Understanding JavaScript Event-Based Interactions

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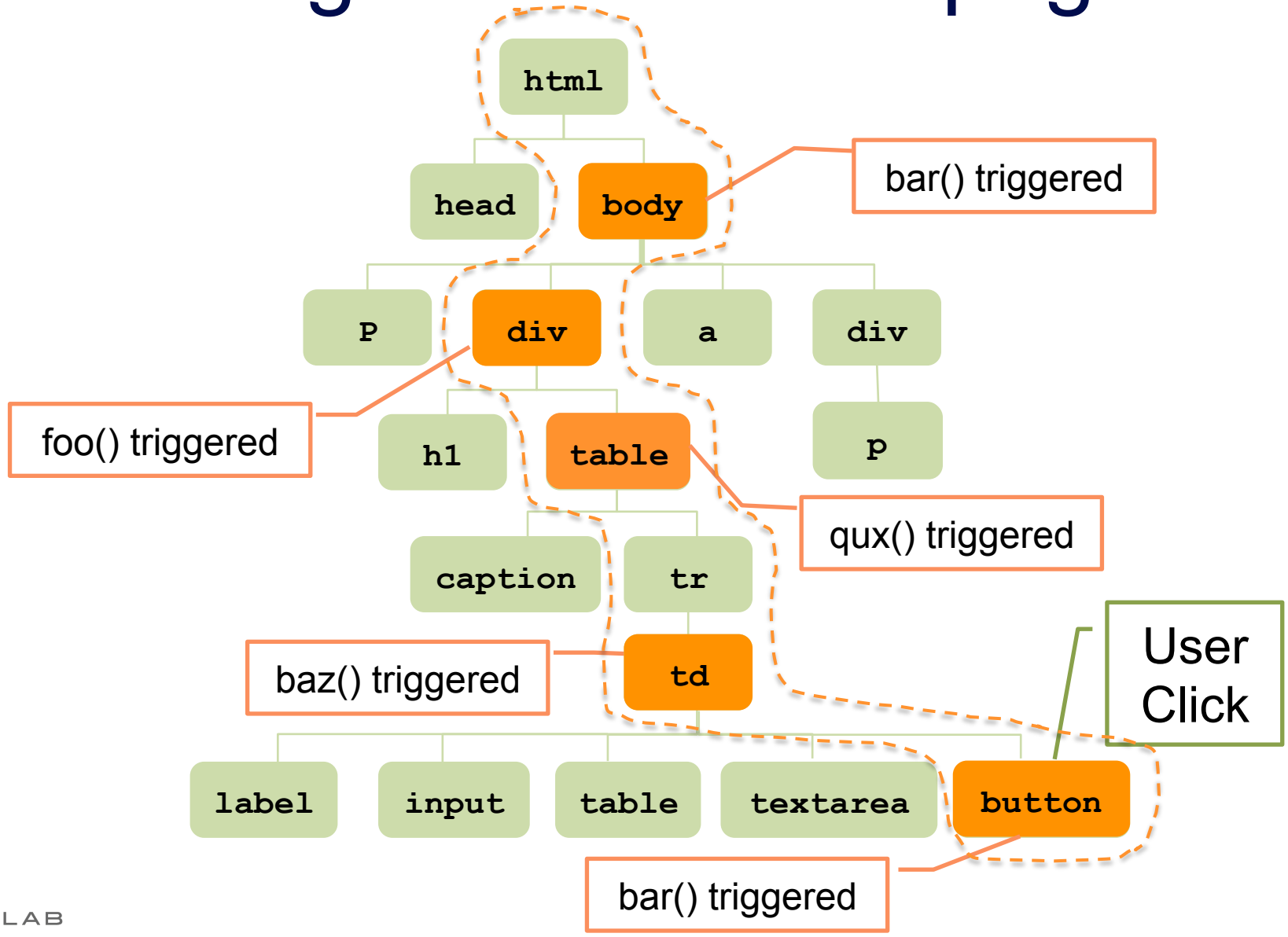
Motivation

- JavaScript
  - Widely used, very popular
  - Event driven, dynamic, asynchronous

- Difficult to understand the dynamic behavior and the control flow
  - Lower level events
  - Their interactions

Challenge 1: Event Propagation



Challenge 2: Asynchronous Events

Timeout for page expiry

Server **request** for login

Server **response** for login

Challenge 2: Asynchronous Events

Timeout for page expiry

Server request for login

Server response for login

Server request

Server request

Server response

Server response

Challenge 2: Asynchronous Events

Timeout for page expiry

Server request for login

Server response for login

Server request

Server request

Server response

Server response

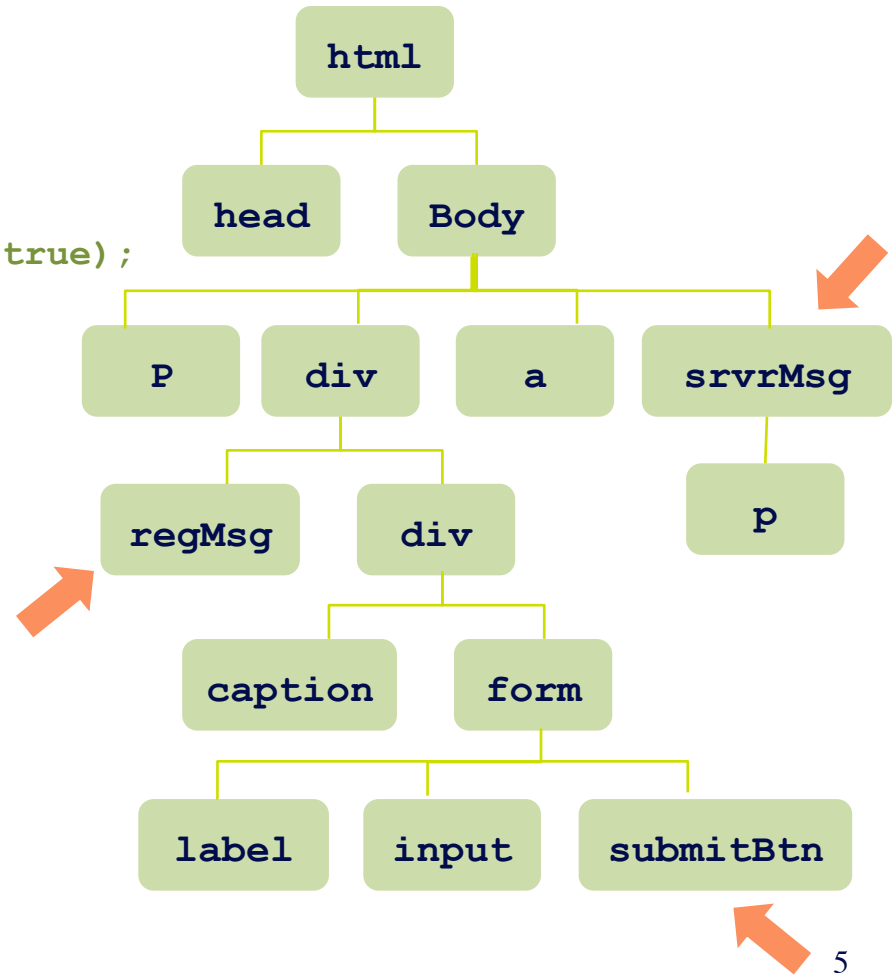
Timeout for next image

Challenge 2: Asynchronous Events

Timeout for page expiry
Server request for login
Server response for login
Server request
Server request
Server response
Server response
Timeout for next image
Server request image
Server response
Timeout callback
Timeout callback page expiry

Challenge 3: DOM State

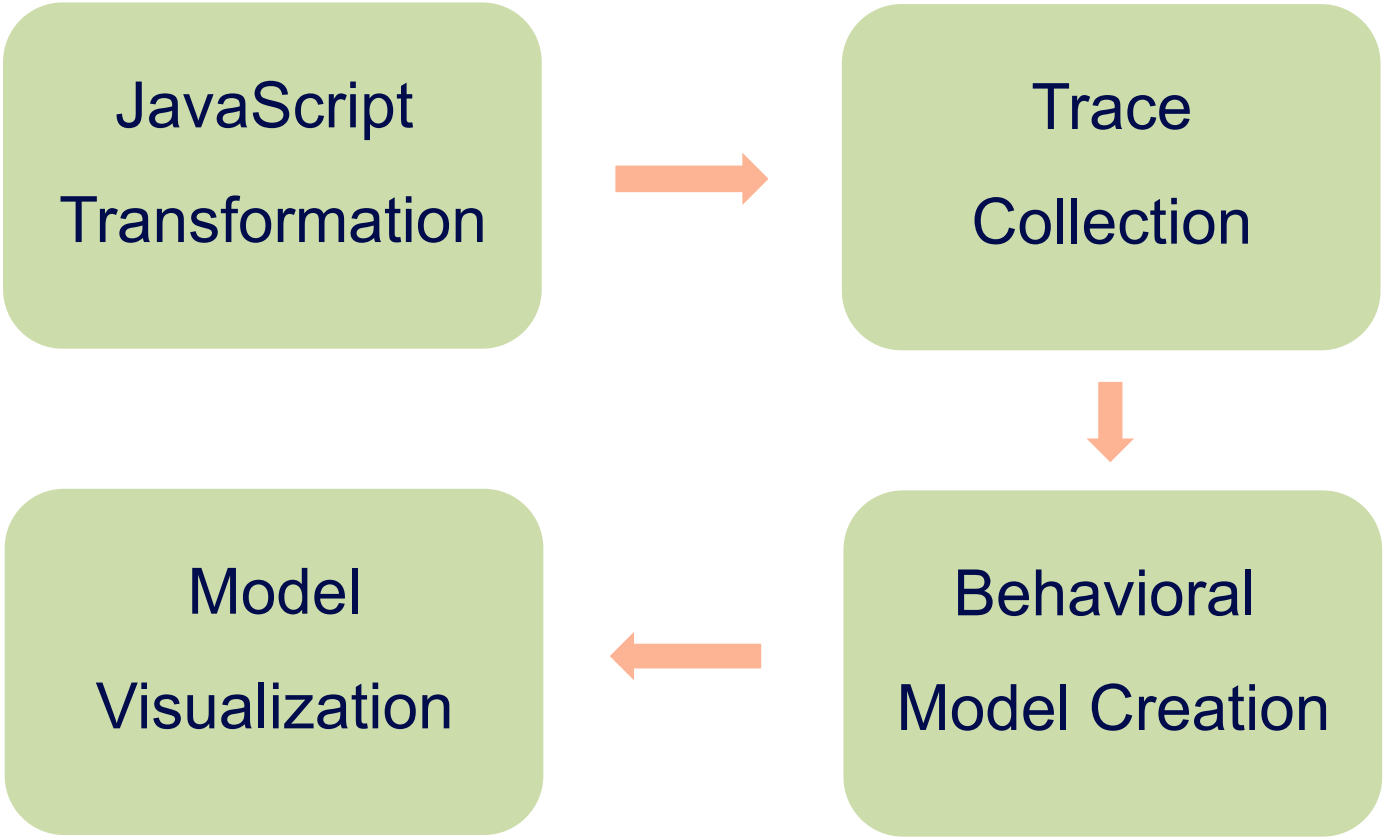
```
function submissionHandler(e) {
   $('#regMsg').html("Submitted!");
   var email = $('#email').val();
   if (isEmailValid(email)) {
      informServer(email);
      $('#submitBtn').attr("disabled", true);
   }
}
. . .
function informServer(email) {
   $.get('/register/', { email }
     , function(data) {
        $('#srvrMsg').append(data);
   });
}
```



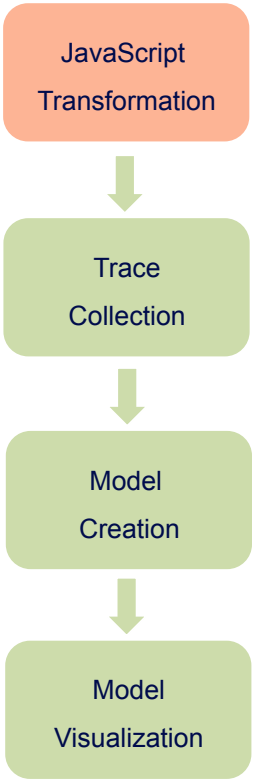
Summary of Challenges

- Event propagation
- Asynchronous events
- Implications of events

Approach

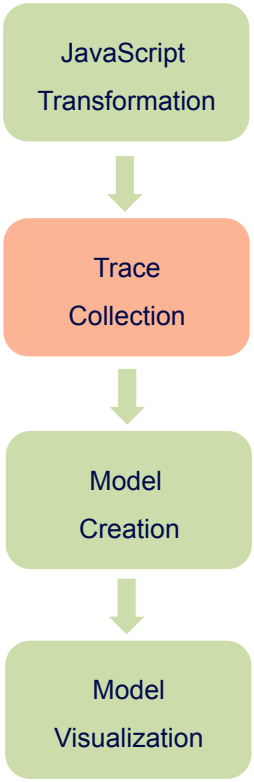

JavaScript Transformation
Trace Collection
Behavioral Model Creation
Model Visualization

JavaScript Transformation



- Interposing on DOM events
- Capturing timeouts and XHRs
- Recording function traces
- Extracting DOM mutations

Trace Collection

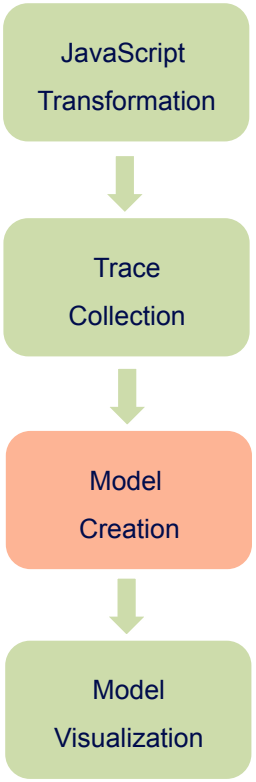


- Interposing on DOM events
- Capturing timeouts and XHRs
- Recording function traces
- Extracting DOM mutations

=> Detailed Trace

- DOM events
- functions
- timeouts
- XHRs
- DOM mutations

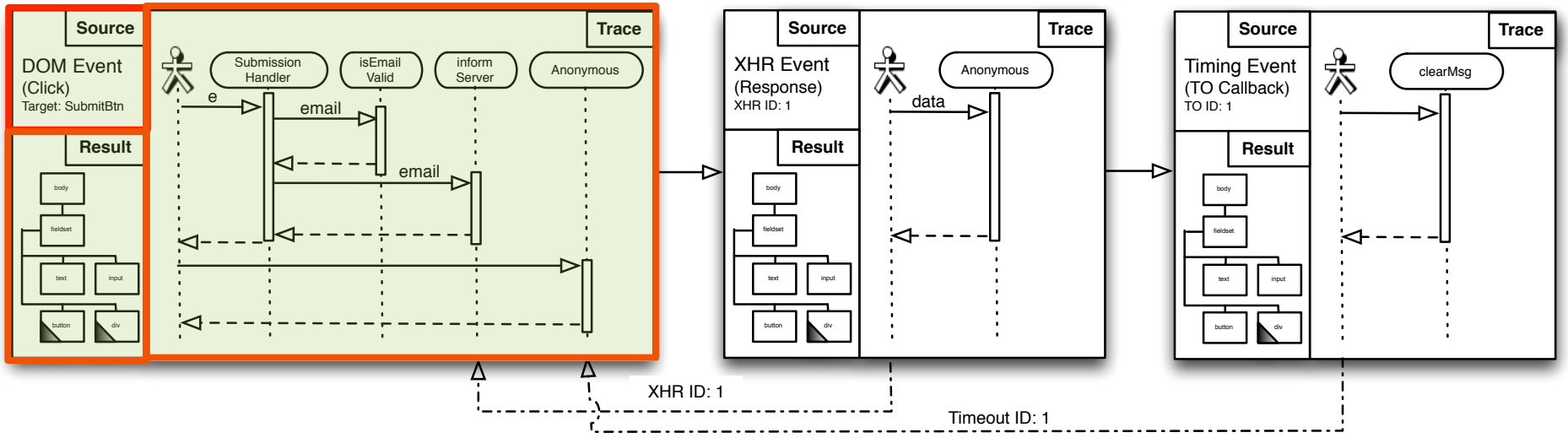
Behavioral Model Creation



- Customized graph

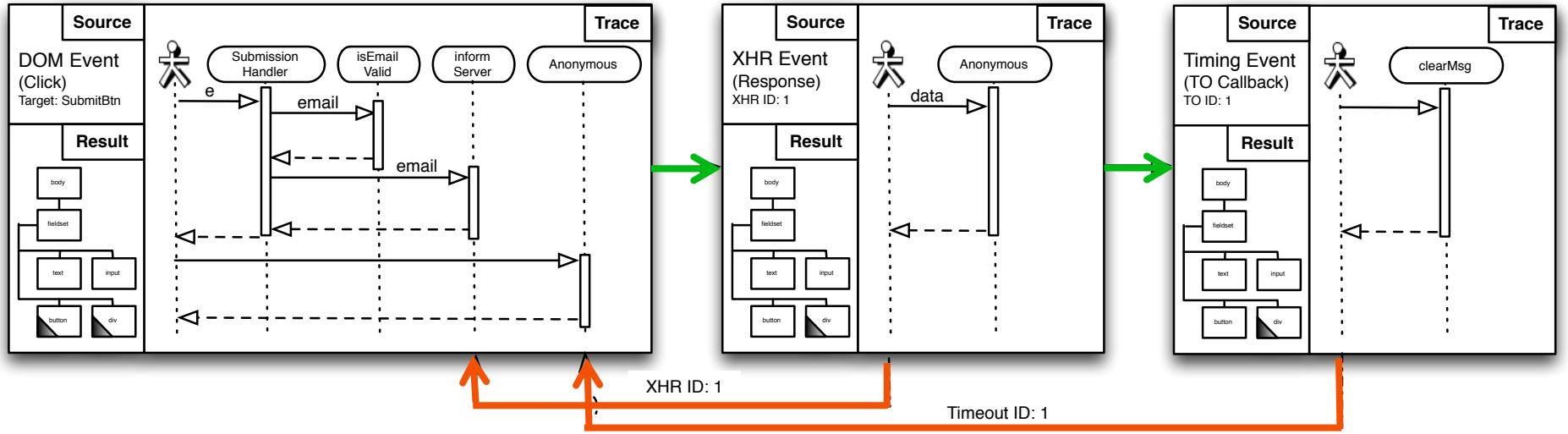
- Nodes: episodes
- Links: temporal and causal

Model: Episodes



- A period of JavaScript execution
- Start and end points

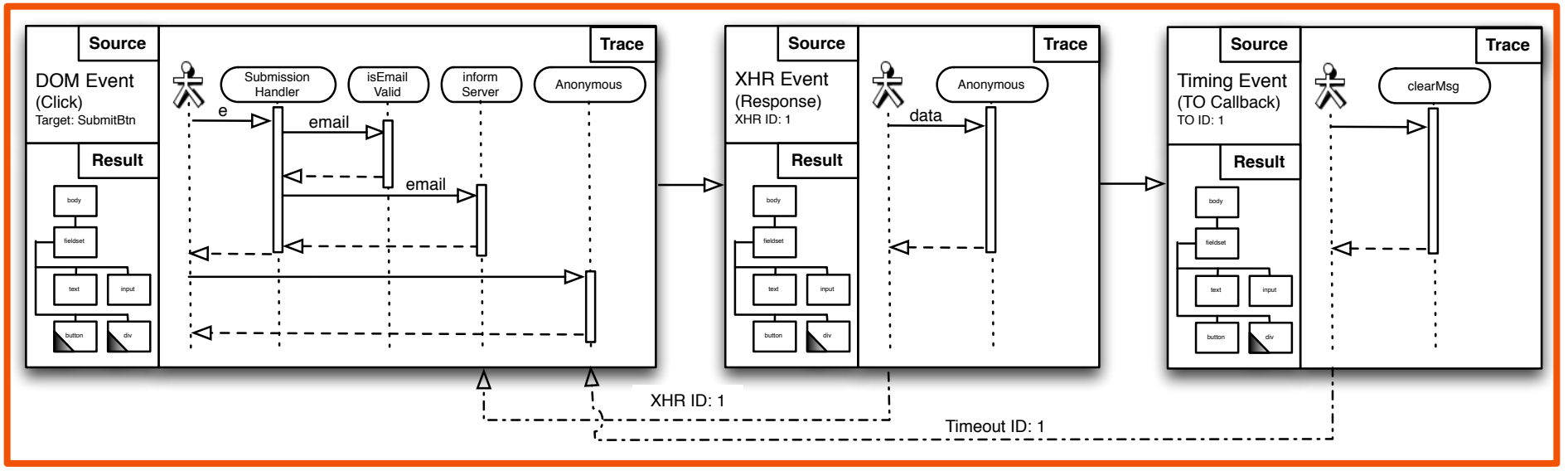
Model: Links



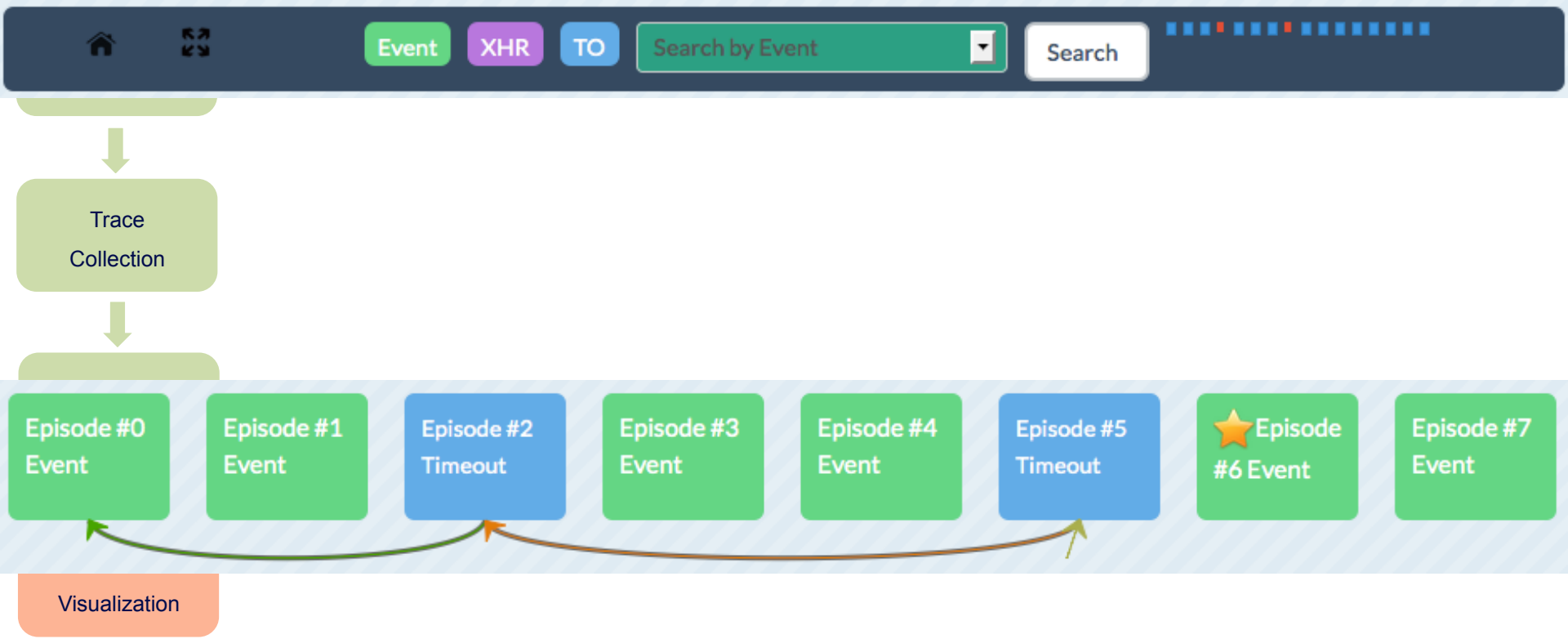
Temporal

Causal

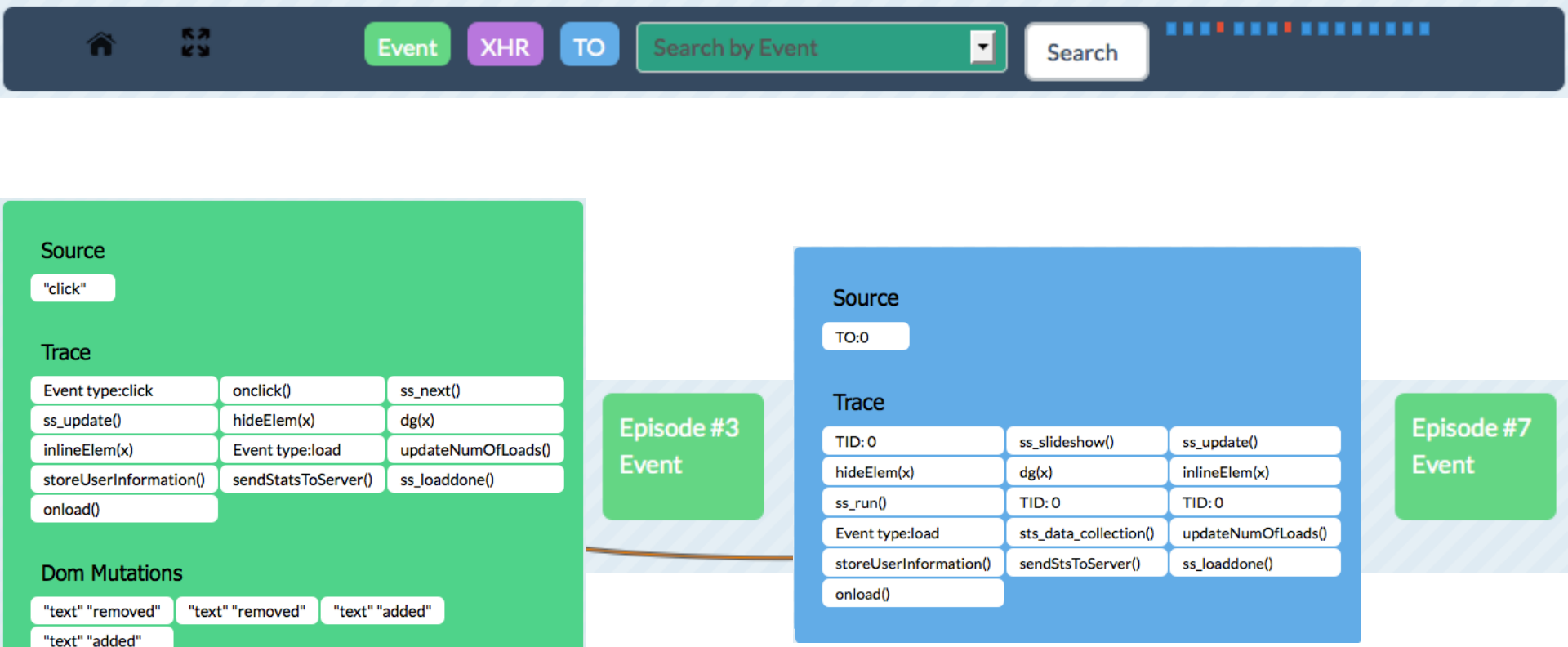
Model: Story

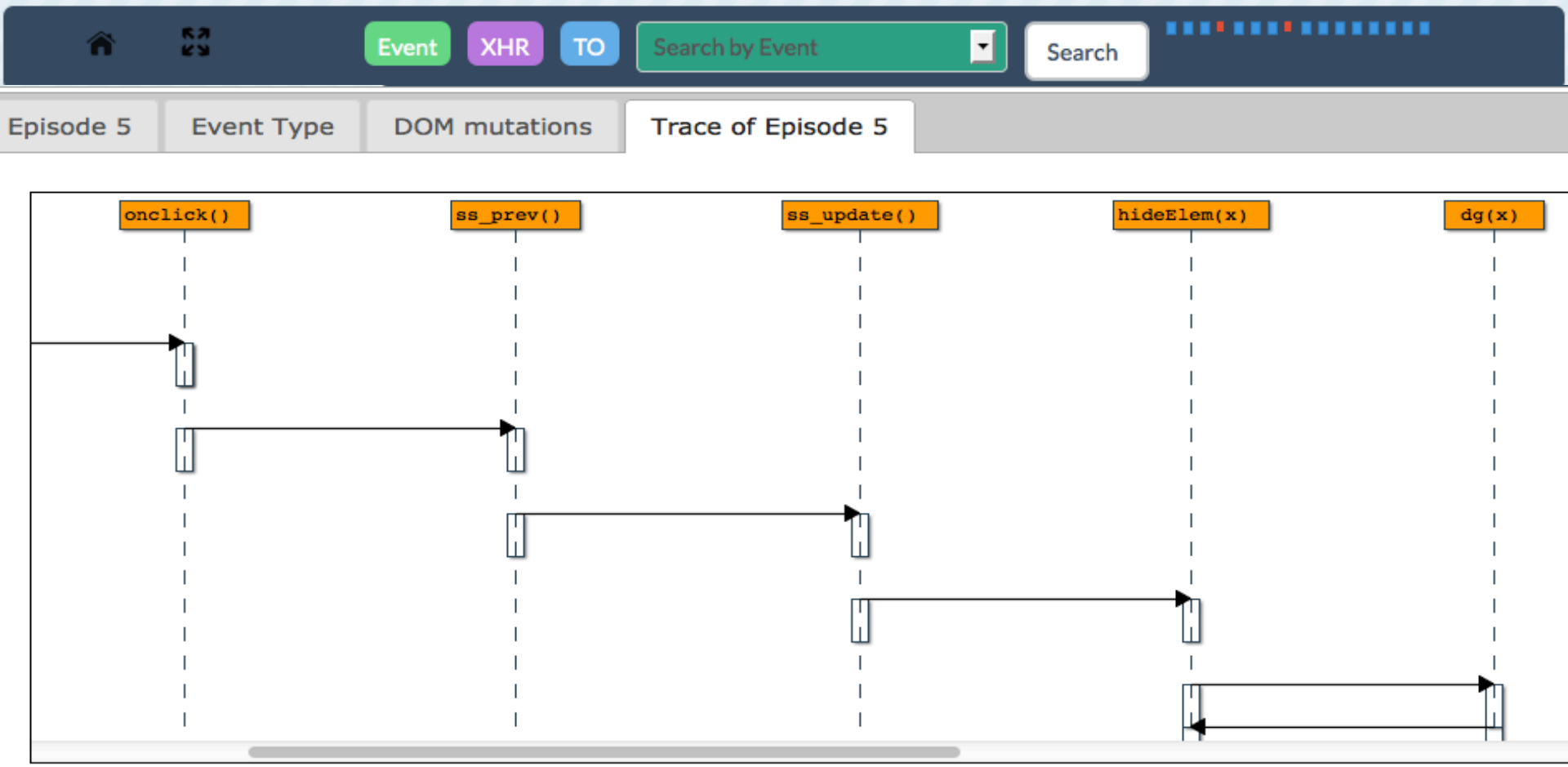

Source
DOM Event
(Click)
Target: SubmitBtn
Result
body
fieldset
text
input
button
div
Trace
Submission Handler
isEmail Valid
inform Server
Anonymous
e
email
email
Source
XHR Event
(Response)
XHR ID: 1
Result
Trace
Anonymous
data
Source
Timing Event
(TO Callback)
TO ID: 1
Result
Trace
clearMsg
XHR ID: 1
Timeout ID: 1

Visualization: Overview



Visualization: Zoom Level 1





phorm.js

```
function ss_update() {
        ss_cur = Math.max(ss_cur, 0);

        if (ss_cur >= ss_date.length) {
                hideElem('ss_link2');
                showElem('ss_theend');
                ss_cur = ss_date.length;
                var a = dg('ss_n');
                a.innerHTML = "Final";
                if (ss_play)
                        ss_playpause();
        }
```

Visualization: Zoom Level 2

Implementation

- **Clematis**

https://github.com/saltlab/clematis

- Languages: Java, JavaScript
- Transform JavaScript & inject toolbar via proxy
- Provide a RESTful API for retrieving data
- Render a web-based visualization

Usage Scenario

Usage Scenario

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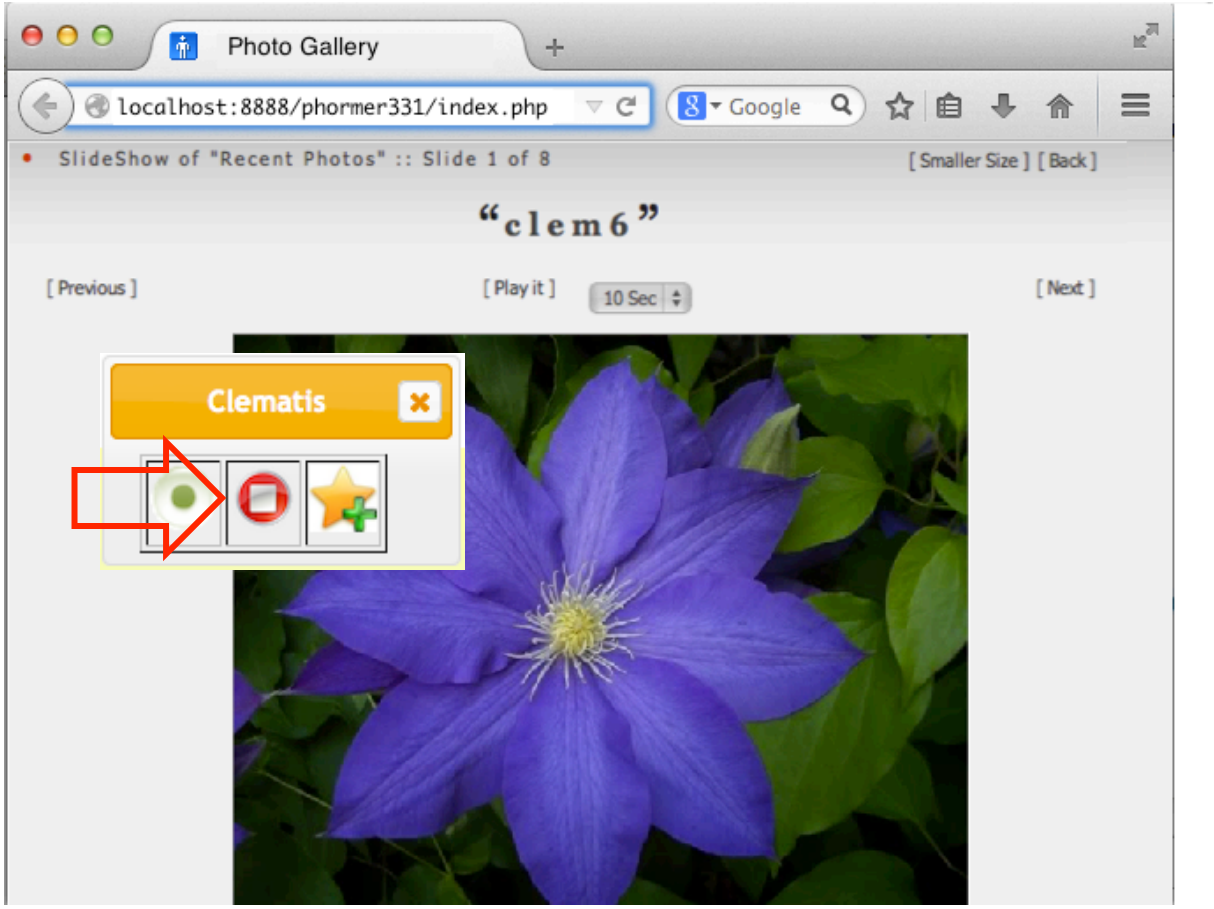
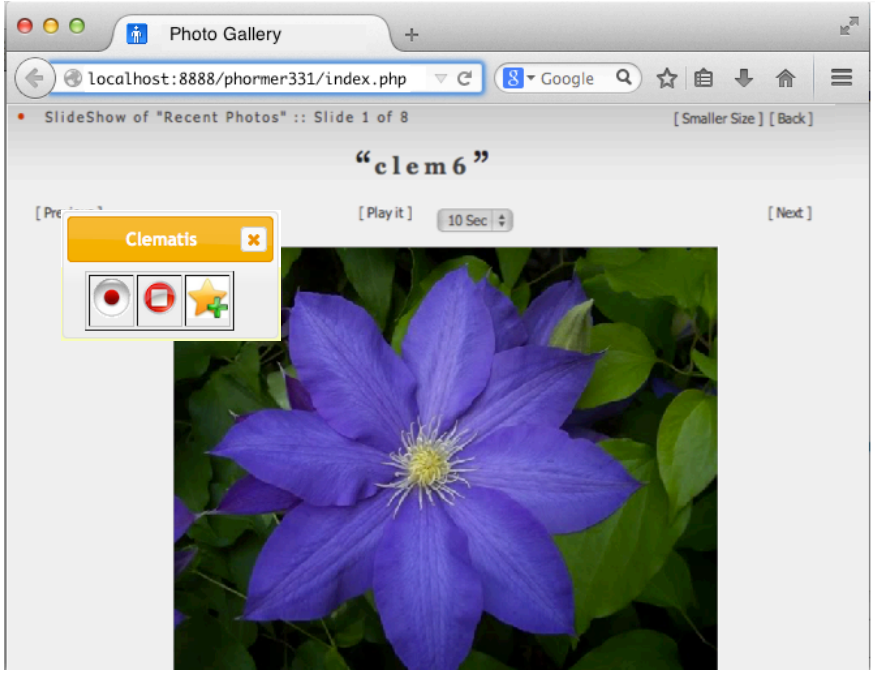
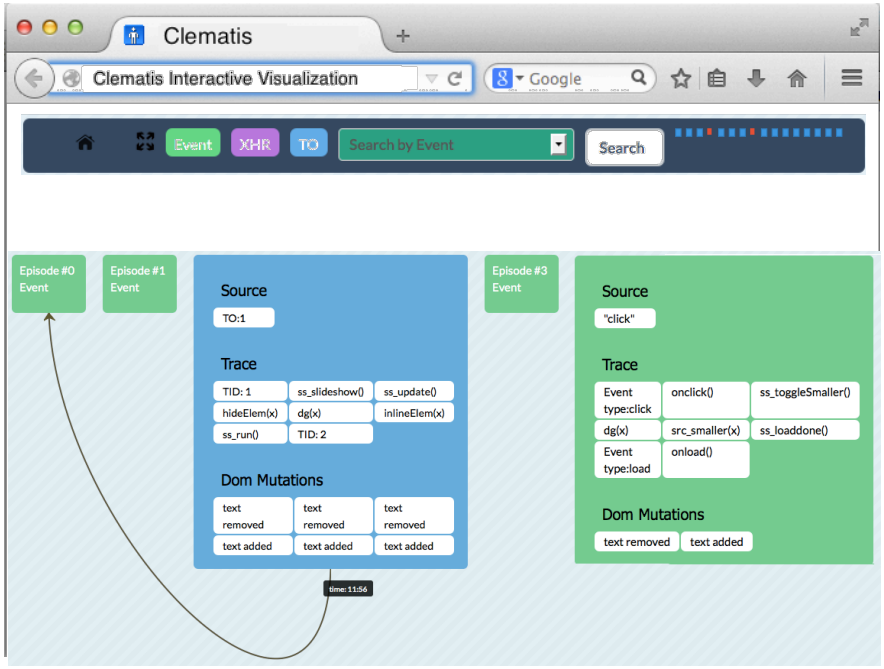


Usage Scenario





Evaluation

RQ1) Does using Clematis decrease the task completion **duration** for web application comprehension?

RQ2) Does using Clematis increase the task completion **accuracy** for web application comprehension?

RQ3) Are there any **certain categories of tasks** for which Clematis improves the performance most?

Industrial Controlled Experiment

- Participants
  - 20 software developers (from a large SW company)
  - Experimental group: Clematis
  - Control group: Chrome, Firefox & Firebug
- Procedure
  - 5 minute tutorial on Clematis
  - Tasks: control flow, feature location, DOM mutations, …
- Data collection
  - Task completion duration & accuracy

Results: Duration

Average Time (mm:ss) Per Task

Task	Clematis		Other	
T1	7:00	<<	11:27	(39%↑)
T2	3:51	<<	7:27	(48%↑)
T3	2:02	<<	6:18	(68%↑)
T4	2:44	<	4:00	(32%↑)

Average Time (mm:ss) in Total

Task	Clematis		Other	
All	15:37	<<	29:12	(47%↑)

Results: Accuracy

Average Accuracy (%) Per Task

Task	Clematis		Other	
T1	84	>>	28	(67%↑)
T2	97	>>	57	(41%↑)
T3	100	>	80	(20%↑)
T4	95	>>	30	(68%↑)

Average Accuracy (%) in Total

Task	Clematis		Other	
All	90	>>	35	(61%↑)

Results

Duration

Task	Improvement
T1	(39%↑)
T2	(48%↑)
T3	(68%↑)
T4	(32%↑)

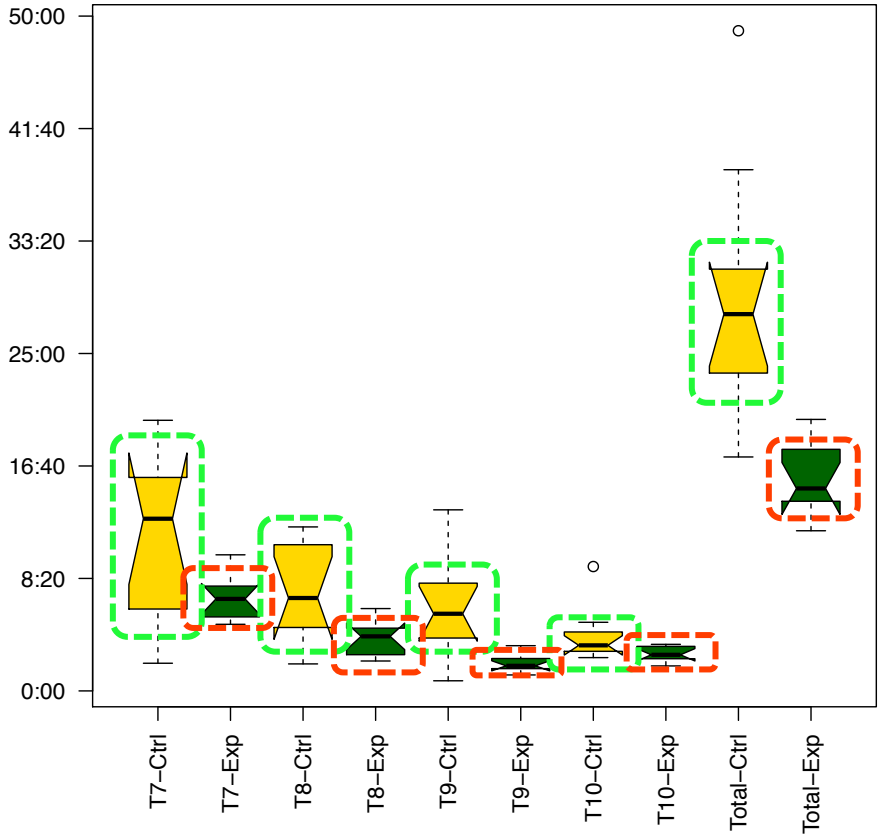
Accuracy

Task	Improvement
T1	(67%↑)
T2	(41%↑)
T3	(20%↑)
T4	(68%↑)

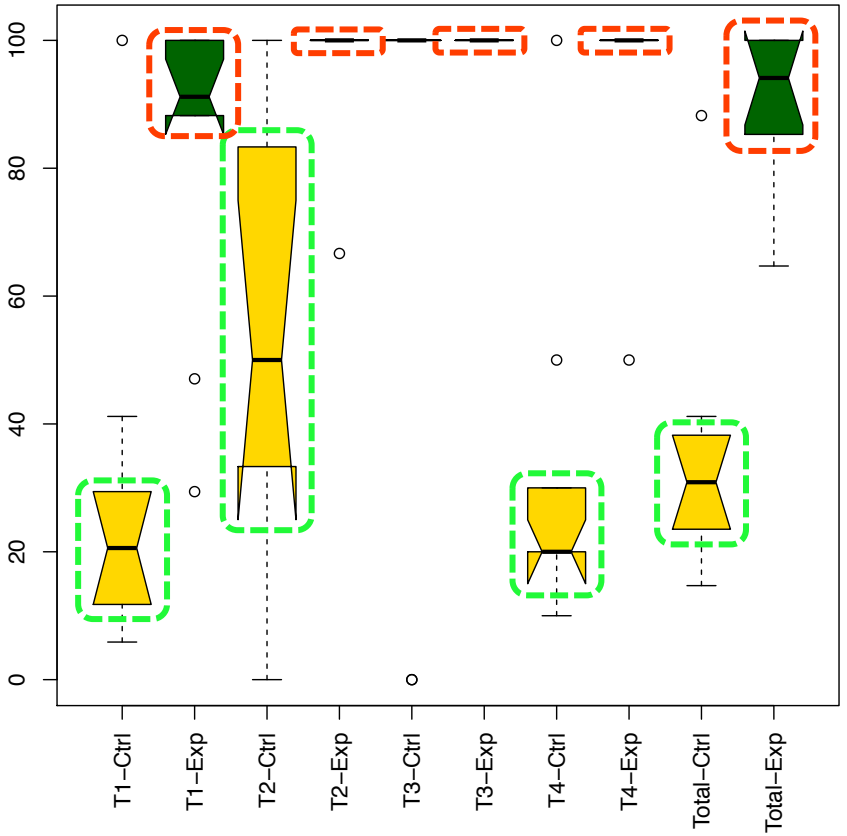
Task	Description
T1	Following control flow in presence of asynchronous events
T2	Finding DOM mutations caused by a DOM event
T3	Locating the implementation of a malfunctioning feature
T4	Detecting control flow in presence of event propagation

Consistent Performance

Duration (mm:ss)



Accuracy (%)



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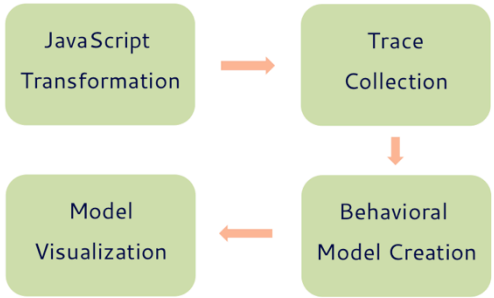
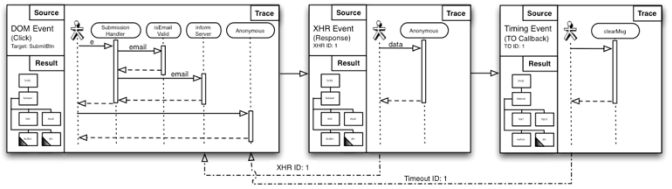
Approach



Model: Episodes



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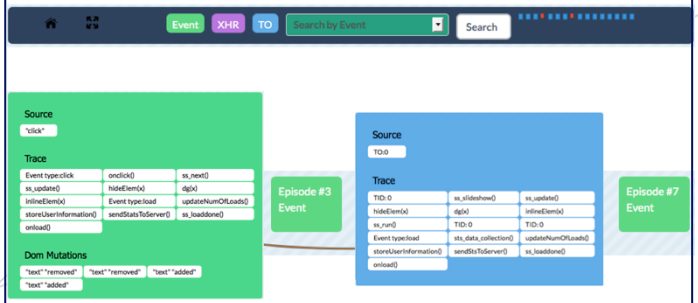

Consistent Performance