DoDOM: Leveraging DOM Invariants for Web 2.0 Application Robustness Testing

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Web 2.0 Application: Amazon.com

Web 2.0 applications have many components, often from different domains

Web 2.0 Applications: JavaScript

Significant amount of JavaScript code executing in the browser

Web 2.0 Application: Amazon.com

Web Apps experience errors, yet they continue executing !

Problem

Web 2.0 applications error-prone because they

1. Are distributed and asynchronous
2. Integrate code and data from multiple domains
3. Have loose error-detection semantics

Need to test web app robustness using fault-injections

Challenging because web applications' behavior is non-deterministic from one execution to another

This Paper

- **Builds a characterization of web applications' behavior for robustness testing (fault-injections)**

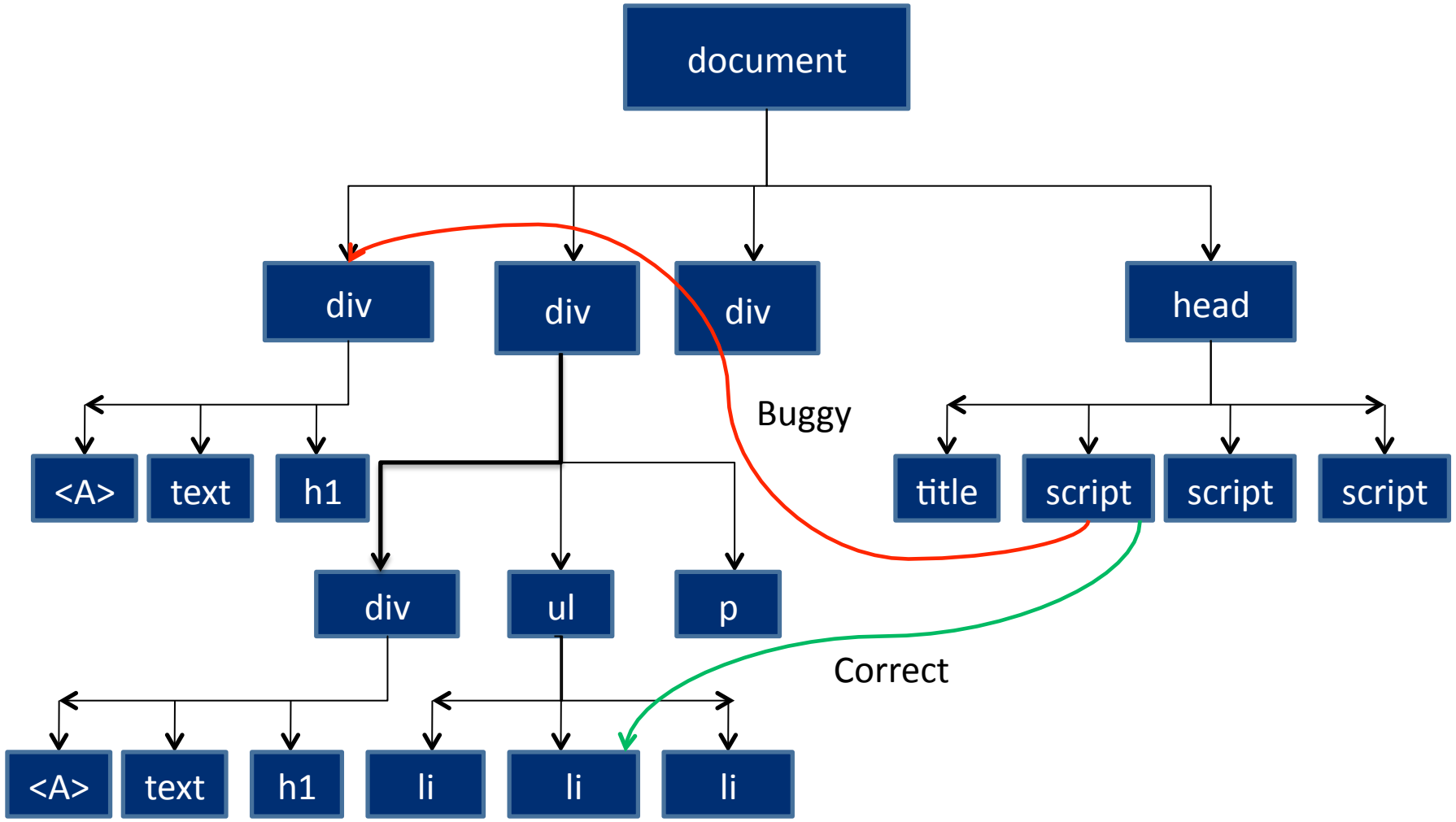
- **Goals**
  - Automated, i.e., no manual intervention
  - Language and platform neutral
  - Capable of handling real web applications

- **Approach: Dynamic extraction of DOM-based invariants in web applications - DoDOM**

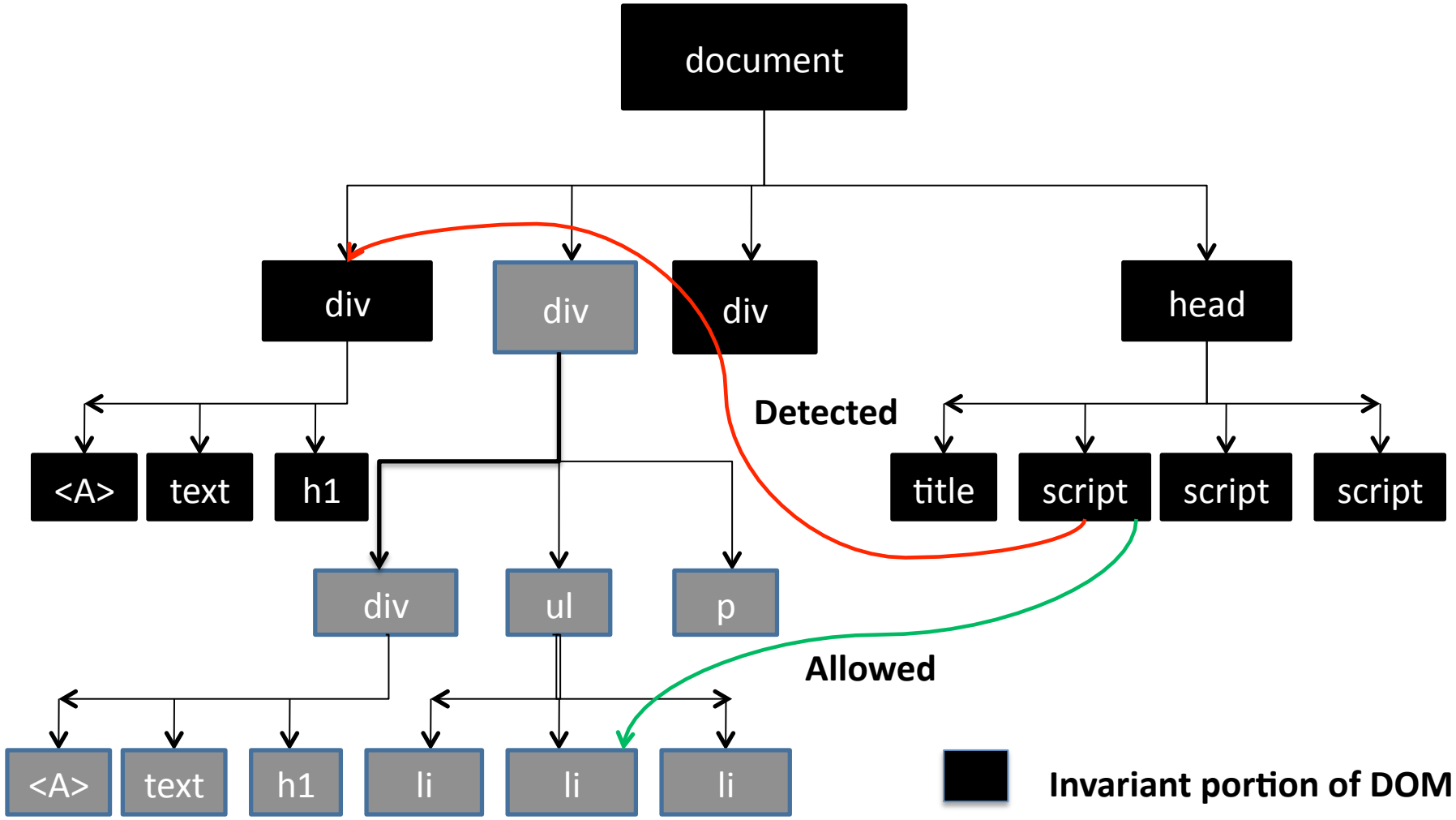
Example: HTML

```
<html>
<head>
        <title> …. </title>
          <script> …. </script>
          <script> … </script>
</head>
<body>
     <div> <A> …. </A> <text> … </text> <hl> … </hl> </div>
     <div>
       <div>…. </div>
       <ul> <li>…</li> <li>…</li><li> … </li> </ul>
       <p> … </p>
     </div>
  <div> … </div>
</body>
</html>
```

Example: DOM


document
div
div
div
head
Buggy
<A>
text
h1
title
script
script
script
div
ul
p
Correct
<A>
text
h1
li
li
li

Example: Invariant DOM



DoDOM: Contributions

- **DOM invariants can be learned dynamically**
  - Automated tool called DoDOM
- **Invariants exist in many Web 2.0 applications**
  - Stabilize within a few executions
  - Incur very few false-positives
- **Invariants are useful for error detection**
  - Both for event errors and domain failures

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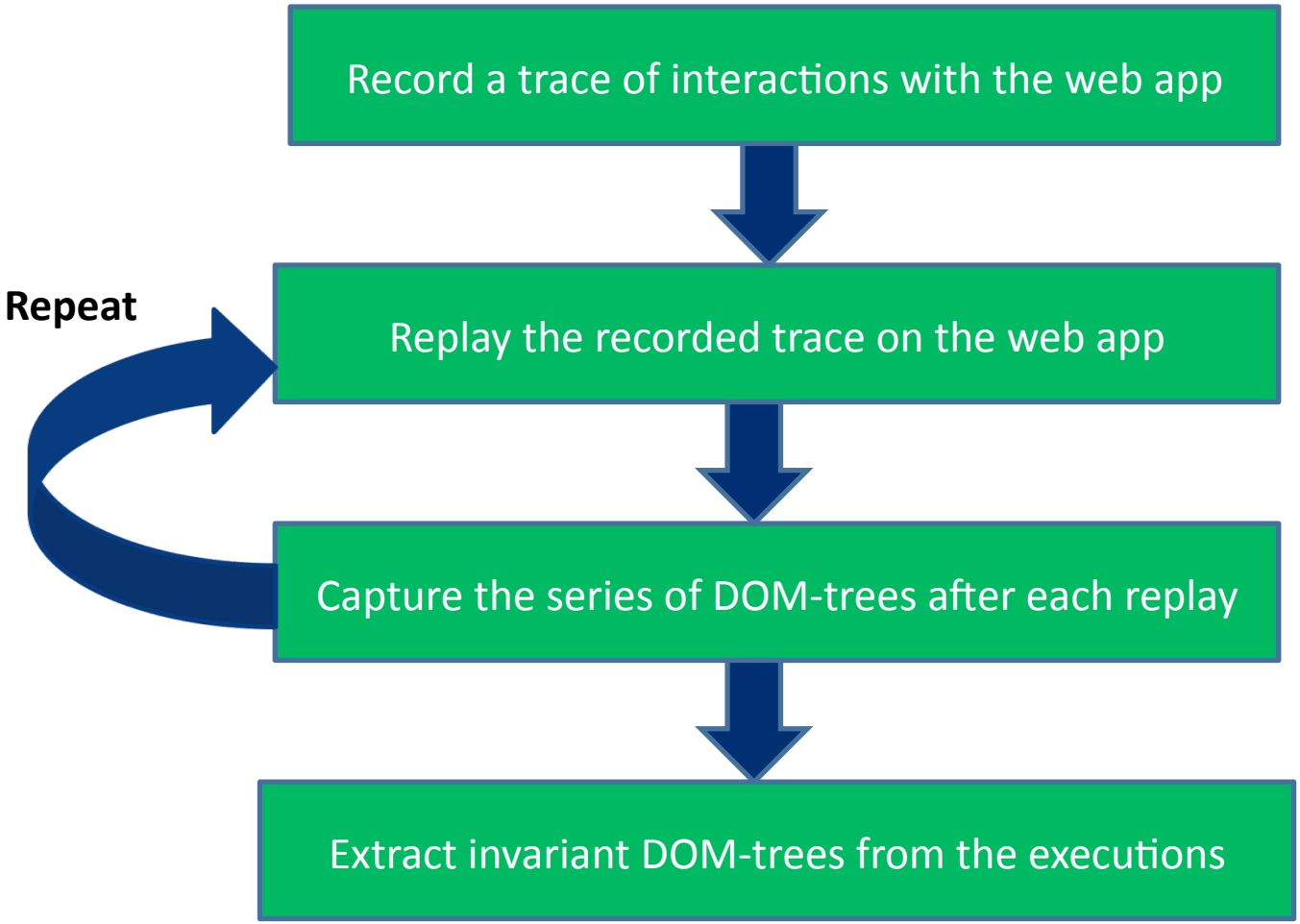
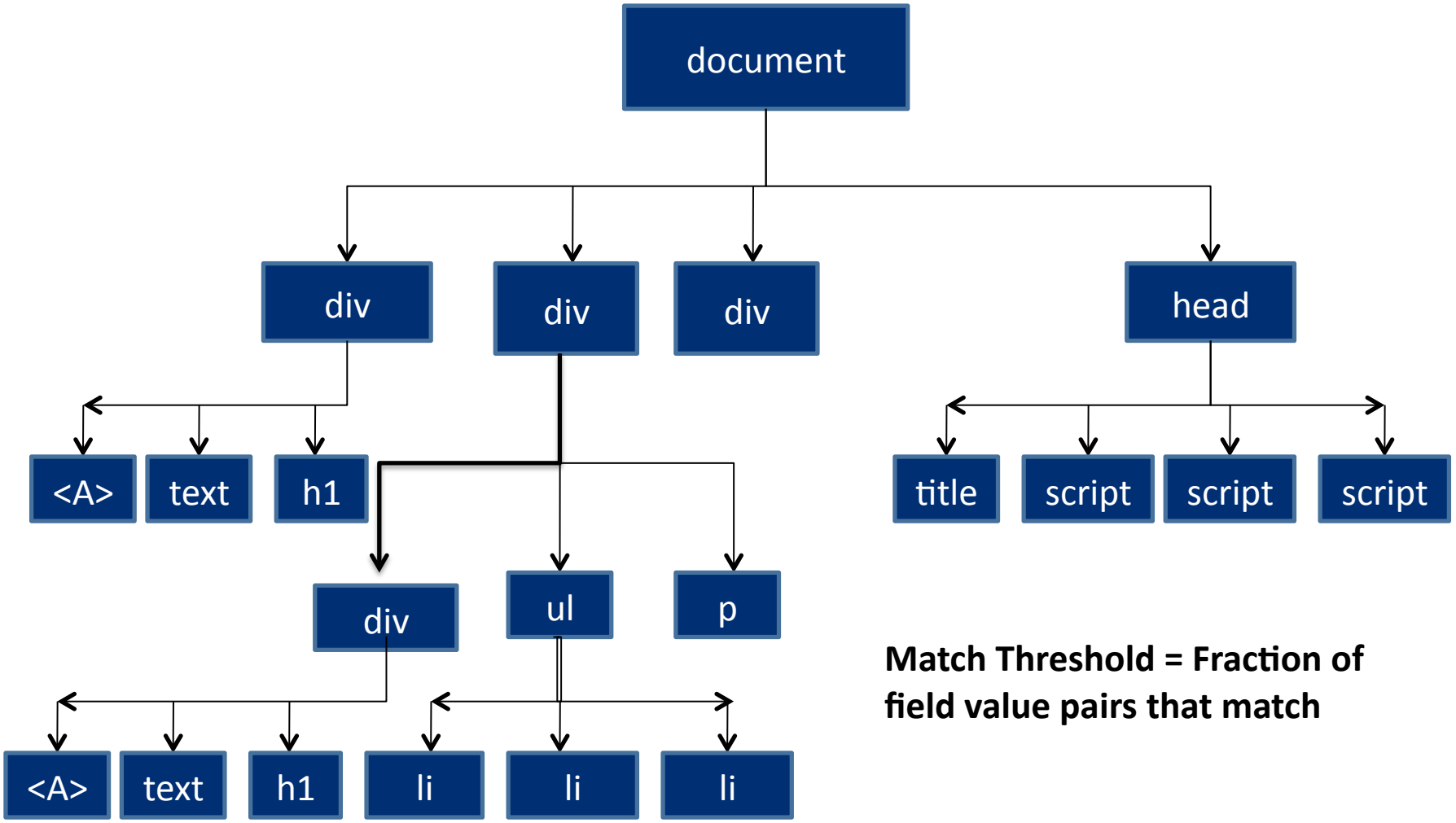
DoDOM: Approach

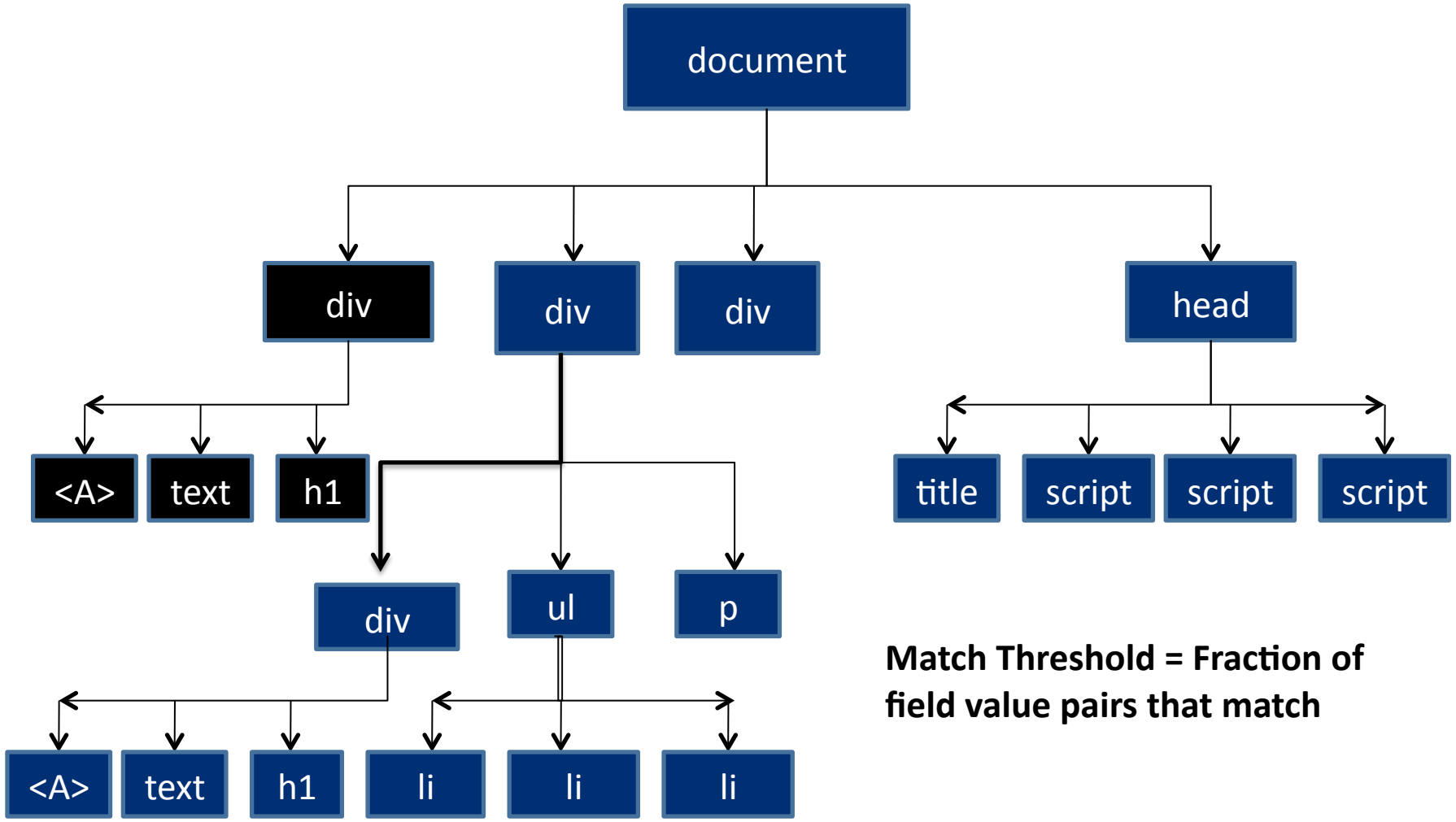


DoDOM: Invariant Extraction



Match Threshold = Fraction of field value pairs that match

DoDOM: Invariant Extraction



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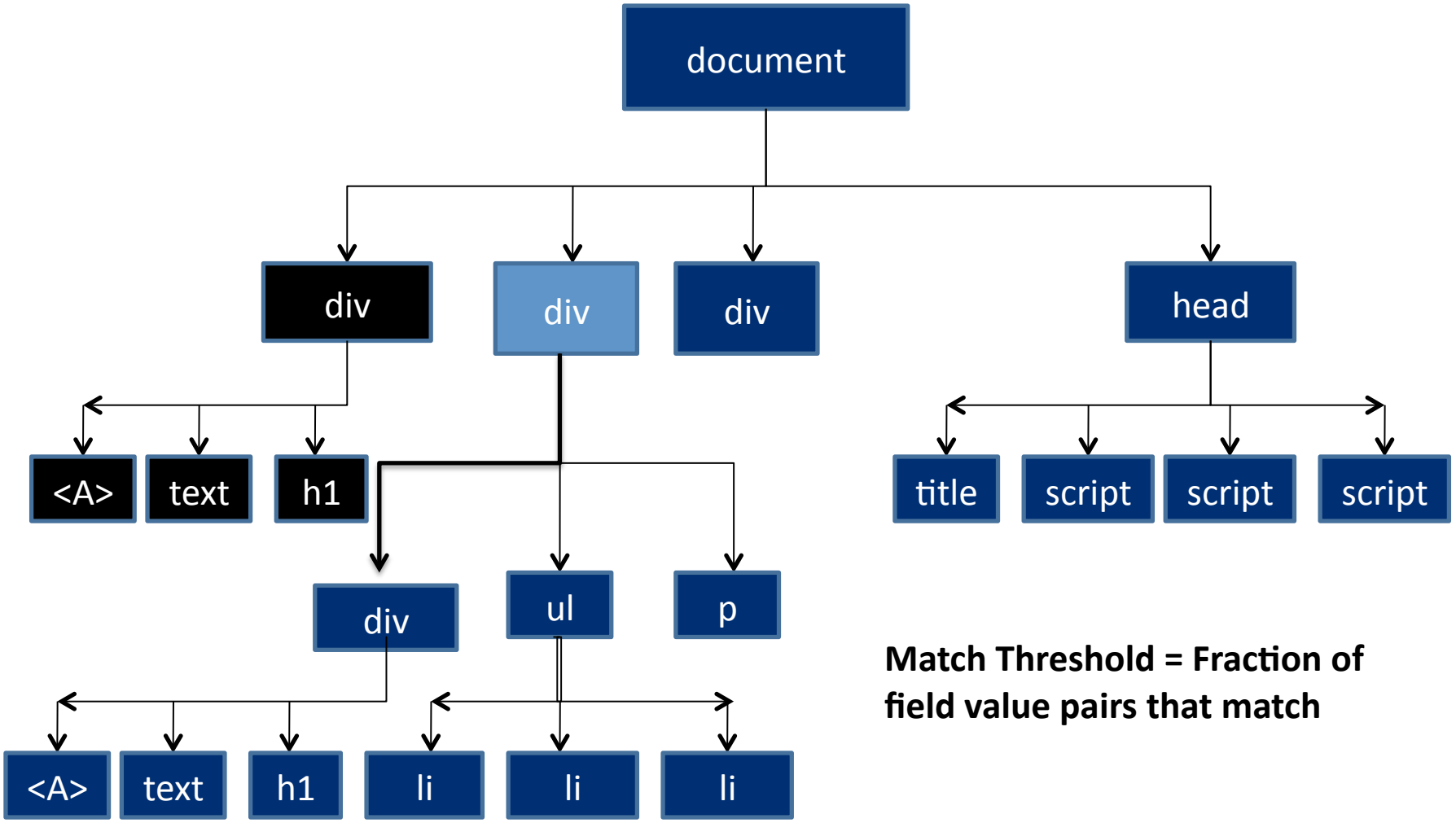

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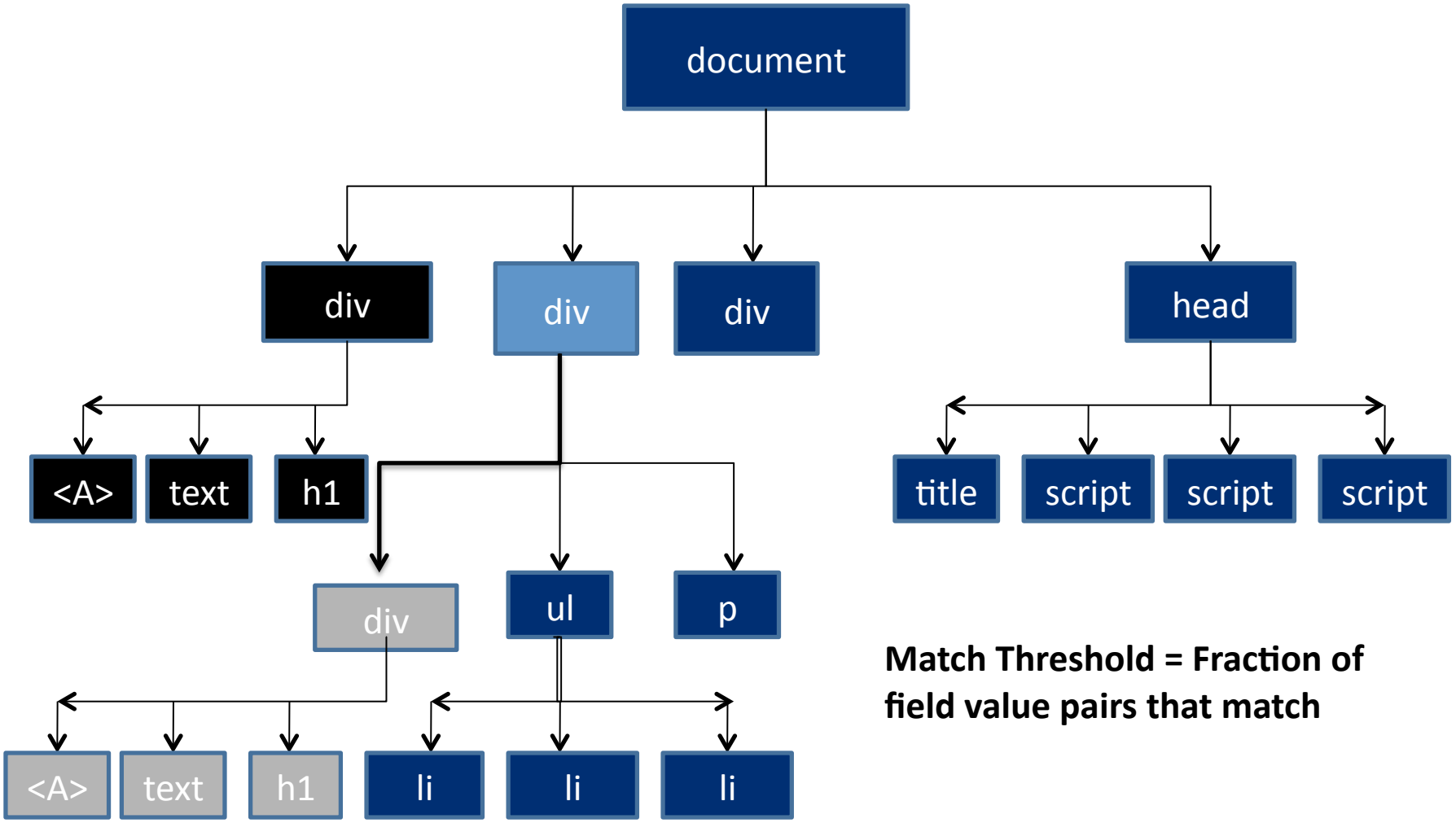

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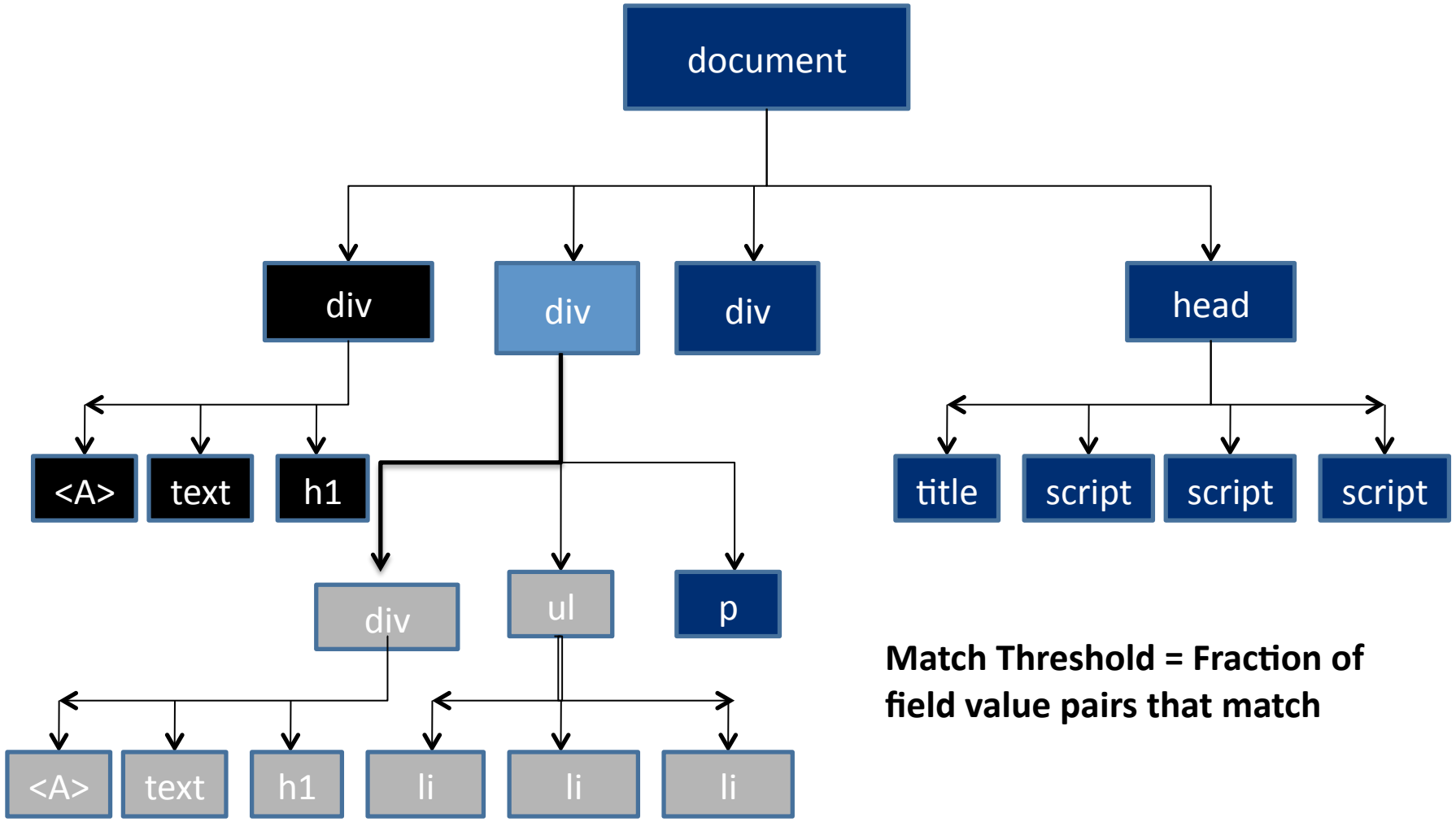

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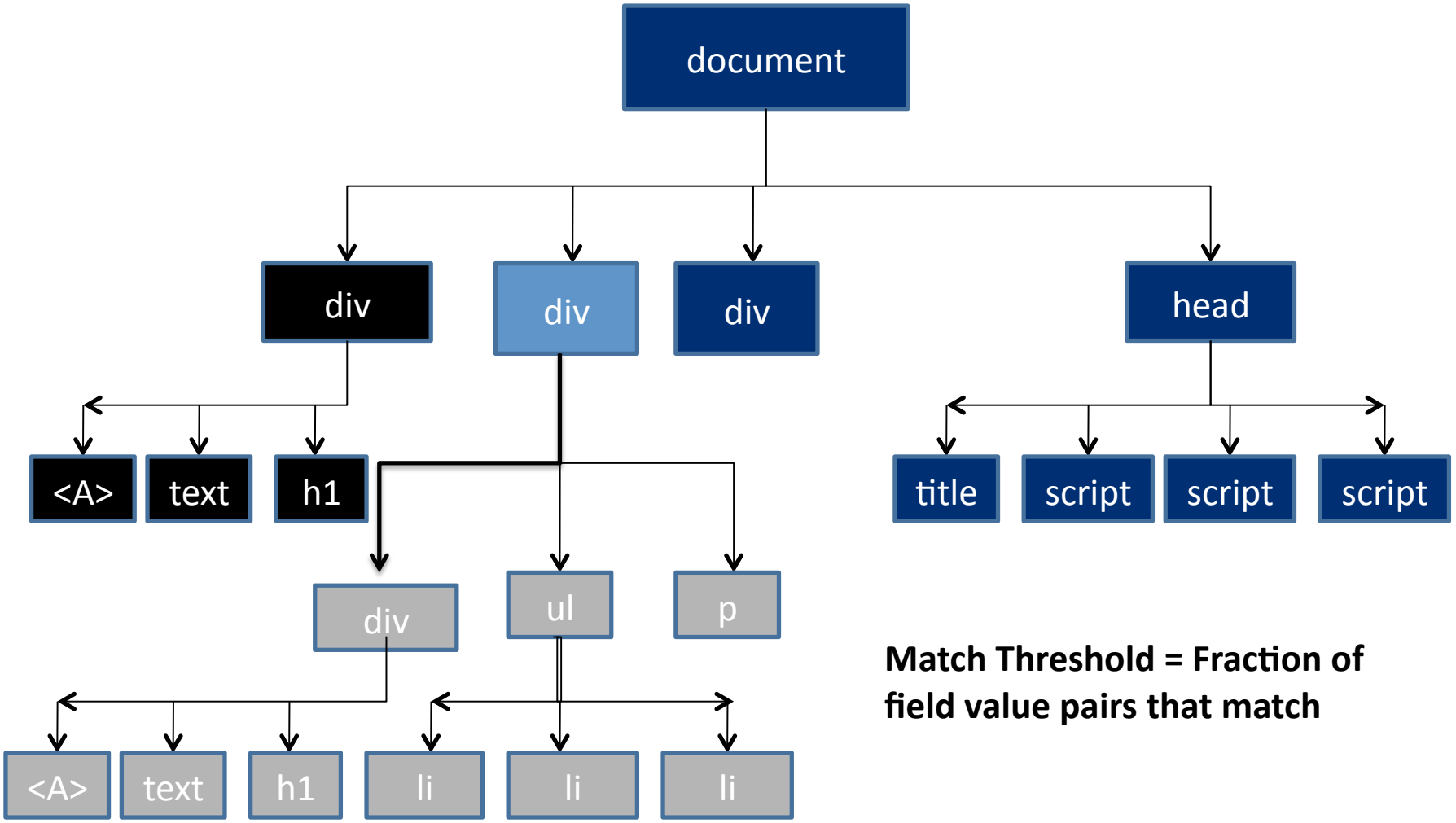

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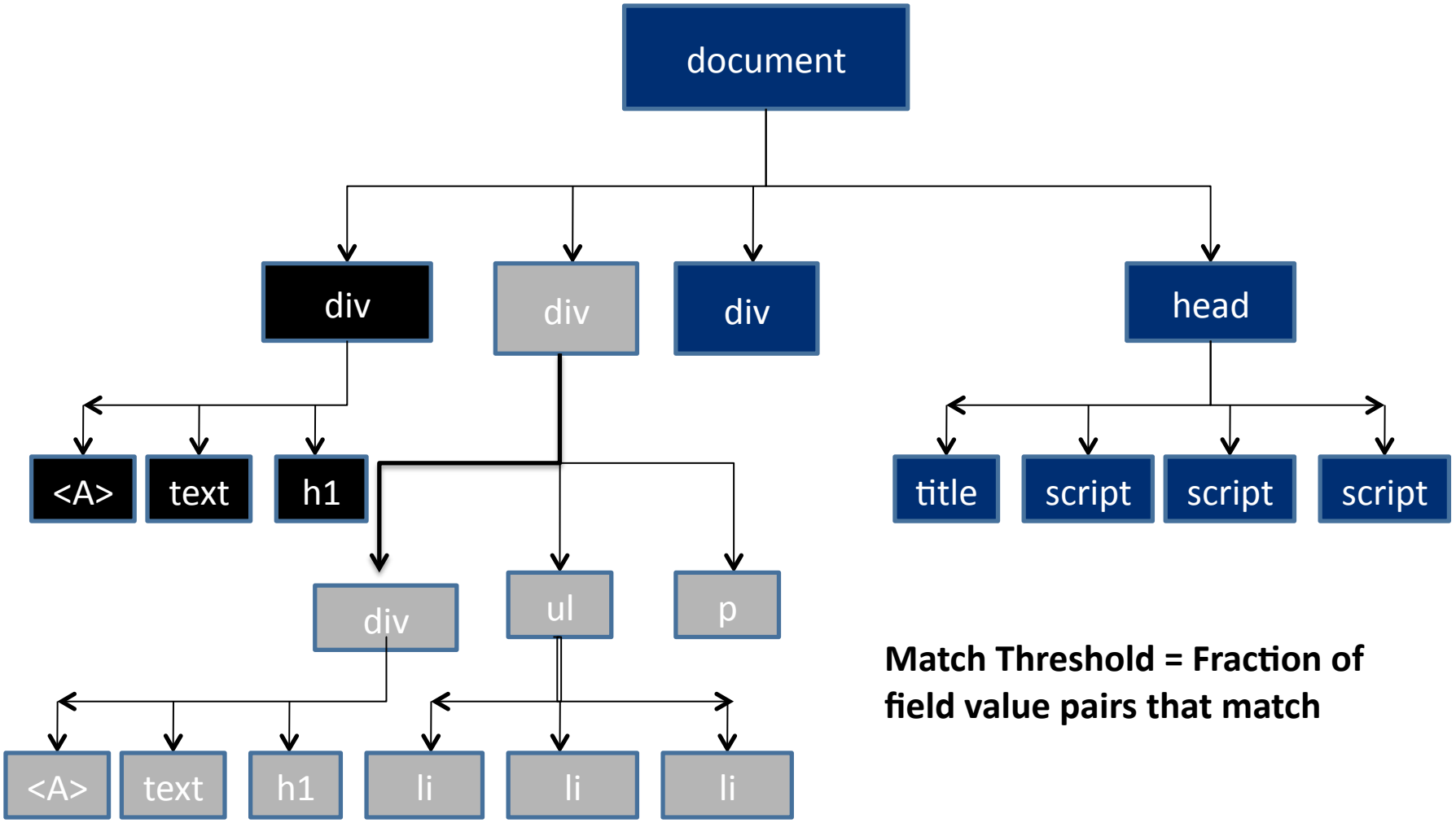

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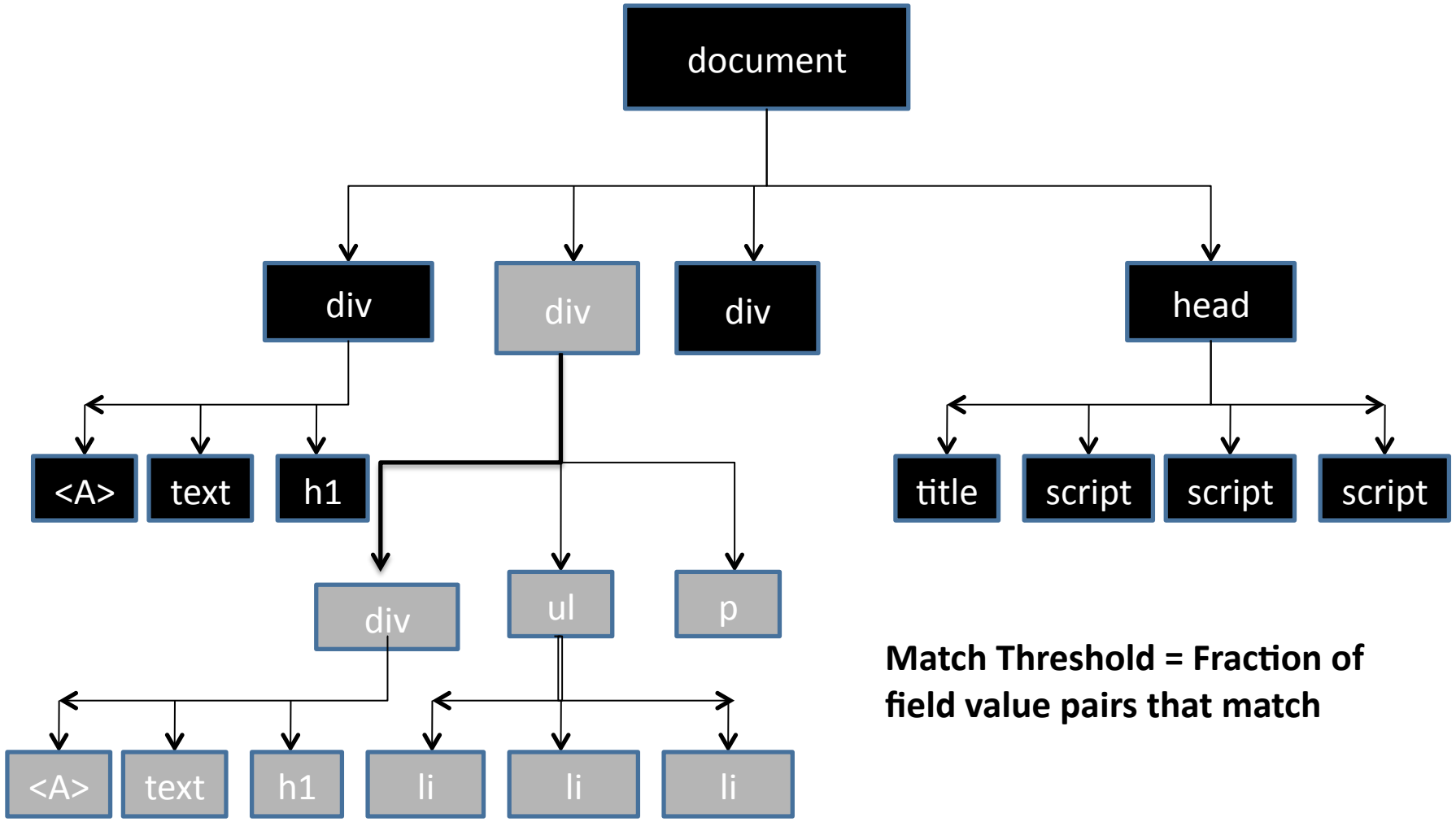
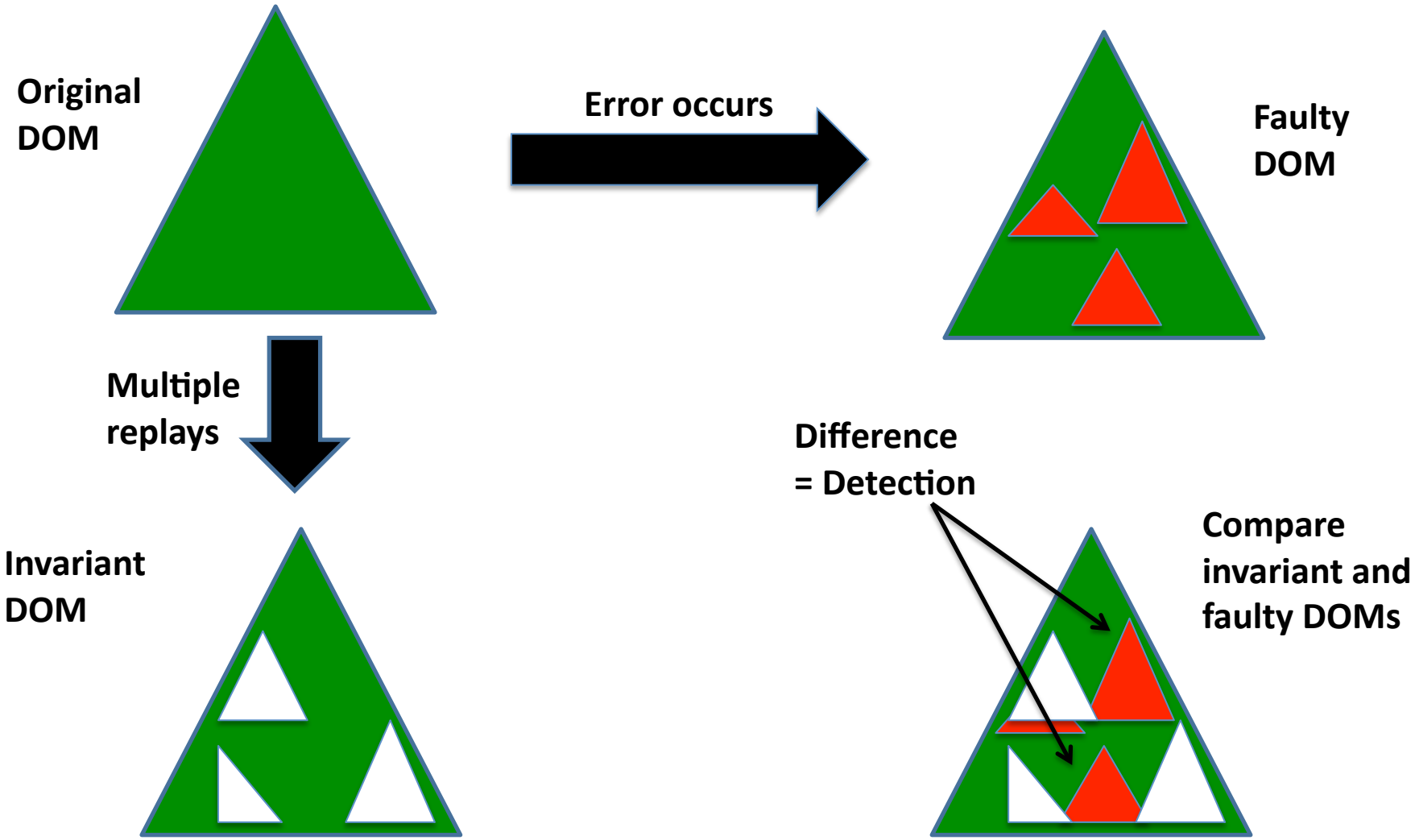


Match Threshold = Fraction of field value pairs that match

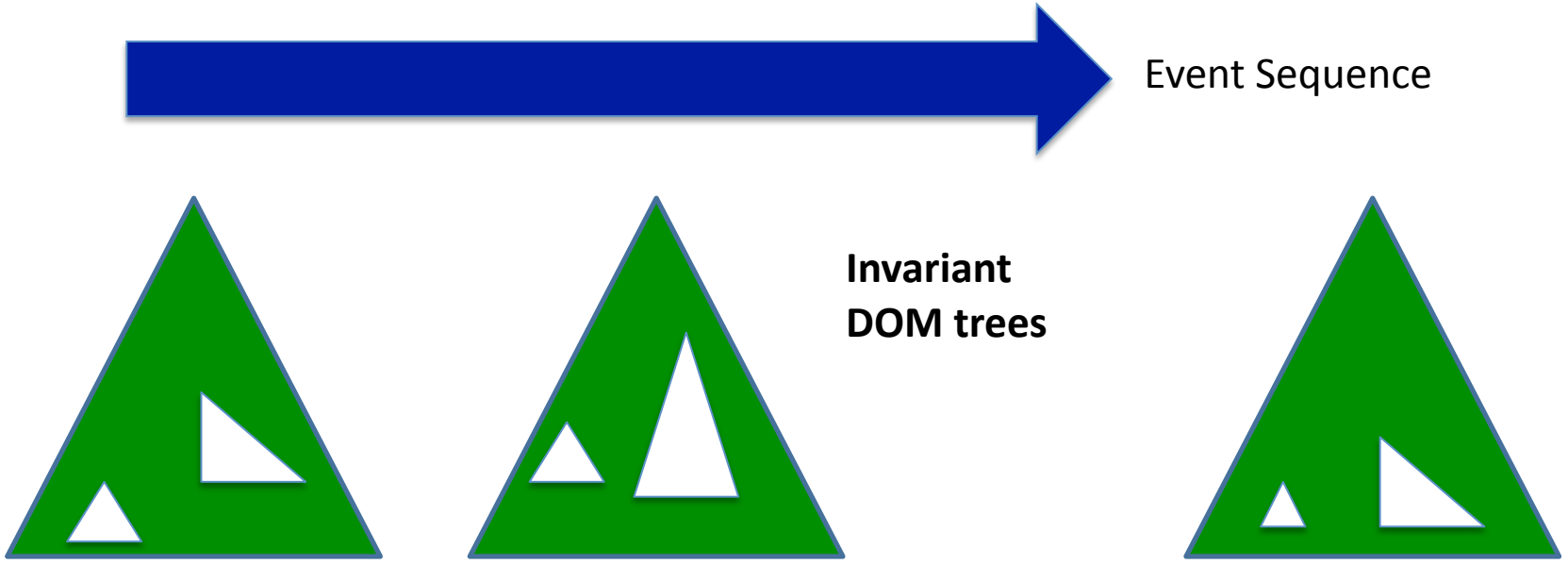
DoDOM: Error Detection



Invariant DOM Sequences

Event Sequence: Sequence of events recorded in a trace

DOM Tree Sequence: Sequence of DOM trees after each event



Event 1 Event 2 … Event N

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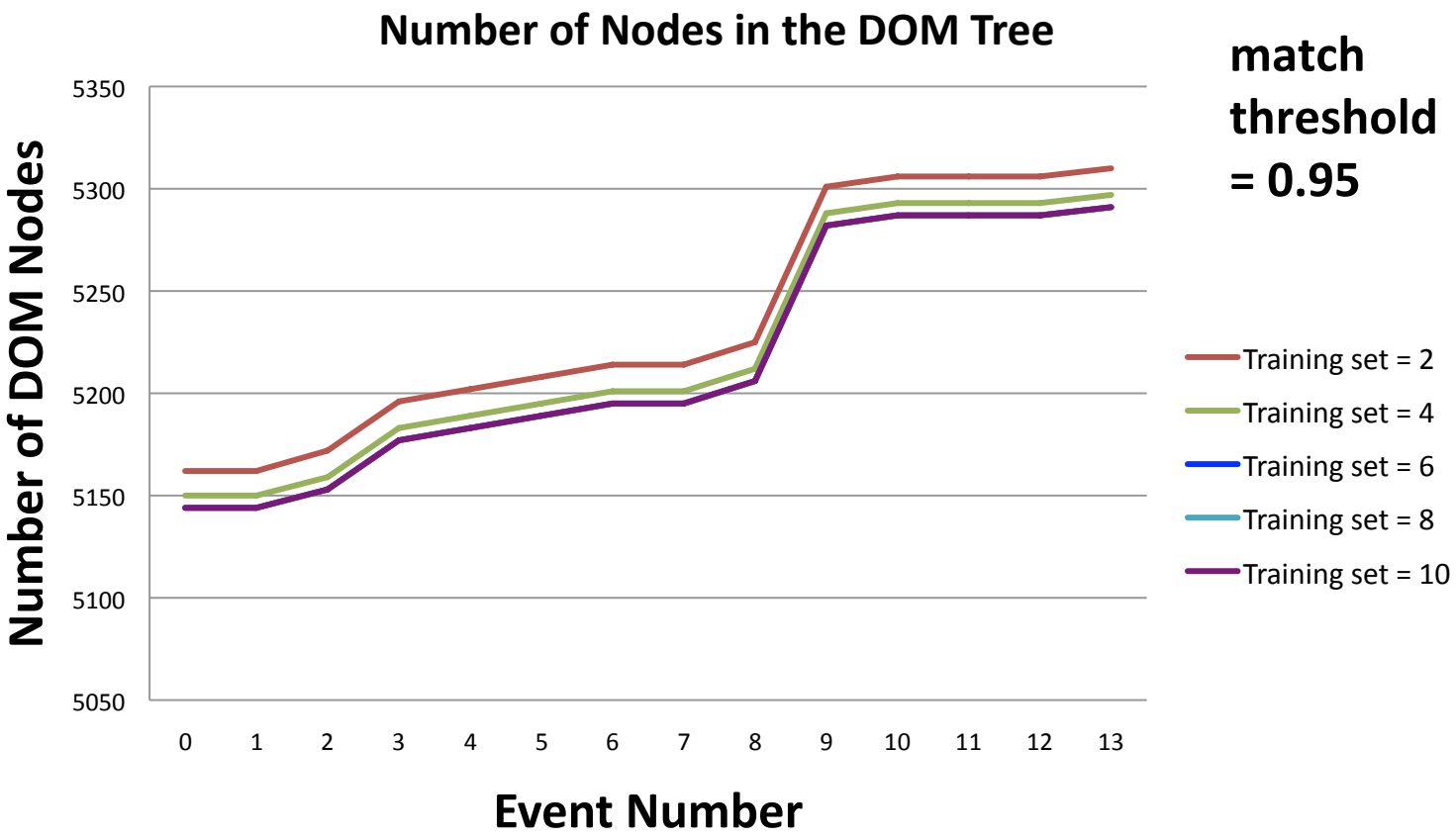
Experimental Setup

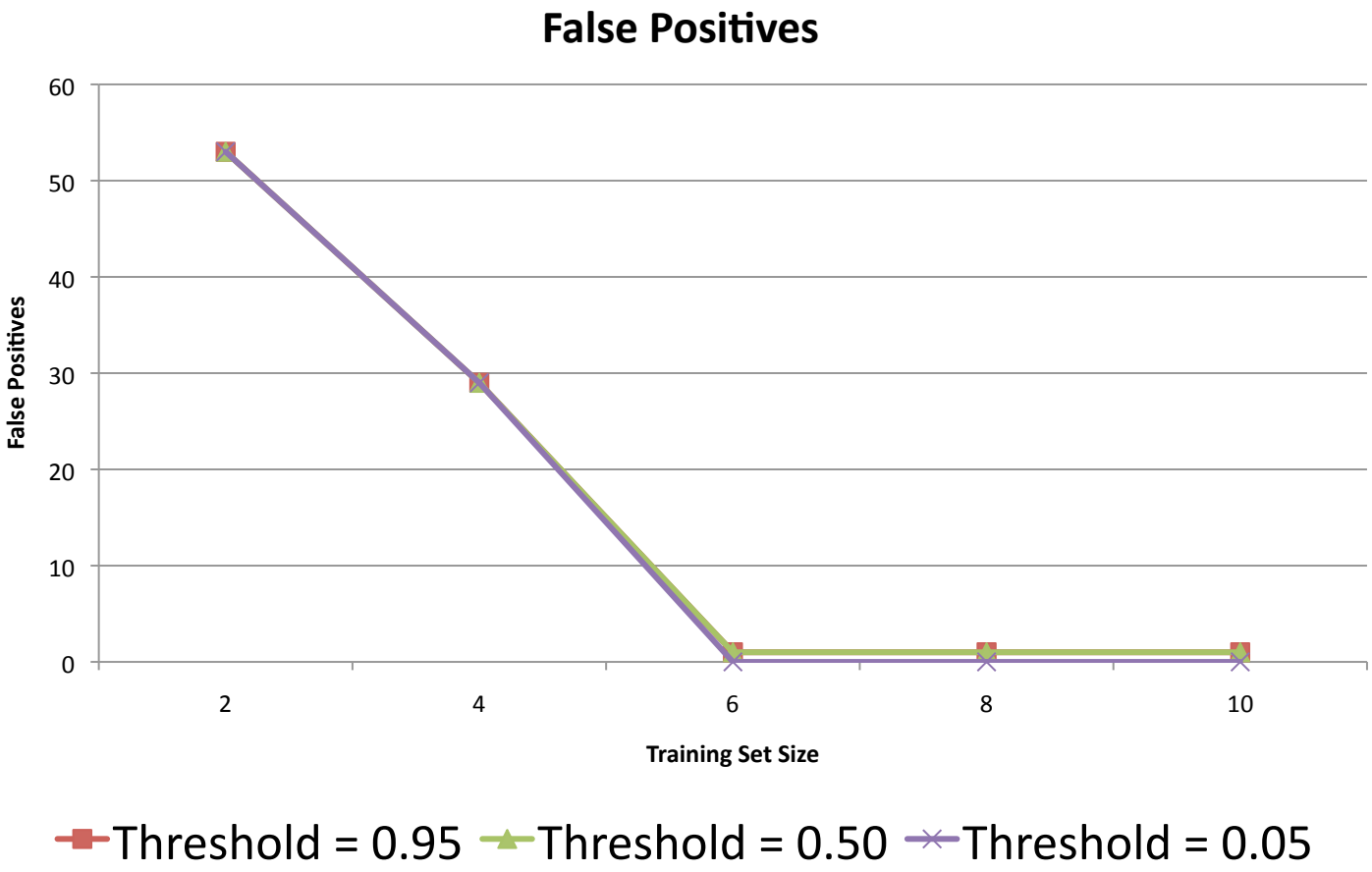
- **Focused mainly on results from Slashdot appln.**
  - Nearly 10000 lines of JS code in the application
  - User interaction by reading and expanding comments
  - Gathered a trace of 13 events with DoDOM
- **Did a replay of the trace 58 times (with DoDOM)**
  - Analyzed the DOM trees and extracted invariant DOM
  - Varied training set size from 1 to 10 executions
  - Chose match thresholds of 0.05, 0.50 and 0.95

Results-1 (Invariants)



Convergence of DOM-trees with a training set size of 6 (~10%)
Invariant DOM tree contains about 99% of original DOM tree nodes

Results - 2 (False-positives)



False positives drop sharply after 6 executions (10% of total)

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Fault Injection Experiments

Event Errors

- Emulated by dropping events from the trace one at a time, during replays

Trace

Fault-injected Trace

Domain Failures

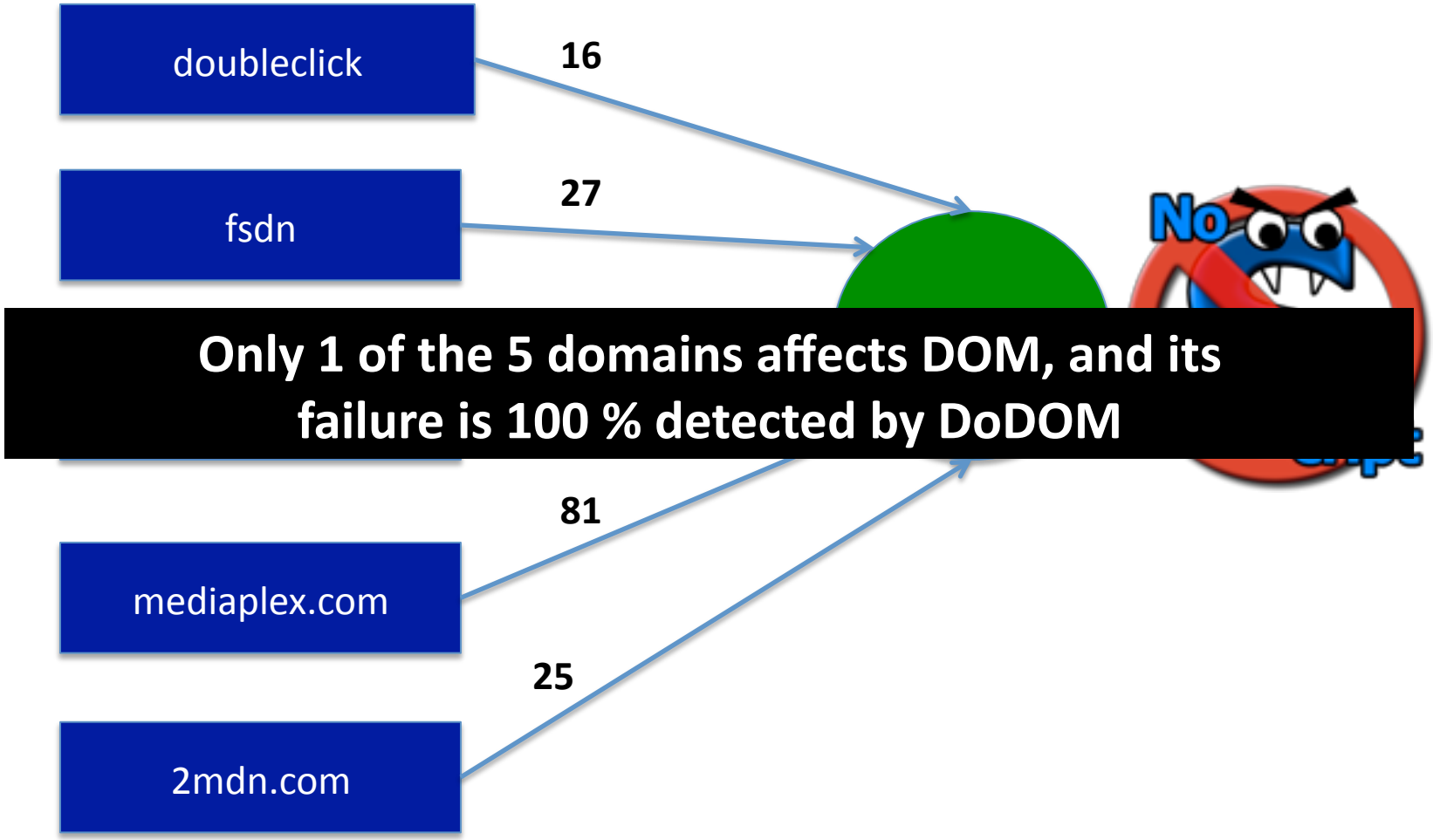
- Blocked domains one at a time during replays
  - All scripts from domain blocked during replays

Results - 3 (Event Errors)

Event No	Affects DOM ?	Injected	Detected
1	No	5	0
2	**Yes**	**5**	**5**
6	**Yes**	**5**	**5**
7	No	5	0
8	**Yes**	**5**	**5**
9	No	5	0
10	**Yes**	**5**	**5**
11	No	5	0
12	No	5	0
13	**Yes**	**5**	**5**

100 % detection for event failures whose handlers affect the DOM

Results – 4 (Domain Failures)



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Other Websites

Training Set Size	JavaPetStore	CNN.com
2	397	2413
4	397	2408
6	387	2407
8	387	2407
10	387	2407

Training set size of 6 is sufficient for deriving invariants

Related Work

- **Regression testing of Web 1.0 Applications**
  - [Sprenkle'05], [Dobolyi'09]
- **Automated testing of Web 2.0 Applications**
  - [Marchetto'08], ATUSA [Mesbah'09]
- **Dynamic invariant detection in programs**
  - DAIKON [Ernst'01], HeapMD[Chilimbi'06]

Summary

- **Web 2.0 applications are error prone**
  - Multiple scripts interact in ad-hoc ways
- **DOM invariants for robustness testing**
  - **DoDOM** tool to dynamically learn the invariants
  - Real web applications exhibit invariants
  - High coverage for errors that impact DOM
- **Future Work**
  - Extension to security attacks
  - Extension to richer fault models

DoDOM: Implementation