SALT LAB
SOFTWARE ANALYSIS AND TESTING

Hybrid DOM-Sensitive Change Impact Analysis for JavaScript

Saba Alimadadi, Ali Mesbah and Karthik Pattabiraman

ECOOP 2015

saba@ece.ubc.ca

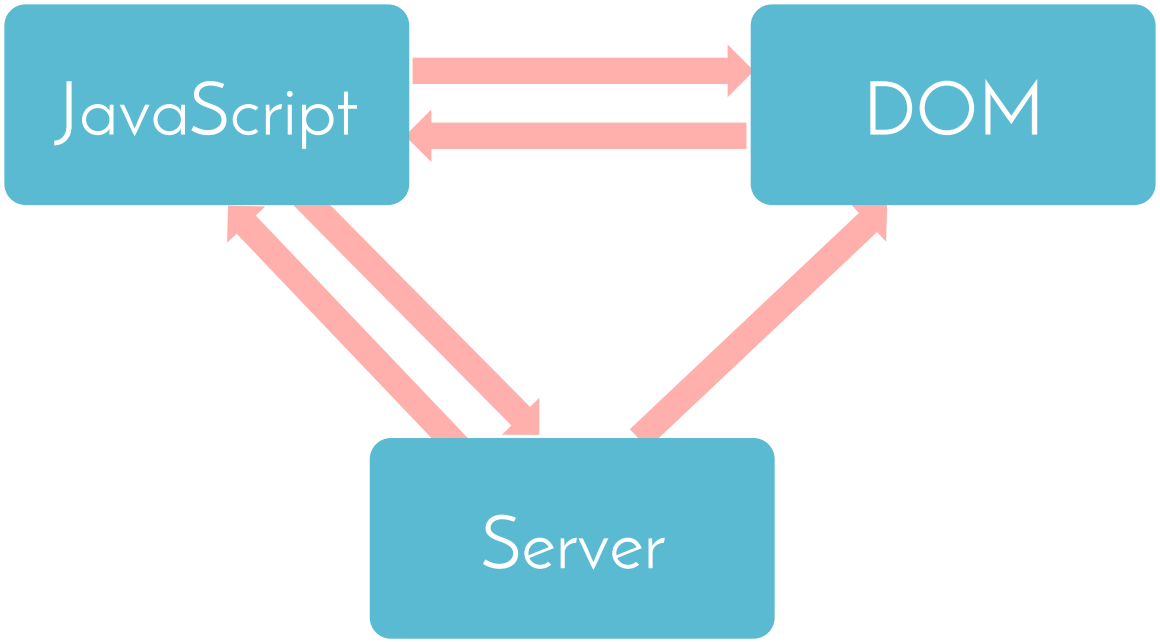
ece Electrical and Computer Engineering

UBC a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

Change Impact Analysis (CIA)

- Software must continually change to adapt to the changing environment.
- **Goal**: identifying parts of the program that are potentially affected by a change.

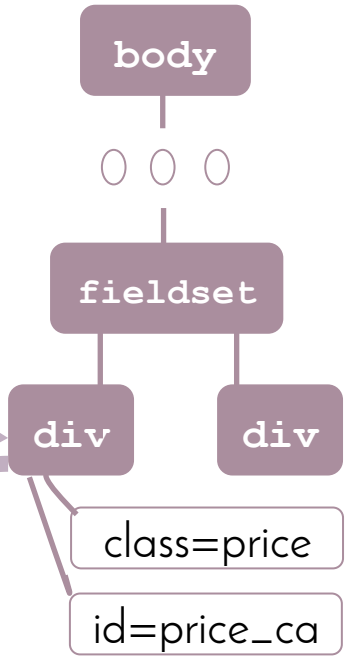
Challenges of CIA for JavaScript



Challenge 1: Impact through the DOM


```
function calculateTax() {
    $('.price').each(function(index) {
        $(this).text(addTaxToPrice(
            $(this).text());
    });
}
```

```
function checkPrice() {
    . . .
    var cad_price = $('#price_ca').innerText();
    . . .
}
```

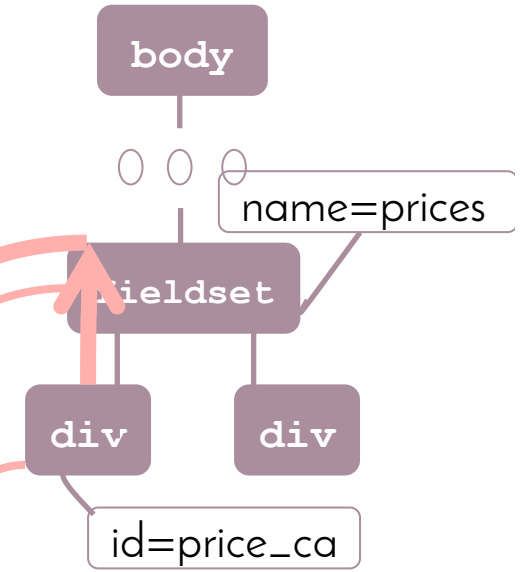


Challenge 2: Impact through Event Propagation

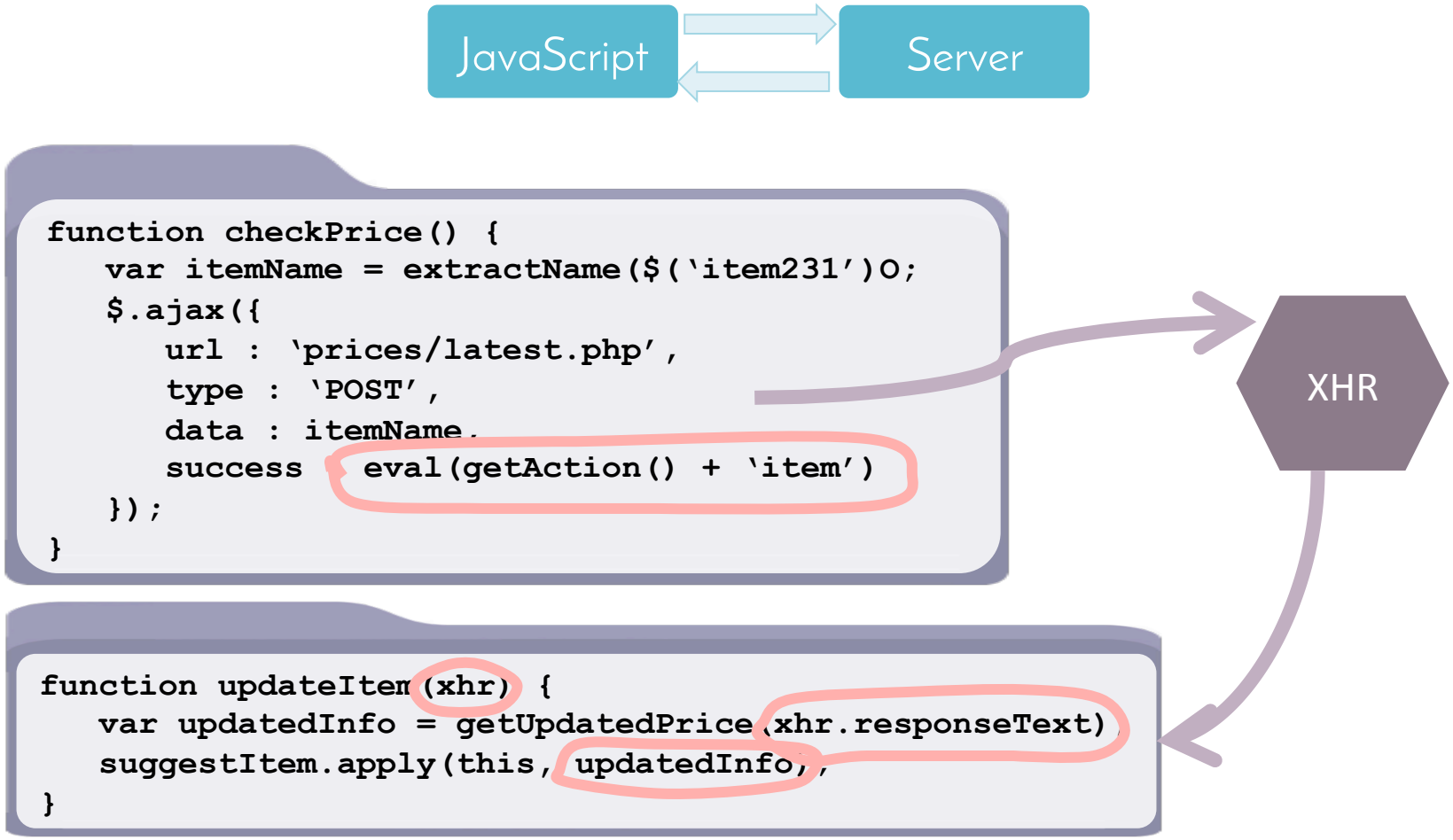

```
$('#price_ca').bind('click', checkPrice);
$('prices').bind('click', calculateTax);
```

```
function calculateTax() {
    . . .
}
```

```
function checkPrice() {
    . . .
}
```



Challenge 3: Impact through XHRs



Challenges of CIA for Client-Side JavaScript

1. JavaScript and Document Object Model (DOM)

2. Events and event propagation

3. JavaScript and XMLHttpRequests (XHRs)

\+ High dynamism of JavaScript

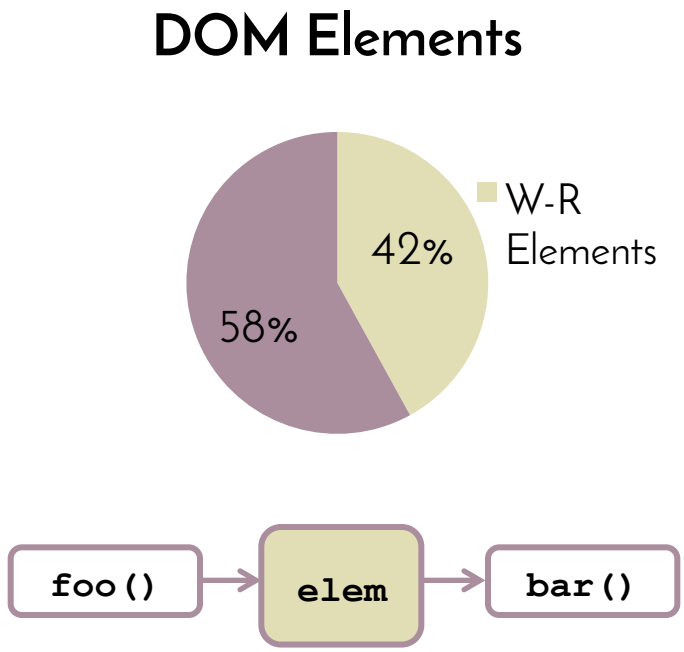
Exploratory Study: DOM-related and Event-based Impacts

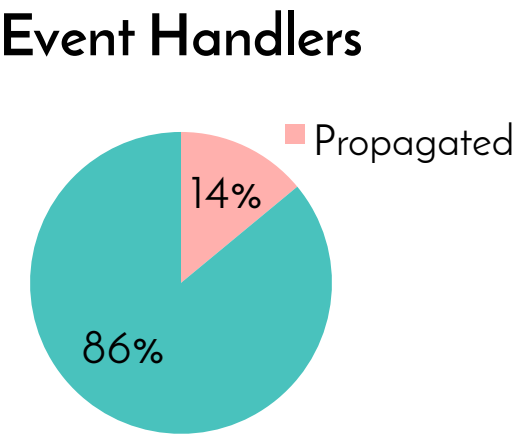
- Subject: 10 web apps (online contests, GitHub trending, etc.)
- Gathered data:
  - JavaScript-DOM interactions (write-read pairs)
  - Event propagation

- Further analysis of the structure of graphs.
  - Measured metrics: fan-in and fan-out of functions and DOM elements, and average path lengths

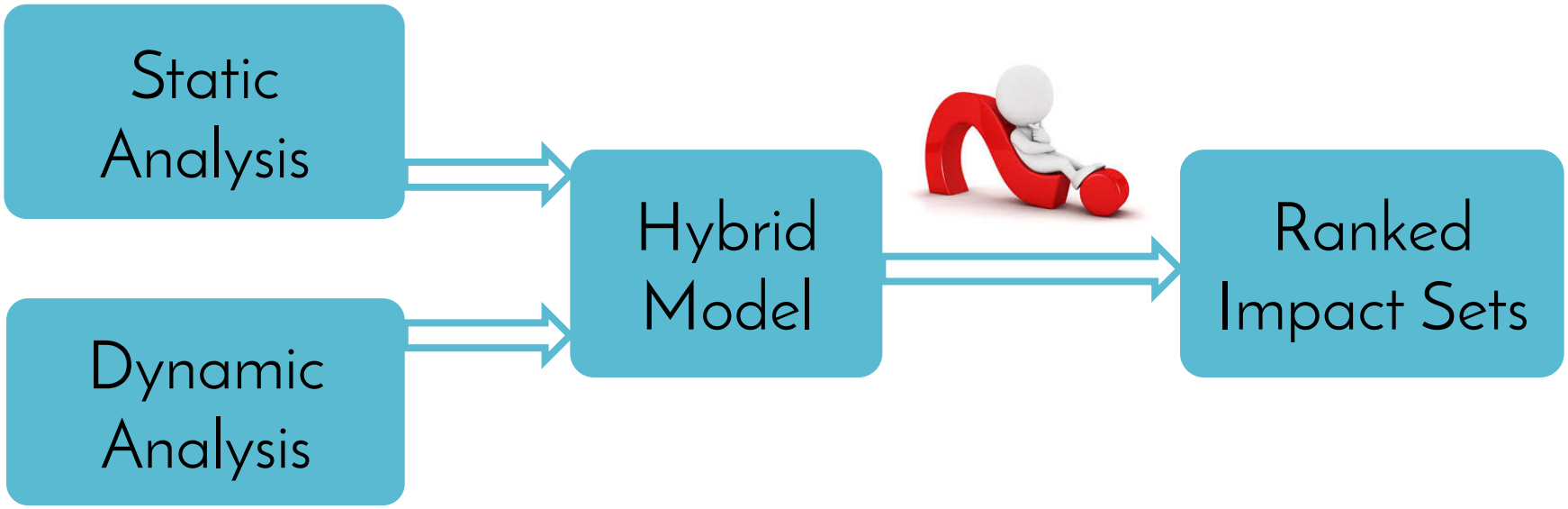
Exploratory Study: Results

- W-R DOM elements: 42%
- Propagated handlers: 14%

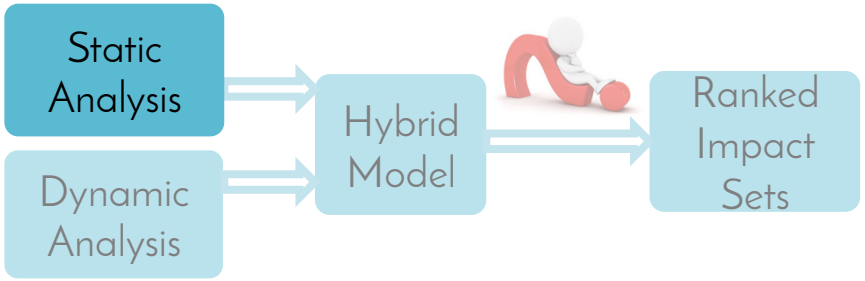




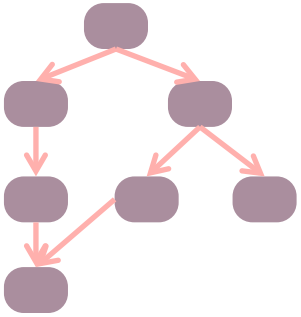
Hybrid Analysis



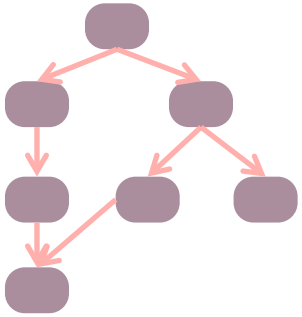
Static Analysis



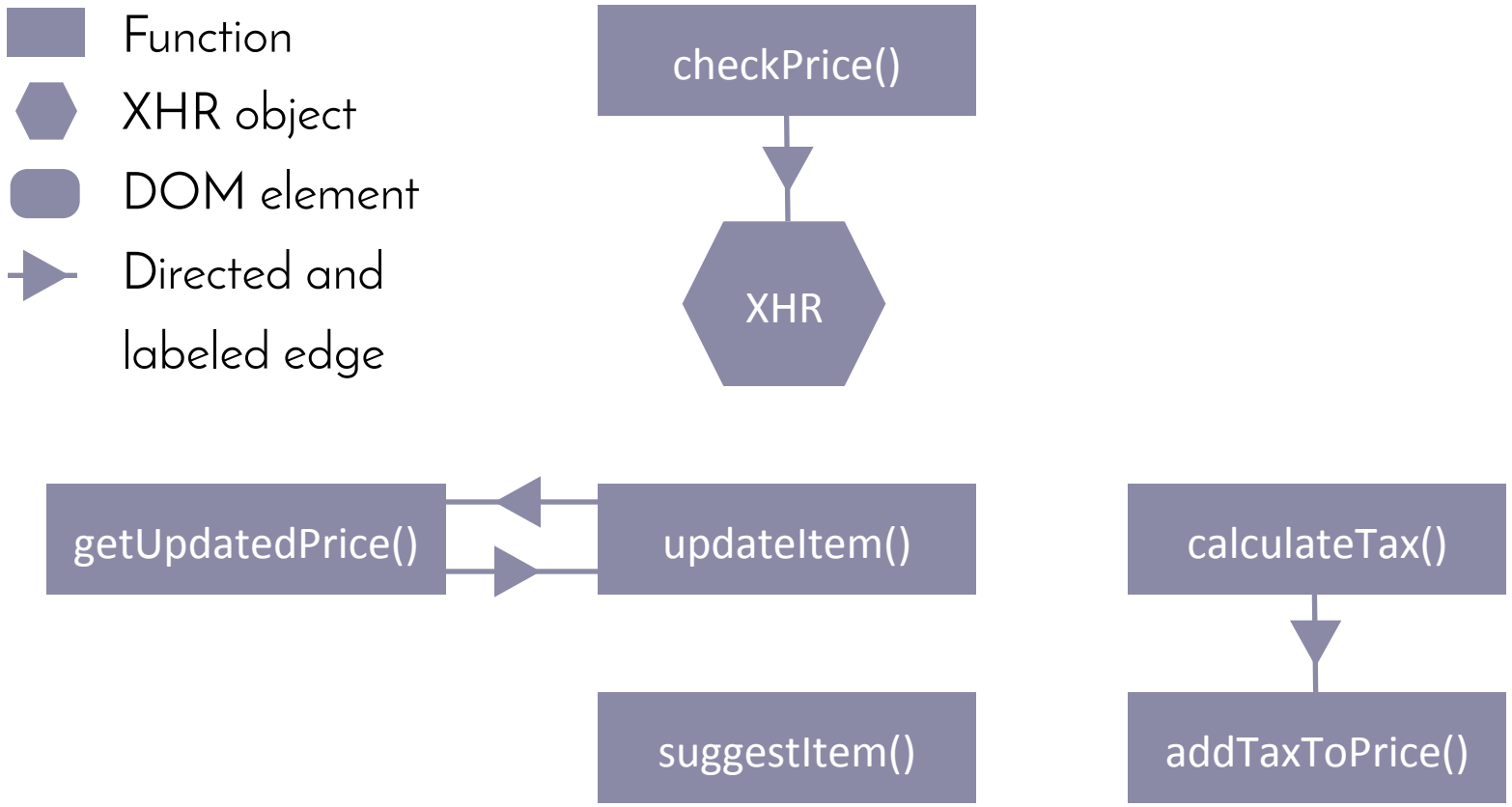
Control (and data) dependencies



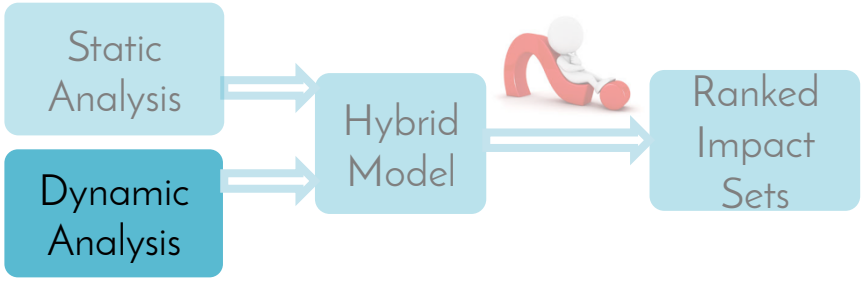
Partial data-flow analysis



Example: Static Model



Dynamic Analysis



Impact through DOM

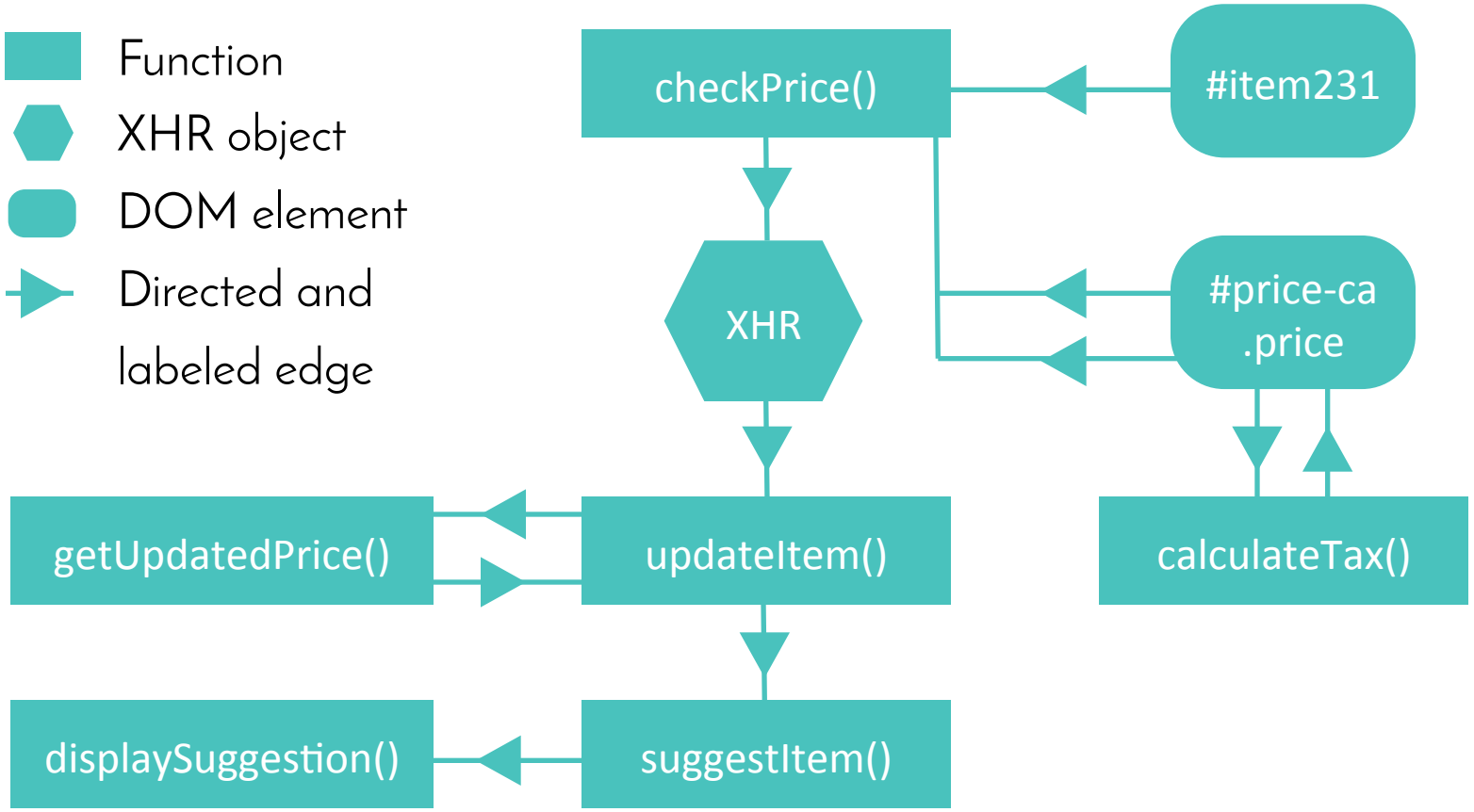
Impact through events

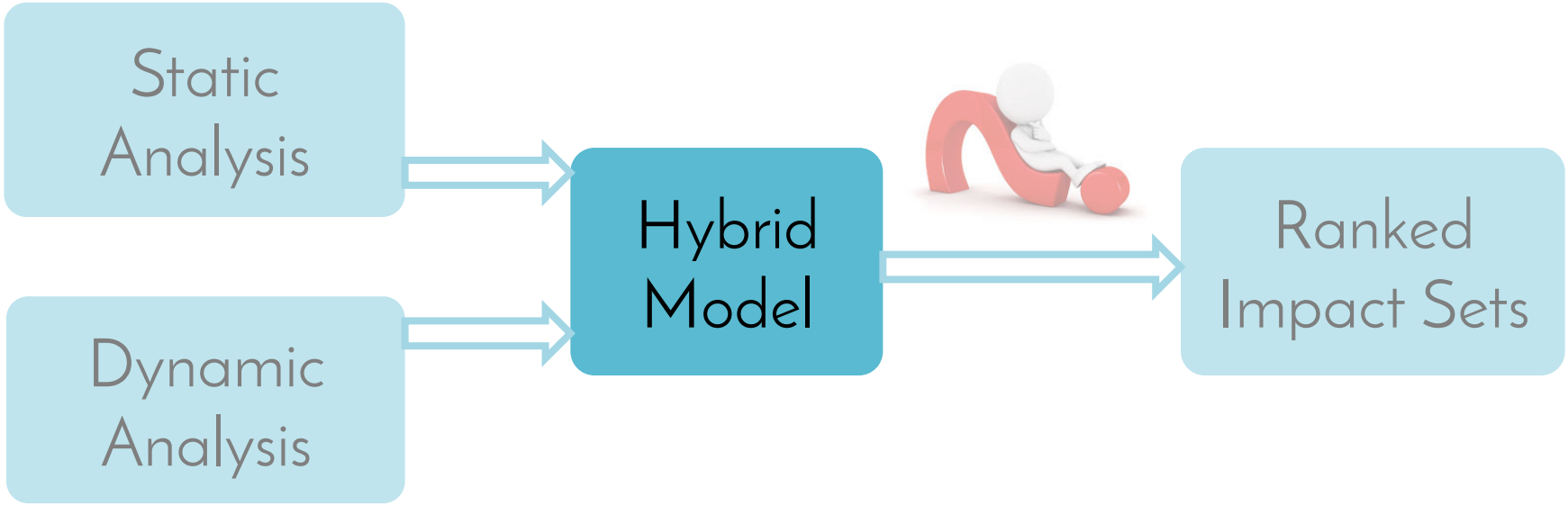
Dynamic call graph

XHR relations
(open, send, response)

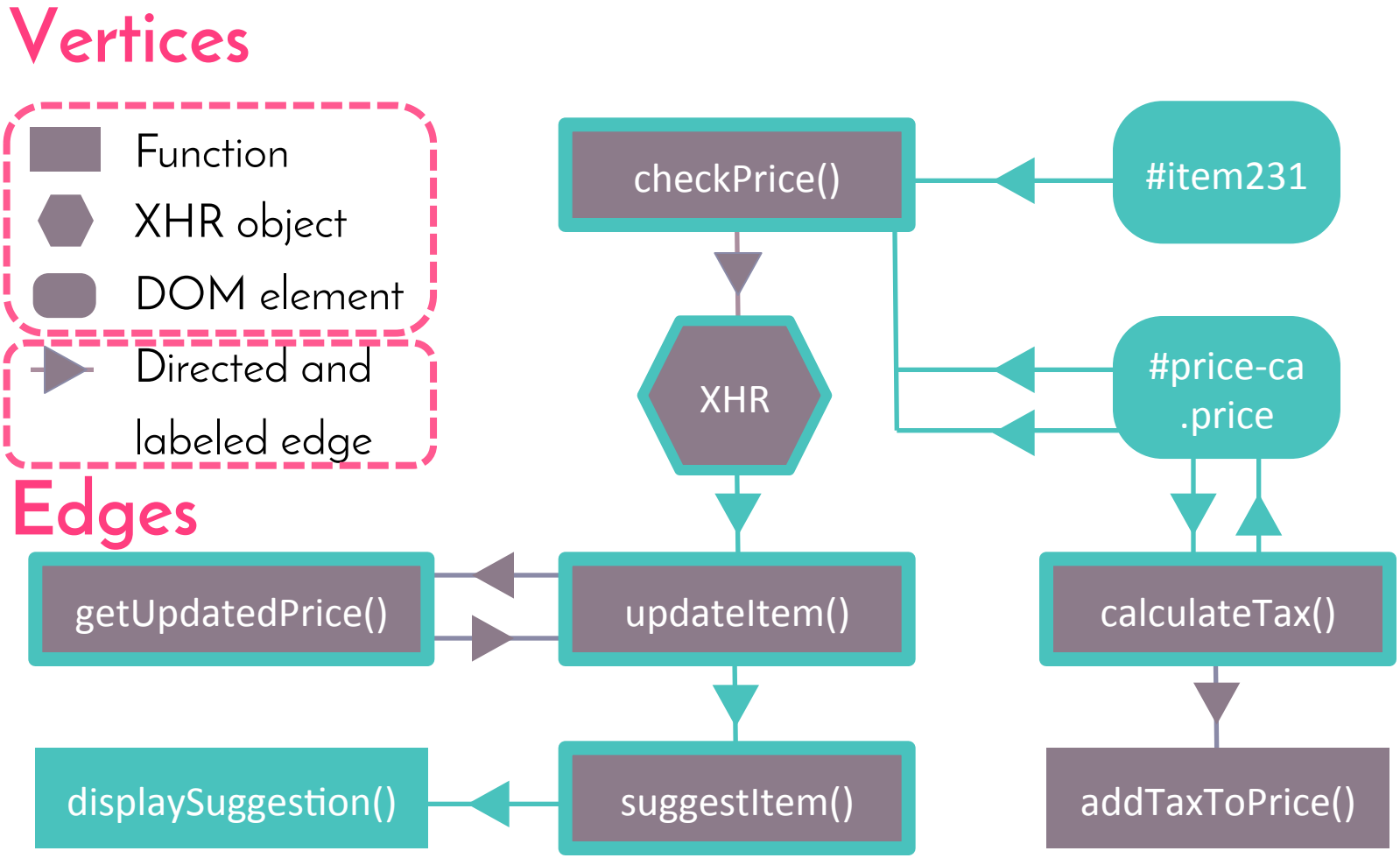
JavaScript dynamism
(eval(), function variadicity)

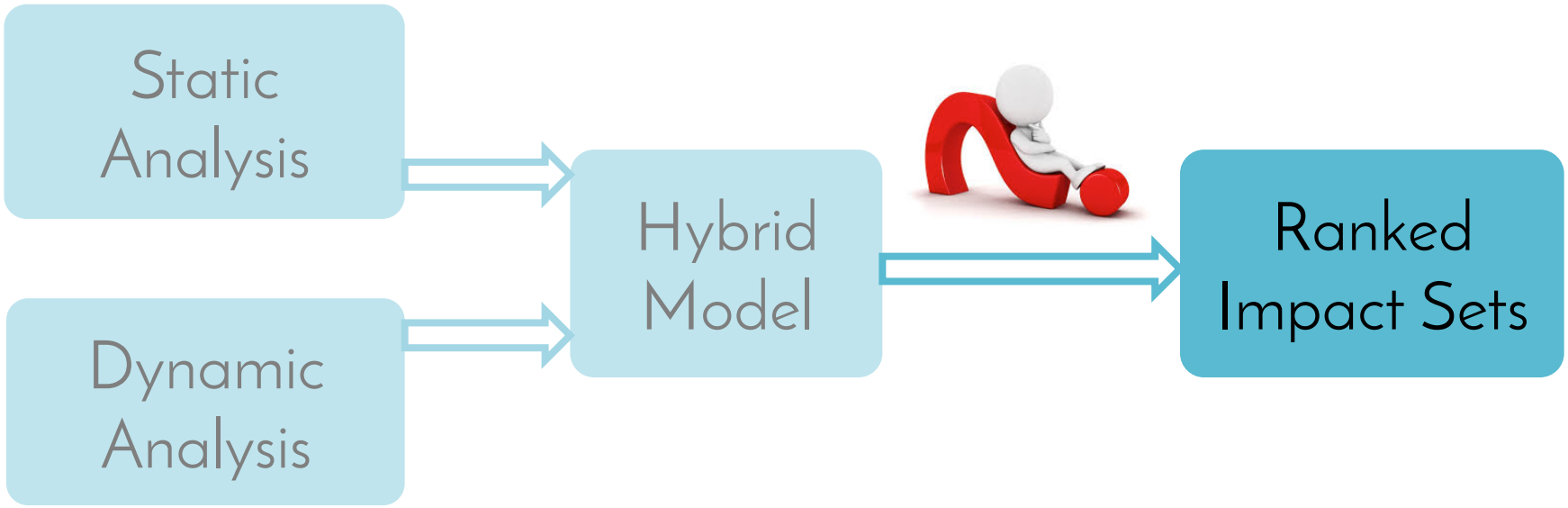
Example: Dynamic Model




Static Analysis
Dynamic Analysis
Hybrid Model
Ranked Impact Sets

Example: Hybrid Analysis



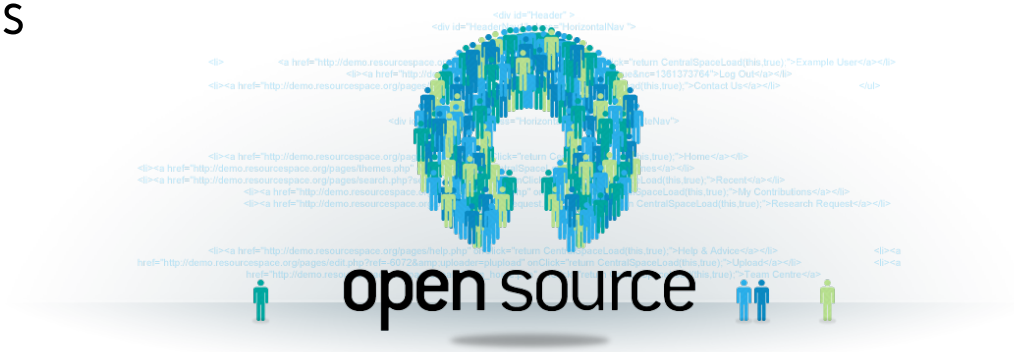

Static Analysis
Dynamic Analysis
Hybrid Model
Ranked Impact Sets

Impact Metrics and Impact Set Ranking

- Problem: size of impact sets
- Solutions: impact ranks, based on impact metrics
  - $f_{in}(d)$: Number of functions f such that $f\ W\ d$
  - $f_{in}(f)$: Number of elements d such that $f\ R\ d$
  - $f_{out}(f)$: Number of elements d such that $f\ W\ d$
  - $L_{avg}(P)$: Average length of impact paths in the app
  - $D_m(e)$: Minimum distance of e from the change set
  - $IR_{pr}(e)$: Impact of previous entity

Tool Implementation: Tochal

- Tochal: open source
  - https://github.com/saltlab/tochal
- Proxy (Java, JavaScript)
  - Esprima, Estraverse, Escodegen, Mutation Summary, WALA
- Client-side (Google Chrome extension)
  - Chrome DevTools



Research Question 1

Does Tochal outperform static and dynamic analysis methods in terms of the completeness of the results obtained?

Study: Static vs. Dynamic vs. Tochal

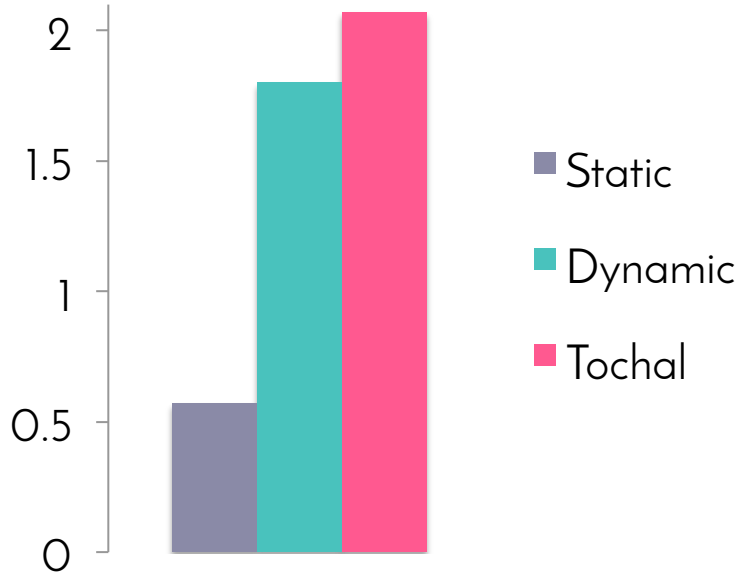
- 10 web applications
- 3 random functions as change sets
- Comparing:
  - Size of impact sets
  - Number of functions in dependency graphs

Results: Impact Sets

- Comparing size of impact sets

$$\frac{\text{Static}}{\text{Hybrid}} : \mathbf{26\%}$$

$$\frac{\text{Dynamic}}{\text{Hybrid}} : \mathbf{80\%}$$

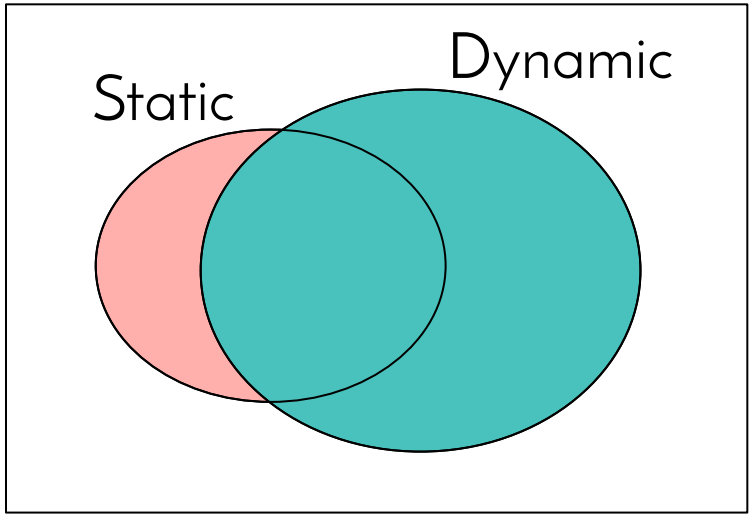


Results: Graphs

- Comparing size of model graphs

$$\frac{\text{Static}}{\text{Hybrid}} : \mathbf{59\%}$$

$$\frac{\text{Dynamic}}{\text{Hybrid}} : \mathbf{84\%}$$

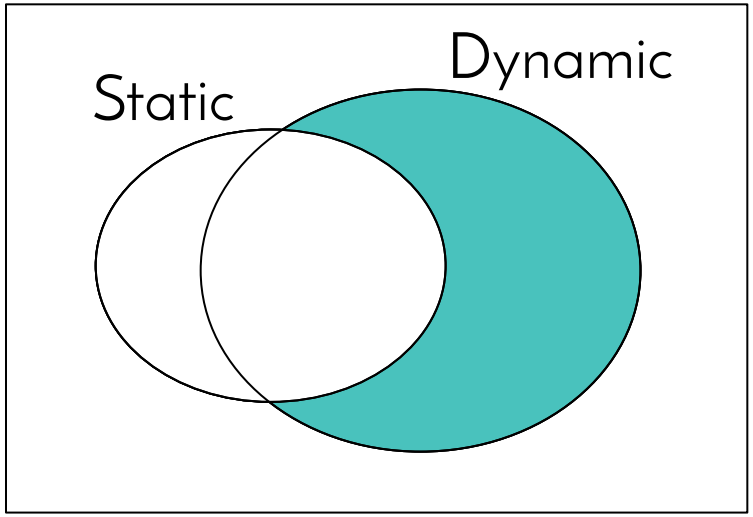


Results: Graphs

- Comparing size of model graphs

$$\frac{\text{Pure Static}}{\text{Hybrid}} : \mathbf{15\%}$$

$$\frac{\text{Pure Dynamic}}{\text{Hybrid}} : \mathbf{42\%}$$



Research Question 2

Does Tochal help developers in practice to perform change impact analysis?

Experiment: Design

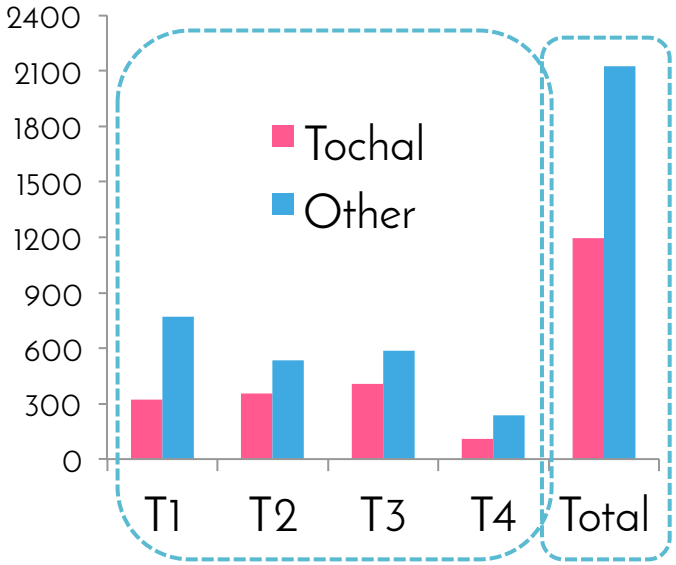
- 12 participants from industry
- Performed 4 tasks

Task	Description
T1	Finding the potential impact of a DOM element
T2	Finding the potential impact of a JavaScript function
T3	Finding a conflict after making a new change (no ranking)
T4	Finding a bug in JavaScript code

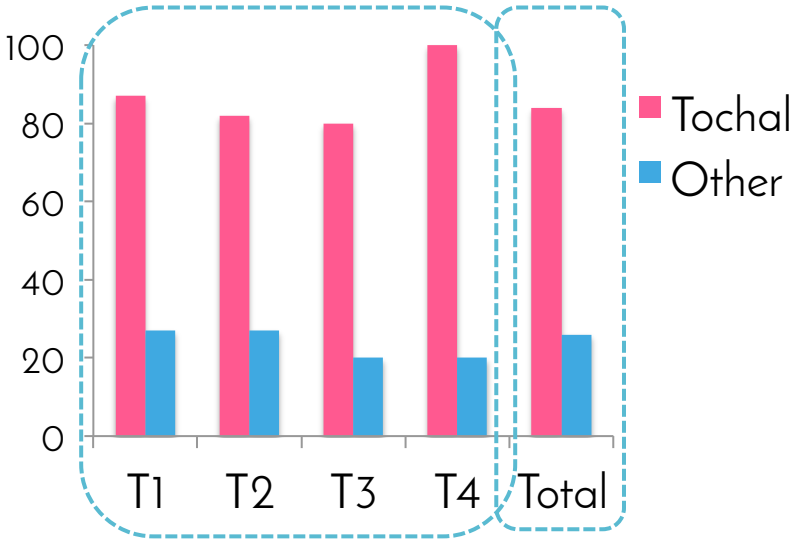
- We measured task completion duration and accuracy

User Experiment: Results

Duration



Accuracy



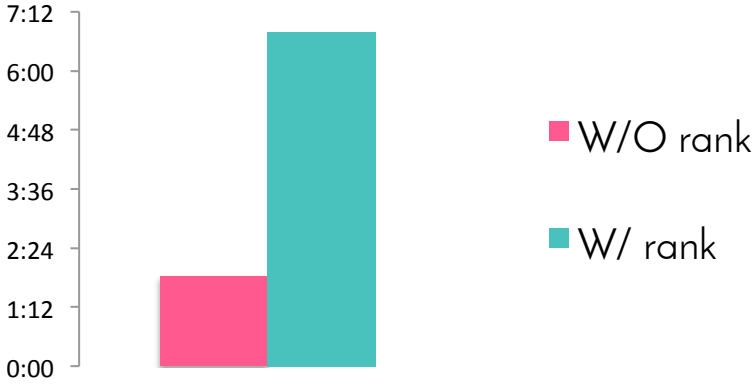
80% faster

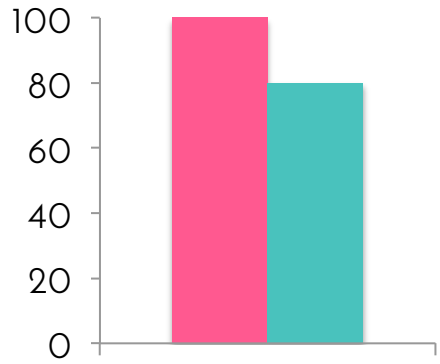
2 times more accurate

Results: Ranking

Duration

Accuracy





2~3 times faster

25% more accurate

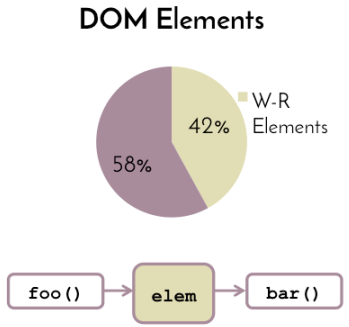
Challenges of CIA for Client-Side JavaScript

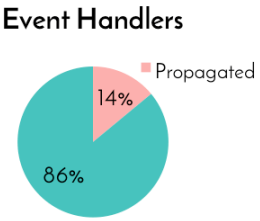
1. JavaScript and Document Object Model (DOM)
2. Events and event propagation
3. JavaScript and XMLHttpRequests (XHRs)

\+ High dynamism of JavaScript

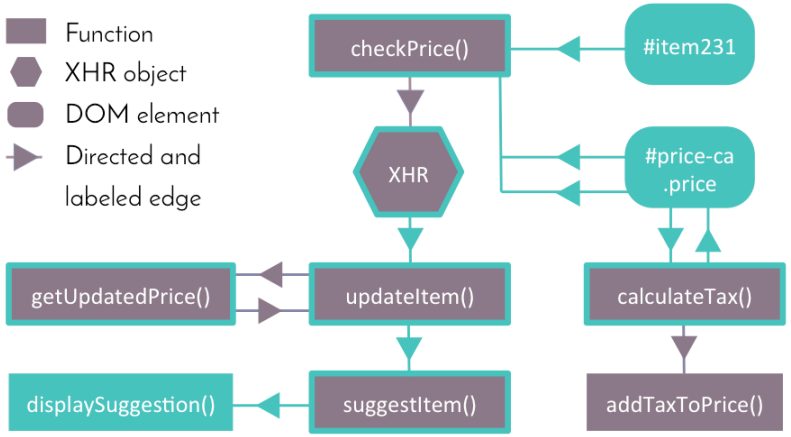
Exploratory Study: Results

- W-R DOM elements: 42%
- Propagated handlers: 14%

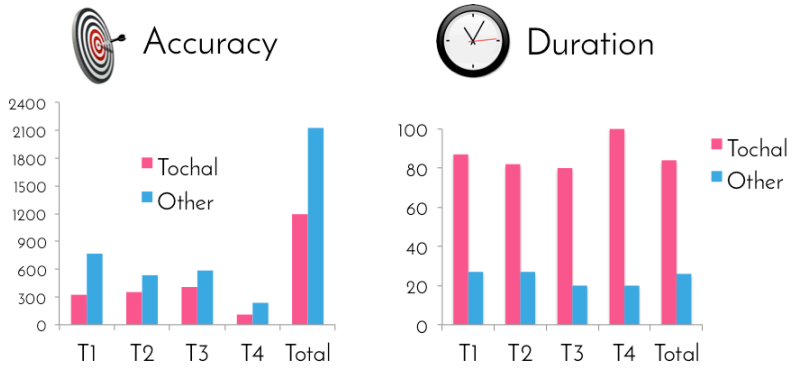




Example: Hybrid Analysis



User Experiment: Results



2 times more accurate

80% faster