defect detection for the wayward web

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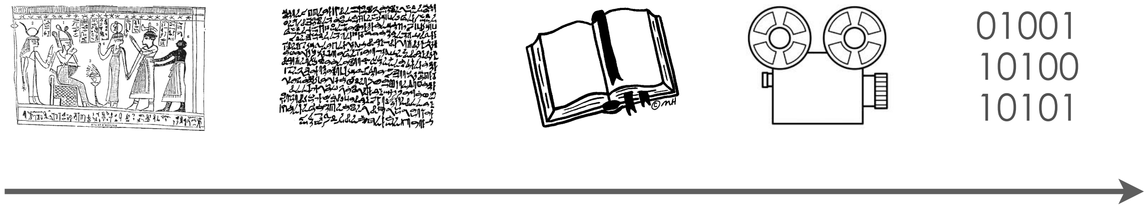


01001
10100
10101

software is a fascinating medium for human expression

I want to make it easier to **express** and **understand** ideas as code

research I've done

studies of software development as if it were created by people

credit to Rob DeLine at MSR

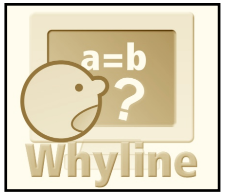
of debugging

of teamwork

of API learning

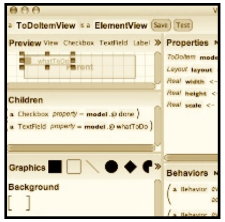
of open source

debugging tools



Question: Why didn't Pac resize 0.5?

Answer:

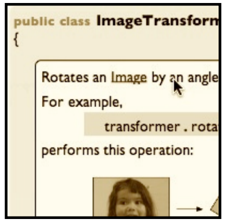


ToDoItemView is a ElementView

a Checkbox property = model.@done

a TextField property = model.@whatToDo

programming tools



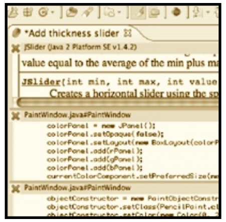
```
public class ImageTransform
{
```

Rotates an Image by an angle

For example,

transformer.rota

performs this operation:


*Add thickness slider
JSlider (Java 2 Platform SE v1.4.2)
PaintWindow.java#PaintWindow
PaintWindow.java#PaintWindow

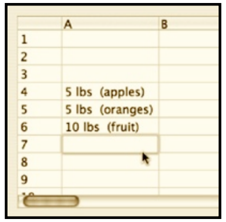
value equal to the average of the min plus ma

JSlider(int min, int max, int value

Creates a horizontal slider using the sp

```
colorPanel = new JPanel();
colorPanel.setOpaque(false);
colorPanel.setLayout(new BoxLayout(colorP
colorPanel.add(rPanel);
colorPanel.add(gPanel);
colorPanel.add(bPanel);
currentColorComponent.setPreferredSize(ne
```

```
objectConstructor = new PaintObjectConstr
objectConstructor.setClass(PencilPoint.cl
```



	A	B
1		
2		
3		
4	5 lbs (apples)	
5	5 lbs (oranges)	
6	10 lbs (fruit)	
7		
8		
9		

research I'm doing with the usegroup

studies

open bug reporting

bug triage meetings

Stack Overflow

diagnostic thinking

tools

next generation help

automating bug severity measurements

improved API documentation

teaching debugging skills

defect detection for the web

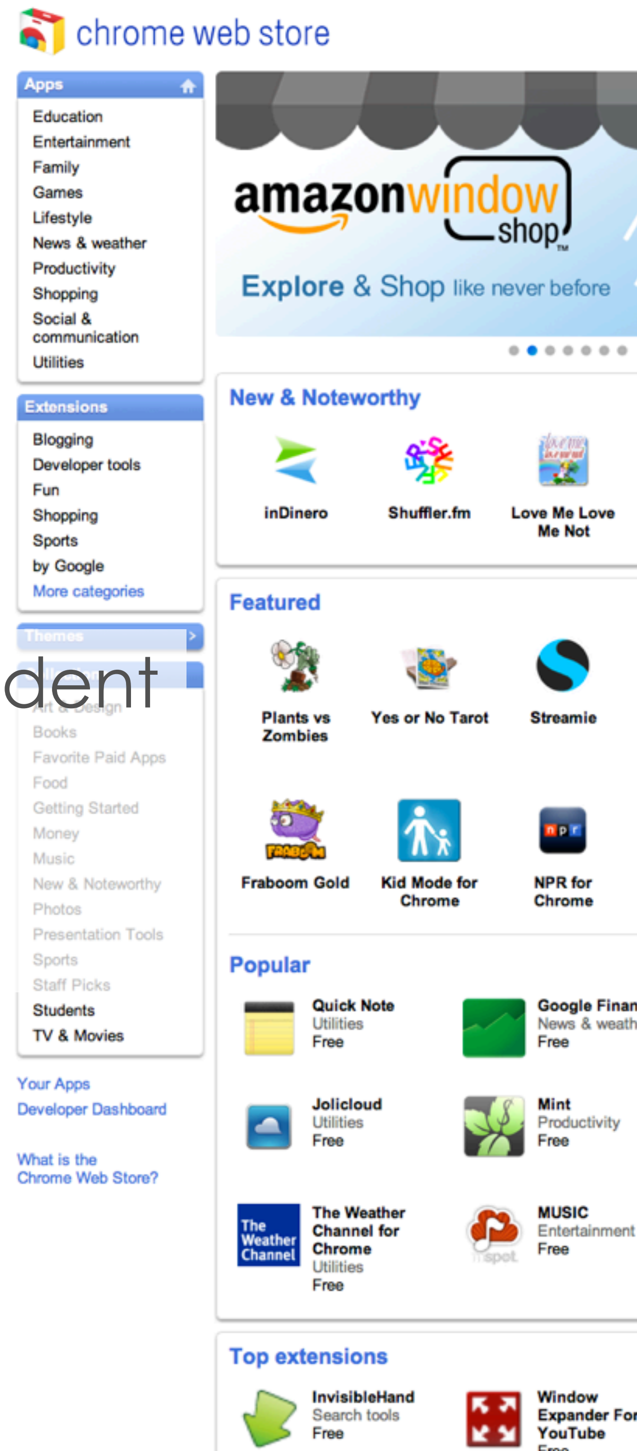
defect detection for the web

an increasingly popular platform for interactive software applications

platform-independent

information rich

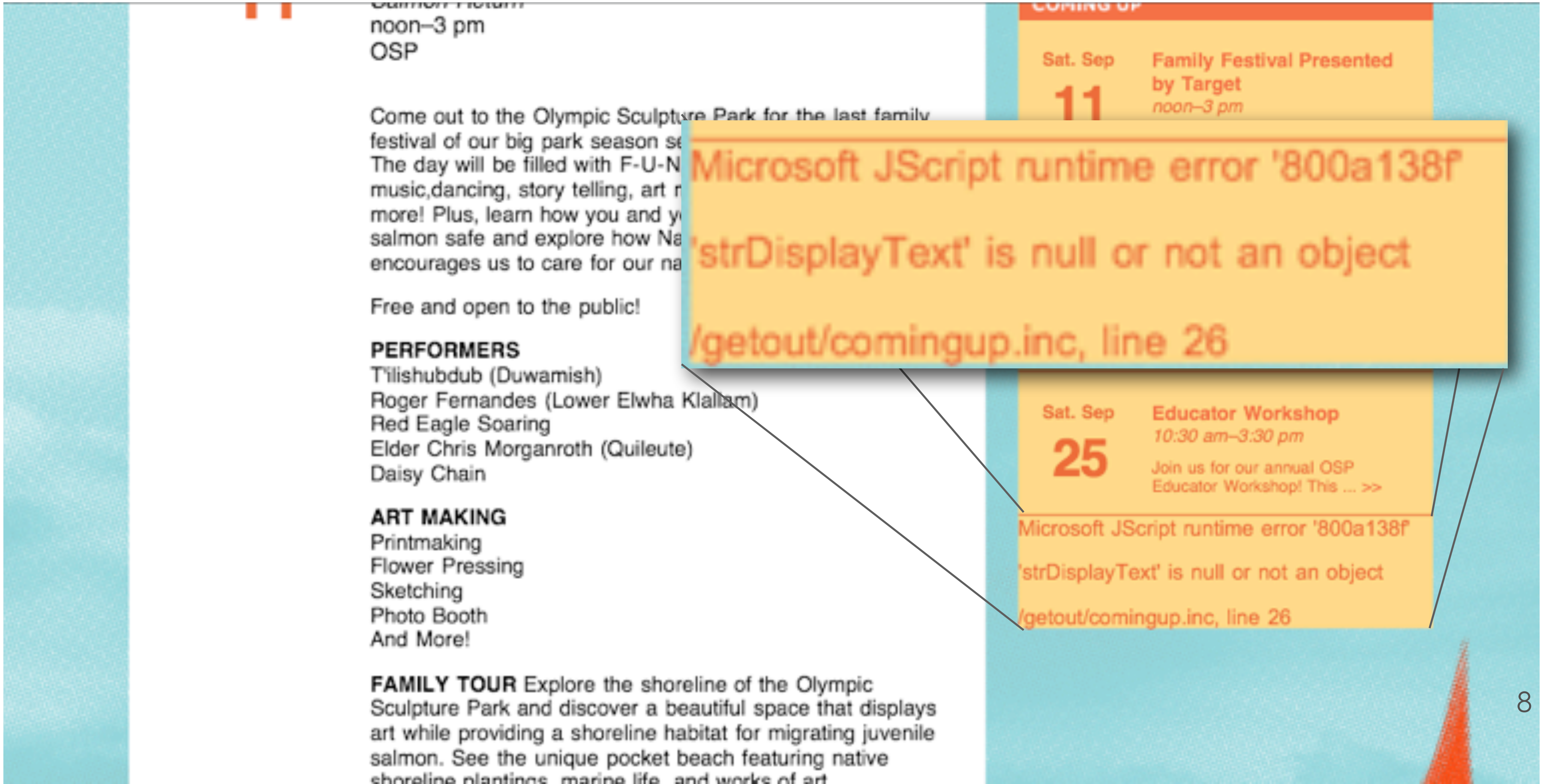
highly flexible



defect detection for the web

the very languages that **enable** this flexibility also impose some serious **tradeoffs**...

dynamic typing means that many errors aren't found until runtime



Salmon Return
noon–3 pm
OSP

Come out to the Olympic Sculpture Park for the last family
festival of our big park season se
The day will be filled with F-U-N
music,dancing, story telling, art m
more! Plus, learn how you and y
salmon safe and explore how Na
encourages us to care for our na

Free and open to the public!

PERFORMERS
T'ilishubdub (Duwamish)
Roger Fernandes (Lower Elwha Klallam)
Red Eagle Soaring
Elder Chris Morganroth (Quileute)
Daisy Chain

ART MAKING
Printmaking
Flower Pressing
Sketching
Photo Booth
And More!

FAMILY TOUR Explore the shoreline of the Olympic Sculpture Park and discover a beautiful space that displays art while providing a shoreline habitat for migrating juvenile salmon. See the unique pocket beach featuring native shoreline plantings, marine life, and works of art

COMING UP

Sat. Sep 11 **Family Festival Presented by Target**
noon–3 pm

Microsoft JScript runtime error '800a138f'

'strDisplayText' is null or not an object

/getout/comingup.inc, line 26

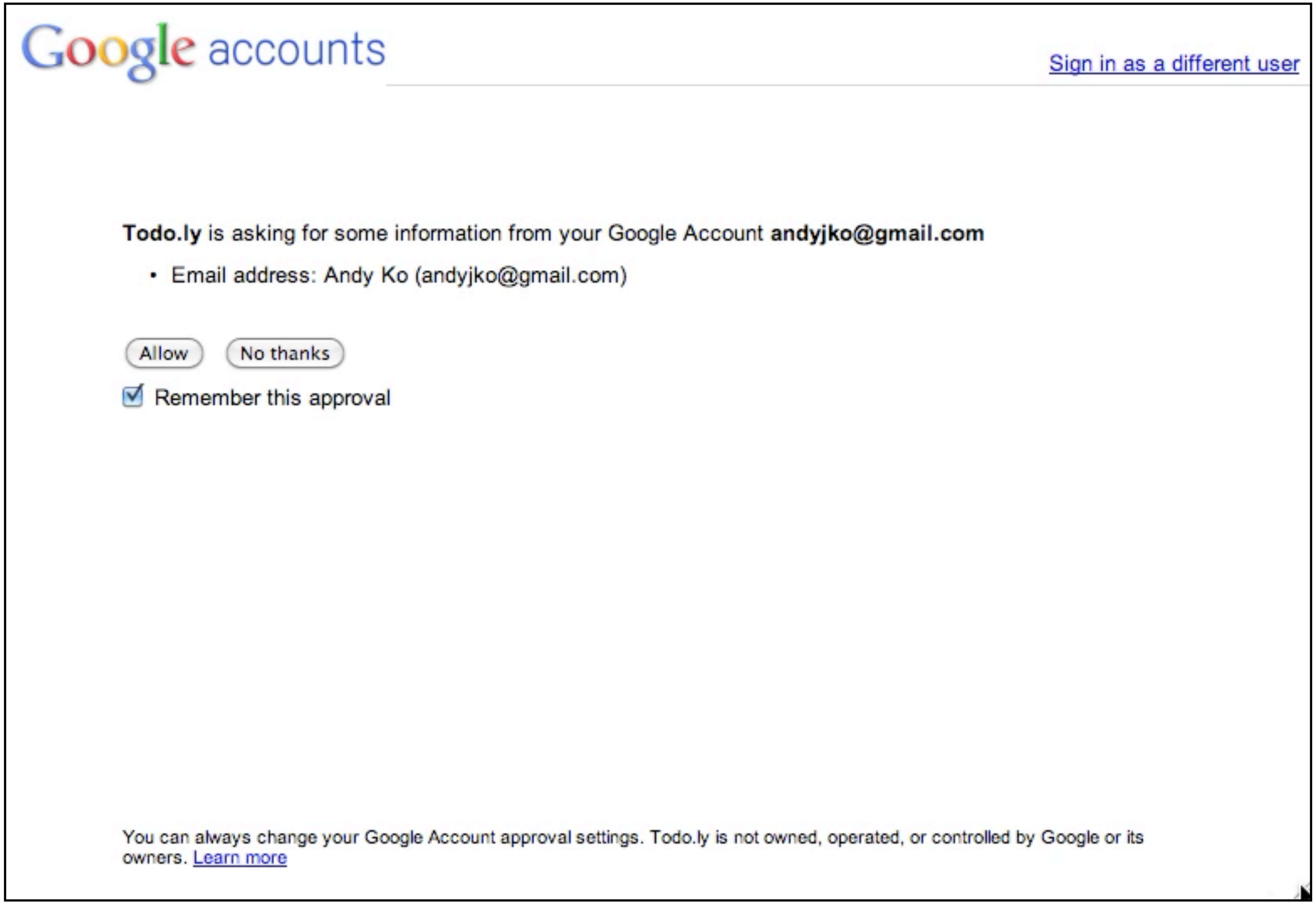
Sat. Sep 25 **Educator Workshop**
10:30 am–3:30 pm
Join us for our annual OSP Educator Workshop! This ... >>

Microsoft JScript runtime error '800a138f'

'strDisplayText' is null or not an object

/getout/comingup.inc, line 26

JavaScript's flexibility in constructing user interfaces **dynamically** makes it easy to overlook broken execution contexts without significant testing



Google accounts

Sign in as a different user

Todo.ly is asking for some information from your Google Account **andyjko@gmail.com**

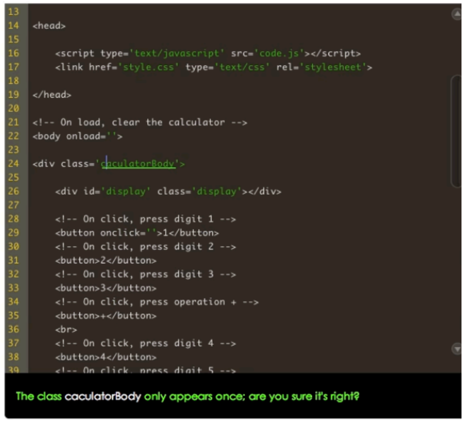
- Email address: Andy Ko (andyjko@gmail.com)

☑ Remember this approval

You can always change your Google Account approval settings. Todo.ly is not owned, operated, or controlled by Google or its owners. Learn more despite all of the **variation** in how web applications are written

there is **uniformity** in developers’ mistakes that we can detect and highlight

Cleanroom



```
<head>

    <script type='text/javascript' src='code.js'></script>
    <link href='style.css' type='text/css' rel='stylesheet'>

</head>

<!-- On load, clear the calculator -->
<body onload=''>

<div class='caculatorBody'>

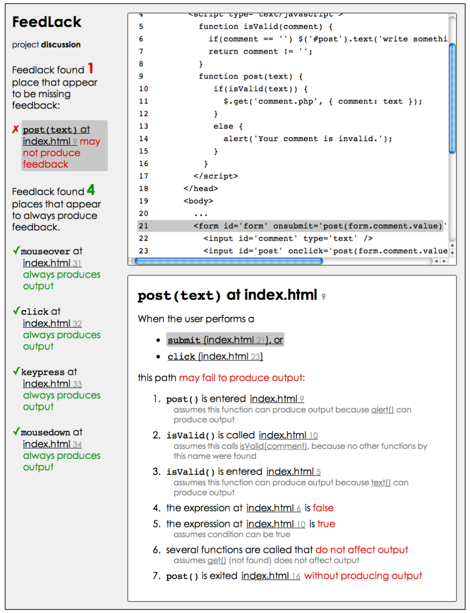
    <div id='display' class='display'></div>

    <!-- On click, press digit 1 -->
    <button onclick=''>1</button>
    <!-- On click, press digit 2 -->
    <button>2</button>
    <!-- On click, press digit 3 -->
    <button>3</button>
    <!-- On click, press operation + -->
    <button>+</button>
    <br>
    <!-- On click, press digit 4 -->
    <button>4</button>
    <!-- On click, press digit 5 -->
```

The class caculatorBody only appears once; are you sure it's right?

statically detecting a large class of JavaScript errors at edit time

FeedLack



FeedLack

project **discussion**

Feedlack found **1** place that appear to be missing feedback:

✗ post(text) at index.html 9 may not produce feedback

Feedlack found **4** places that appear to always produce feedback.

✓ mouseover at index.html 31 always produces output

✓ click at index.html 32 always produces output

✓ keypress at index.html 33 always produces output

✓ mousedown at index.html 34 always produces output

```
4          <script type='text/javascript'>
5            function isValid(comment) {
6              if(comment == '') $('#post').text('write somethi
7              return comment != '';
8            }
9            function post(text) {
10              if(isValid(text)) {
11                $.get('comment.php', { comment: text });
12              }
13              else {
14                alert('Your comment is invalid.');
15              }
16            }
17          </script>
18        </head>
19        <body>
20          ...
21          <form id='form' onsubmit='post(form.comment.value)'
22            <input id='comment' type='text' />
23            <input id='post' onclick='post(form.comment.value
```

post(text) at index.html 9

When the user performs a

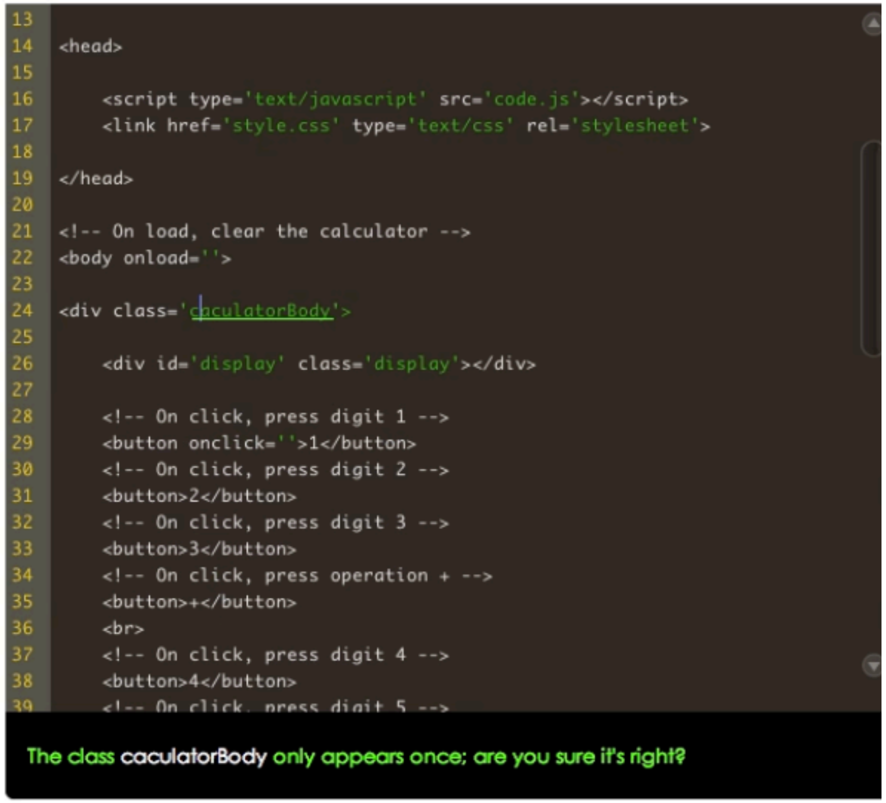
- submit (index.html 21), or
- click (index.html 23)

this path may fail to produce output:

1. post() is entered index.html 9
   assumes this function can produce output because alert() can produce output
2. isValid() is called index.html 10
   assumes this calls isValid(comment), because no other functions by this name were found
3. isValid() is entered index.html 5
   assumes this function can produce output because text() can produce output
4. the expression at index.html 6 is false
5. the expression at index.html 10 is true
   assumes condition can be true
6. several functions are called that do not affect output
   assumes get() (not found) does not affect output
7. post() is exited index.html 16 without producing output

verifying the presence of feedback in response to user input

Cleanroom



```
<head>

    <script type='text/javascript' src='code.js'></script>
    <link href='style.css' type='text/css' rel='stylesheet'>

</head>

<!-- On load, clear the calculator -->
<body onload=''>

<div class='caculatorBody'>

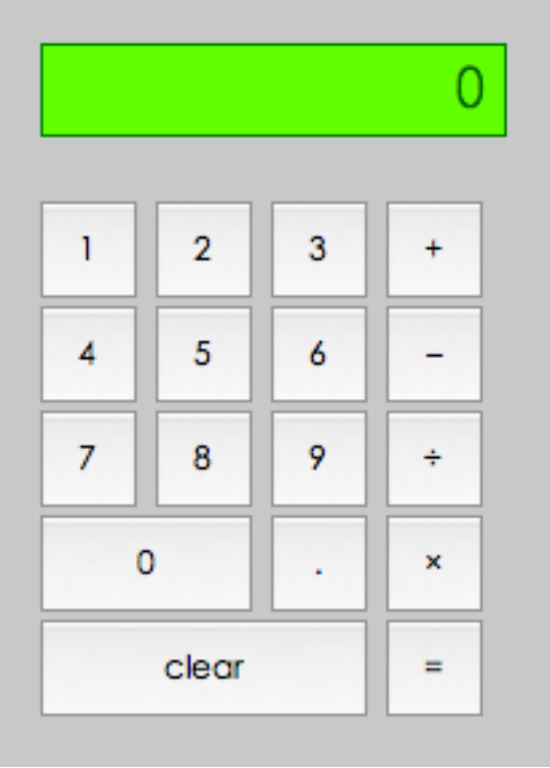
    <div id='display' class='display'></div>

    <!-- On click, press digit 1 -->
    <button onclick=''>1</button>
    <!-- On click, press digit 2 -->
    <button>2</button>
    <!-- On click, press digit 3 -->
    <button>3</button>
    <!-- On click, press operation + -->
    <button>+</button>
    <br>
    <!-- On click, press digit 4 -->
    <button>4</button>
    <!-- On click, press digit 5 -->
```

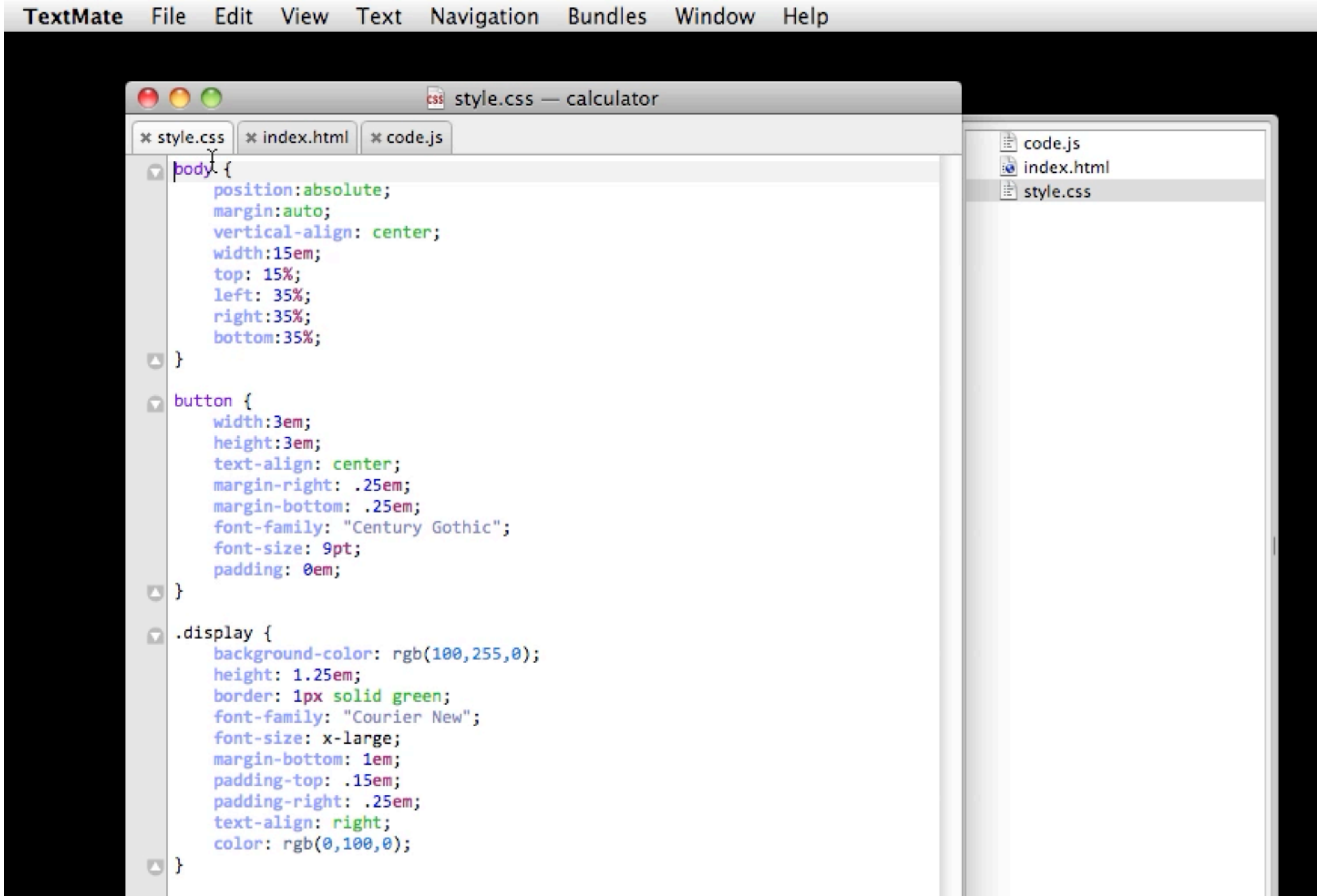
The class caculatorBody only appears once; are you sure it's right?

with
Jacob Wobbrock
Assistant Professor
The Information School

the web is great for rapid prototyping ...



the web is great for rapid prototyping ...



```
body {
    position:absolute;
    margin:auto;
    vertical-align: center;
    width:15em;
    top: 15%;
    left: 35%;
    right:35%;
    bottom:35%;
}

button {
    width:3em;
    height:3em;
    text-align: center;
    margin-right: .25em;
    margin-bottom: .25em;
    font-family: "Century Gothic";
    font-size: 9pt;
    padding: 0em;
}

.display {
    background-color: rgb(100,255,0);
    height: 1.25em;
    border: 1px solid green;
    font-family: "Courier New";
    font-size: x-large;
    margin-bottom: 1em;
    padding-top: .15em;
    padding-right: .25em;
    text-align: right;
    color: rgb(0,100,0);
}
```

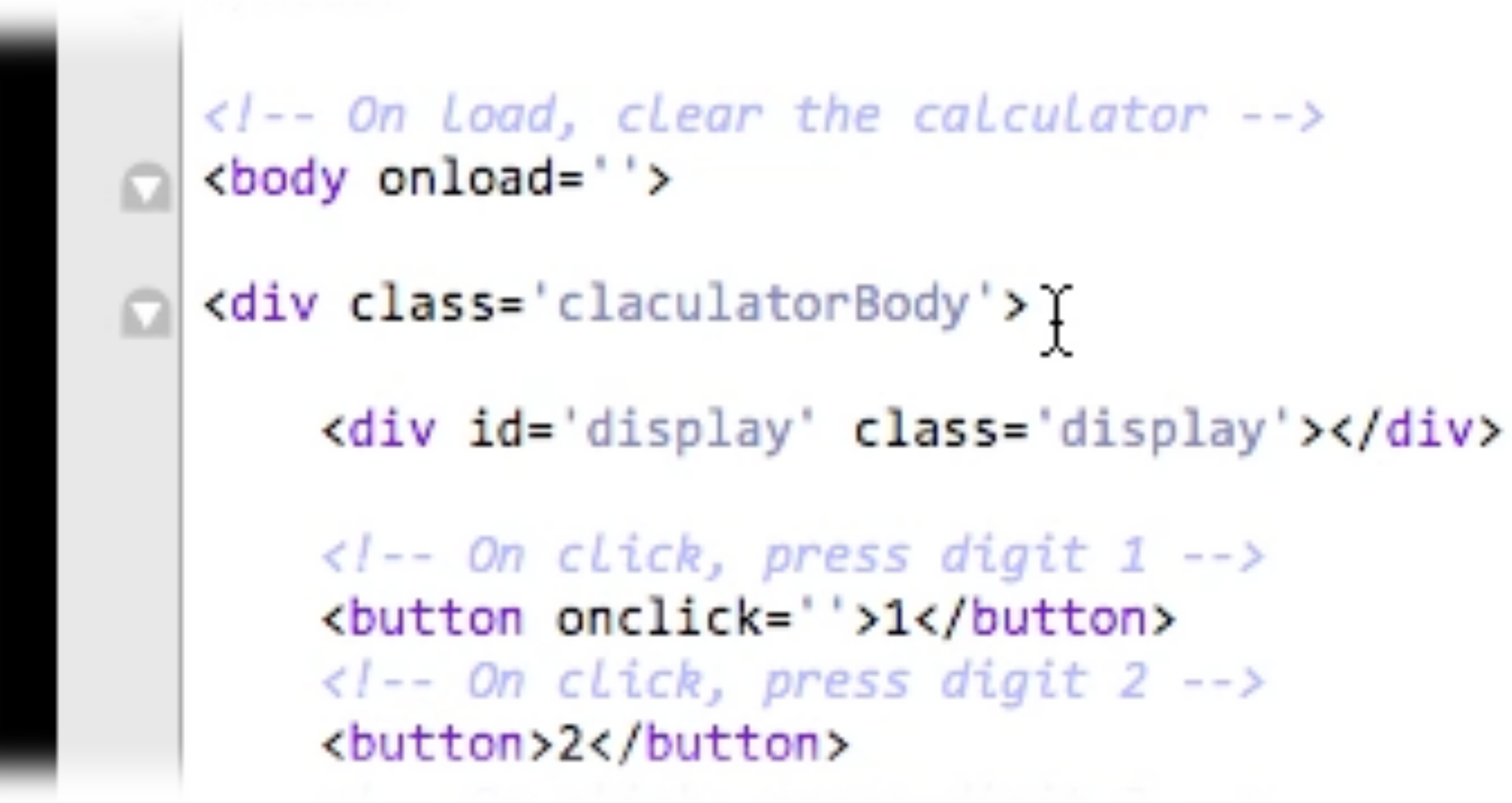
5 minutes later ...

of testing

of debugging

of reviewing my code

dynamic languages strike again...



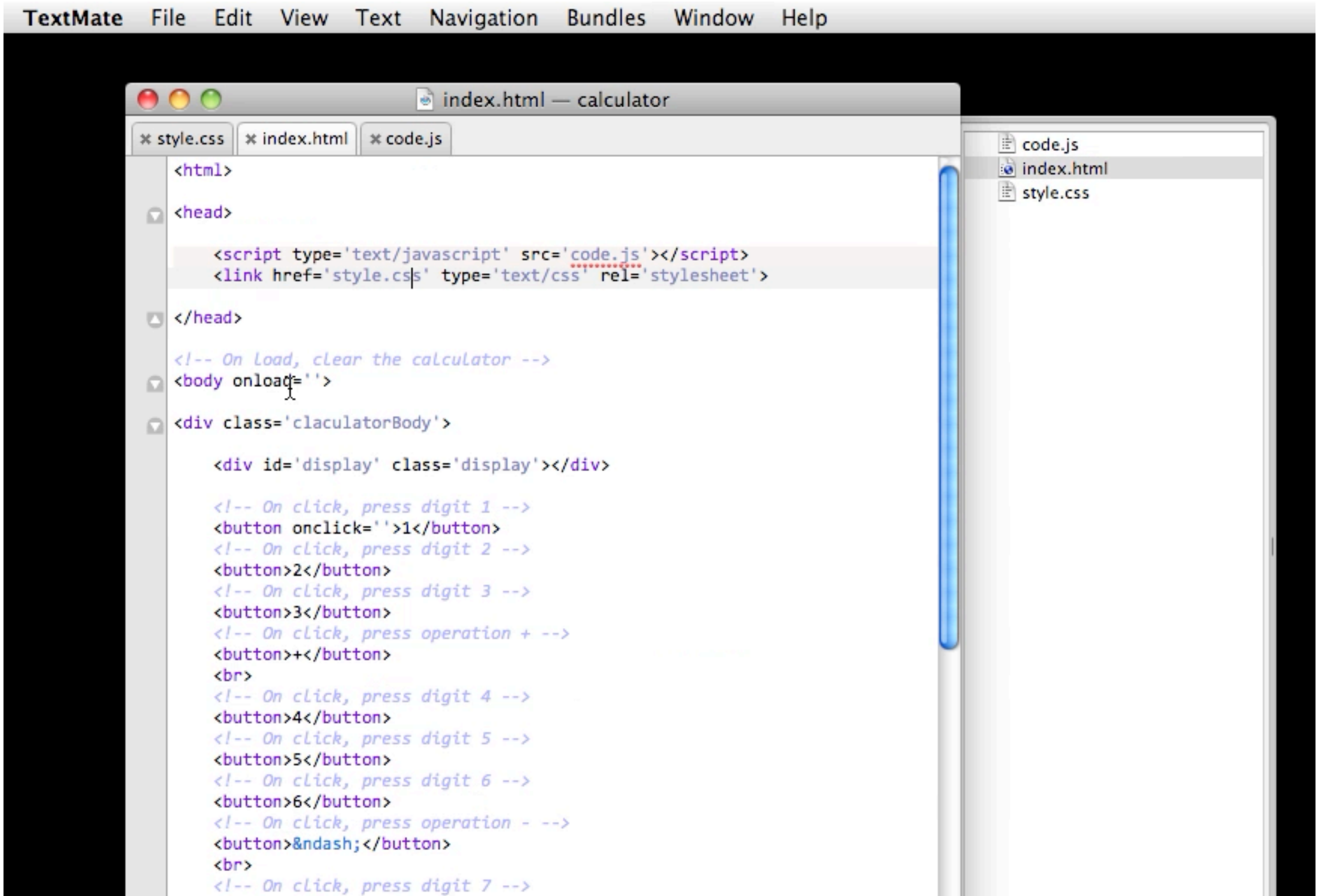
```
<!-- On load, clear the calculator -->
<body onload=''>

<div class='claculatorBody'>

    <div id='display' class='display'></div>

    <!-- On click, press digit 1 -->
    <button onclick=''>1</button>
    <!-- On click, press digit 2 -->
    <button>2</button>
```

only after testing was this typo apparent...



```
<html>

<head>

    <script type='text/javascript' src='code.js'></script>
    <link href='style.css' type='text/css' rel='stylesheet'>

</head>

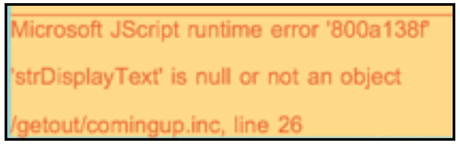
<!-- On load, clear the calculator -->
<body onload=''>

<div class='claculatorBody'>

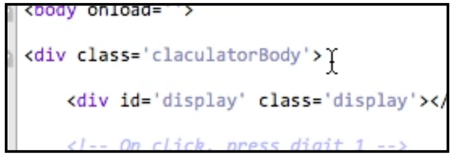
    <div id='display' class='display'></div>

    <!-- On click, press digit 1 -->
    <button onclick=''>1</button>
    <!-- On click, press digit 2 -->
    <button>2</button>
    <!-- On click, press digit 3 -->
    <button>3</button>
    <!-- On click, press operation + -->
    <button>+</button>
    <br>
    <!-- On click, press digit 4 -->
    <button>4</button>
    <!-- On click, press digit 5 -->
    <button>5</button>
    <!-- On click, press digit 6 -->
    <button>6</button>
    <!-- On click, press operation - -->
    <button>&ndash;</button>
    <br>
    <!-- On click, press digit 7 -->
```

current tools do not detect these **name errors**...



```
Microsoft JScript runtime error '800a138f'
'strDisplayText' is null or not an object
/getout/comingup.inc, line 26
```



```
<body onload=''>
<div class='claculatorBody'>
    <div id='display' class='display'></
    <!-- On click, press digit 1 -->
```

HTML/CSS **validators** don’t catch them

JSLint doesn’t catch them

Google’s **Closure** compiler doesn’t catch them

code completion can help prevent them, but type inference isn’t always possible...

what can we do about them?

spell checking?

text entry error detection?

fancy static type inference? (DoctorJS)

we tried all of these...

two observations

in any programming language, names are used to **uniquely refer** to data and behavior

human motor performance with keyboards is prone to **duplication**, **omission**, **transposition**, and **substitution** errors leading to “off-by-one” errors in names

the resulting hypothesis

$$\textbf{frequency}(\text{name}) \propto \textbf{validity}(\text{name})$$

the uniqueness heuristic

any **name** or **name sequence** that appears once in a program is **wrong**

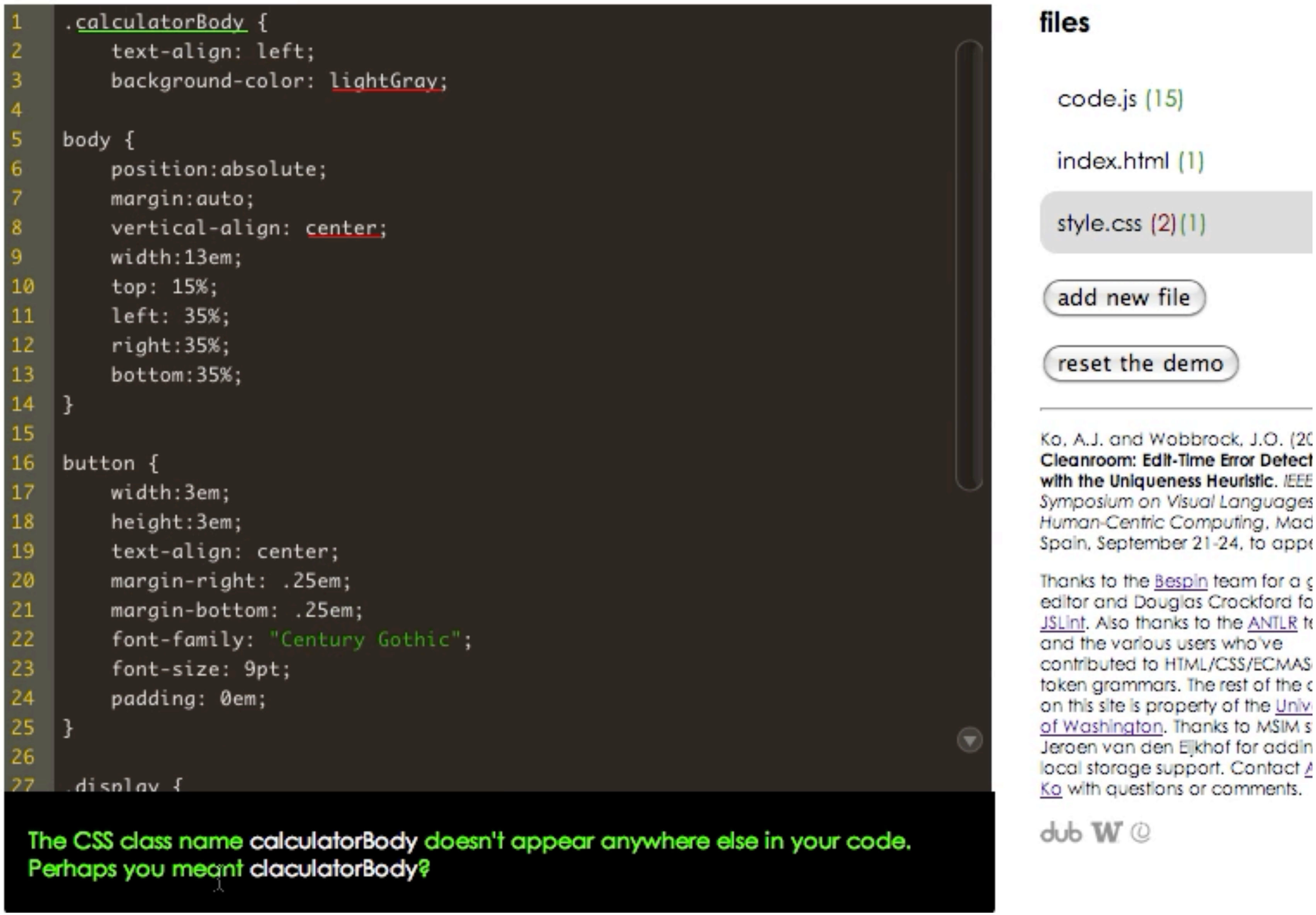
e.g., claculatorBody, consloe.log()

how often is this right?

would warnings based on it be useful?

Cleanroom

highlights violations of the uniqueness heuristic after each keystroke



```
.calculatorBody {
    text-align: left;
    background-color: lightGray;

body {
    position:absolute;
    margin:auto;
    vertical-align: center;
    width:13em;
    top: 15%;
    left: 35%;
    right:35%;
    bottom:35%;
}

button {
    width:3em;
    height:3em;
    text-align: center;
    margin-right: .25em;
    margin-bottom: .25em;
    font-family: "Century Gothic";
    font-size: 9pt;
    padding: 0em;
}

.display {
```

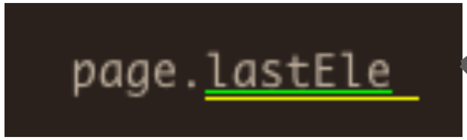
The CSS class name calculatorBody doesn't appear anywhere else in your code. Perhaps you meant claculatorBody?

Ko, A.J. and Wobbrock, J.O. (20 **Cleanroom: Edit-Time Error Detect with the Uniqueness Heuristic.** *IEEE Symposium on Visual Languages Human-Centric Computing*, Mad Spain, September 21-24, to appe

Thanks to the Bespin team for a g editor and Douglas Crockford fo JSLint. Also thanks to the ANTLR t and the various users who've contributed to HTML/CSS/ECMAS token grammars. The rest of the c on this site is property of the Univ of Washington. Thanks to MSIM s Jeroen van den Eijkhof for addin local storage support. Contact A Ko with questions or comments.

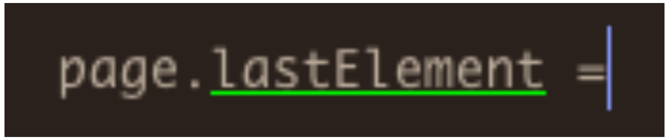
interaction design

during typing,
validation that name
isn't complete



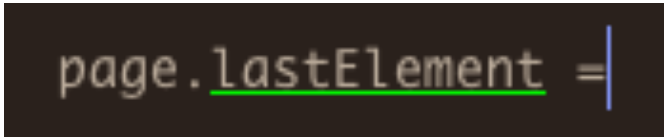
```
page.lastEle
```

if it's an error,
developer is warned



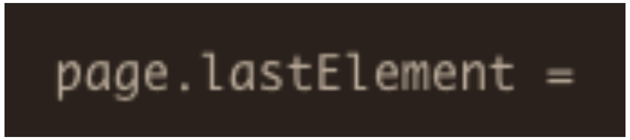
```
page.lastElement =
```

if it's an unused variable,
developer is reminded



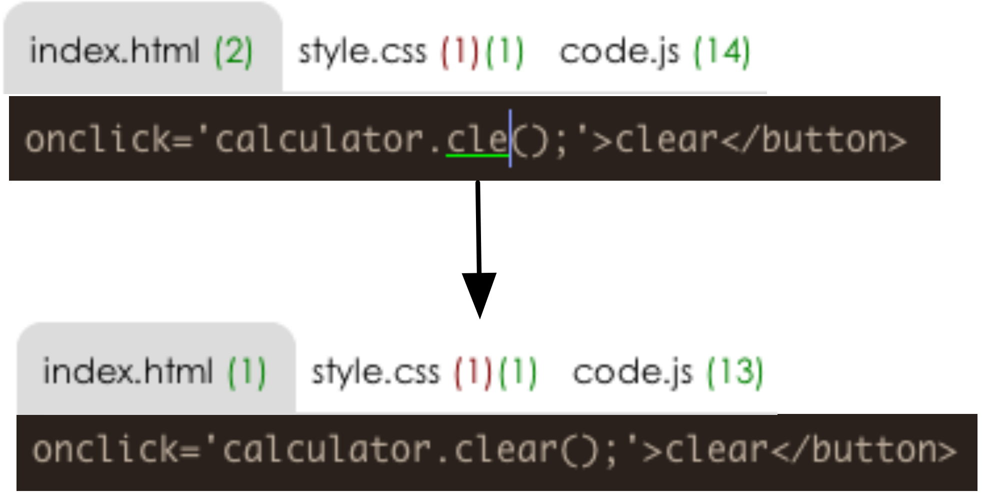
```
page.lastElement =
```

if declared, developer
developer gets
confirmation



```
page.lastElement =
```

interaction design

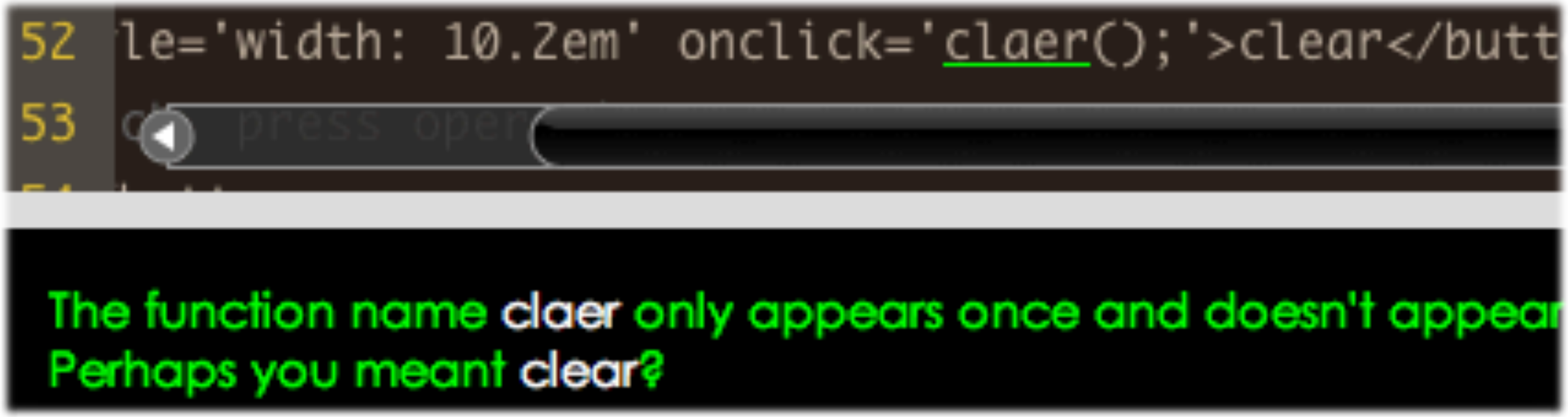


```
onclick='calculator.cle();'>clear</button>
```

```
onclick='calculator.clear();'>clear</button>
```

file-level counts updated on each keystroke to notify of cross-file changes

interaction design



```
le='width: 10.2em' onclick='claer();'>clear</butt
  press oper
```

```
The function name claer only appears once and doesn't appear
Perhaps you meant clear?
```

alternate names are suggested using Levenstein string distance

implementation

after **each keystroke**

- incremental tokenization
- identifiers tagged with one or more token types
    - HTMLTag
    - HTMLAttributeName
    - HTMLClass
    - HTMLID
    - CSSPropertyName
    - CSSValue
    - JSFunction
    - JSProperty
    - JSVariable
    - JSLiteral

implementation

…

string literals are tagged as JavaScript identifiers, HTML ids, HTML classes, CSS values since they are often used to refer to identifiers

Cleanroom has a dictionary of W3C standard API names

works even in the presence of **parsing errors**

implementation

…

table of name tokens by tag is created

table of adjacent **two name sequences** is created.

names or pairs of names that appear once are selected for warnings

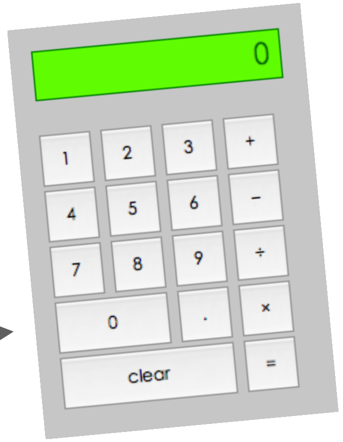
names for which **Levenshtein string distance** from warned name < 1 are suggested as alternatives

evaluation

online experiment

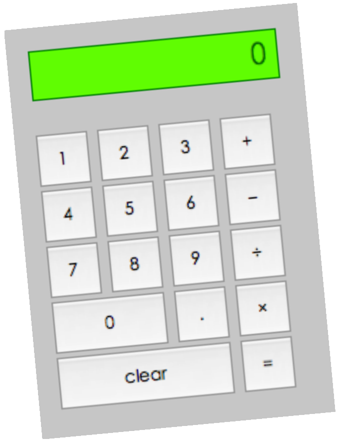
Cleanroom + JSlint versus **JSLint** only

developers asked to finish



Cleanroom warnings were tracked in JSLint condition, **but not displayed**

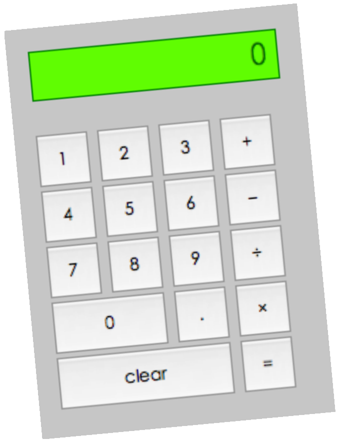
participants asked to finish...



18 inline **onclick** event handlers

~76 lines of calculator function implementations

the tests



automated test launched the web site and tested whether programmatic clicks on the the calculator would provide correct answers for

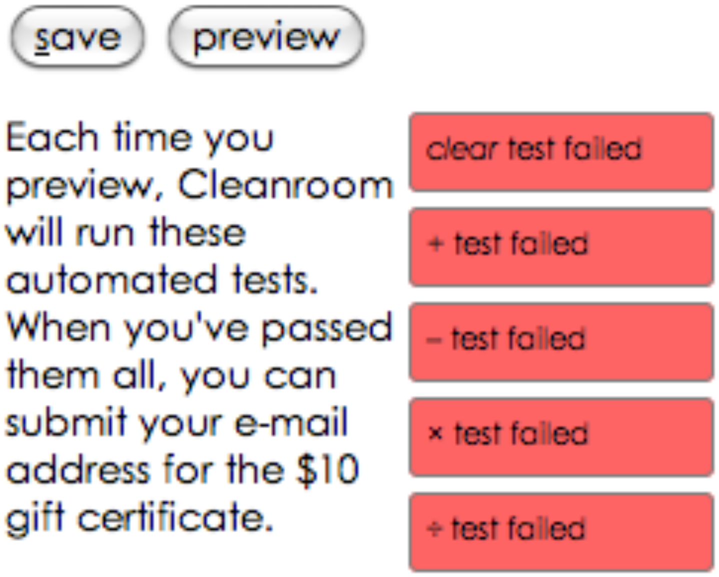
clear → 0

9 + 5

9 – 5

9 x 5

9 / 5



Each time you preview, Cleanroom will run these automated tests. When you've passed them all, you can submit your e-mail address for the $10 gift certificate.

clear test failed

+ test failed

− test failed

× test failed

÷ test failed

the participants

94 visited

40 started task

22 typed for more than 3 minutes

16 made substantial progress on the task

8 Cleanroom and **8 control** participants

no significant difference in JavaScript experience

“In the past month, I’ve written JavaScript **weekly”**

data collected

whether a warning was **active** after the last recorded keystroke

the **duration** a warning was active

the **kind** of token warned

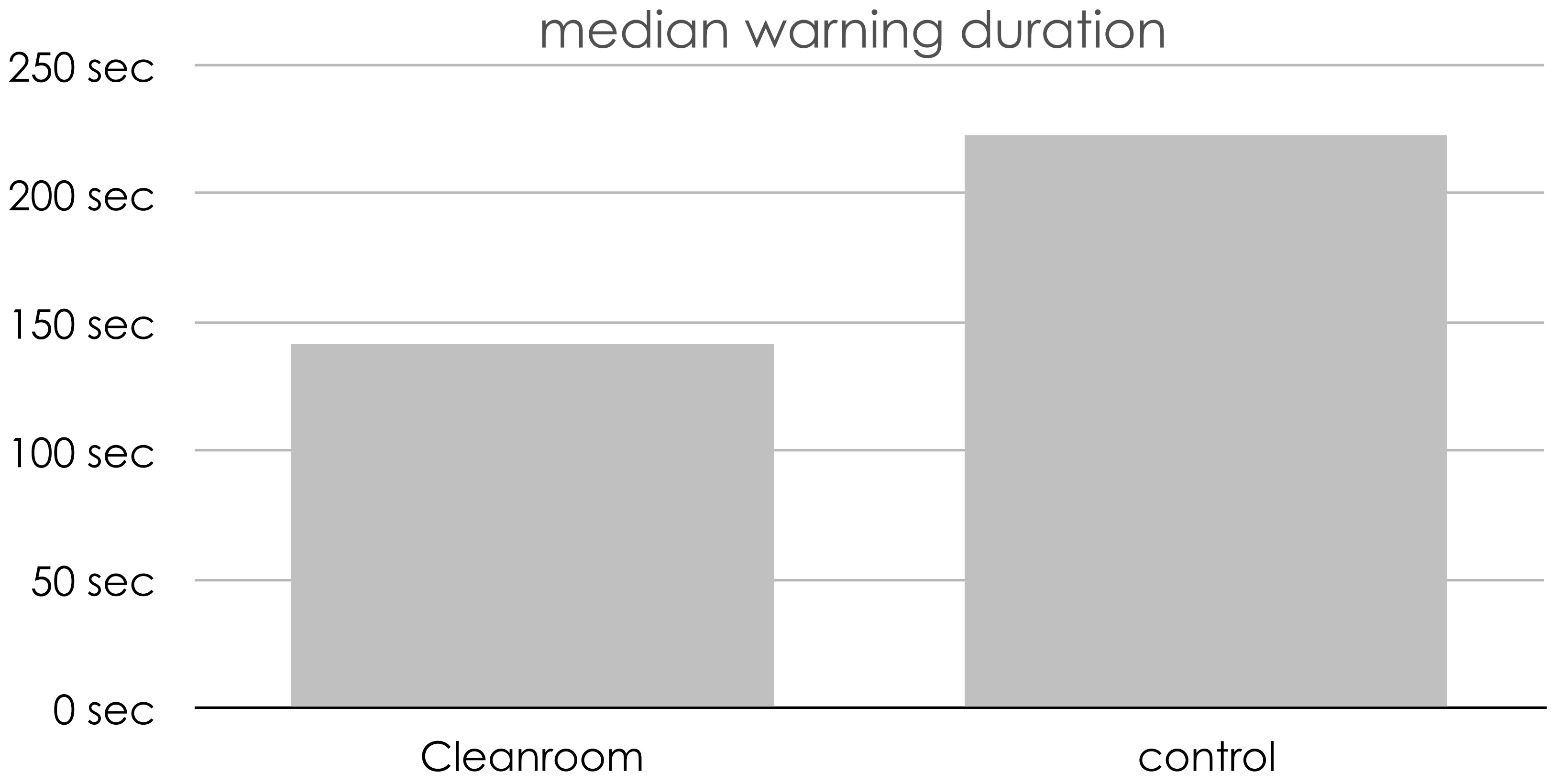
whether the warning was on a **declaration**

whether the warning disappeared because of a **direct** edit on the name

how many times a warning was **executed** while active

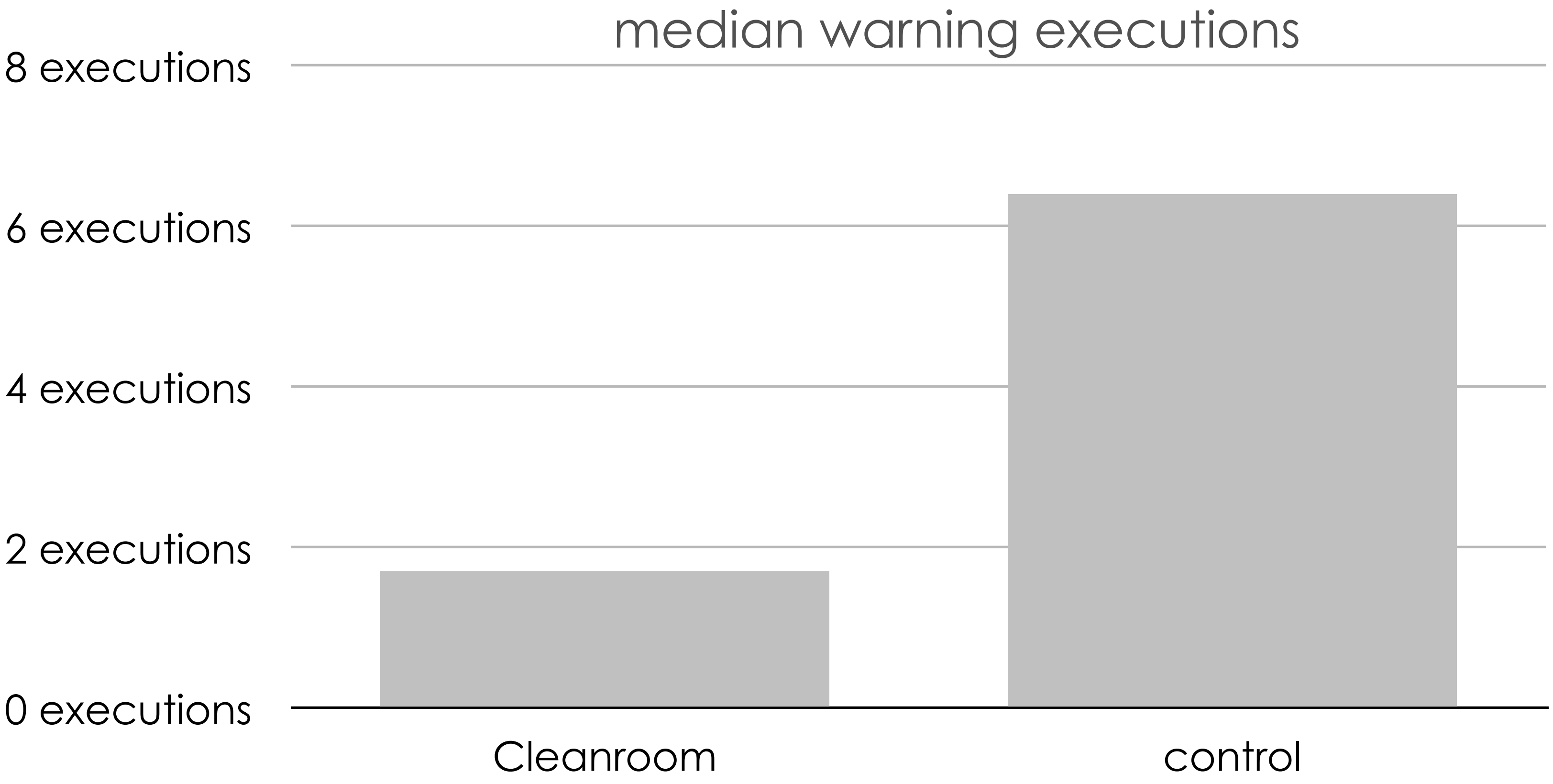
results

warnings were **active for significantly less time** in the Cleanroom condition (p < .01)



results

Cleanroom developers **executed** warned names significantly fewer times (p < .01)



results

errors that Cleanroom developers fixed

undeclared names

unused names

typos (e.g., `parseFLoat`, `getElementByID`, `onlcick`, `alert_box`)

syntax from other languages (e.g., `dim` from Visual Basic)

APIs from other languages (e.g., `sum` instead of `add`)

type declarations (e.g., `int`)

results

none of the warnings in the program were false positives

some of the warnings were not severe

e.g., unused variables had no consequence on behavior

limitations

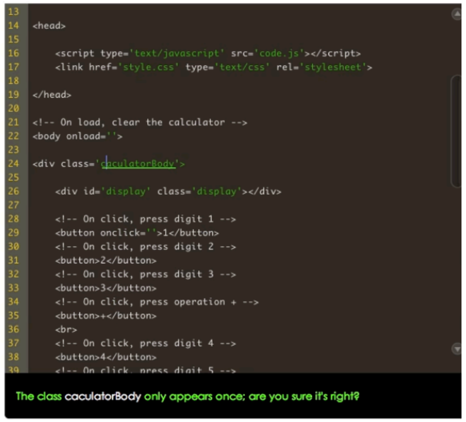
can’t detect errors that occur more than once

can’t detect errors in dynamically generated names

there are bound to be a variety of false positives in the wild

e.g., pre- and postfix literals of dynamically generated names, as in (“week” + number)

Cleanroom



```
<head>

    <script type='text/javascript' src='code.js'></script>
    <link href='style.css' type='text/css' rel='stylesheet'>

</head>

<!-- On load, clear the calculator -->
<body onload=''>

<div class='caculatorBody'>

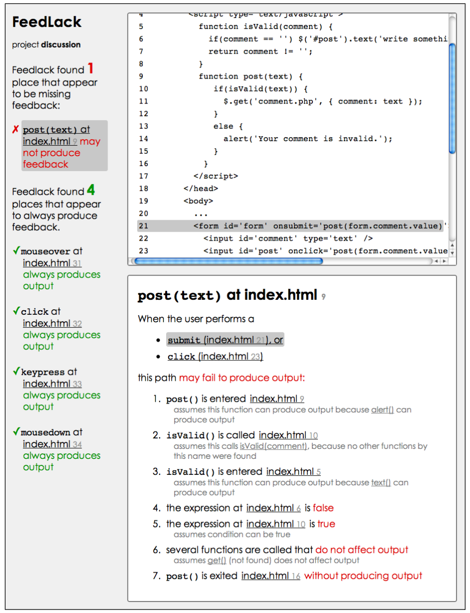
    <div id='display' class='display'></div>

    <!-- On click, press digit 1 -->
    <button onclick=''>1</button>
    <!-- On click, press digit 2 -->
    <button>2</button>
    <!-- On click, press digit 3 -->
    <button>3</button>
    <!-- On click, press operation + -->
    <button>+</button>
    <br>
    <!-- On click, press digit 4 -->
    <button>4</button>
    <!-- On click, press digit 5 -->
```

The class caculatorBody only appears once; are you sure it's right?

statically detecting a large class of JavaScript errors at edit time

FeedLack



FeedLack

project **discussion**

Feedlack found **1** place that appear to be missing feedback:

✗ post(text) at index.html 9 may not produce feedback

Feedlack found **4** places that appear to always produce feedback.

✓ mouseover at index.html 31 always produces output

✓ click at index.html 32 always produces output

✓ keypress at index.html 33 always produces output

✓ mousedown at index.html 34 always produces output

```
4     <script type='text/javascript'>
5        function isValid(comment) {
6          if(comment == '') $('#post').text('write somethi
7          return comment != '';
8        }
9        function post(text) {
10          if(isValid(text)) {
11            $.get('comment.php', { comment: text });
12          }
13          else {
14            alert('Your comment is invalid.');
15          }
16        }
17      </script>
18    </head>
19    <body>
20      ...
21      <form id='form' onsubmit='post(form.comment.value)'
22        <input id='comment' type='text' />
23        <input id='post' onclick='post(form.comment.value
```

post(text) at index.html 9

When the user performs a

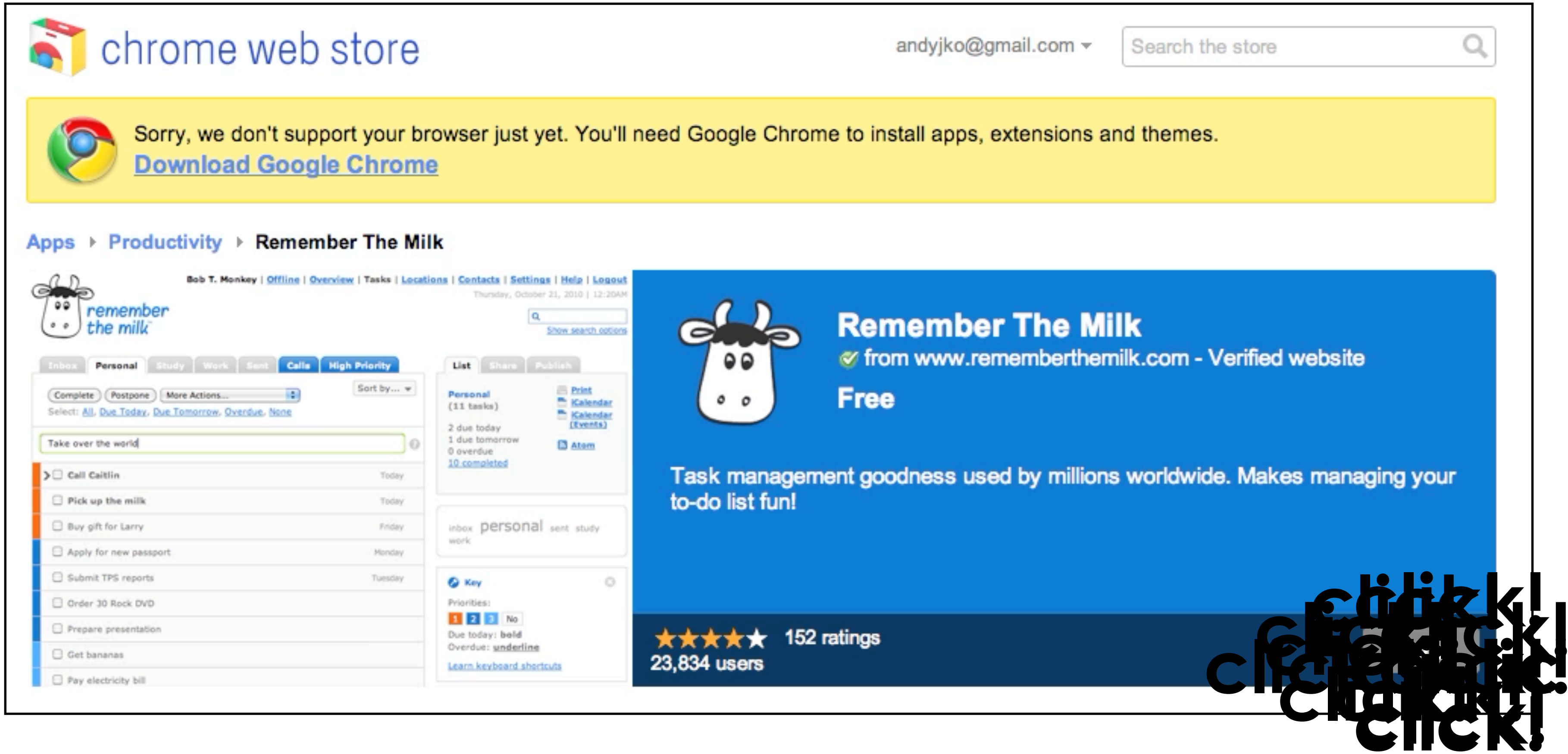
- submit (index.html 21), or
- click (index.html 23)

this path may fail to produce output:

1. post() is entered index.html 9
   assumes this function can produce output because alert() can produce output
2. isValid() is called index.html 10
   assumes this calls isValid(comment), because no other functions by this name were found
3. isValid() is entered index.html 5
   assumes this function can produce output because text() can produce output
4. the expression at index.html 6 is false
5. the expression at index.html 10 is true
   assumes condition can be true
6. several functions are called that do not affect output
   assumes get() (not found) does not affect output
7. post() is exited index.html 16 without producing output

verifying the presence of feedback in response to user input

all over the web, apps are ignoring people



Sorry, we don't support your browser just yet. You'll need Google Chrome to install apps, extensions and themes.
Download Google Chrome

Apps ▸ Productivity ▸ Remember The Milk

remember the milk
Bob T. Monkey | Offline | Overview | Tasks | Locations | Contacts | Settings | Help | Logout
Thursday, October 21, 2010 | 12:20AM
Show search options
Inbox
Personal
Study
Work
Sent
Calls
High Priority
Complete
Postpone
More Actions...
Sort by...
Select: All, Due Today, Due Tomorrow, Overdue, None
List
Share
Publish
Print
iCalendar
iCalendar (Events)
Atom

Take over the world

□ Call Caitlin	Today
□ Pick up the milk	Today
□ Buy gift for Larry	Friday
□ Apply for new passport	Monday
□ Submit TPS reports	Tuesday
□ Order 30 Rock DVD	
□ Prepare presentation	
□ Get bananas	
□ Pay electricity bill	

Personal
(11 tasks)

2 due today
1 due tomorrow
0 overdue
10 completed

Remember The Milk
✓ from www.rememberthemilk.com - Verified website
Free

Task management goodness used by millions worldwide. Makes managing your to-do list fun!

★★★★★ 152 ratings
23,834 users

click!
click!
click!
click!
click!
click!

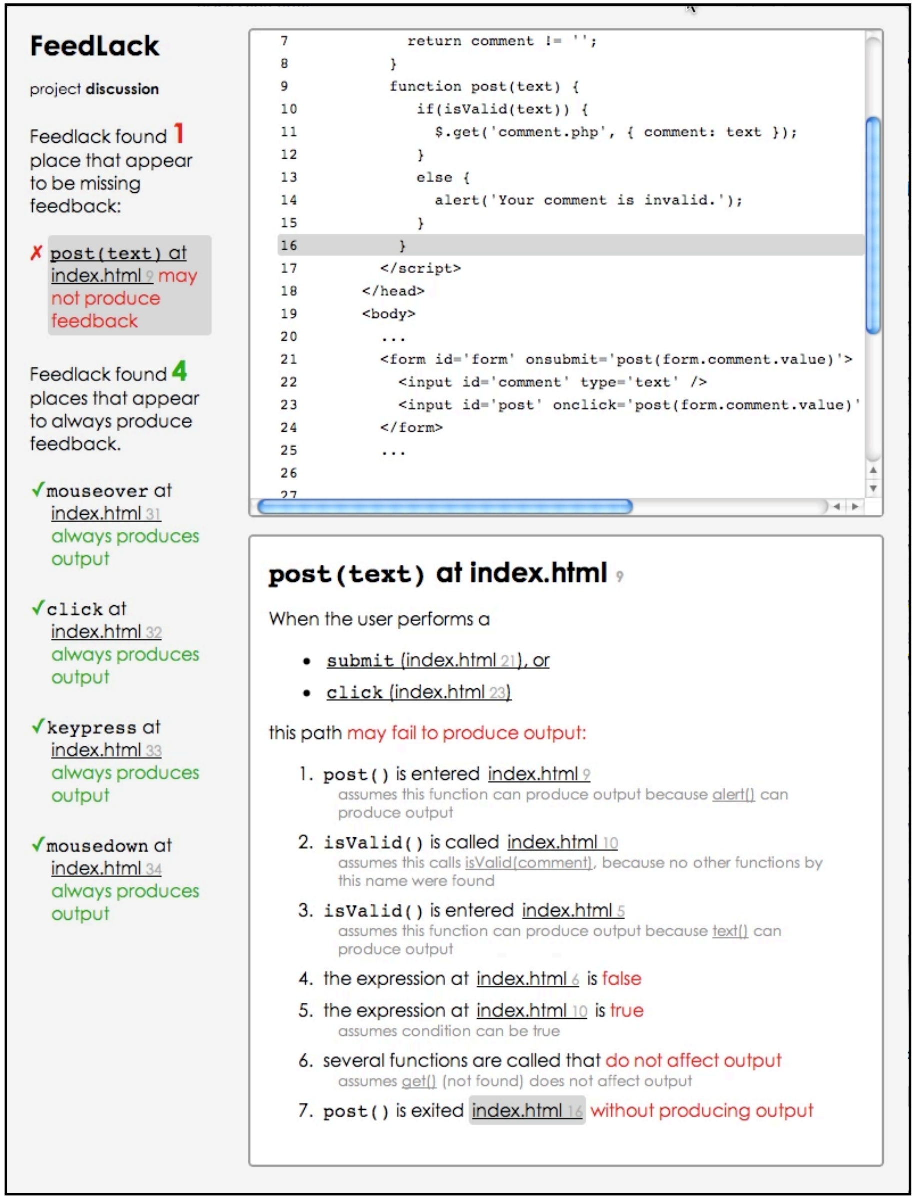
where's the feedback?

web apps are full of flaws like these

```
if(everything is normal) {
    provideFeedback();
} else {} // TODO
```

and the **TODO** is rarely done

FeedLack



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15         }
16       }
17     </script>
18   </head>
19   <body>
20     ...
21     <form id='form' onsubmit='post(form.comment.value)'>
22       <input id='comment' type='text' />
23       <input id='post' onclick='post(form.comment.value)'
24     </form>
25     ...
26
27
```

`post(text)` at index.html 9

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with
Xing Zhang
undergraduate
University of Washington

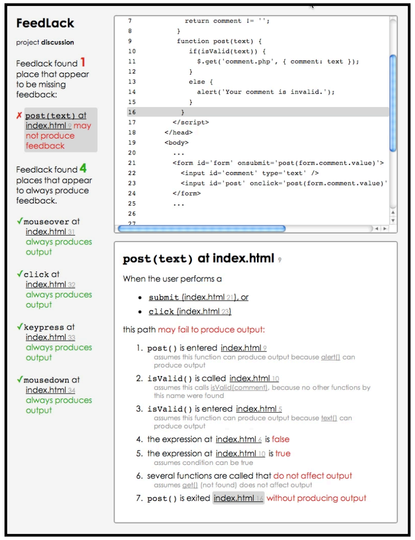
FeedLack

verifies that

all control flow paths

originating from user input

produce output



FeedLack

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15             }
16           }
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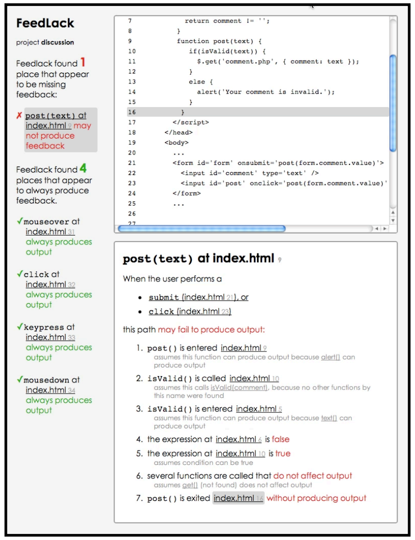
for example...

FeedLack



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17         </script>
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21         <form id='form' onsubmit='post(form.comment.value)'>
22           <input id='comment' type='text' />
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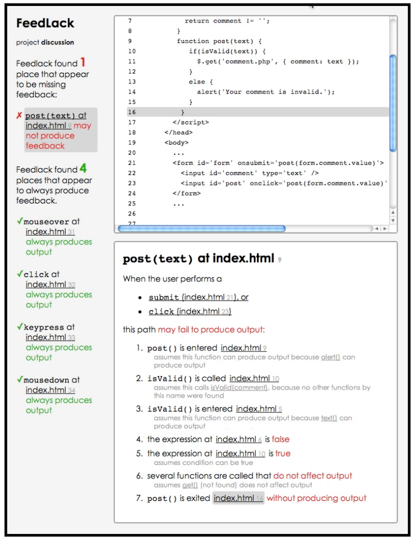
for example...

```
<form id='form' onsubmit="post(form.comment.value)">
   <input id='comment' type='text' />
   <input onclick=post(form.comment.value)”>
</form>
```

here’s a form that posts the value of a comment field when **enter** is typed or **submit** is clicked.

FeedLack



FeedLack

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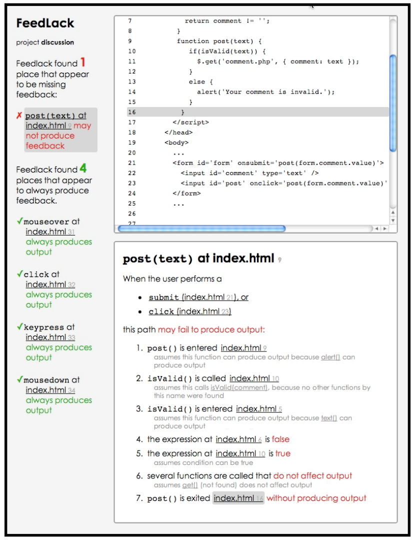
for example...

```
<form id='form' onsubmit="post(form.comment.value)">
   <input id='comment' type='text' />
   <input onclick=post(form.comment.value)”>
</form>
<script type='text/javascript'>
   function post(text) {
      if(isValid(comment))
         $.get("comment.php", { comment: text });
      else
         alert("Your comment is invalid.");
   }
```

when post() is called, the comment is posted if valid; otherwise, an alert is shown.

FeedLack



FeedLack

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25         ...
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```

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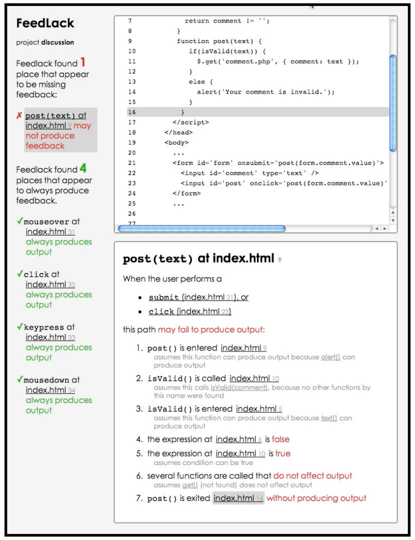
for example...

```
<form id='form' onsubmit="post(form.comment.value)">
    <input id='comment' type='text' />
    <input onclick=post(form.comment.value)”>
</form>
<script type='text/javascript'>
    function post(text) {
        if(isValid(comment))
            $.get("comment.php", { comment: text });
        else
            alert("Your comment is invalid.");
    }
    function isValid(comment) {
        if(comment == '')
            $('#comment').text('write something!');
        return comment != '';
    }
</script>
```

isValid() provides feedback on empty comments.

FeedLack



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8            }
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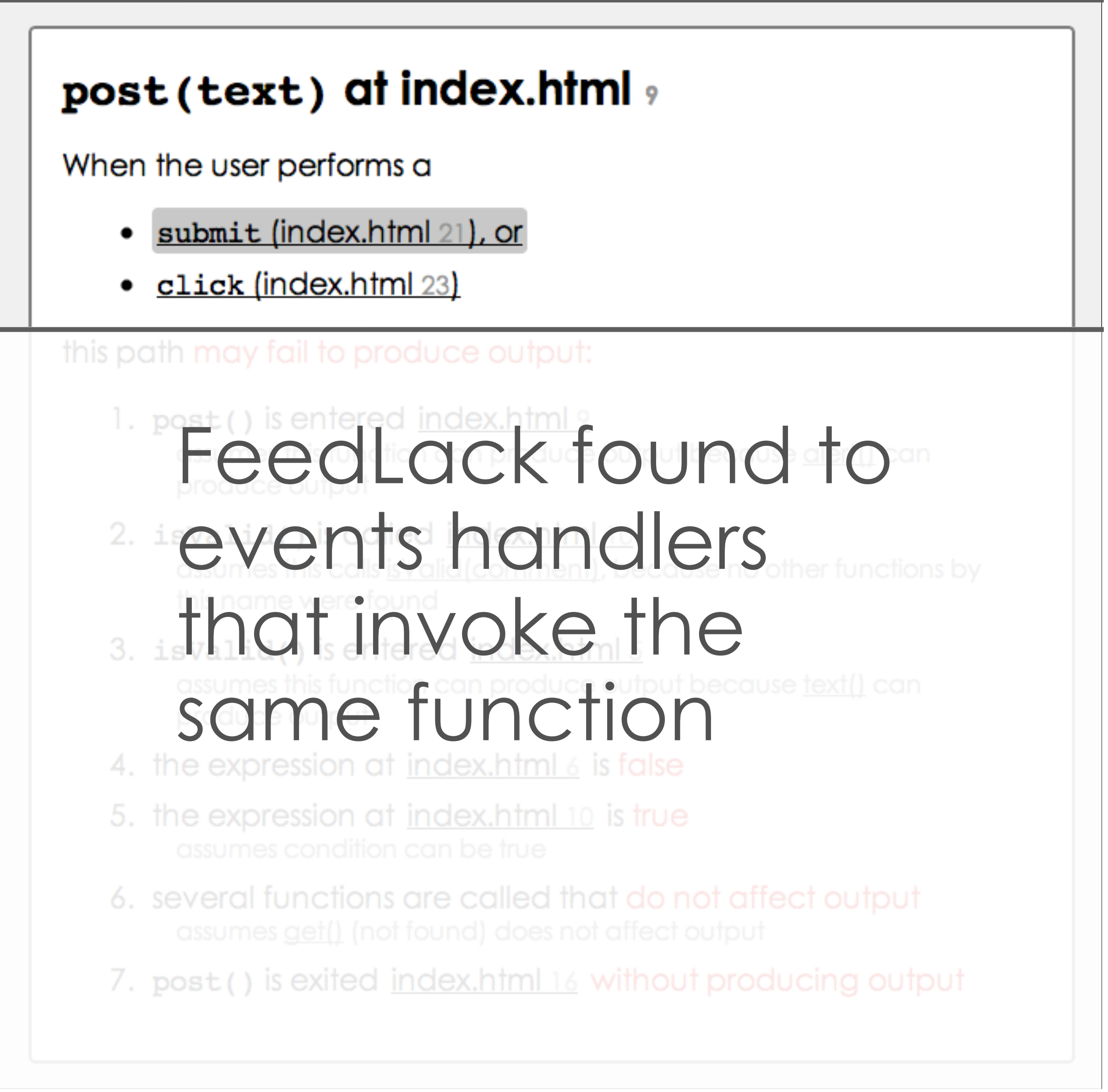
6. several functions are called that do not affect output
   assumes get() (not found) does not affect output
7. post() is exited index.html 16 without producing output

for example...

```
<form id='form' onsubmit="post(form.comment.value)">
    <input id='comment' type='text' />
    <input onclick=post(form.comment.value)”>
</form>
<script type='text/javascript'>
    function post(text) {
        if(isValid(comment))
            $.get("comment.php", { comment: text });
        else
            alert("Your comment is invalid.");
    }
    function isValid(comment) {
        if(comment == '')
            $('#comment').text('write something!');
        return comment != '';
    }
</script>
```

what’s wrong?



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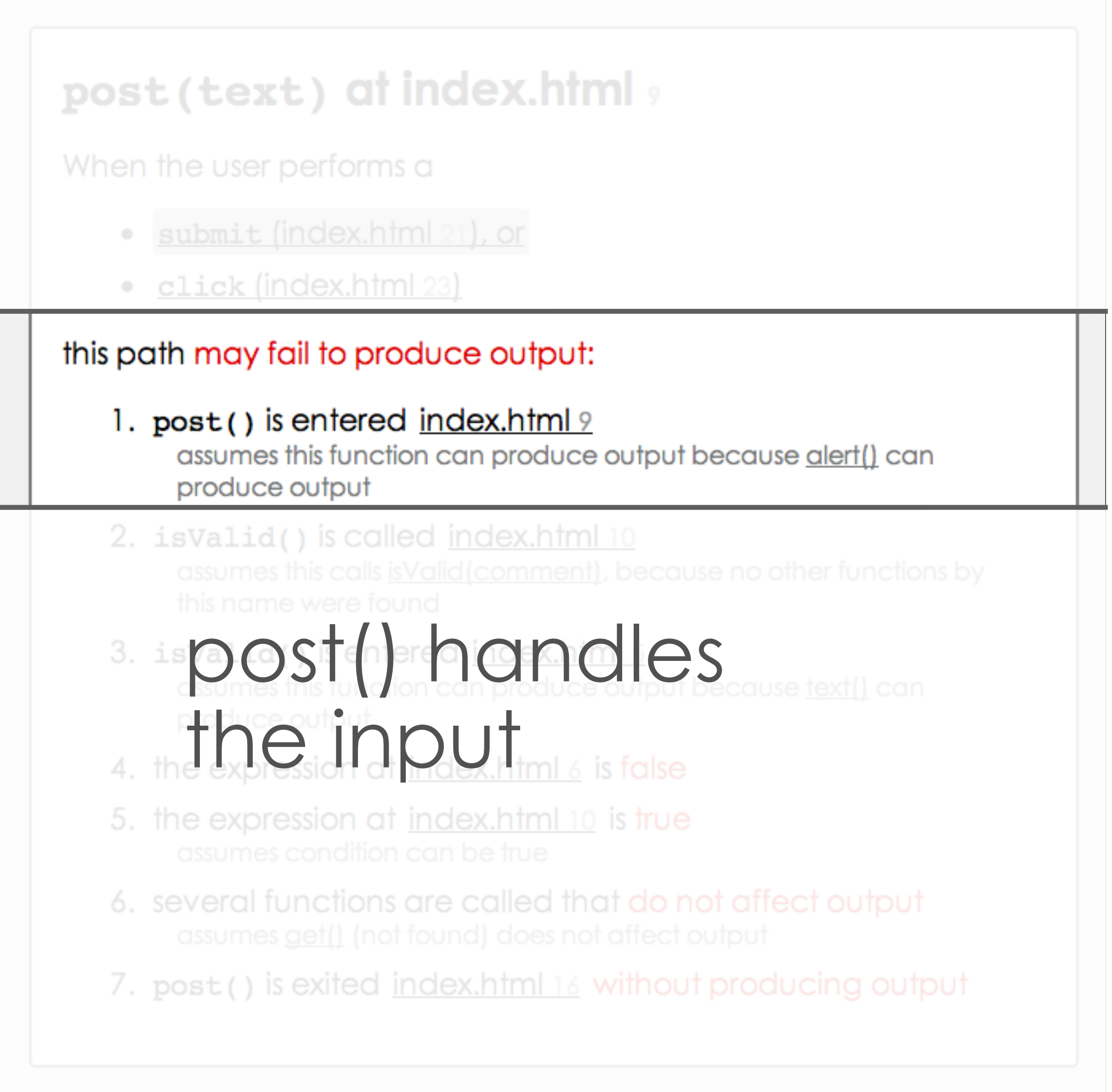
FeedLack found to events handlers that invoke the same function

```
<form id='form' onsubmit="post
    <input id='comment' type='t
    <input onclick=post(form.co
</form>
<script type='text/javascript'
    function post(text) {
        if(isValid(comment))
            $.get("comment.php",
        else
            alert("Your comment
    }
    function isValid(comment)
        if(comment == '')
            $('#comment').text(
        return comment != '';
    }
</script>
```



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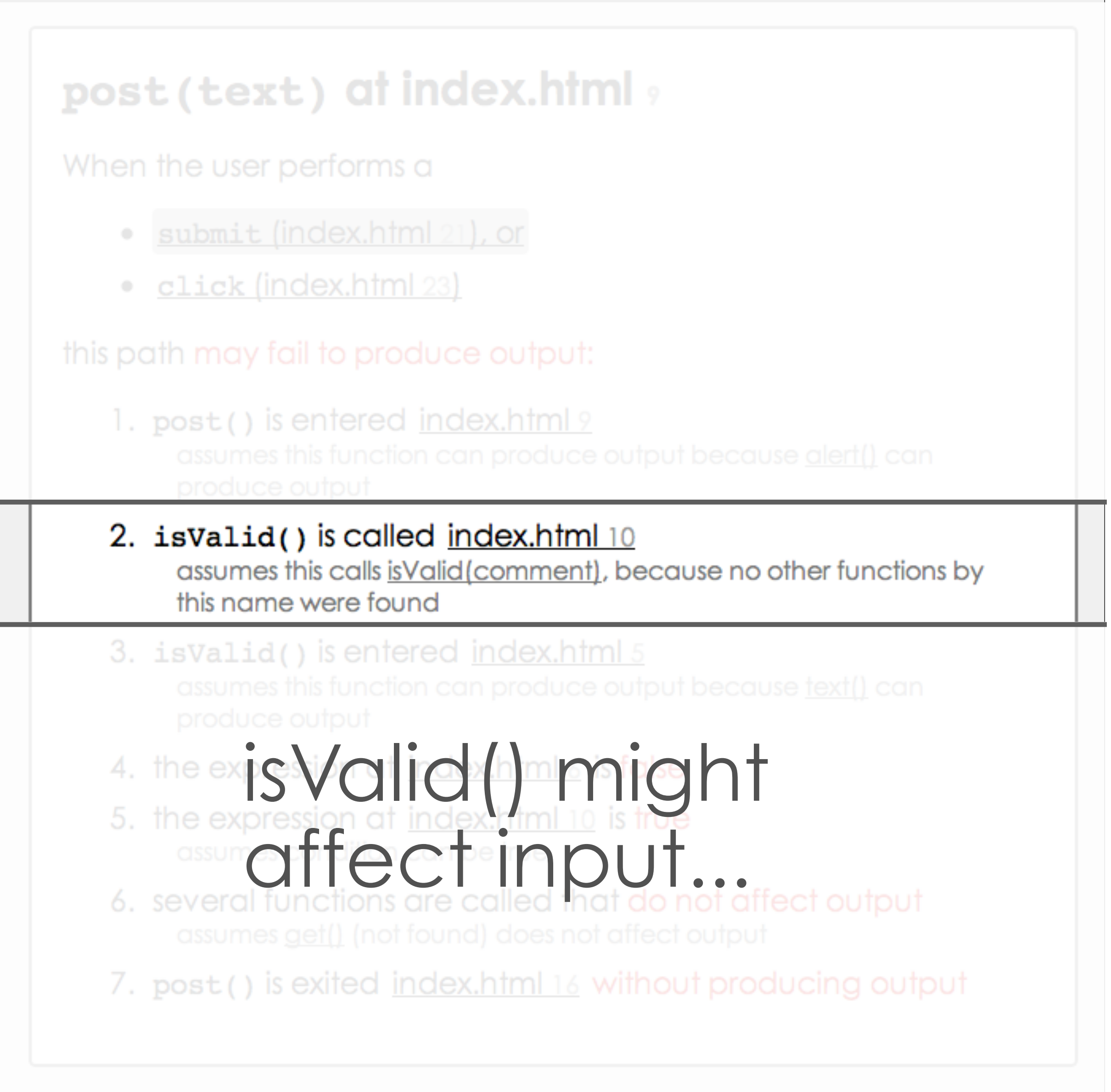
   assumes get() (not found) does not affect output
7. post() is exited index.html 16 without producing output

post() handles the input

```
<form id='form' onsubmit="post
    <input id='comment' type='t
    <input onclick=post(form.co
</form>
<script type='text/javascript'
    function post(text) {
        if(isValid(comment))
            $.get("comment.php",
        else
            alert("Your comment
    }
    function isValid(comment)
        if(comment == '')
            $('#comment').text(
        return comment != '';
    }
</script>
```



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3. isValid() is entered index.html 5
   assumes this function can produce output because text() can produce output
4. the expression at index.html is false
5. the expression at index.html 10 is true
   assumes condition can be [illegible]
6. several functions are called that do not affect output
   assumes get() (not found) does not affect output
7. post() is exited index.html 16 without producing output

isValid() might affect input...

```
<form id='form' onsubmit="post
    <input id='comment' type='t
    <input onclick=post(form.co
</form>
<script type='text/javascript'
    function post(text) {
        if(isValid(comment))
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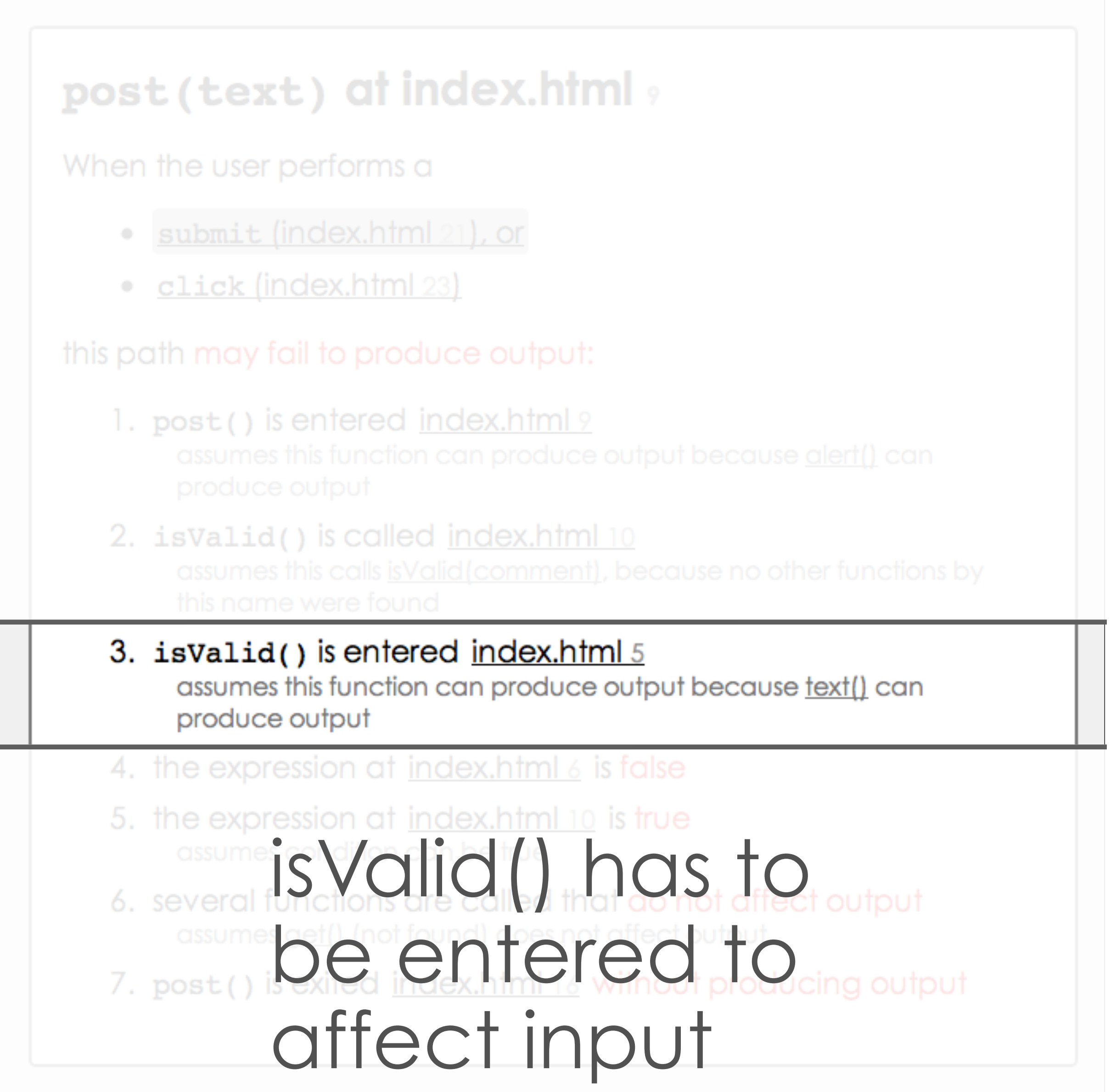

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isValid() has to be entered to affect input

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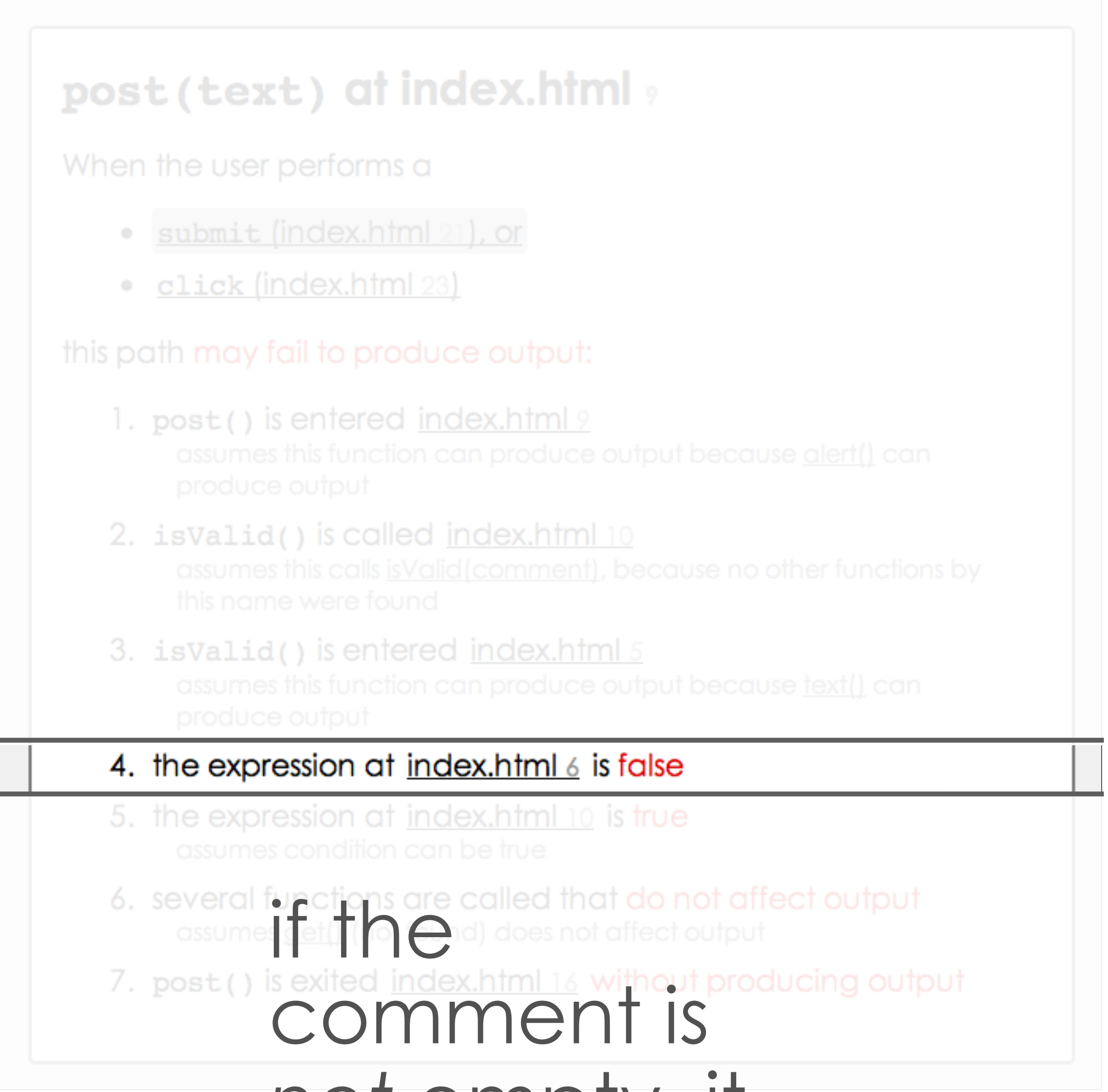

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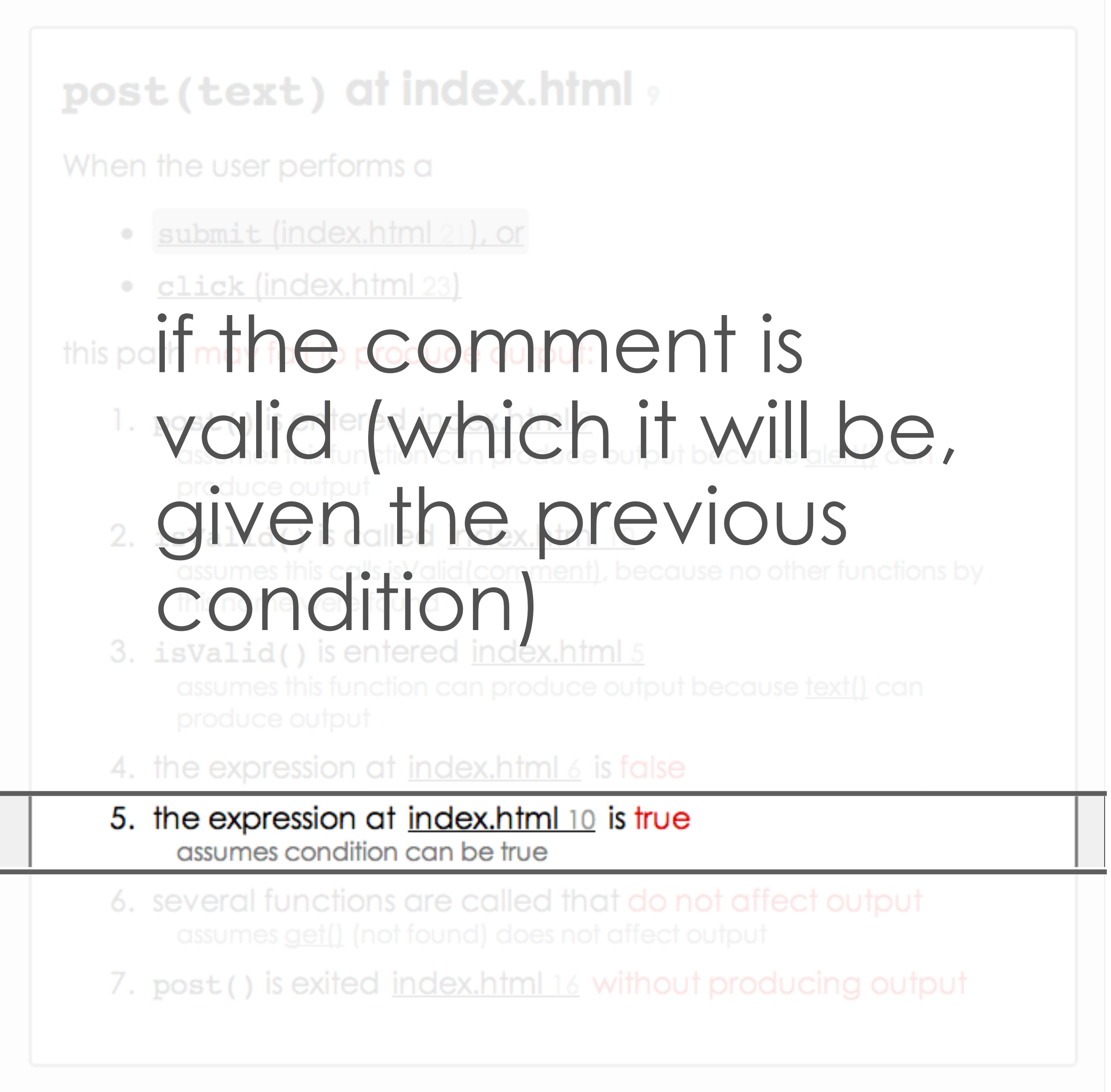
   assumes get() (not found) does not affect output
7. post() is exited index.html 16 without producing output

if the comment is *not* empty, it will skip output

```
<form id='form' onsubmit="post
    <input id='comment' type='t
    <input onclick=post(form.co
</form>
<script type='text/javascript'
    function post(text) {
        if(isValid(comment))
            $.get("comment.php",
        else
            alert("Your comment
    }
    function isValid(comment)
        if(comment == '')
            $('#comment').text(
        return comment != '';
    }
</script>
```

if the comment is valid (which it will be, given the previous condition)



post(text) at index.html 9

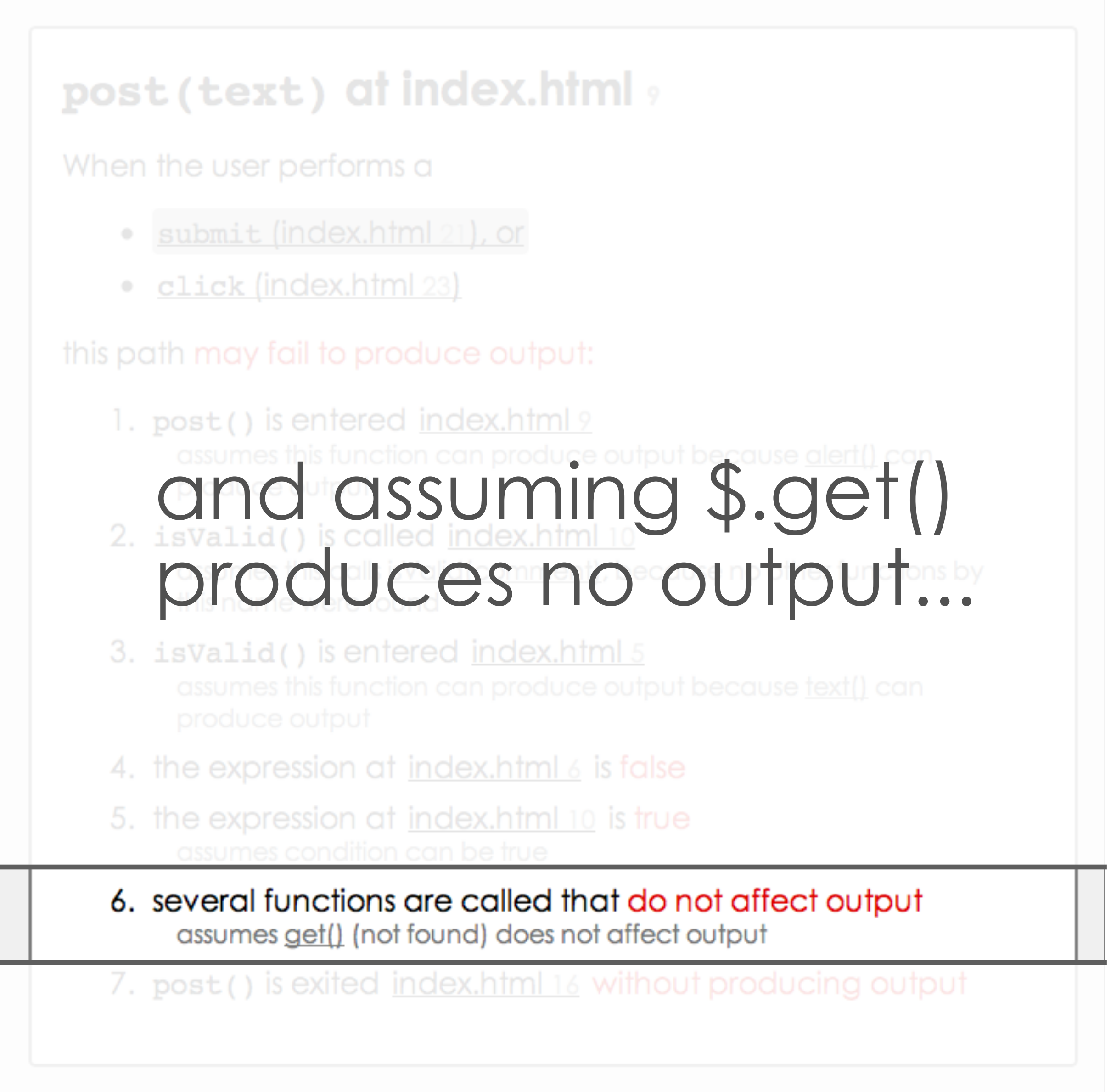
When the user performs a

- submit (index.html 21), or
- click (index.html 23)

this path may fail to produce output:

1. post() is entered index.html 9
   assumes this function can produce output because alert() can produce output
2. isValid() is called index.html 10
   assumes this calls isValid(comment), because no other functions by this name were found
3. isValid() is entered index.html 5
   assumes this function can produce output because text() can produce output
4. the expression at index.html 6 is false
5. the expression at index.html 10 is true
   assumes condition can be true
6. several functions are called that do not affect output
   assumes get() (not found) does not affect output
7. post() is exited index.html 16 without producing output

```
<form id='form' onsubmit="post
    <input id='comment' type='t
    <input onclick=post(form.co
</form>
<script type='text/javascript'
    function post(text) {
        if(isValid(comment))
            $.get("comment.php",
        else
            alert("Your comment
    }
    function isValid(comment)
        if(comment == '')
            $('#comment').text(
        return comment != '';
    }
</script>
```



post(text) at index.html 9

When the user performs a

- submit (index.html 21), or
- click (index.html 23)

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1. post() is entered index.html 9
   assumes this function can produce output because alert() can produce output
2. isValid() is called index.html 10
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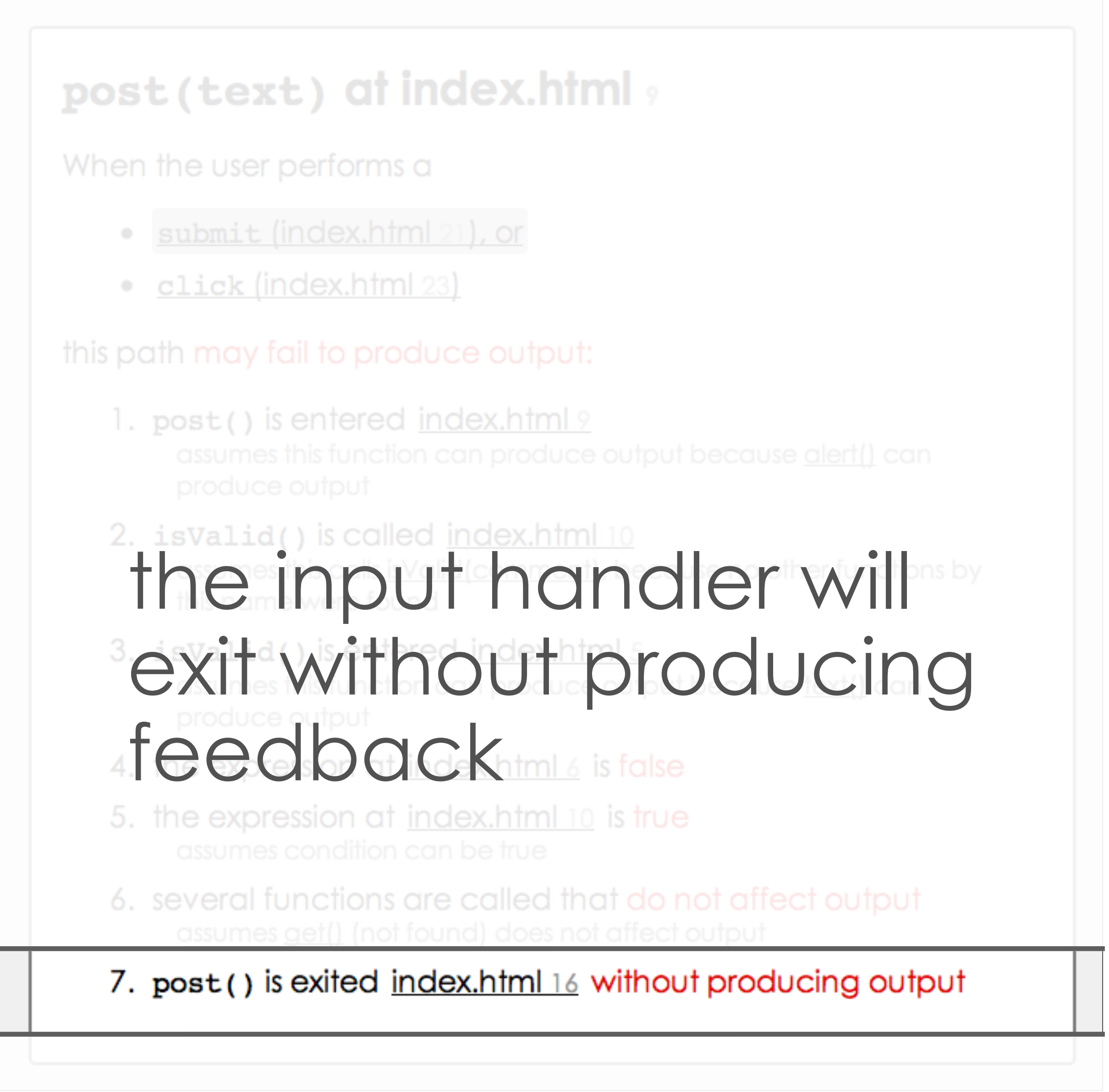
   assumes this function can produce output because text() can produce output
4. the expression at index.html 6 is false
5. the expression at index.html 10 is true
   assumes condition can be true
6. several functions are called that do not affect output
   assumes get() (not found) does not affect output
7. post() is exited index.html 16 without producing output

and assuming $.get() produces no output...

```
<form id='form' onsubmit="post
    <input id='comment' type='t
    <input onclick=post(form.co
</form>
<script type='text/javascript'
    function post(text) {
        if(isValid(comment))
            $.get("comment.php",
        else
            alert("Your comment
    }
    function isValid(comment)
        if(comment == '')
            $('#comment').text(
        return comment != '';
    }
</script>
```



post(text) at index.html 9

When the user performs a

- submit (index.html 21), or
- click (index.html 23)

this path may fail to produce output:

1. post() is entered index.html 9
   assumes this function can produce output because alert() can produce output
2. isValid() is called index.html 10
   assumes this calls isValid(comment) because no other functions by this name were found
3. isValid() is entered index.html 5
   assumes this function can produce output because text() can produce output
4. the expression at index.html 6 is false
5. the expression at index.html 10 is true
   assumes condition can be true
6. several functions are called that do not affect output
   assumes get() (not found) does not affect output
7. post() is exited index.html 16 without producing output

the input handler will exit without producing feedback

```
<form id='form' onsubmit="post
    <input id='comment' type='t
    <input onclick=post(form.co
</form>
<script type='text/javascript'
    function post(text) {
        if(isValid(comment))
            $.get("comment.php",
        else
            alert("Your comment
    }
    function isValid(comment)
        if(comment == '')
            $('#comment').text(
        return comment != '';
    }
</script>
```

```
<form id='form' onsubmit="post(form.comment.value)">
   <input id='comment' type='text' />
   <input onclick=post(form.comment.value)”>
</form>
<script type='text/javascript'>
   function post(text) {
      if(isValid(comment)){
         $.get("comment.php", { comment: text })
         .success(function() { alert(“submitted!”); }
         .error(function() { alert(“didn’t work.”); })
      }
      else
         alert("Your comment is invalid.");
   }
   function isValid(comment) {
      if(comment == '')
         $('#comment').text('write something!');
      return comment != '';
   }
</script>
```

the obvious solution is to add feedback on success

implementation

ten steps

1) identifying and naming functions
2) generating function control flow graphs
3) propagating type information
4) resolving function calls
5) identifying output-affecting statements
6) identifying input-handling functions
7) enumerating paths through input handlers
8) expanding paths through input handlers
9) Identifying output-lacking paths
10) clustering output-lacking paths

implementation

1) identifying and naming functions

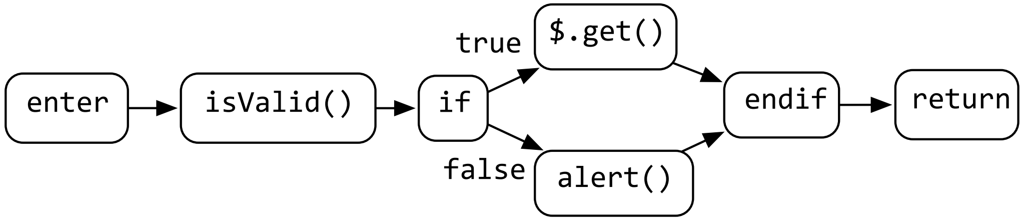
- only analyze client side JavaScript and HTML
  - all feedback is ultimately displayed by client
- all functions are found
  - except those generated dynamically

implementation

2) generating function control flow graphs

standard CFGs are created for each function

for example, **post()** from earlier



implementation

3) propagating type information

types of variables and properties are propagated through ASTs from literals, W3C DOM API properties and functions, and object literal declarations

e.g., document.getElementById() is assumed to return an HTMLElement

implementation

4) resolving function calls

all function calls are resolved using inferred type information

- when types aren't available, all functions are searched

to mitigate false positives

- **apply**() and **call**() are assumed to produce output

- **asynchronous calls** are are treated as synchronous

implementation

5) identifying output-affecting statements

output-affecting statements include

assignments to W3C DOM properties

e.g., **document.location**, **el.style.top**

jQuery, Prototype, and W3C DOM calls with DOM side effects

e.g., $(this).hide(), el.removeChild()

implementation

6) identifying input-handling functions

any function directly invoked by W3C input event handlers

includes assignments to properties that represent input handlers

e.g., el.onclick = goHome

also includes jQuery and Prototype bindings

e.g., $(this).click(goHome)

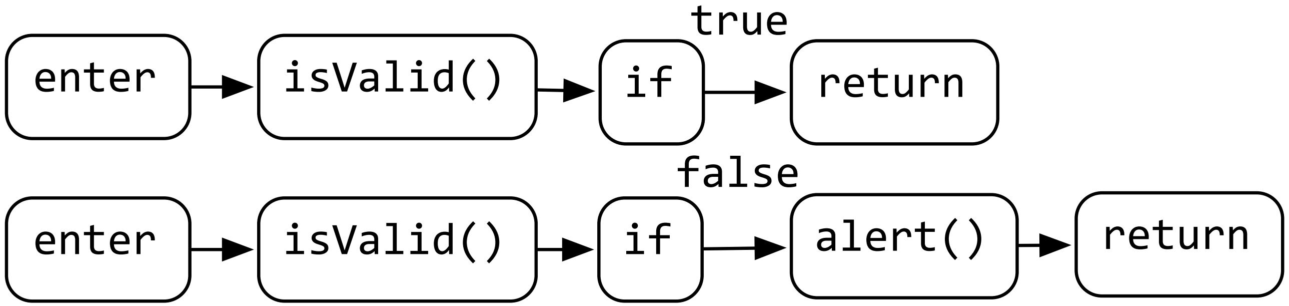
implementation

7) enumerating paths through input handlers

depth-first traversal through each input handler's CFG

only includes calls, returns, conditionals, and output-affecting statements

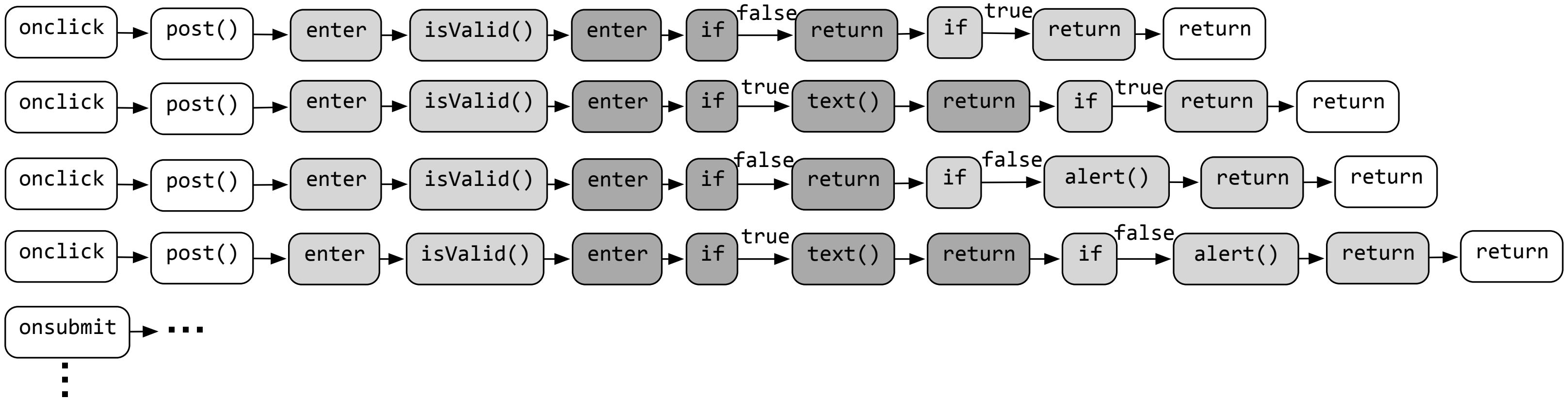
blocks that do not contain output-affecting statement are ignored



implementation

8) expanding paths through input handlers

all calls in the resulting paths through input handlers are expanded to all possible resolved functions



onclick → post() → enter → isValid() → enter → if → false → return → if → true → return → return

onclick → post() → enter → isValid() → enter → if → true → text() → return → if → true → return → return

onclick → post() → enter → isValid() → enter → if → false → return → if → false → alert() → return → return

onclick → post() → enter → isValid() → enter → if → true → text() → return → if → false → alert() → return → return

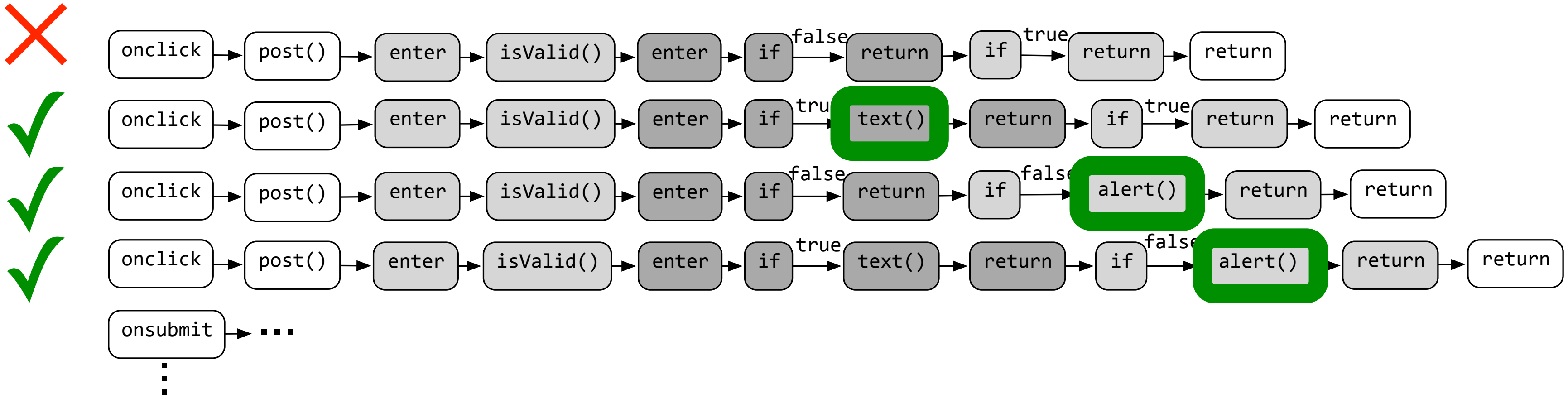
onsubmit → ...

⋮

implementation

9) Identifying output-lacking paths

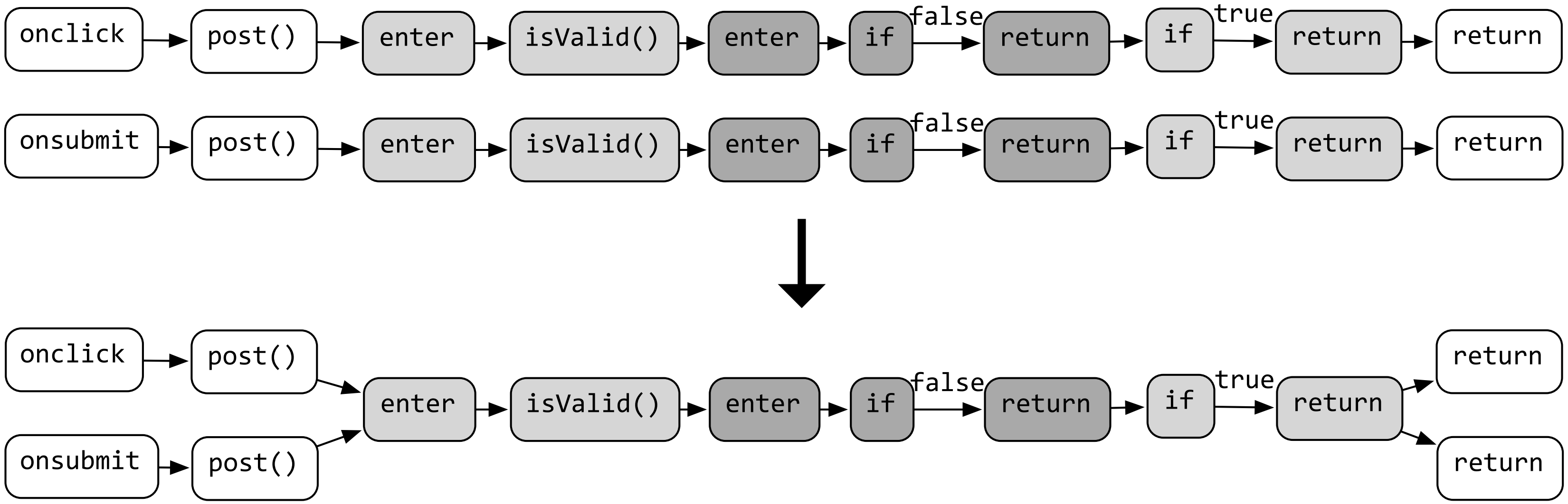
paths lacking an output affecting statement are marked as **output lacking**



implementation

10) clustering output-lacking paths

because handlers often reuse functions that produce output, paths with similar **critical paths** are clustered by identifying largest common subsequences



evaluation

are FeedLack’s warnings legitimate?

sampled 129 web application’s client-side code

- 14 failed due to **path explosion**

33/115 applications had no warnings

the 82 remaining had **647 output-lacking paths**

evaluation

classified each of the 647 warnings as one of

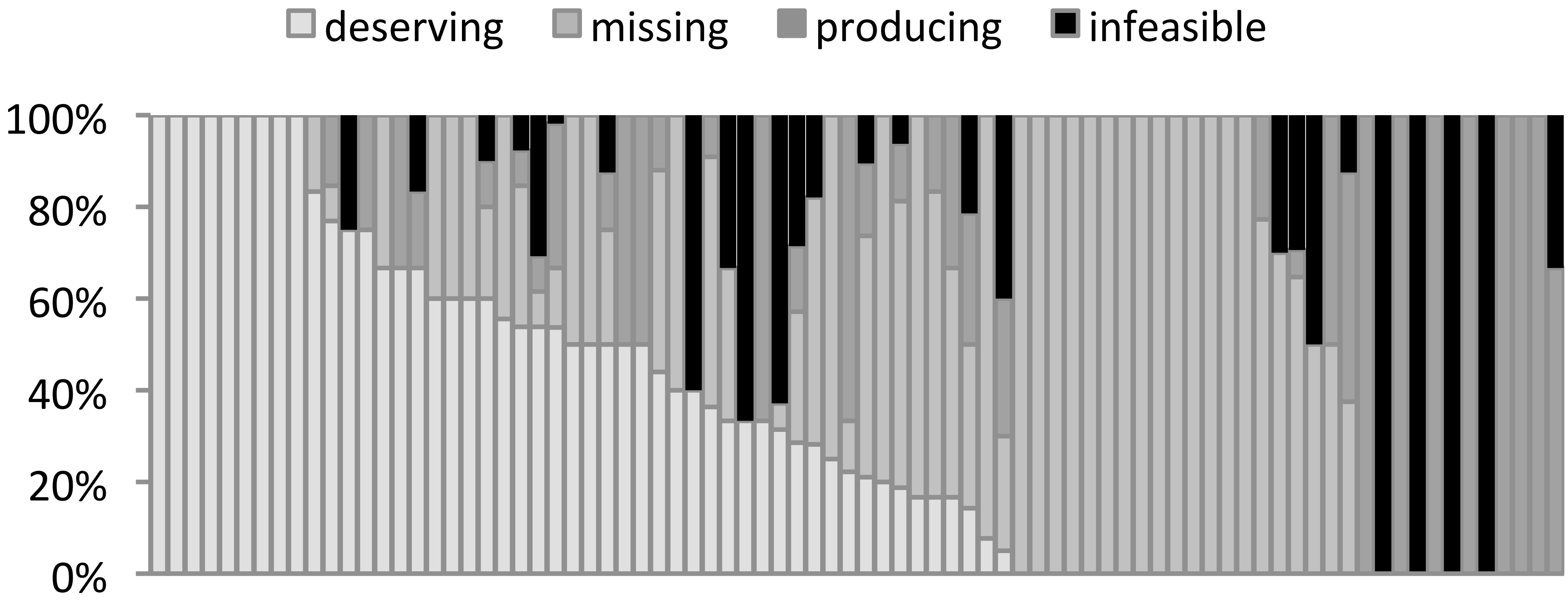
12% **infeasible paths**

18% **output-producing** false positives

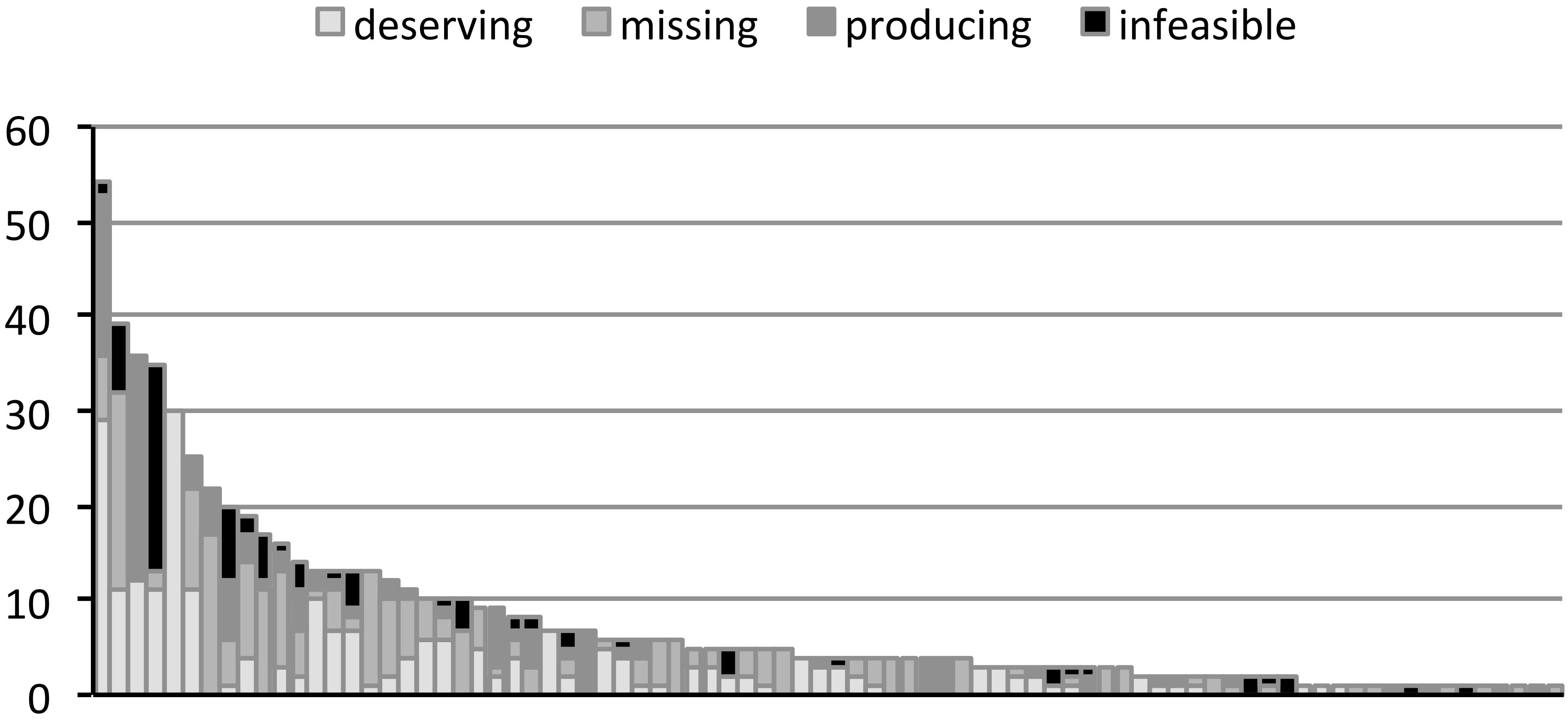
34% **output-missing** true positives that followed standard UI conventions

e.g., buttons that appeared disabled but did not produce feedback

36% **output-deserving** true positives that violated standard UI conventions



proportion of warning types per app



absolute warning counts per app

evaluation

- how severe were the true positives?
  - buttons that ignored input in certain modes
  - text controls that ignored keystrokes
  - dead links
  - silent errors
  - silent success
  - missing hover feedback
  - significantly delayed asynchronous feedback

limitations

- many false positives
  - due primarily to **imprecision** in type inference and call graph construction
- many true negatives
  - paths that produce output that is **imperceptible**

despite all of the **variation** in how web applications are written

there is **uniformity** in developers’ mistakes that we can detect and highlight

there is **uniformity** in developers' mistakes that we can detect and highlight

developers mistype names

developers overlook execution contexts that deserve user feedback

developers rarely comprehend the full extent of contexts in which their programs execute

what other details do developers overlook in web development?

control flow paths they’ve never executed

the full set of dependencies on the code they’re changing

silent failure of changes to the DOM

the device an app is being viewed on

the vision impairments of app users

the context in which user interface string literals appear

variations in the meaning of data

user interface dead ends

defect detection for the web

the very languages that **enable** this flexibility also impose some ~~serious~~ acceptable **tradeoffs**...

the result may be dynamic languages that have **some** of the benefits of static ones

...*without* imposing undue burden on developers

questions?

Cleanroom

FeedLack

etc.