How I Learned to Stop Worrying and Love the DOM

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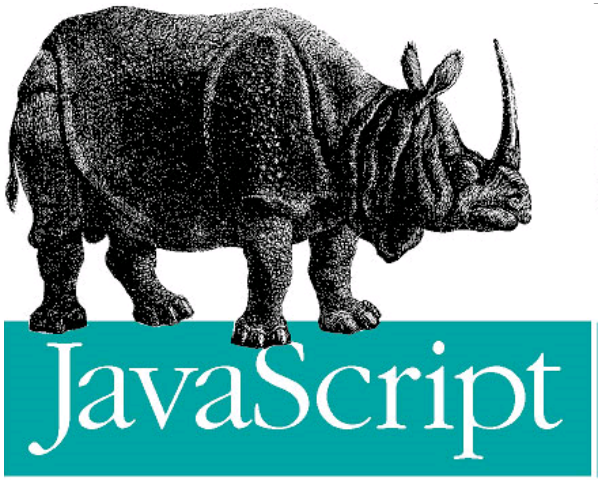
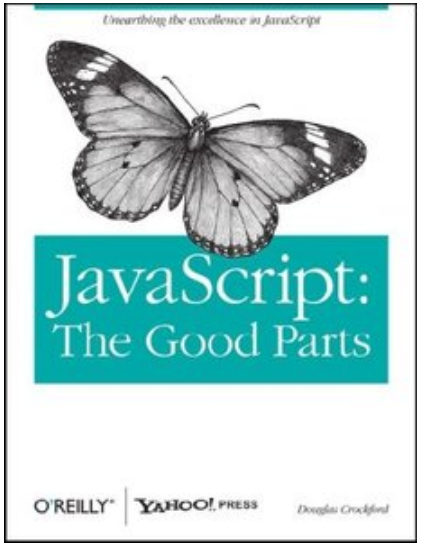
Web Applications: JavaScript

- JavaScript: Implementation of ECMAScript standard
- Executes in client's browser – thousands of lines of code
- 97 of the Alexa top 100 websites use JavaScript
- Number 1 language on both **Github** and **StackOverflow**
- Not easy to write code in – has many "evil" features





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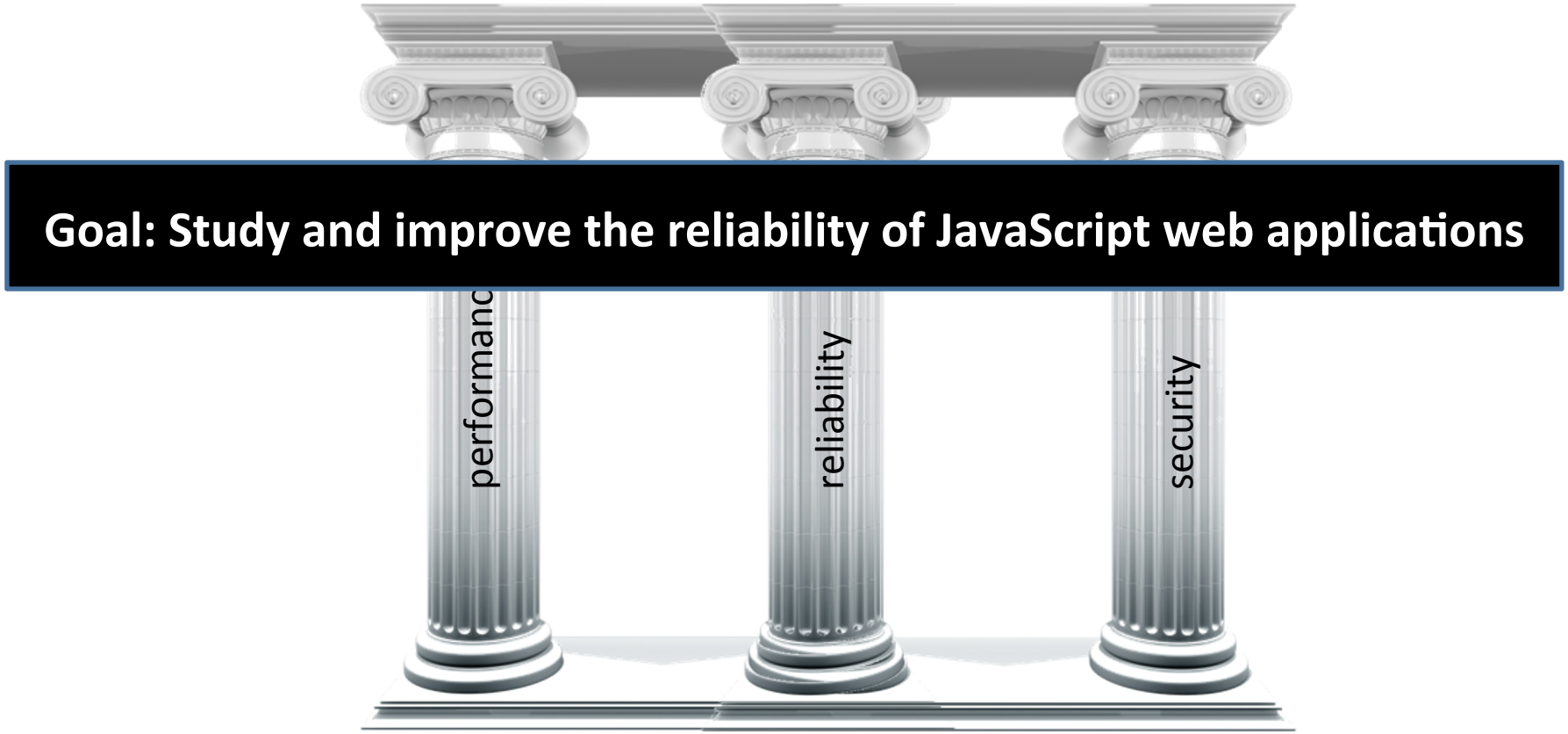
Web Applications: Prior Studies

Performance and parallelism:
JSMeter [Ratanaworabhan-2010], [Richards-2009], [Fortuna-2011]

Reliability

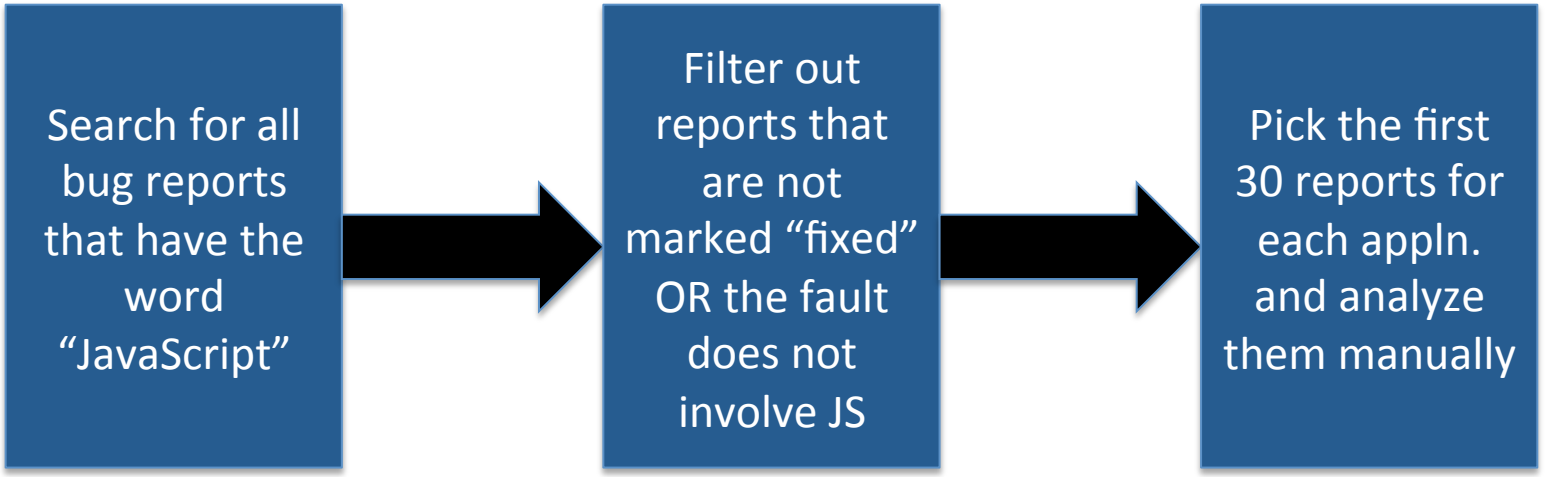
?

Security and Privacy:
[Yue-2009], Gatekeeper[Guarnieri-2009], [Jang-2010]



Web Applications: Study Method

- Collect bug reports from bug repositories
  - Focus on bugs that are marked fixed to avoid spurious bugs
  - Manually verify that the fix involves JavaScript



Web Applications: Research Questions

- What programming errors or bugs ***cause*** JavaScript faults?
- What ***impact*** do JavaScript faults have?
- How long does it take to fix these errors?

Bug Report Study of 19 popular and open source JavaScript applications & libraries

- Over a span of 10 years
- Over 500 bug reports

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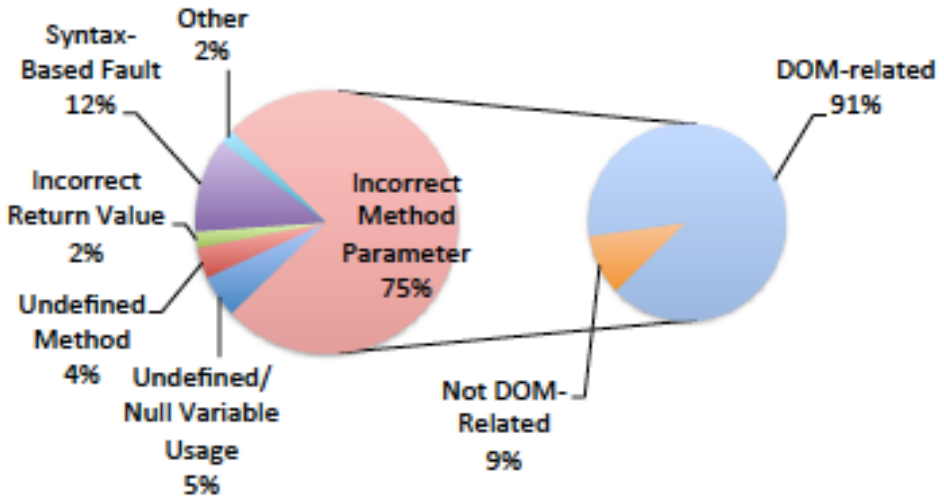
Web Applications: Bug Categories

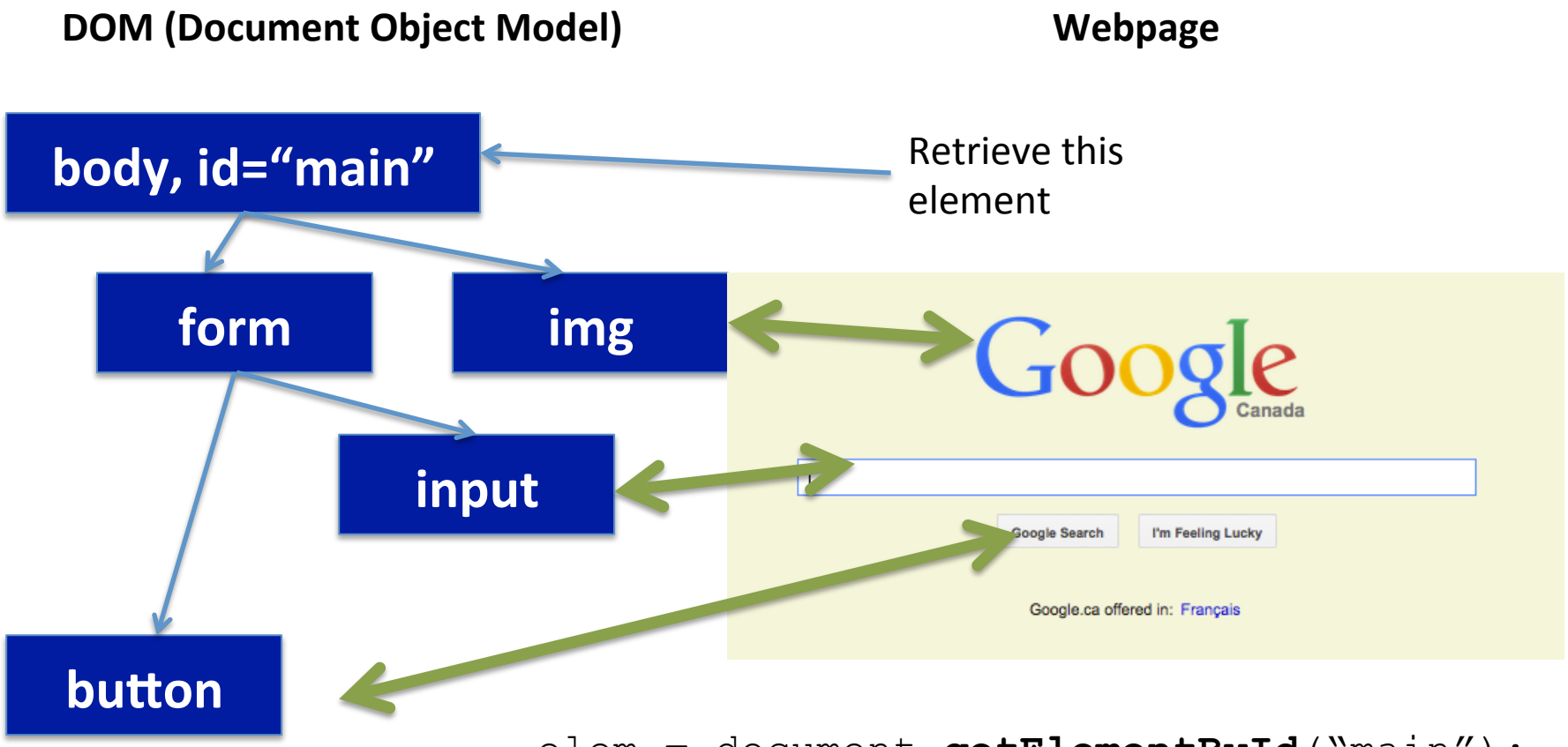


Incorrect Method Parameter Fault: Wrong or invalid value passed to some JavaScript method

DOM-Related Fault: The method is a DOM API method

- Account for nearly two-thirds of JavaScript Faults (68%)

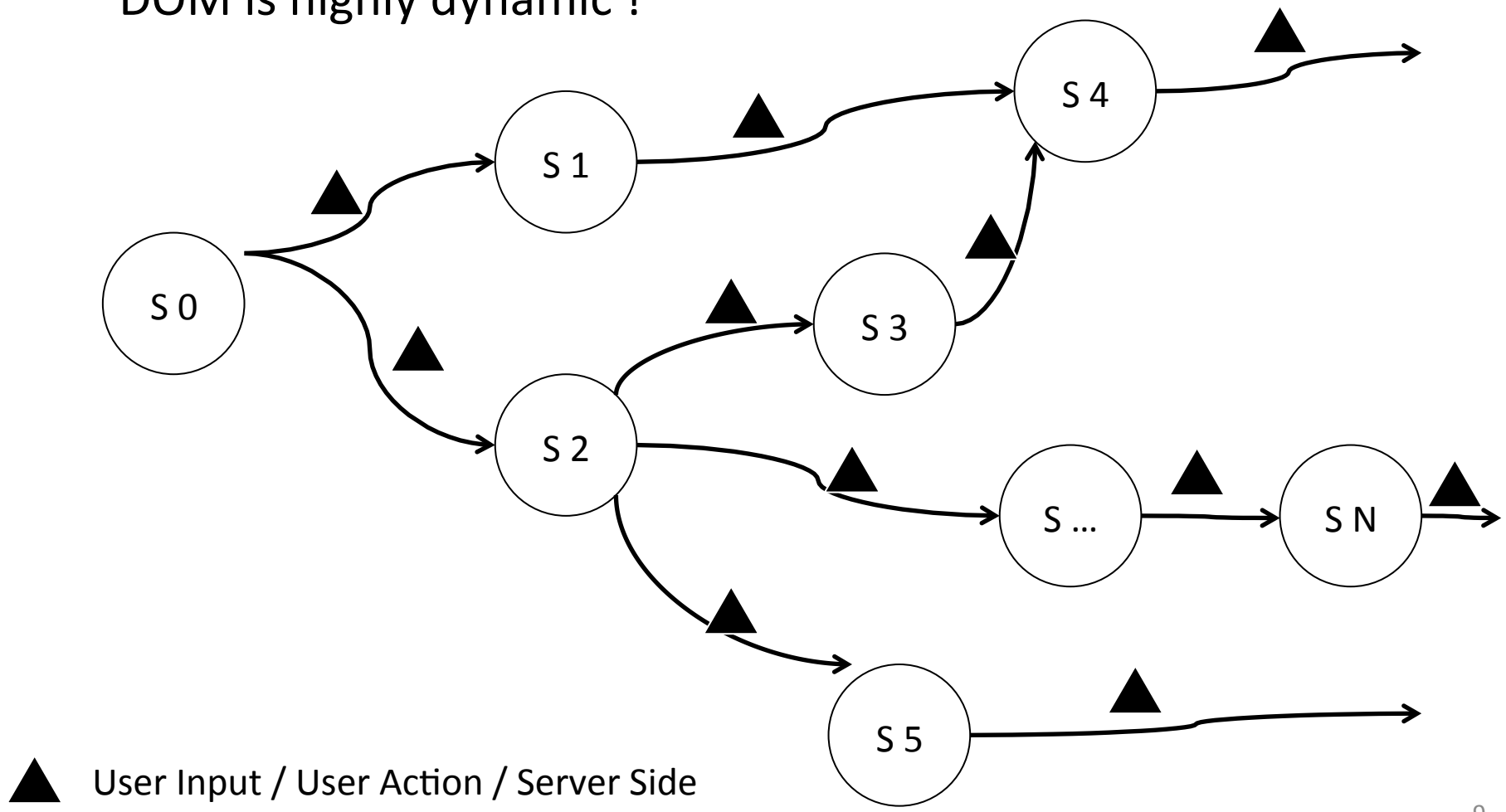
Web Applications: DOM-Related Faults




```
elem = document.getElementById("main");
```

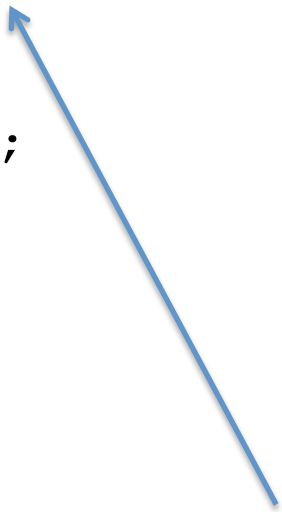
Web Applications: Challenge

DOM is highly dynamic !



DOM-Related Faults: Example

```
var elem, retrievedStr = [Retrieved via XHR];
var dotsInStr = retrievedStr.split(".").length;
if (dotsInStr == 0) {
    var prefix = "id_";
    elem = $("#" + prefix + retrievedStr);
}
else {
    elem = $(retrievedStr);
}
elem[0].focus()
```



Find the number of dots in the string

DOM-Related Faults: Example

```
var elem, retrievedStr = [Retrieved via XHR];
var dotsInStr = retrievedStr.split(".").length;
if (dotsInStr == 0) {
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```

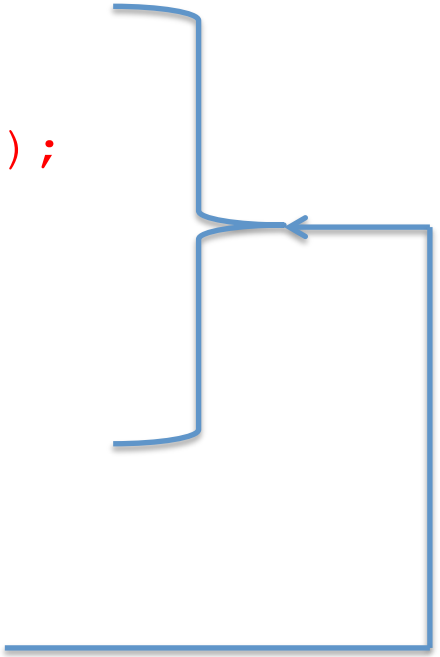

If there are no dots, prefix “id_” to the string. Otherwise, leave it as is. Access the DOM element via a ‘$’

DOM-Related Faults: Example

```
var elem, retrievedStr = [Retrieved via XHR];
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    elem = $("#" + prefix + retrievedStr);
}
else {
    elem = $(retrievedStr);
}
elem[0].focus()
```

UNDEFINED EXCEPTION!

Retrieved string of “editor” would go here even though it has no dots, which would erroneously cause $ to select “editor”, which returns Undefined

DOM-Related Faults: Example

```
var elem, retrievedStr = [Retrieved via XHR];
var dotsInStr = retrievedStr.split(".").length;
if (dotsInStr == 0) {
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    elem = $("#" + prefix + retrievedStr);
}
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}
elem[0].focus()
```

BUG: The assigned value should be retrievedStr.split(“.”).length – 1, as length always returns at least 1.

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- What ***impact*** do JavaScript faults have?

- How long does it take to fix these errors?

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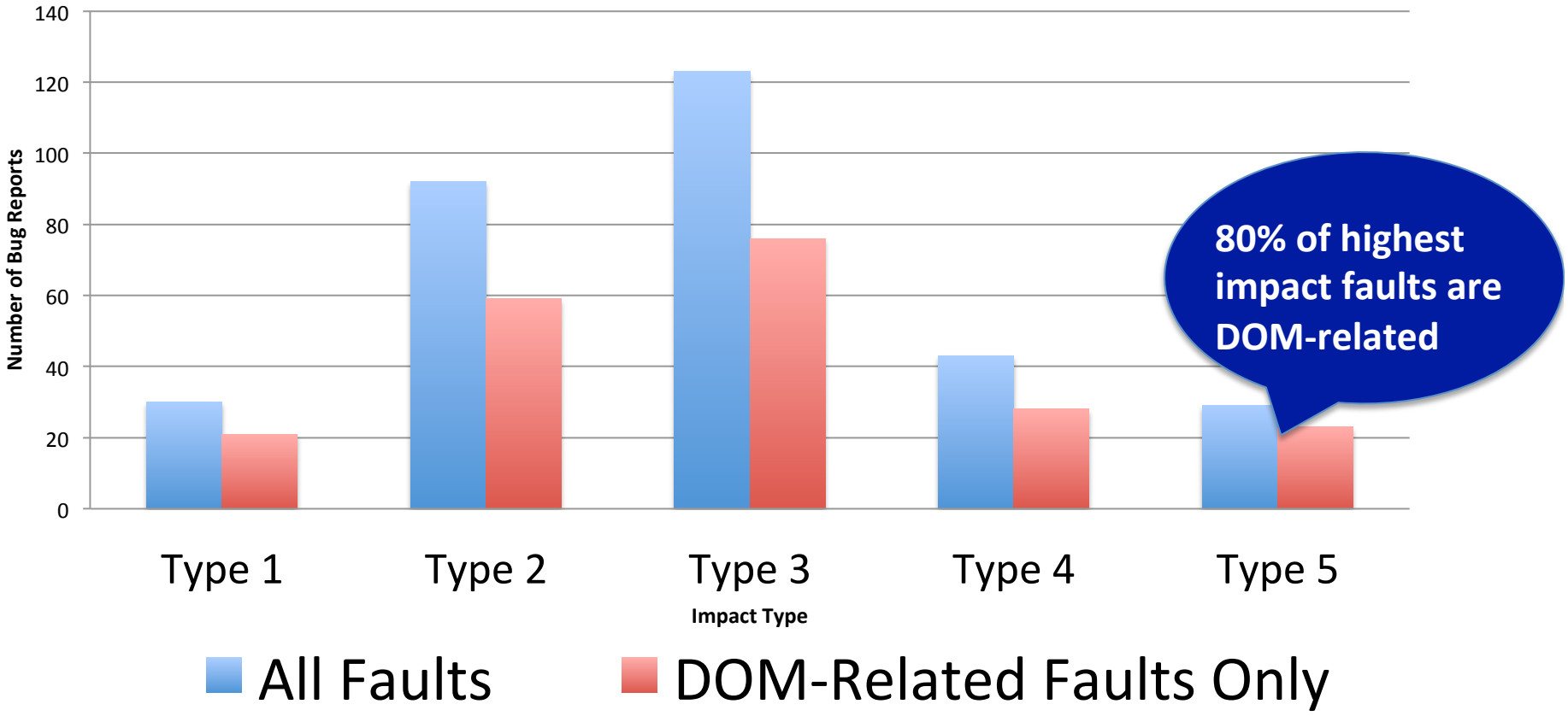
Web Applications: Bug Impact

- Impact Types – Based on Bugzilla's classification
  - Type 1 (lowest impact), Type 5 (highest impact)



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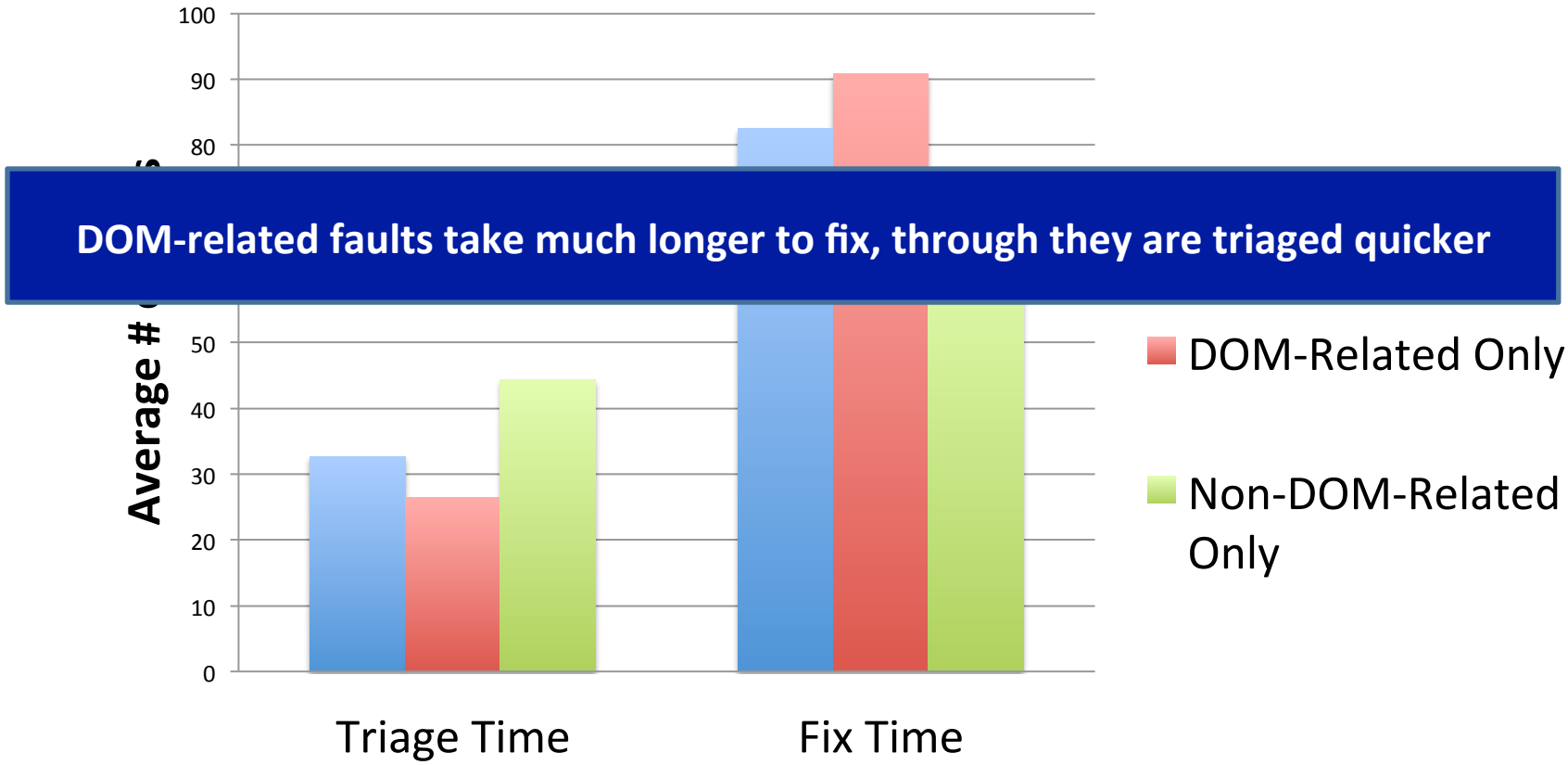
Web Applications: Bug Fix Times

- **Triage Time**: Time it took to assign or comment on the bug
- **Fix Time**: Time it took to fix the bug since it was triaged



Web Applications: Findings Summary

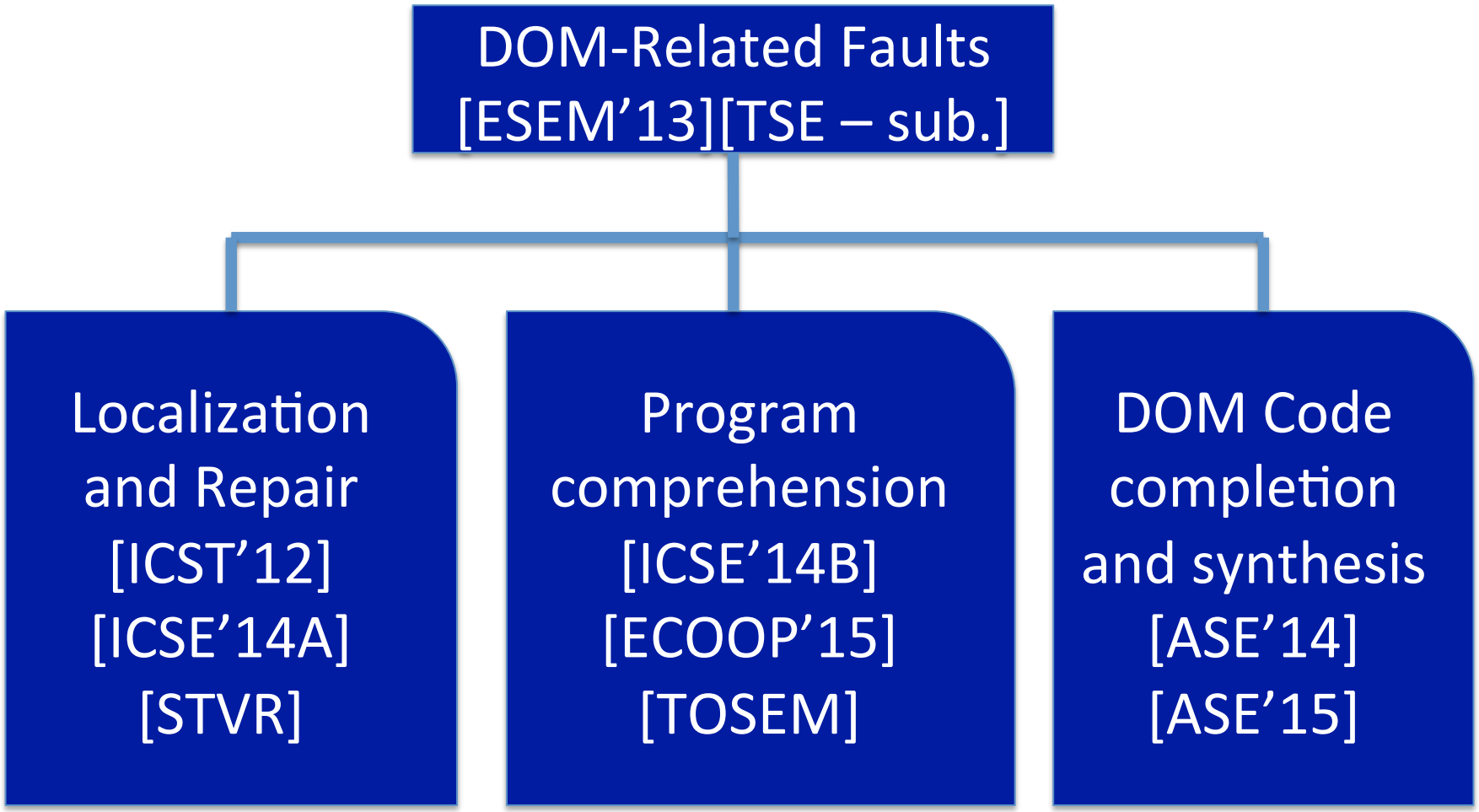
DOM-related faults dominate JavaScript faults

- Responsible for **nearly two-thirds (68%)** of all the JavaScript faults in web applications
- Responsible for **80**% of the **highest impact** faults, including security vulnerabilities
- Take **40%** longer time to fix though they're triaged quicker than non-DOM related faults

Web Applications: Existing Techniques

- **Add gradual typing to JavaScript (e.g., TypeScript from MS, DART from Google, Flow from Facebook …)**
  - Typically ignore the DOM or provide only limited support
- **Use higher-level programming idioms in JavaScript**
  - MVC Frameworks (e.g., AngularJS)
  - Functional Reactive Programming (e.g., RxJS)
- **Detecting errors in web applications**
  - Spelling Errors and Type Errors [Moeller – FSE'11]
  - Race conditions [Vechev - OOPSLA'13][Livshits - FSE'15]
  - Type Coercion Errors [Pradel – ICSE'15][Pradel – ECOOP'15]

Web Applications: Our Research



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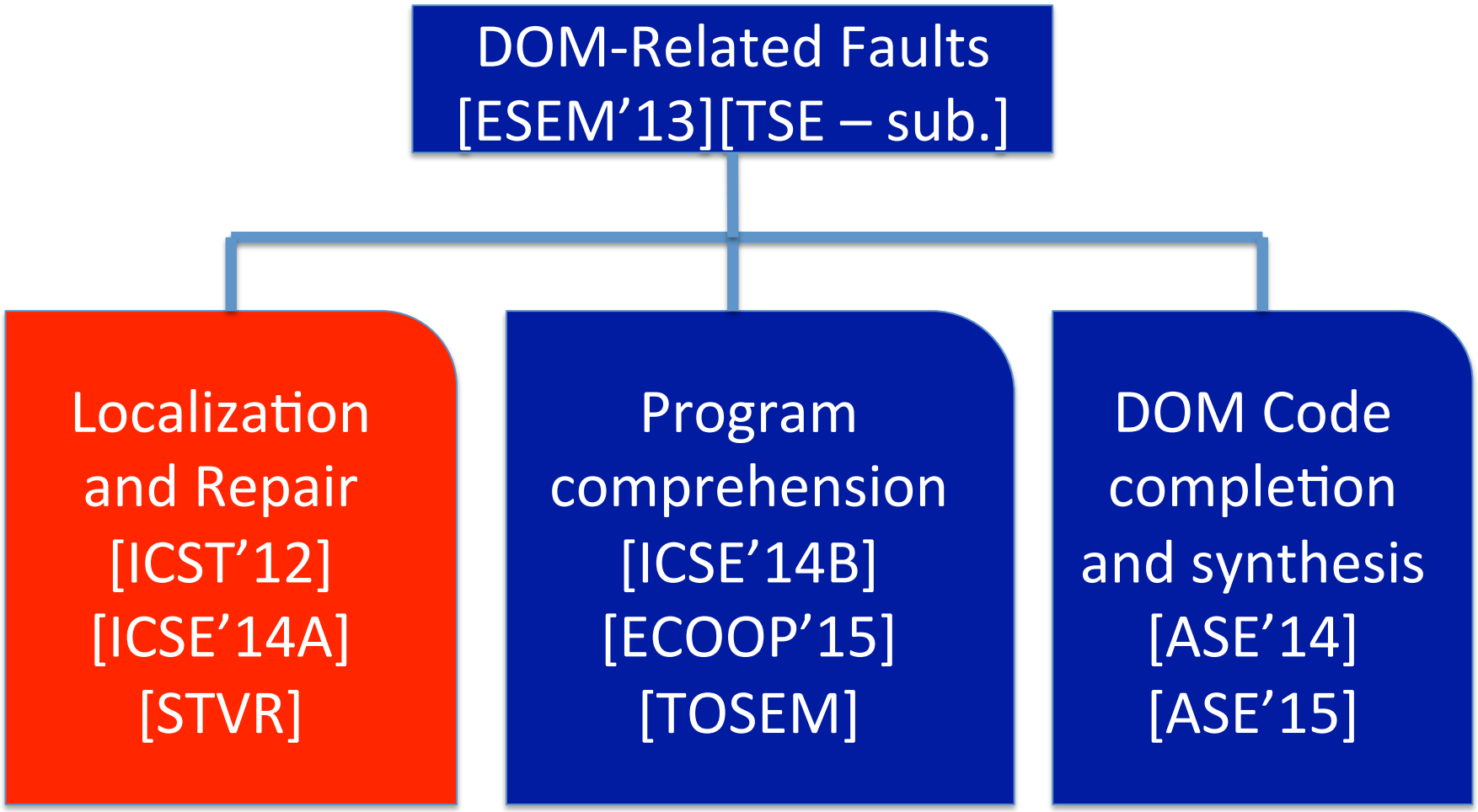
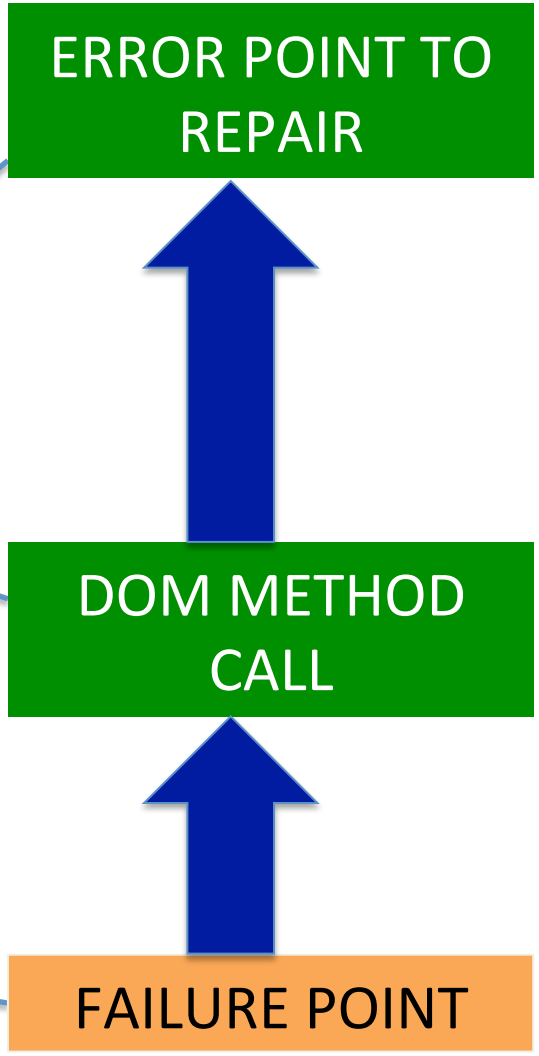


AutoFlox [ICST'12, STVR]

```
1   function generateId(index) {
2       var prefix = "bar";
3       var id = prefix + index;
4       return id;
5   }
6
7   function retrieveElement(index) {
8       var id = generateId(index);
9       var e = document.getElementById(id);
10      return e;
11  }
12
13  for (var i = 1; i <= 4; i++) {
14      var elem = retrieveElement(i);
15      elem.innerHTML = "Item #" + i;
16  }
```



Vejovis [ICSE'14A]

```
1   function generateId(index) {
2       var prefix = "bar";
3       var id = prefix + index;
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6
7   function retrieveElement(index) {
8       var id = generateId(index);
9       var e = document.getElementById(id);
10      return e;
11  }
12
13  for (var i = 1; i <= 4; i++) {
14      var elem = retrieveElement(i);
15      elem.innerHTML = "Item #" + i;
16  }
```
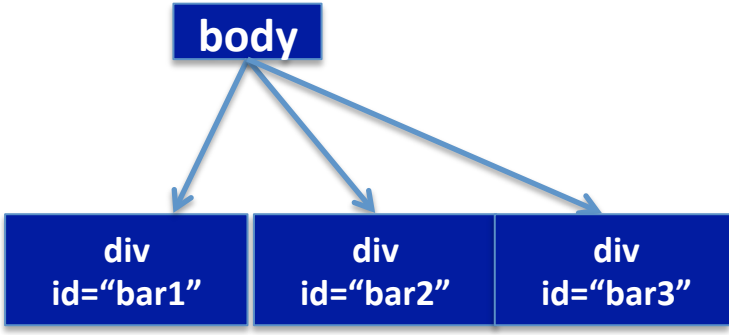

"bar"

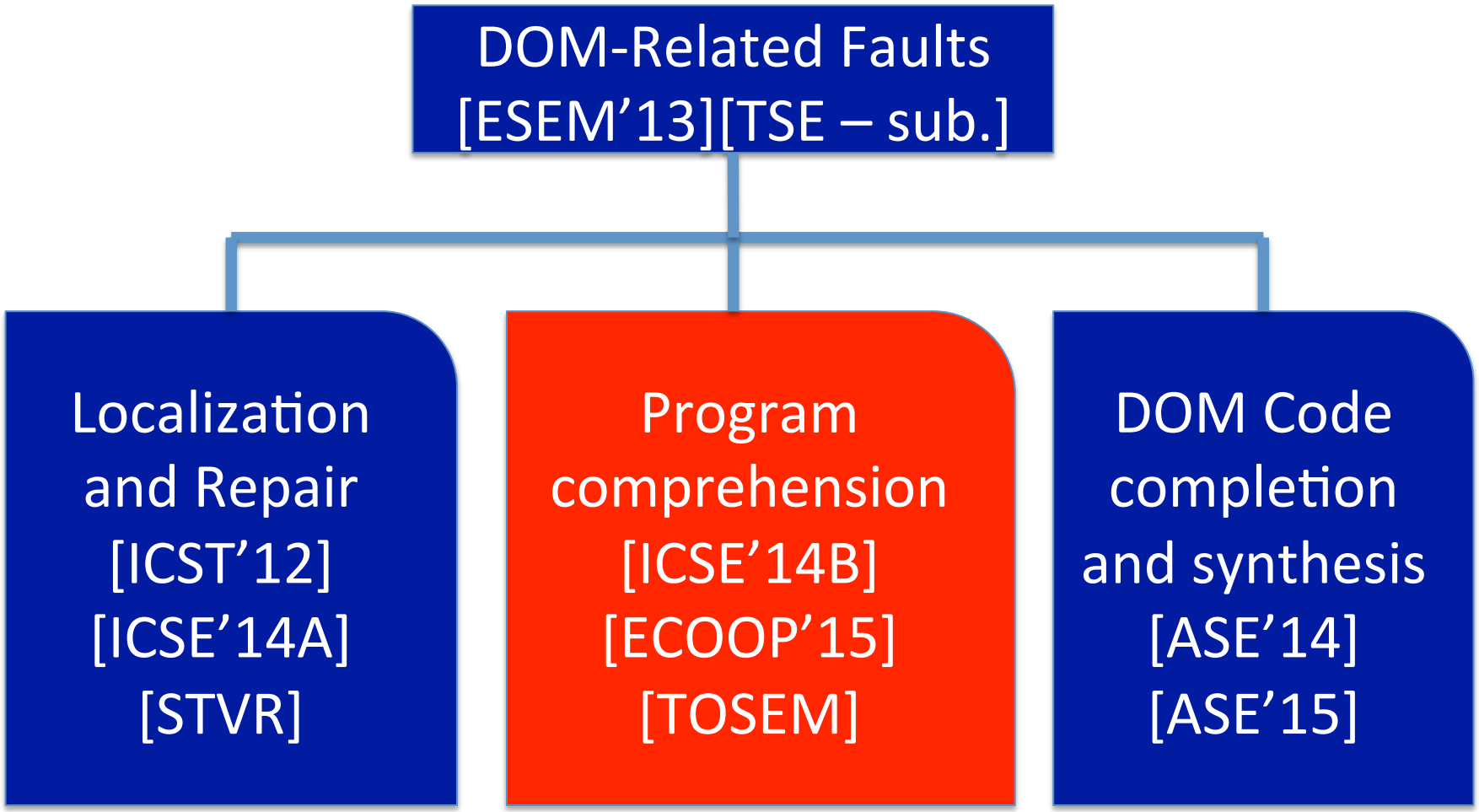


Evaluates to "bar4"

"4"

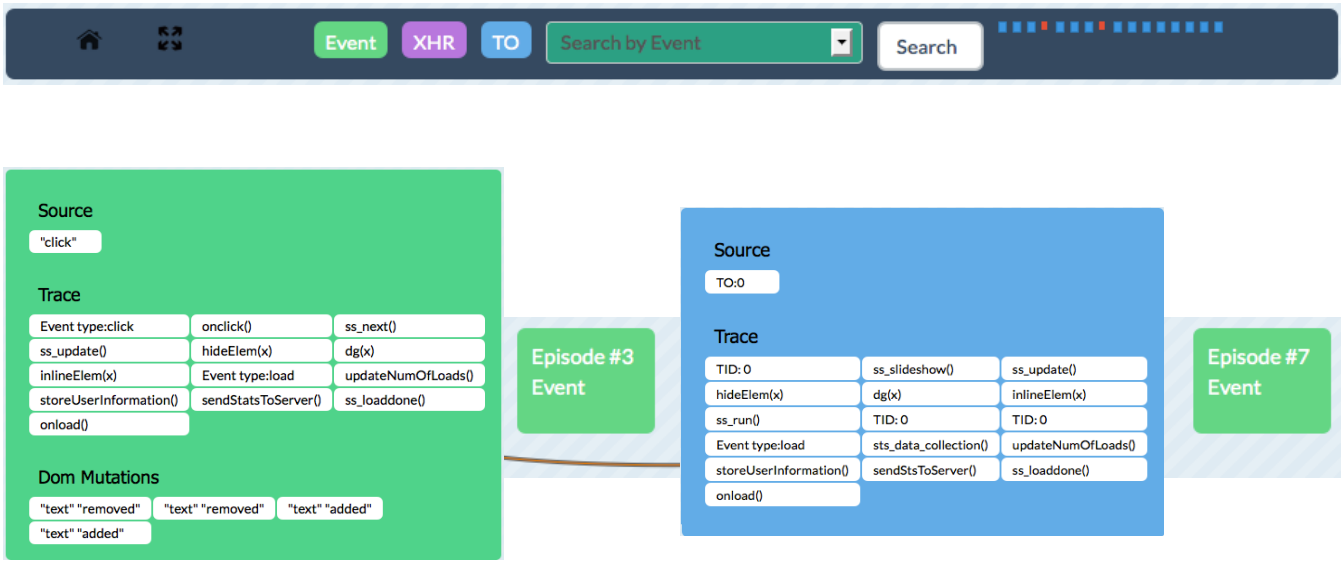
Suggestion: REMOVE last iteration of for loop in line 13

Web Applications: Our Research



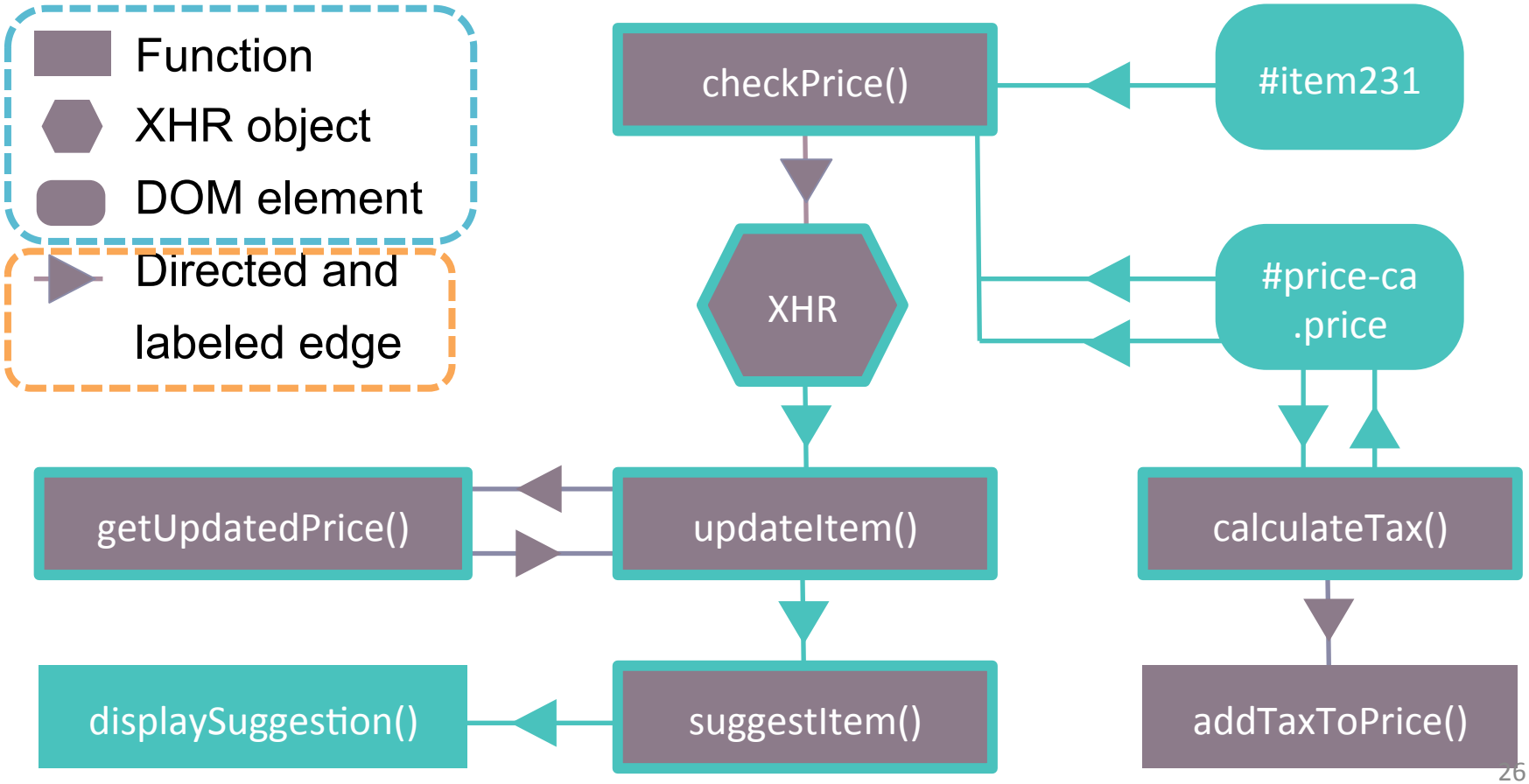
Clematis [ICSE'14B – distinguished paper award][TOSEM]

- **Challenge:** Web applications are complex, and consist of DOM interactions, AJAX messages and timeouts
- Clematis allows users to visualize causal dependencies between events and code, and between async. events

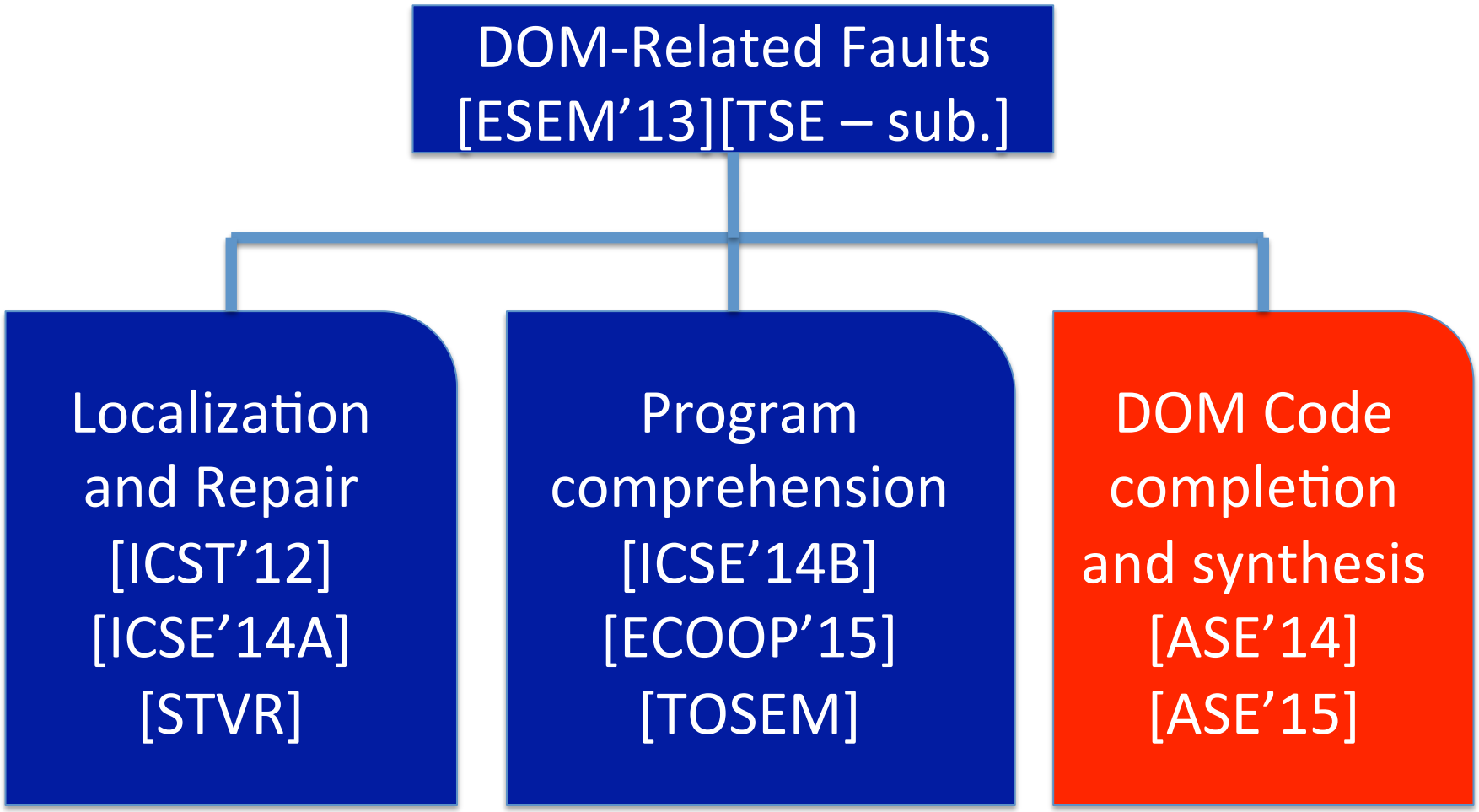


ToChal [ECOOP'15]

- Change Impact analysis for JavaScript

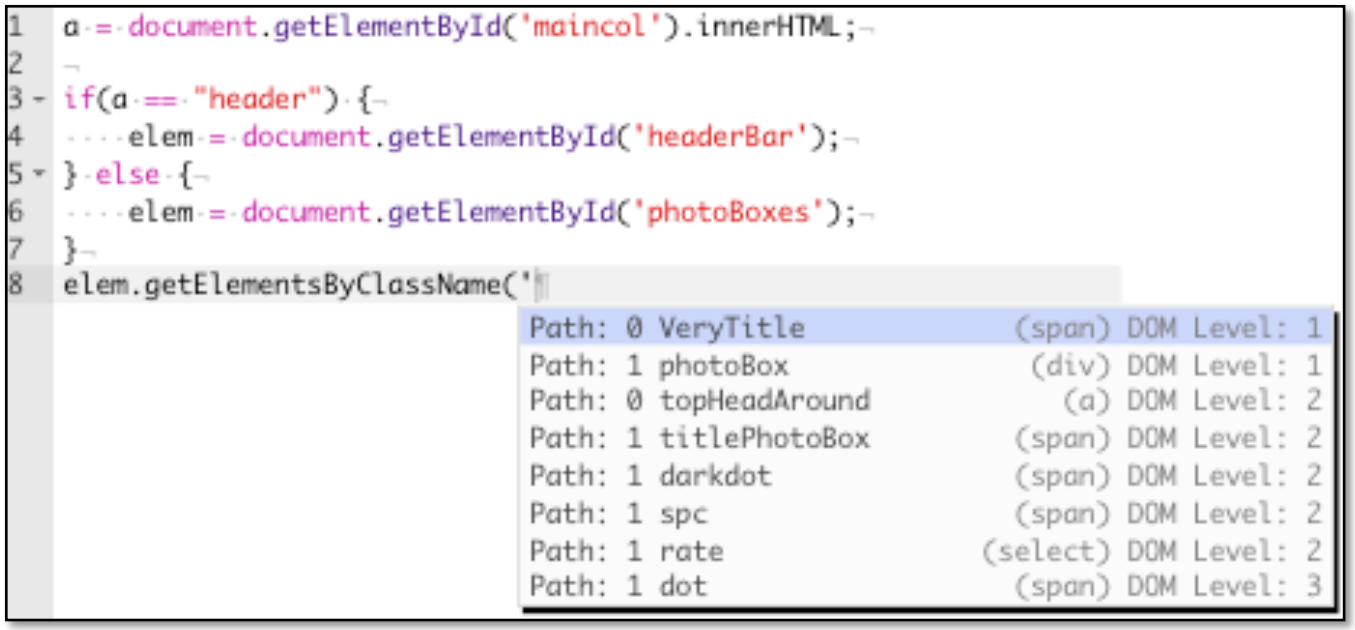


Web Applications: Our Research



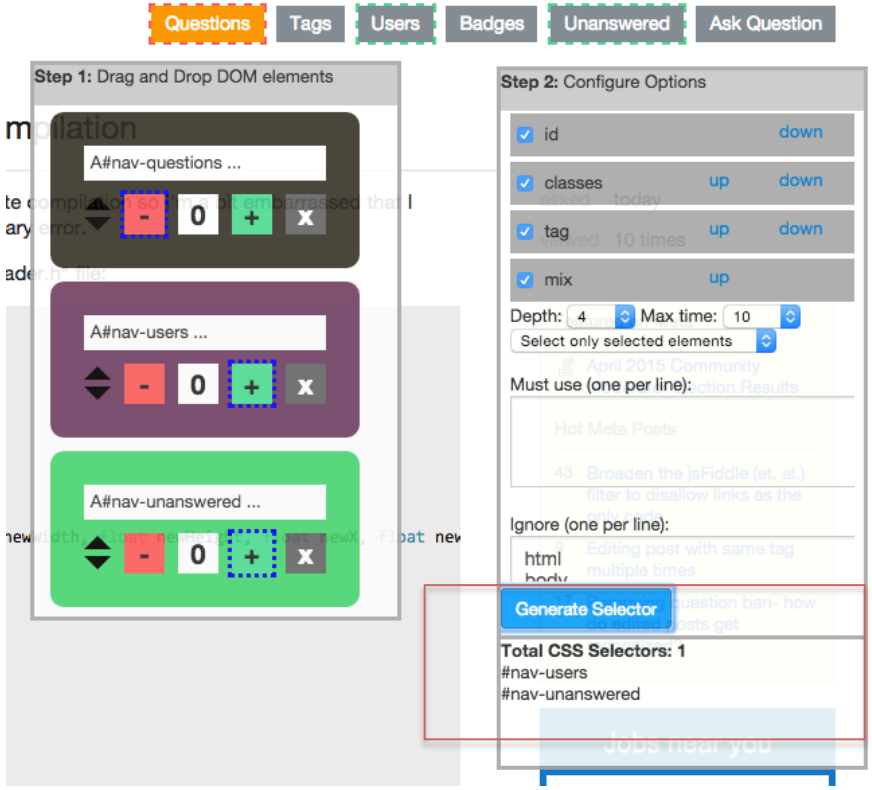
Dompletion [ASE'14]

- Automatically perform code completion for DOM-JS interactions within the IDE
- Symbolic execution for finding DOM nodes



LED [ASE'15]

- Synthesize DOM element selectors automatically through programmer-supplied examples



Our Recent Work

MVC Frameworks for JS

- Static analysis tools for JavaScript MVC Frameworks such as AngularJS [ICSE'15]

Server-side JavaScript

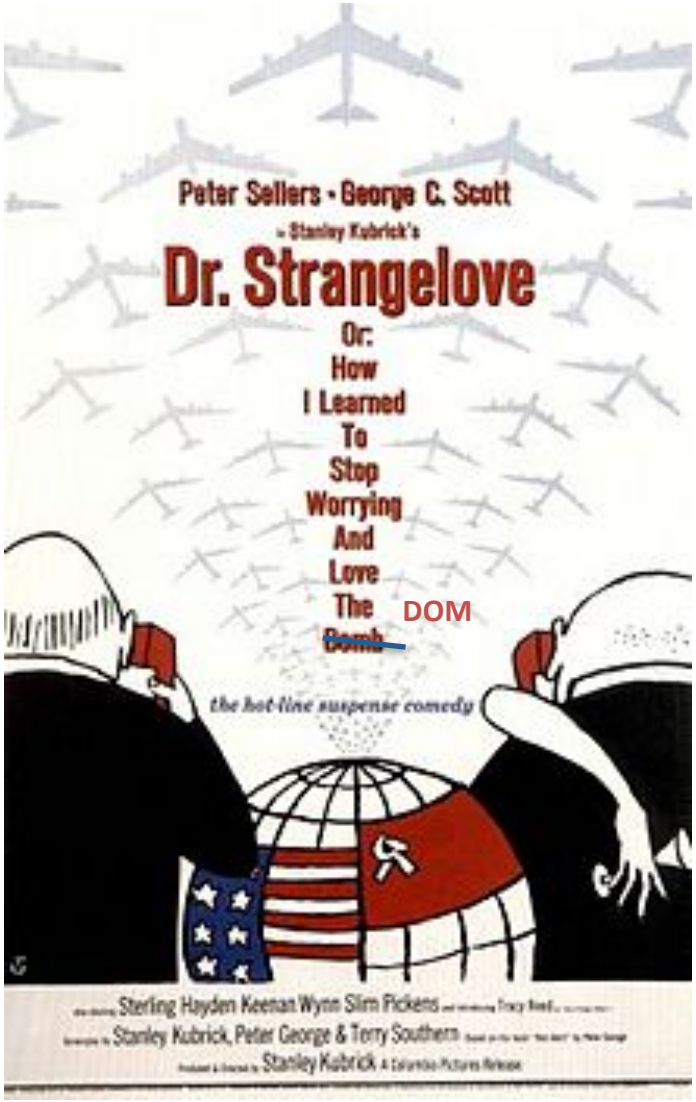
- Program Comprehension for server side JavaScript such as Node.js [ICSE'16]

Conclusion and Future Work

- **DOM-related faults prevalent in JavaScript**
  - Responsible for 2/3rds of all real-world bugs, and 80% of the most critical ones (highest impact)
  - Need efficient techniques to fix the bugs, understand root causes, and write error-free code

- **Future Work**
  - Extensions for JavaScript in the IoT context
  - Considering security in addition to reliability
  - Extension to web languages beyond JavaScript

Coming Soon to a Theater Near You !



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Software and Datasets:

http://blogs.ubc.ca/karthik/software