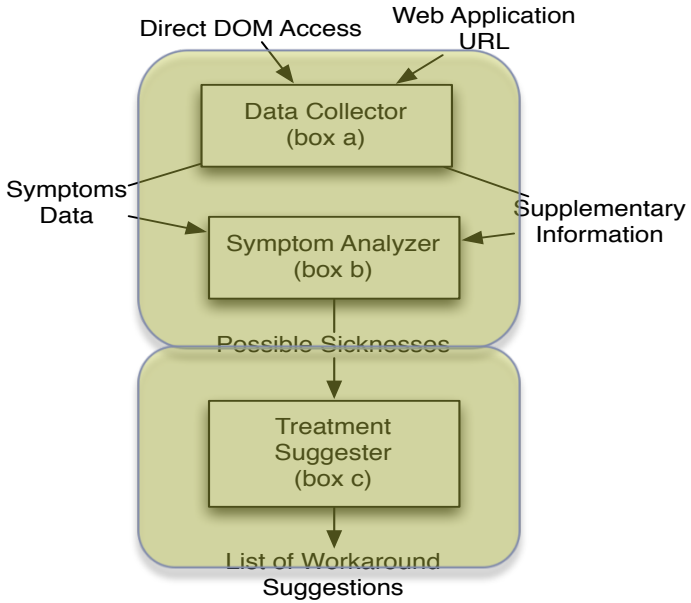
Would return empty set!

Constructed selector: div#pain-elem span.cls

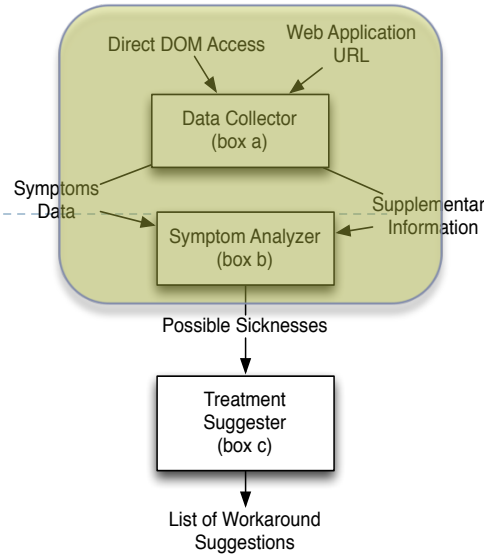


Main Idea

- **Parameter Analysis**: What portion of the parameter do we replace?
- **Context Analysis**: How do we perform the replacement in the code?



Parameter Analysis: Dividing Components

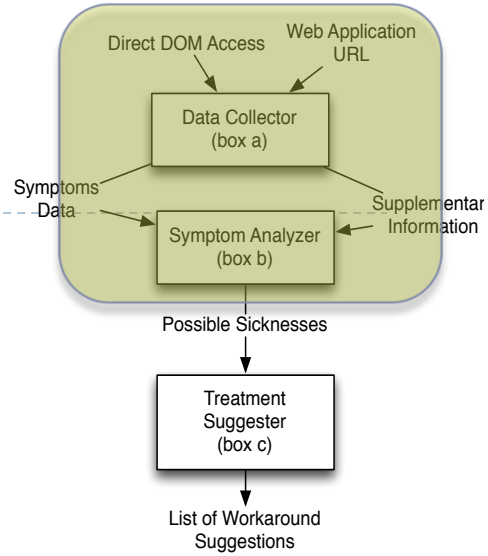


Invalid selector: div#pain-elem span.cls

Divide into components

div | # | pain-elem | | span | . | cls

Parameter Analysis: Dividing Components



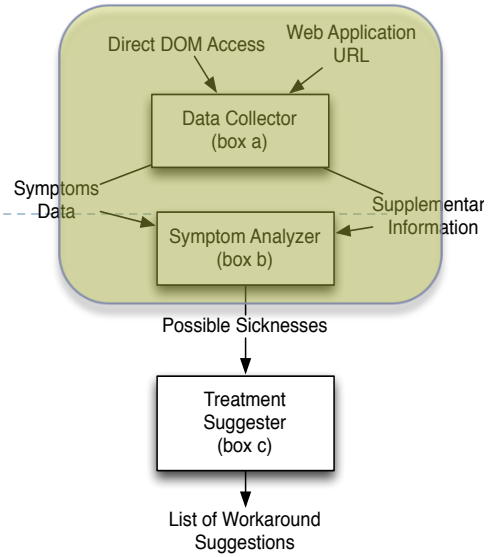
Invalid selector: div#pain-elem span.cls

Divide into components

div | # | pain-elem | | span | . | cls

tag has-id id has-descendant tag has-class class

Parameter Analysis: Dividing Components



Invalid selector: div#pain-elem span.cls

Subdivide each component according to dynamic backward slice

div | # | pain- | elem | | span | . | cls

Line 2

Line 3

Parameter Analysis: Dividing Components

```
1 firstTag = “div”;
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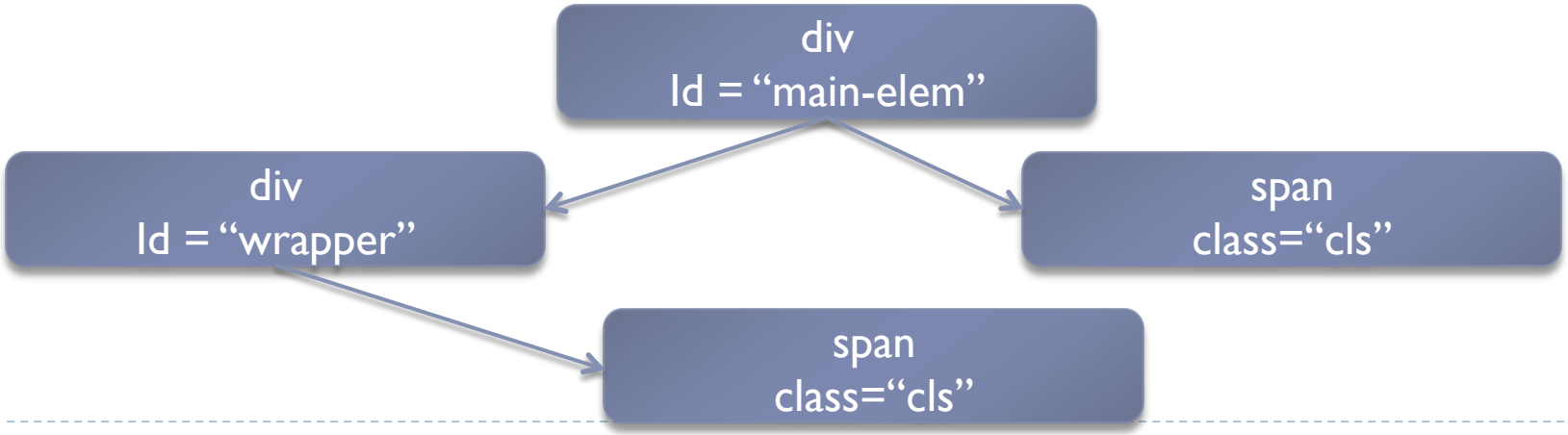
```

Backward slice of “pain-elem”

Invalid selector: div#pain-elem span.cls



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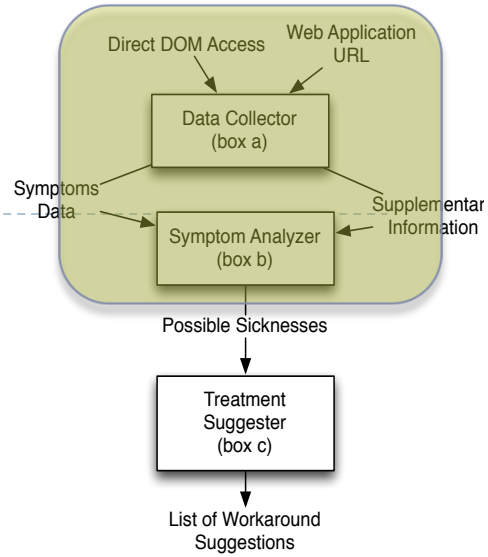
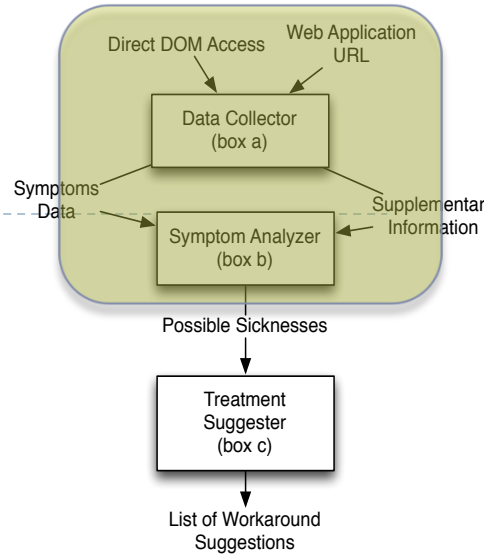


Invalid selector: div#pain-elem span.cls

Subdivide each component according to dynamic backward slice

div | # | pain- | elem | | span | . | cls

Parameter Analysis: Finding Valid Selectors



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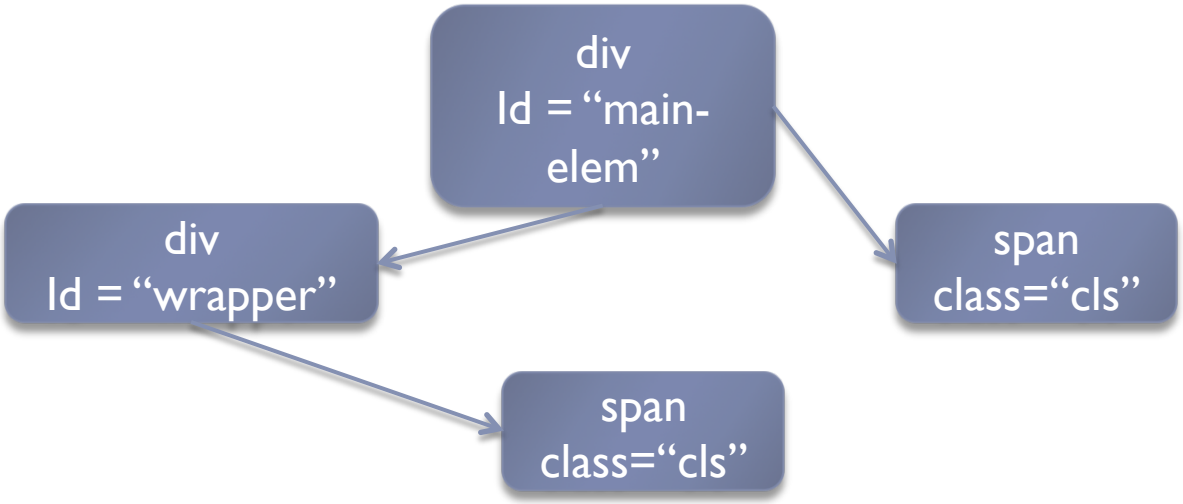
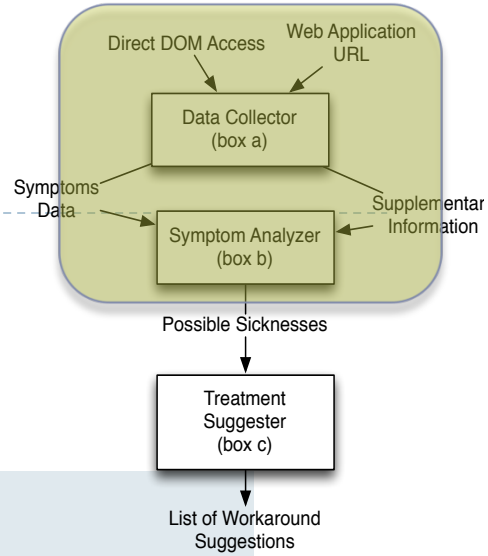


Construct VALID selectors from current DOM that are "sufficiently close" to the erroneous one

Parameter Analysis: Finding Valid Selectors



Invalid selector: div#pain-elem span.cls

List of valid selectors:

div#main-elem span.cls

div#wrapper span.cls

d
Id = "w

span
class="cls"

Construct VALID selectors from current DOM that are "sufficiently close" to the erroneous one

Parameter Analysis: Inferring Possible Replacements [Example]

Invalid selector: div#pain-elem span.cls

div | # | pain- | elem | | span | . | cls

Parameter Analysis: Inferring Possible Replacements [Example]

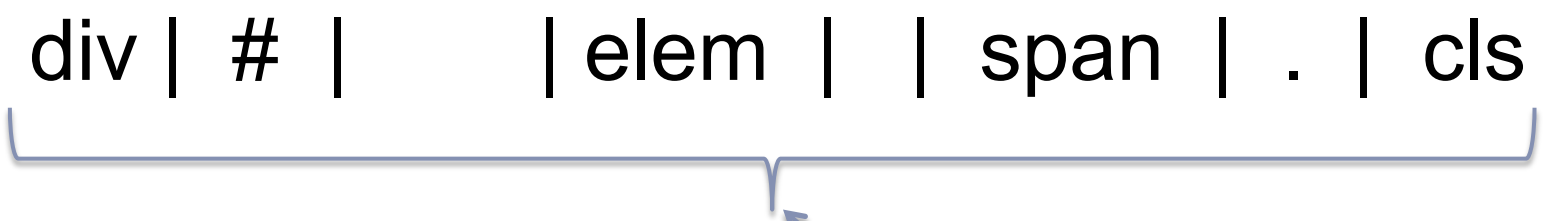
Invalid selector: div#pain-elem span.cls

div | # | pain- | elem | | span | . | cls

Assumed incorrect

Parameter Analysis: Inferring Possible Replacements [Example]

Invalid selector: div#pain-elem span.cls



List of valid selectors:

div#main-elem span.cls
div#wrapper span.cls

Use as pattern

Parameter Analysis: Inferring Possible Replacements [Example]

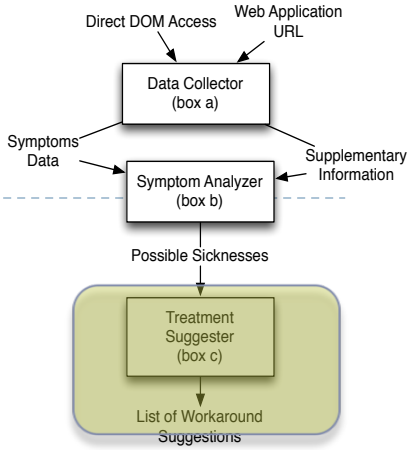
Invalid selector: div#pain-elem span.cls

div | # | | elem | | span | . | cls

List of valid selectors:

div#main-elem span.cls – **MATCHES PATTERN!**
div#wrapper span.cls

Context Analysis

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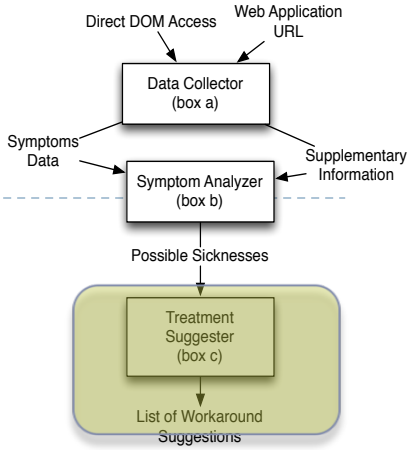
```

Invalid selector: div#pain-elem span.cls

Replacement selector: div#main-elem span.cls

Context Analysis

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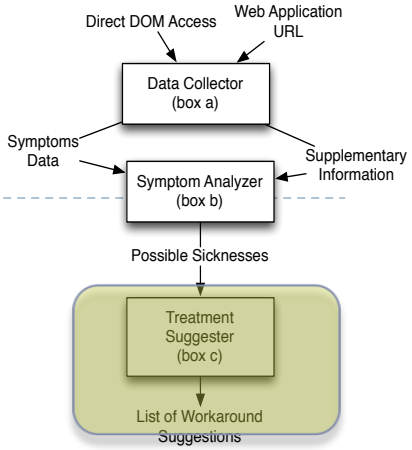
String literal replaced

Invalid selector: div#pain-elem span.cls

Replacement selector: div#main-elem span.cls

Context Analysis

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```

String literal replaced

Invalid selector: div#pain-elem span.cls

Replacement selector: div#main-elem span.cls

Message:
REPLACE STRING LITERAL “pain-” in line 2 with string literal “main-”

Context Analysis: Non-"Replace" Messages

- Loops – "replace" may be unsafe
- String value doesn't originate from string literal

- **Analyze the context!**

MESSAGE TYPES
REPLACE
REPLACE AT ITERATION
OFF BY ONE AT BEGINNING
OFF BY ONE AT END
MODIFY UPPER BOUND
EXCLUDE ITERATION
ENSURE

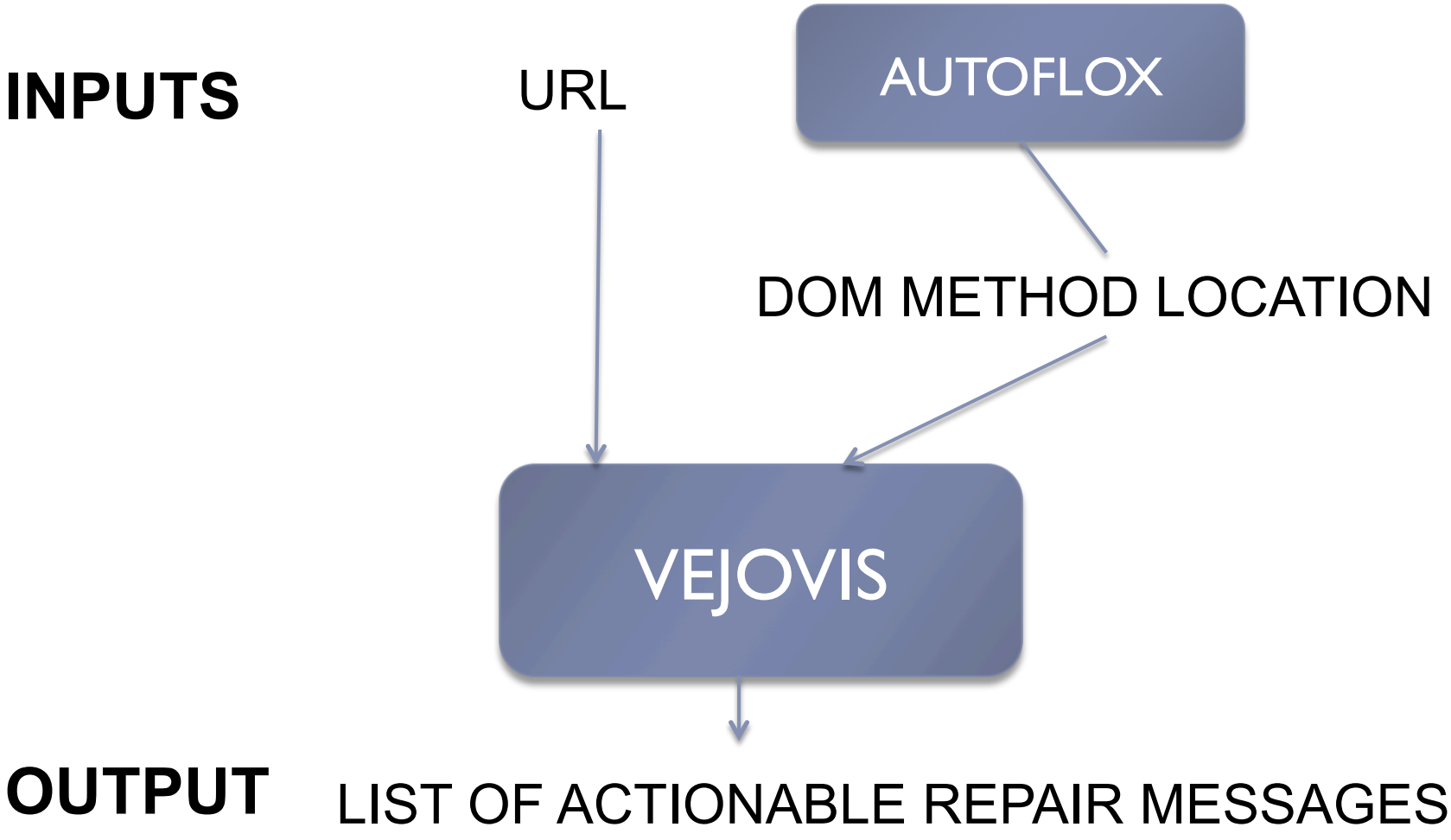
Implementation

- **Vejovis**

http://ece.ubc.ca/~frolino/projects/vejovis

- Data collection: Rhino and Crawljax
- Pattern matching: Hampi

Usage Model


INPUTS
URL
AUTOFLOX
DOM METHOD LOCATION
VEJOVIS
OUTPUT
LIST OF ACTIONABLE REPAIR MESSAGES

Evaluation: Research Questions

RQ1: What is the accuracy of Vejovis in suggesting a correct repair?

RQ2: How quickly can Vejovis determine possible replacements? What is its performance overhead?

RQ1: Accuracy of Vejovis

Subjects	JS Code Size (KB)
Drupal	213
Ember.js	745
Joomla	434
jQuery	94
Moodle	352
MooTools	101
Prototype	164
Roundcube	729
TYPO3	2252
WikiMedia	160
WordPress	197

- 22 bug reports (2 per app, and randomly chosen)
- Replicated bug and ran with Vejovis
- ***Recall*** and ***Precision***

RECALL: 100% if correct fix appears; 0% otherwise

PRECISION: Measure of extraneous suggestions

RQ1: Recall

Subject	Bug Report #1	Bug Report #2
Drupal	✔	✔
Ember.js	✔	✔
Joomla	✔	✔
jQuery	✔	✗
Moodle	✔	✔
MooTools	✔	✔
Prototype	✔	✔
Roundcube	✔	✗
TYPO3	✔	✔
WikiMedia	✔	✔
WordPress	✔	✔

Overall Recall: 91%

RQ1: Precision

Subject	Bug Report #1	Bug Report #2
Drupal	3%	25%
Ember.js	50%	33%
Joomla	1%	1%
jQuery	1%	0%
Moodle	3%	3%
MooTools	50%	50%
Prototype	17%	50%
Roundcube	1%	0%
TYPO3	1%	100%
WikiMedia	4%	1%
WordPress	3%	1%

Avg. Precision: 2%

49 suggestions per bug on average!

Improvements

1. Edit distance bound
2. Ranked suggestions

Alternative: Ranking

Subject	Bug Report #1	Bug Report #2
Drupal	31 / 40	1 / 4
Ember.js	1 / 2	1 / 3
Joomla	1 / 88	1 / 88
jQuery	2 / 108	-
Moodle	2 / 37	1 / 37
MooTools	2 / 2	1 / 2
Prototype	1 / 6	1 / 2
Roundcube	4 / 79	-
TYPO3	1 / 187	1 / 1
WikiMedia	6 / 24	1 / 71
WordPress	13 / 30	1 / 170

#1 Ranking in 13 out of 20 bugs

Conservative ranking

Ranking seems to be beneficial

RQ2: Performance

- Takes average of **44 seconds** to find correct fix
- Worst case: 91.1 seconds (Joomla)

Threats to Validity

- **External**: Evaluated on 11 web apps
- **Internal**: Took bugs from earlier empirical study

Conclusion

- Vejovis: replacement suggestor for DOM-related faults
  - Project Link: http://ece.ubc.ca/~frolino/projects/vejovis
- Evaluated on 22 real-world bugs
  - Good recall – 91%
  - Correct fix ranked #1 in 13/20 cases
  - Average 44 s to complete