Detecting and Diagnosing Errors in Replaying Archived Web Pages

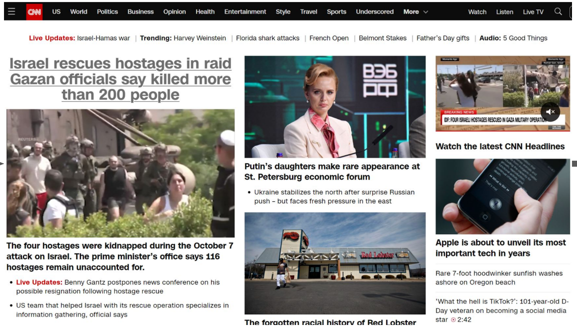
Jingyuan Zhu Huanchen Sun Harsha V. Madhyastha

UNIVERSITY OF MICHIGAN

USC University of Southern California

Web archives capture and serve snapshots of webpages

Record: Crawler → Crawl →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BREAKING NEWS
IDF: FOUR ISRAELI HOSTAGES RESCUED IN GAZA MILITARY OPERATION
Red Lobster

Israel rescues hostages in raid Gazan officials say killed more than 200 people

The four hostages were kidnapped during the October 7 attack on Israel. The prime minister's office says 116 hostages remain unaccounted for.

- Live Updates: Benny Gantz postpones news conference on his possible resignation following hostage rescue
- US team that helped Israel with its rescue operation specializes in information gathering, official says

Putin's daughters make rare appearance at St. Petersburg economic forum

- Ukraine stabilizes the north after surprise Russian push – but faces fresh pressure in the east

The forgotten racial history of Red Lobster

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Apple is about to unveil its most important tech in years

Rare 7-foot hoodwinker sunfish washes ashore on Oregon beach

'What the hell is TikTok?': 101-year-old D-Day veteran on becoming a social media star ⊙ 2:42

→ Generate →

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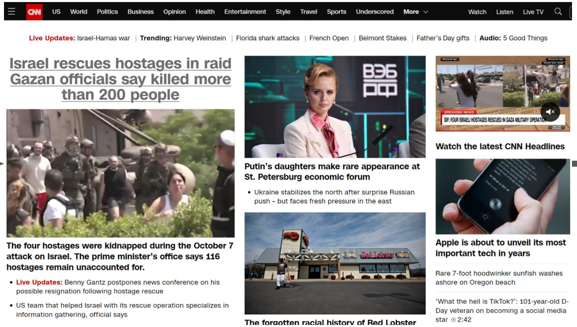

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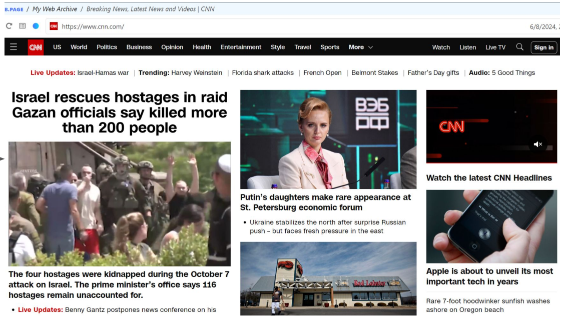
→ Generate → .warc

Replay: .warc → Input → INTERNET ARCHIVE WayBackMachine pywb →



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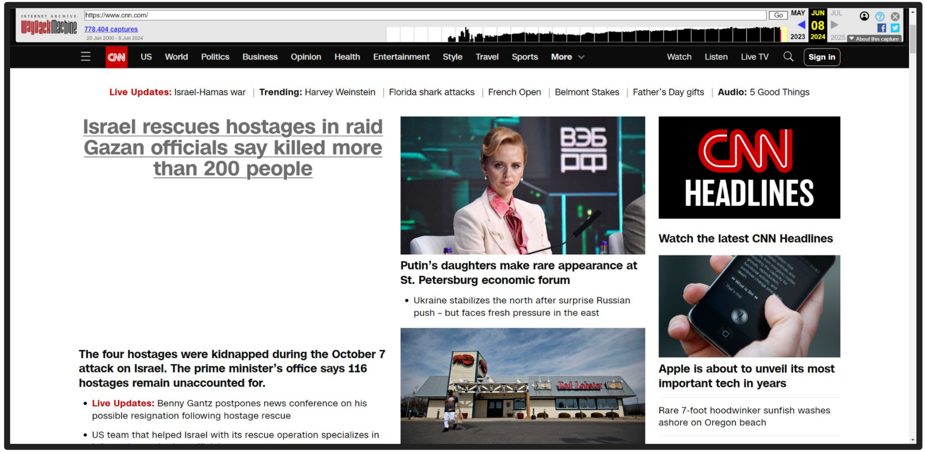
Need to rewrite URLs for crawled resources

With rewriting



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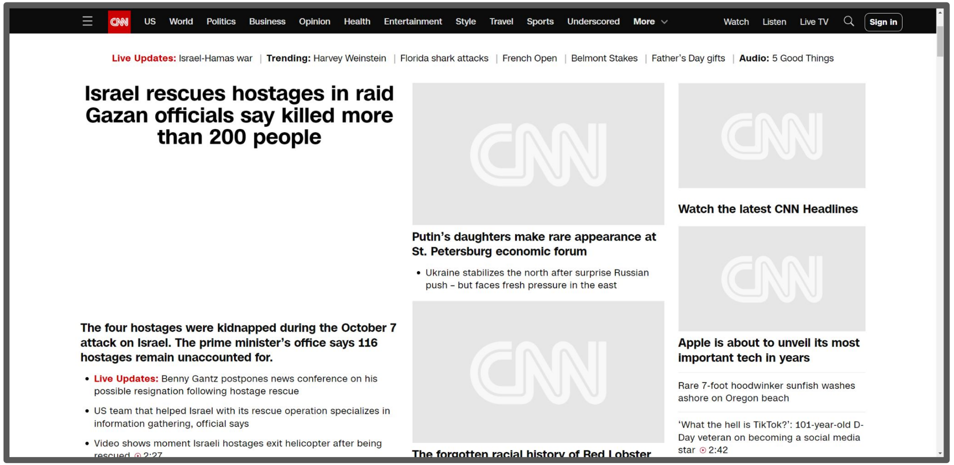
Without rewriting



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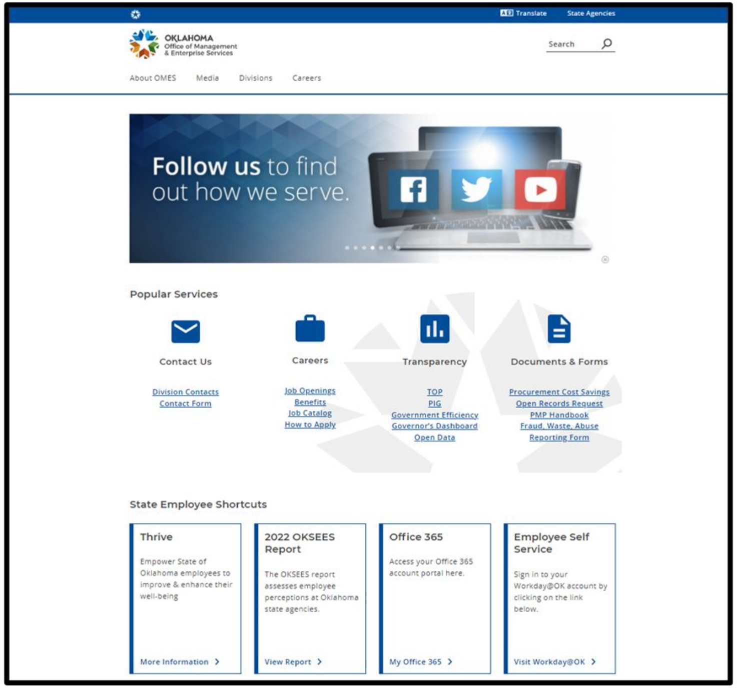
- **Live Updates:** Benny Gantz postpones news conference on his possible resignation following hostage rescue
- US team that helped Israel with its rescue operation specializes in information gathering, official says
- Video shows moment Israeli hostages exit helicopter after being rescued ⦿ 2:27

The forgotten racial history of Red Lobster

However, JS rewrites can lead to fidelity issues

Live web page



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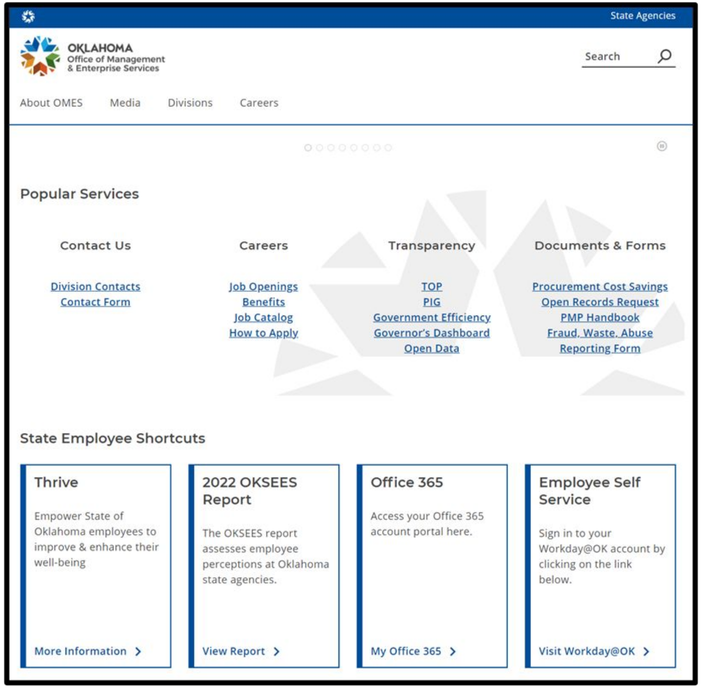

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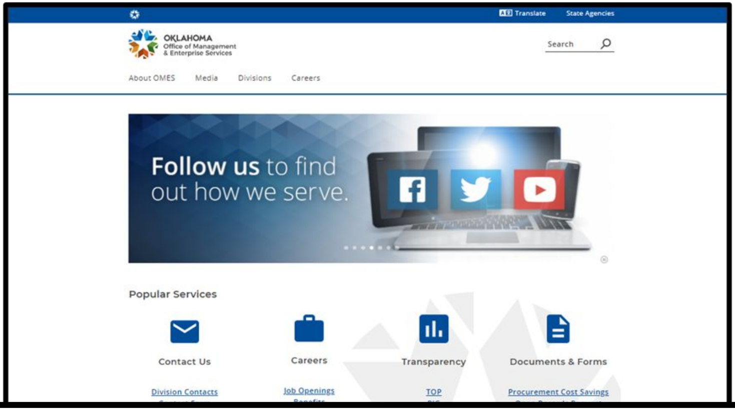
However, JS rewrites can lead to fidelity issues

Live web page



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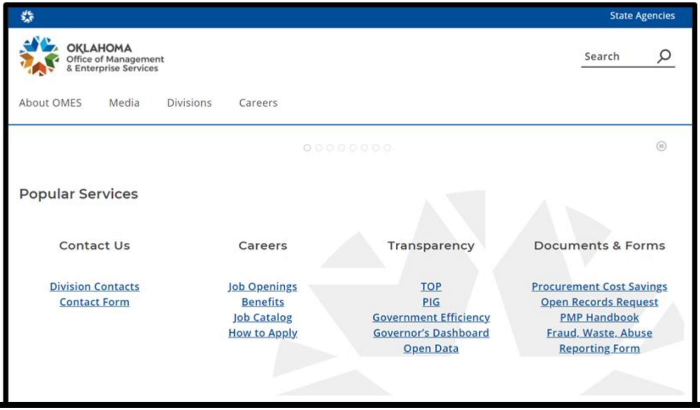

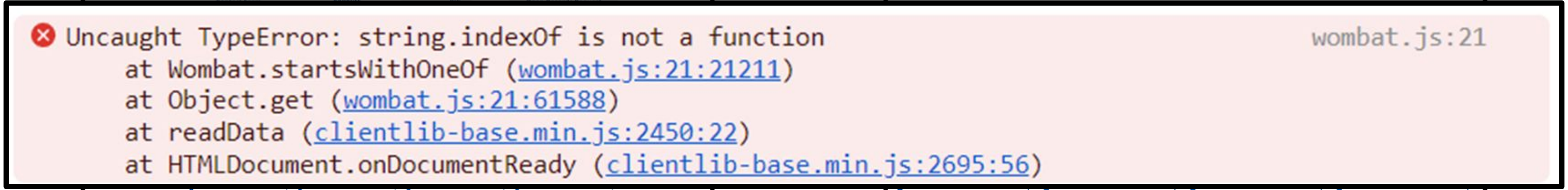

```
✖ Uncaught TypeError: string.indexOf is not a function                wombat.js:21
     at Wombat.startsWithOneOf (wombat.js:21:21211)
     at Object.get (wombat.js:21:61588)
     at readData (clientlib-base.min.js:2450:22)
     at HTMLDocument.onDocumentReady (clientlib-base.min.js:2695:56)
```

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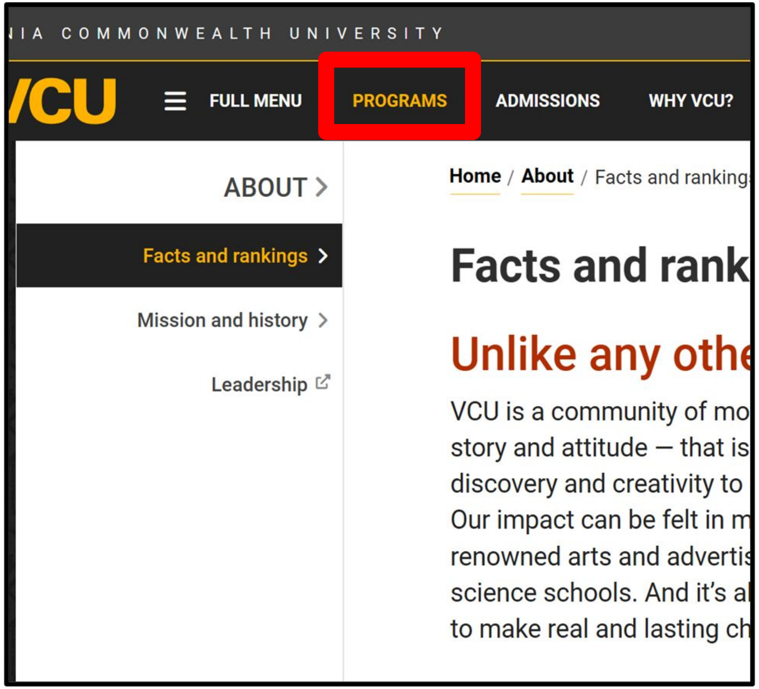
Live web page



IA COMMONWEALTH UNIVERSITY

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Facts and rank

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VCU is a community of mo
story and attitude — that is
discovery and creativity to
Our impact can be felt in m
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science schools. And it's al
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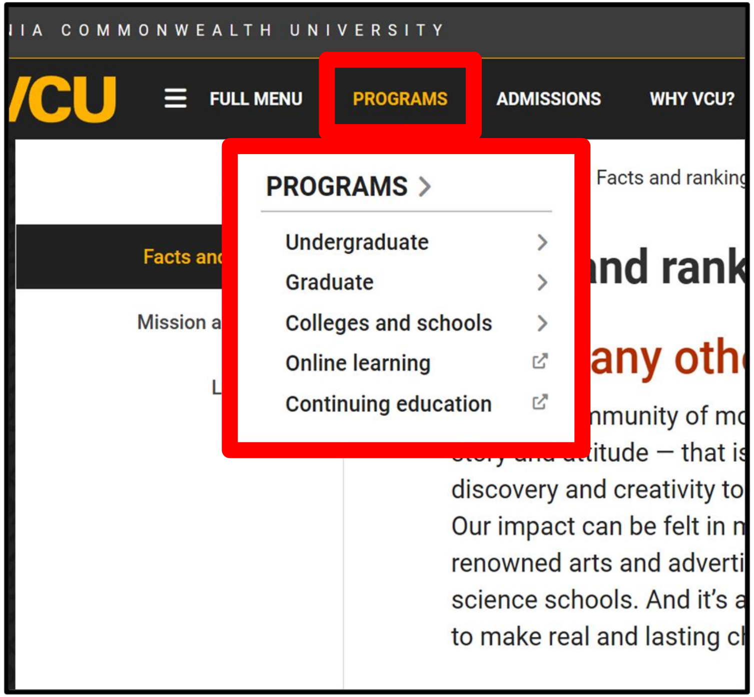

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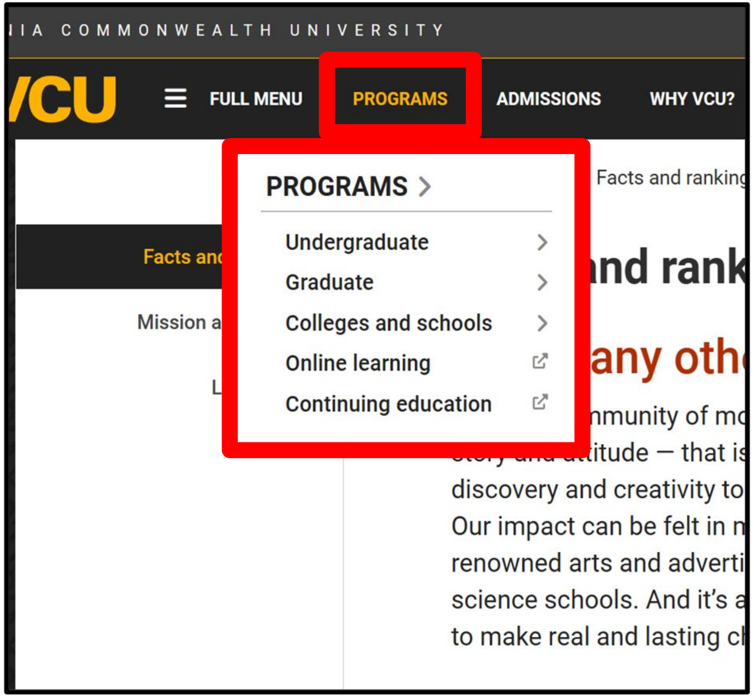

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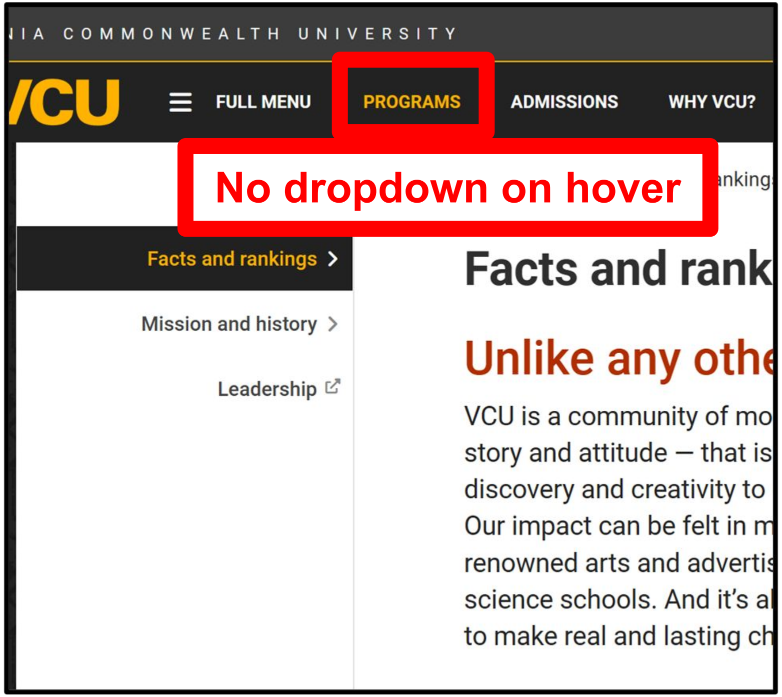

No dropdown on hover

Facts and rank

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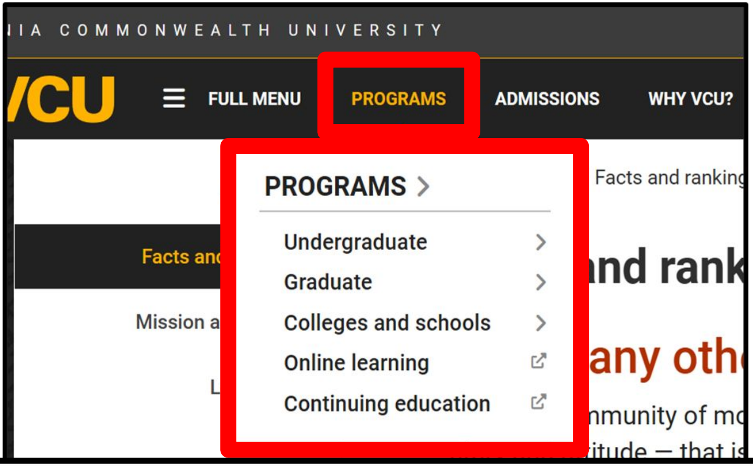

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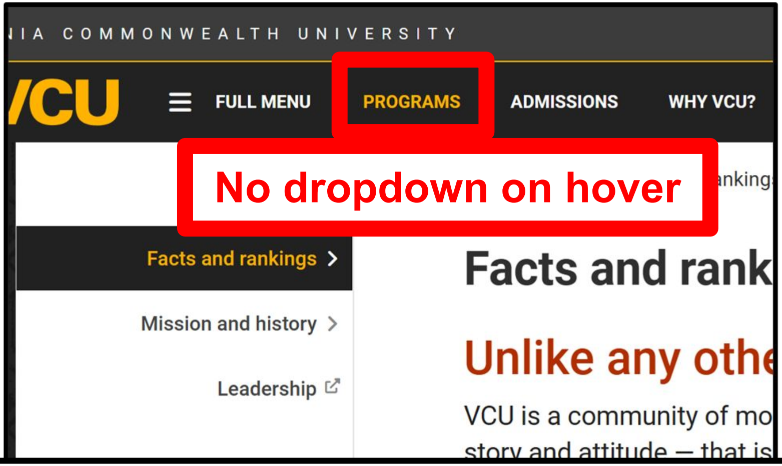
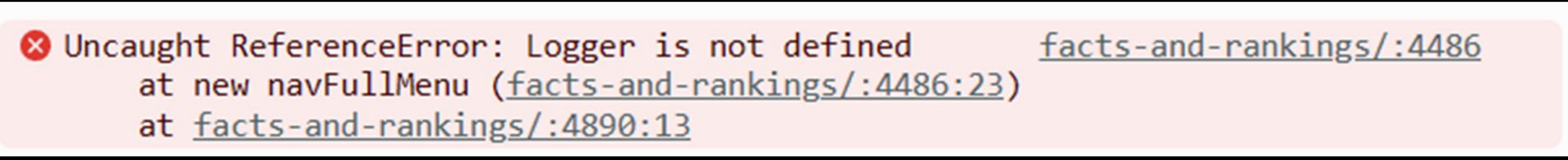


No dropdown on hover



```
Uncaught ReferenceError: Logger is not defined        facts-and-rankings/:4486
    at new navFullMenu (facts-and-rankings/:4486:23)
    at facts-and-rankings/:4890:13
```

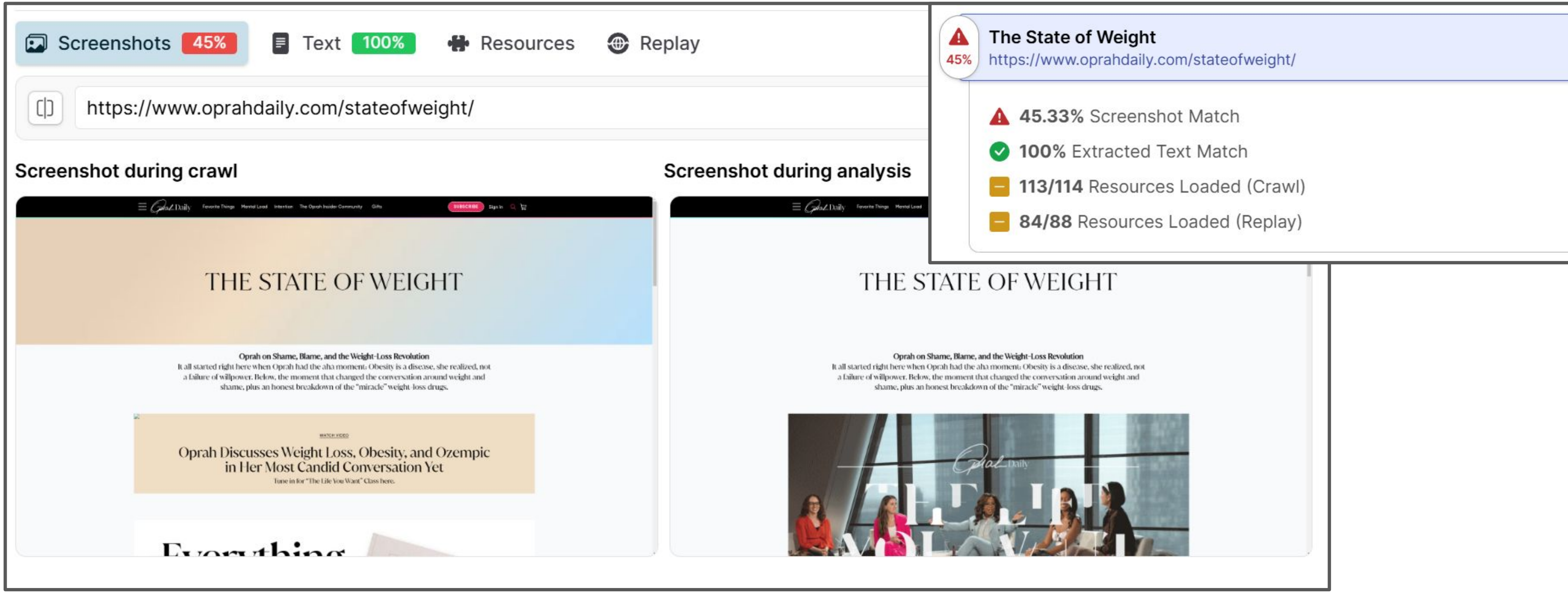
Goals of our project

- Detect fidelity violations when replaying page snapshots
    - Focus only on fidelity violations caused due to rewriting
    - We do not address incomplete/inaccurate recording

Goals of our project

- Detect fidelity violations when replaying page snapshots
  - Focus only on fidelity violations caused due to rewriting
  - We do not address incomplete/inaccurate recording
- Diagnose erroneous rewrites which lead to fidelity issues
  - Not trying to *fix* fidelity issues
  - Once diagnosed, developers will need to identify necessary fixes

Existing Quality Assurance in Web Archiving



https://www.oprahdaily.com/stateofweight/

Screenshot during crawl

THE STATE OF WEIGHT

Oprah on Shame, Blame, and the Weight-Loss Revolution

It all started right here when Oprah had the aha moment: Obesity is a disease, she realized, not a failure of willpower. Below, the moment that changed the conversation around weight and shame, plus an honest breakdown of the "miracle" weight-loss drugs.

WATCH VIDEO

Oprah Discusses Weight Loss, Obesity, and Ozempic in Her Most Candid Conversation Yet

Tune in for "The Life You Want" Class here.

Everything

Screenshot during analysis

THE STATE OF WEIGHT

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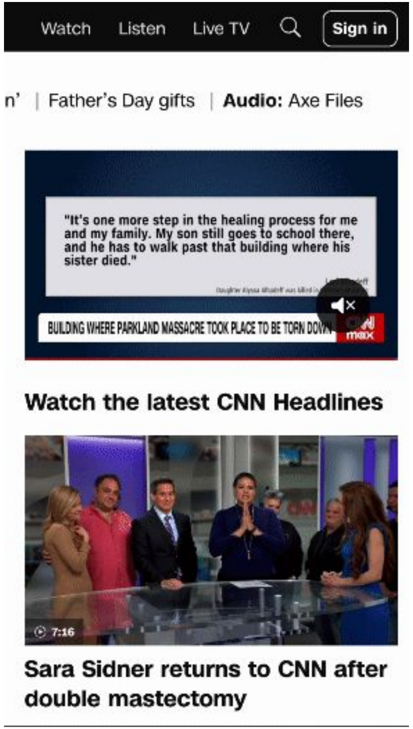
45% **The State of Weight**
https://www.oprahdaily.com/stateofweight/

- ⚠ **45.33%** Screenshot Match
- ✓ **100%** Extracted Text Match
- – **113/114** Resources Loaded (Crawl)
- – **84/88** Resources Loaded (Replay)

Screenshots Differ across Multiple Loads of Same Page



"It's one more step in the healing process for me and my family. My son still goes to school there, and he has to walk past that building where his sister died."

BUILDING WHERE PARKLAND MASSACRE TOOK PLACE TO BE TORN DOWN

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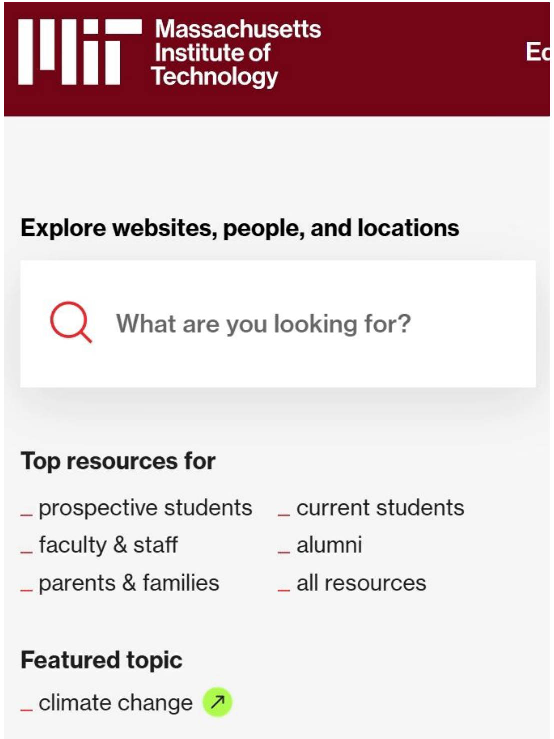
Sara Sidner returns to CNN after double mastectomy



Explore websites, people, and locations

What are you looking for?

Top resources for

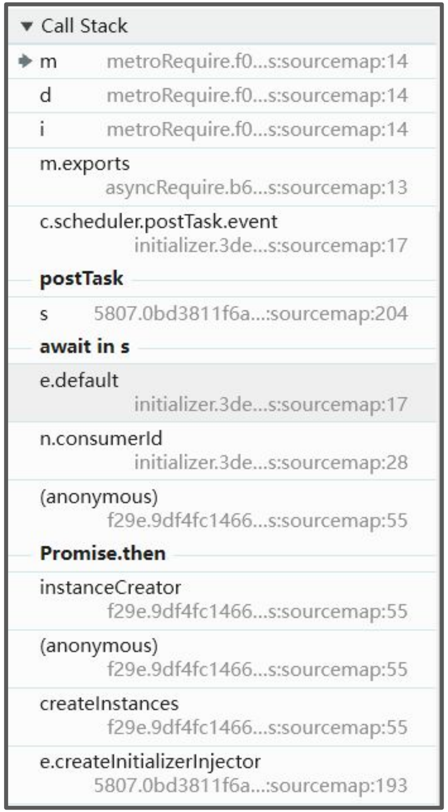
_ prospective students	_ current students
_ faculty & staff	_ alumni
_ parents & families	_ all resources

Featured topic

_ climate change ↗

Runtime Error ↛ Fidelity Violation

Hard to analyze if an error will cause violations by manually inspecting its stack trace

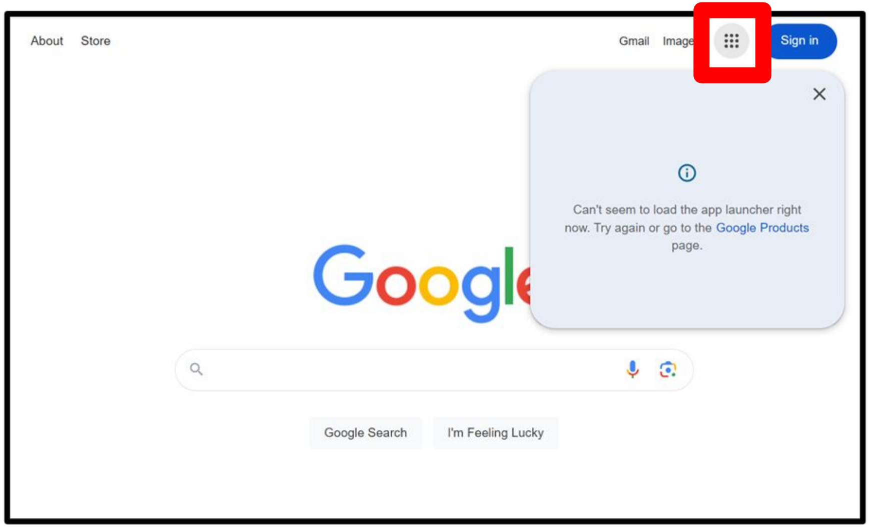


```
▼ Call Stack
➧ m        metroRequire.f0...s:sourcemap:14
  d        metroRequire.f0...s:sourcemap:14
  i        metroRequire.f0...s:sourcemap:14
  m.exports
           asyncRequire.b6...s:sourcemap:13
  c.scheduler.postTask.event
              initializer.3de...s:sourcemap:17
  postTask
  s      5807.0bd3811f6a...:sourcemap:204
  await in s
  e.default
              initializer.3de...s:sourcemap:17
  n.consumerId
              initializer.3de...s:sourcemap:28
  (anonymous)
           f29e.9df4fc1466...s:sourcemap:55
  Promise.then
  instanceCreator
           f29e.9df4fc1466...s:sourcemap:55
  (anonymous)
           f29e.9df4fc1466...s:sourcemap:55
  createInstances
           f29e.9df4fc1466...s:sourcemap:55
  e.createInitializerInjector
         5807.0bd3811f6a...:sourcemap:193
```

Fidelity Violation ⇏ Runtime Error

Errors can be hard to detect

- Semantic errors, no error messages



Can't seem to load the app launcher right now. Try again or go to the Google Products page.

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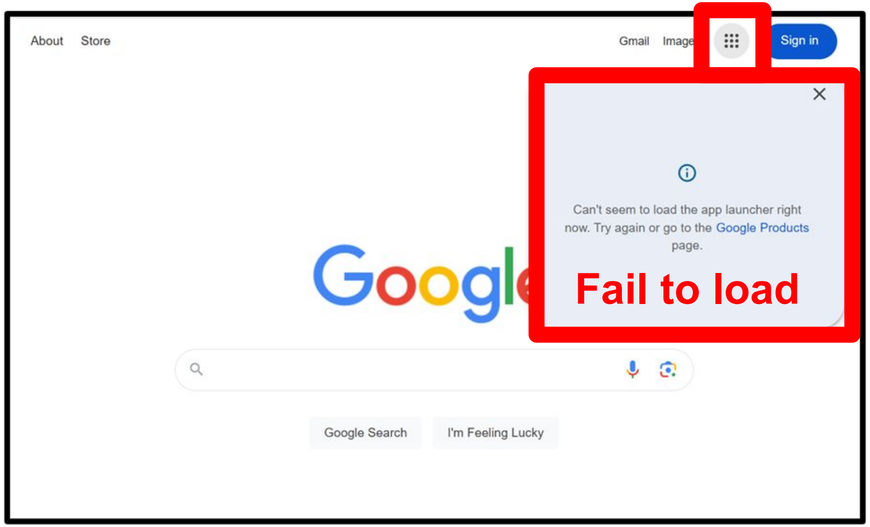

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Fail to load

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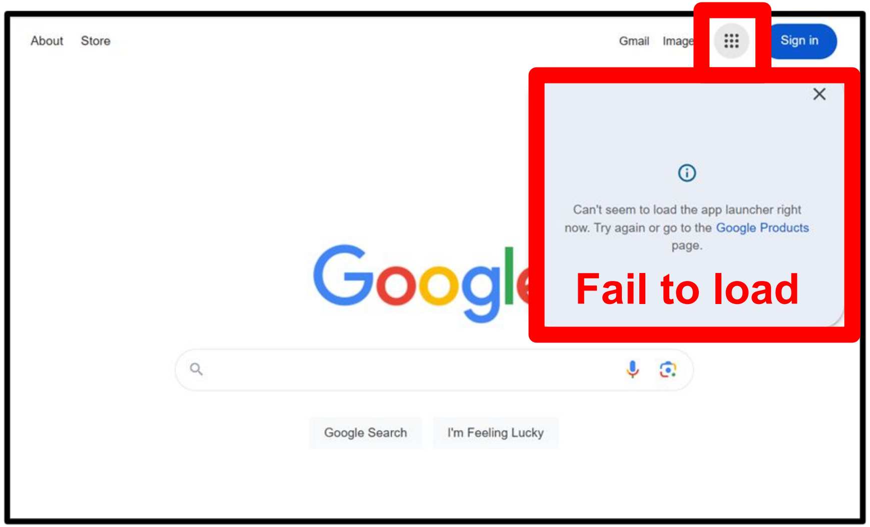

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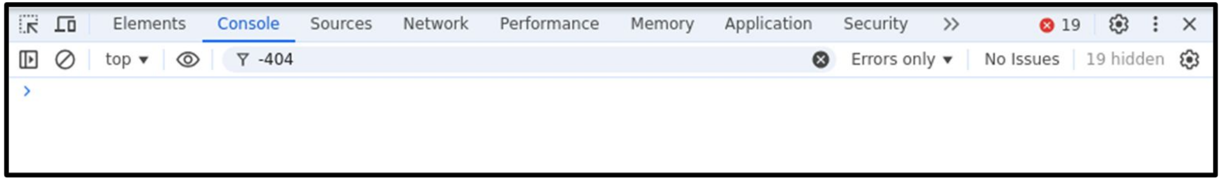
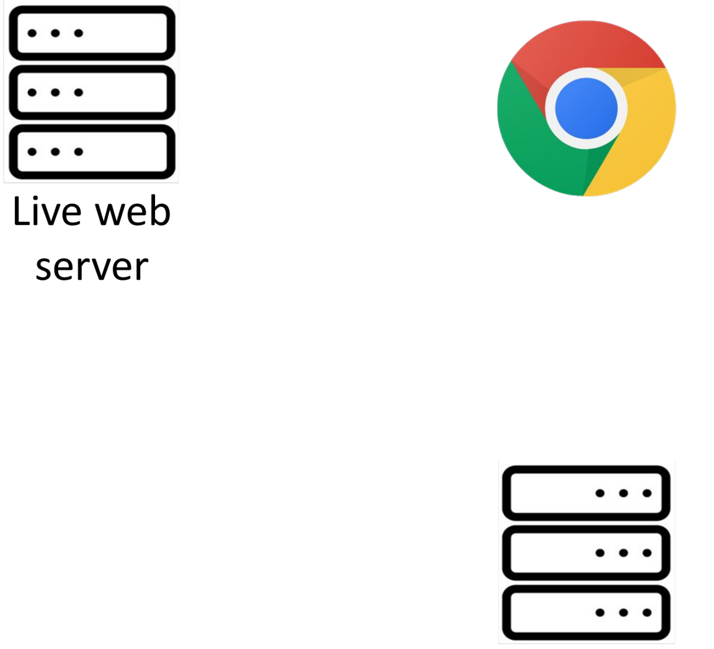


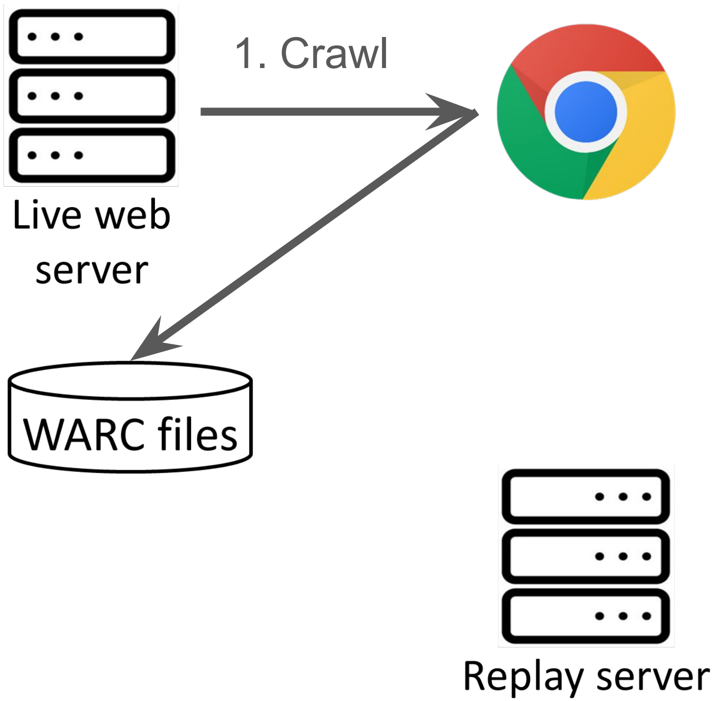
FidEx (**Fid**elity violation **Ex**poser)



Live web server

Replay server

FidEx (**Fid**elity violation **Ex**poser)



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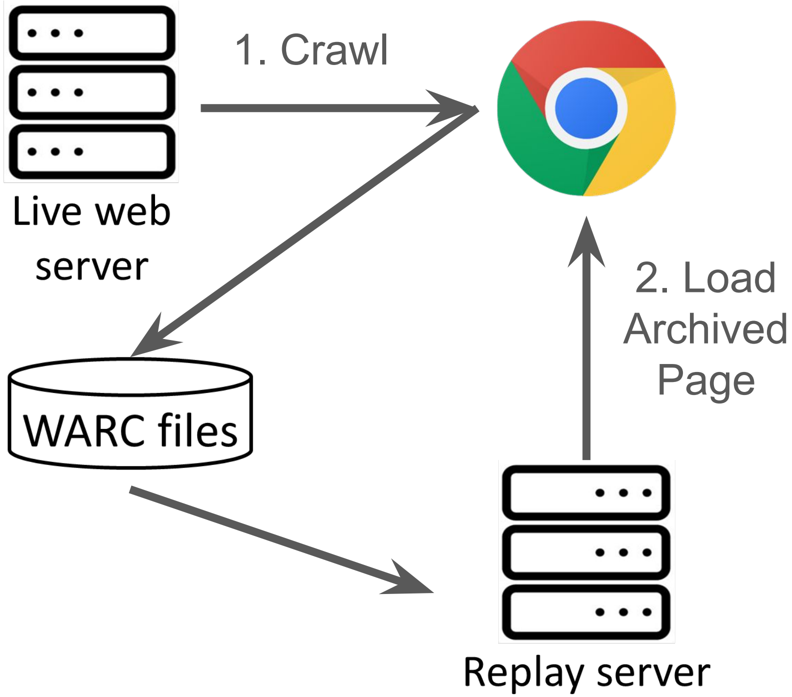

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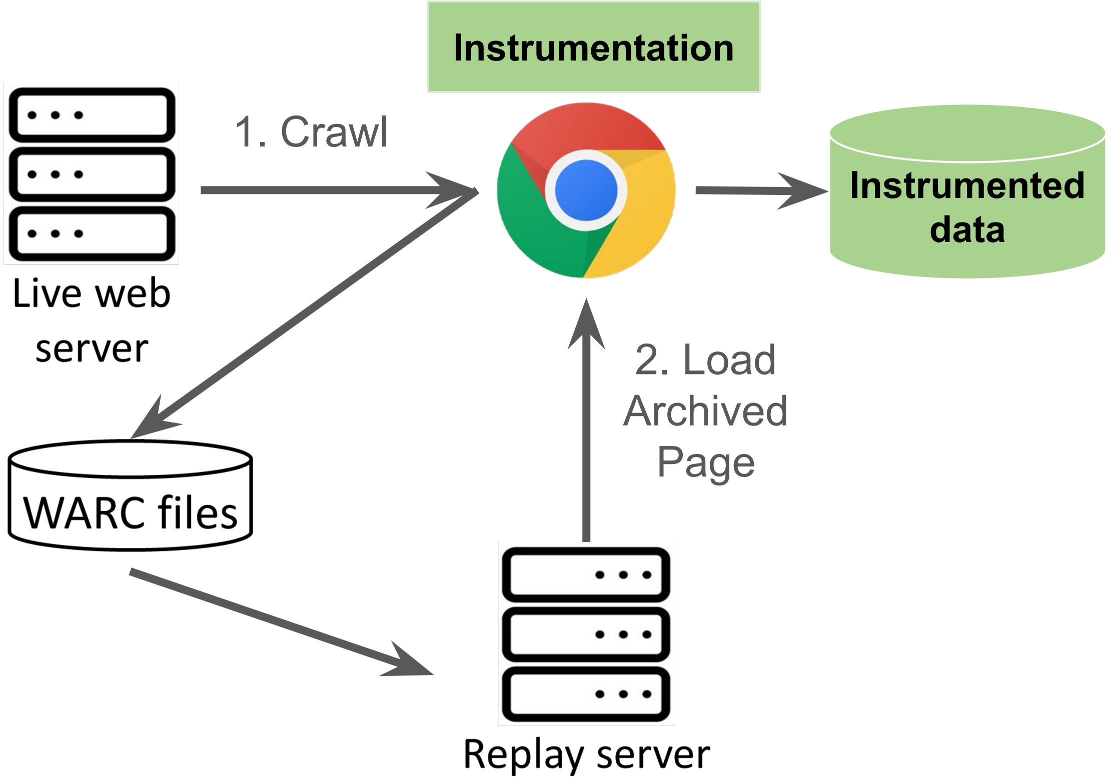

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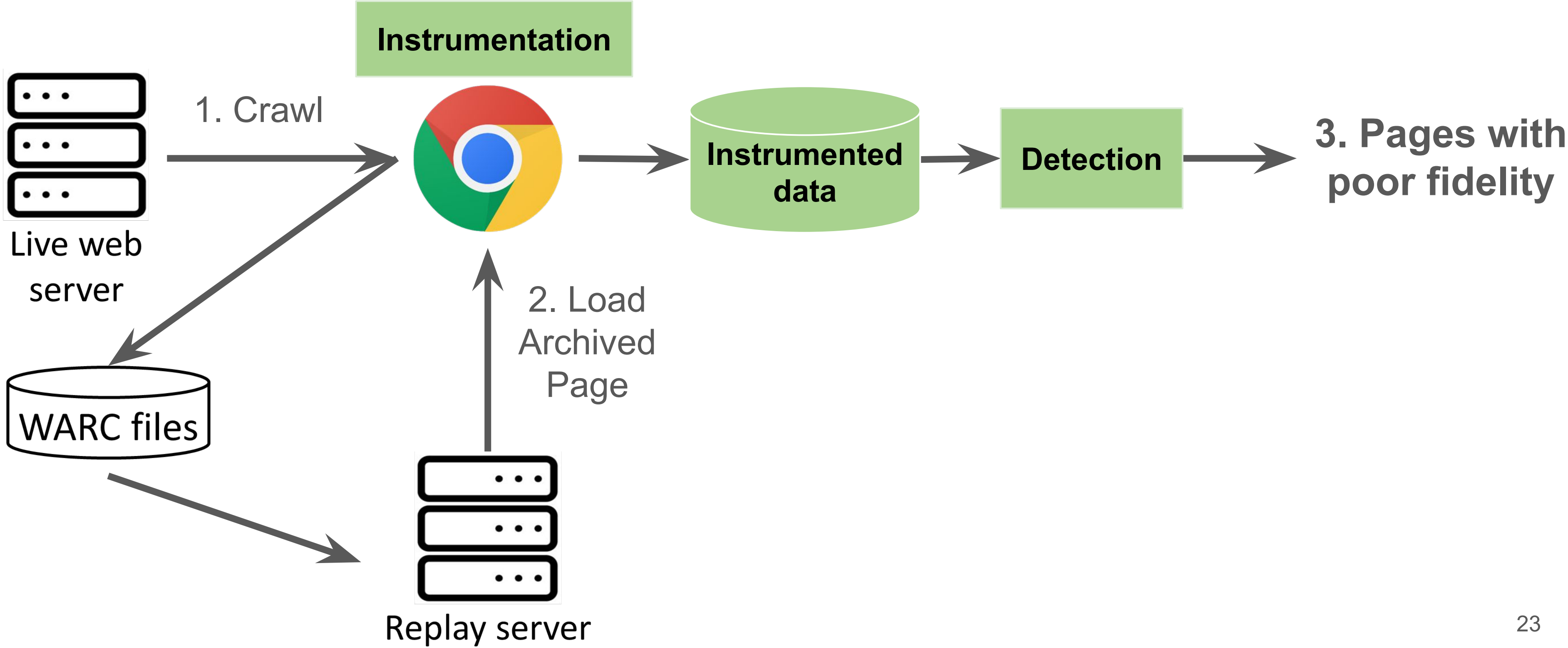

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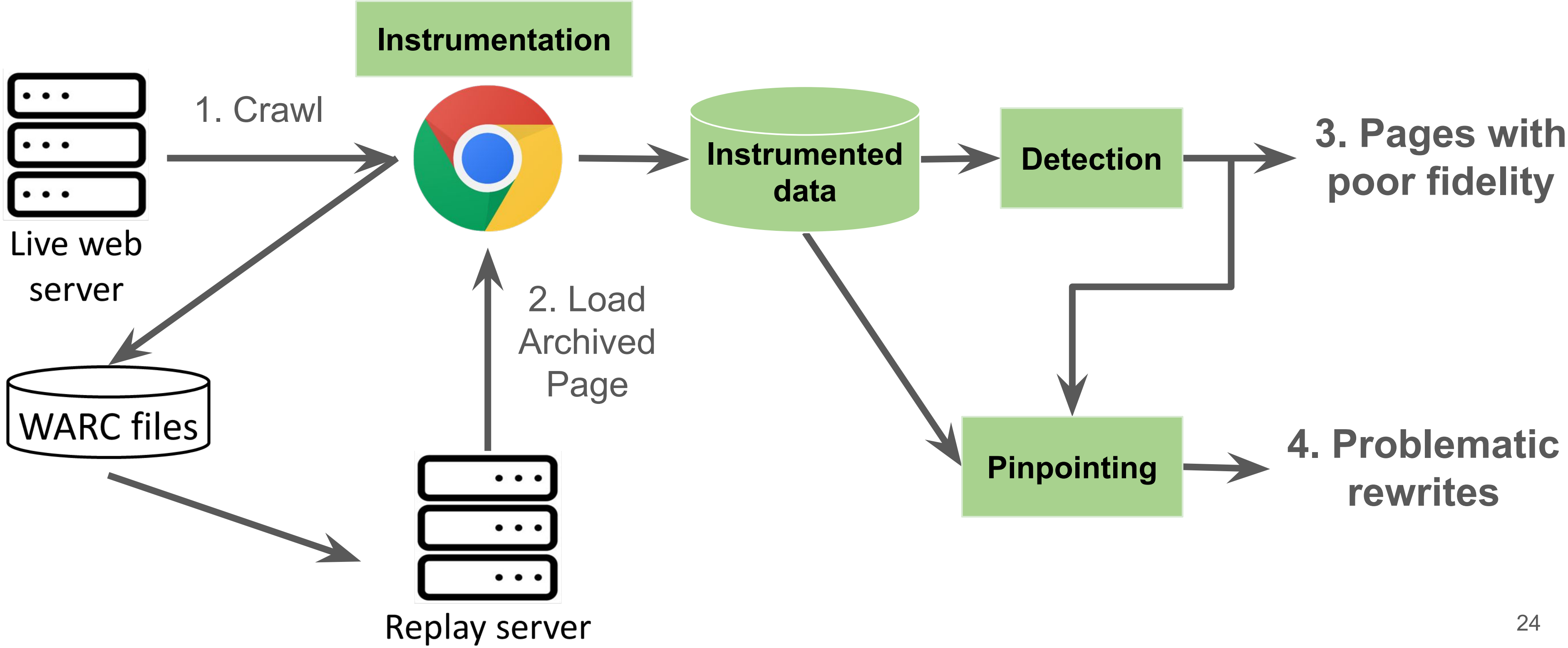
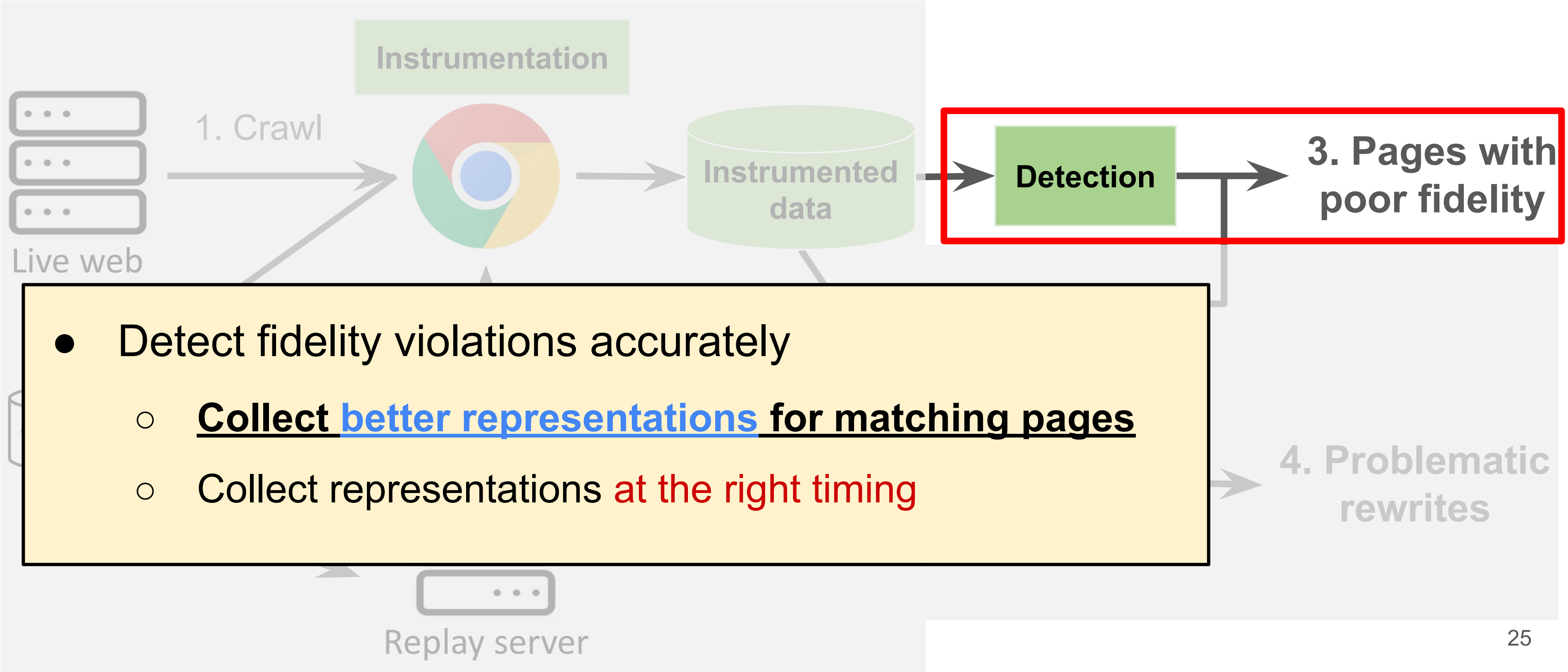


Fidelity violation detection

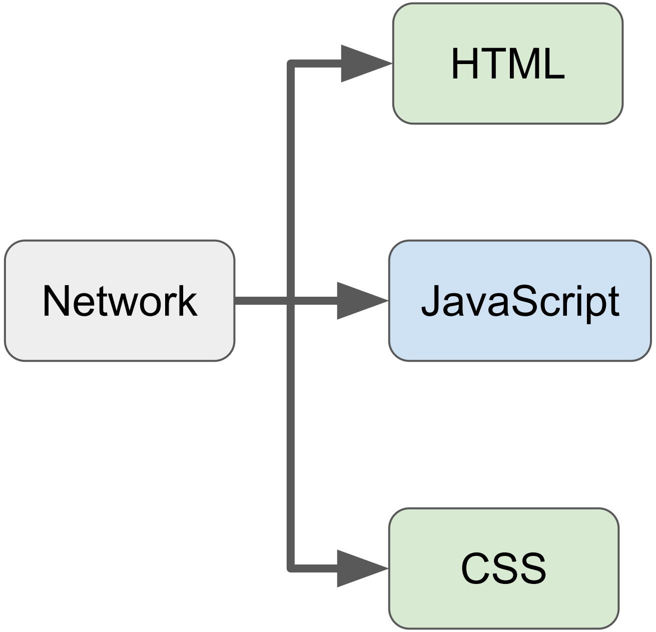


- Detect fidelity violations accurately
  - **Collect better representations for matching pages**
  - Collect representations at the right timing

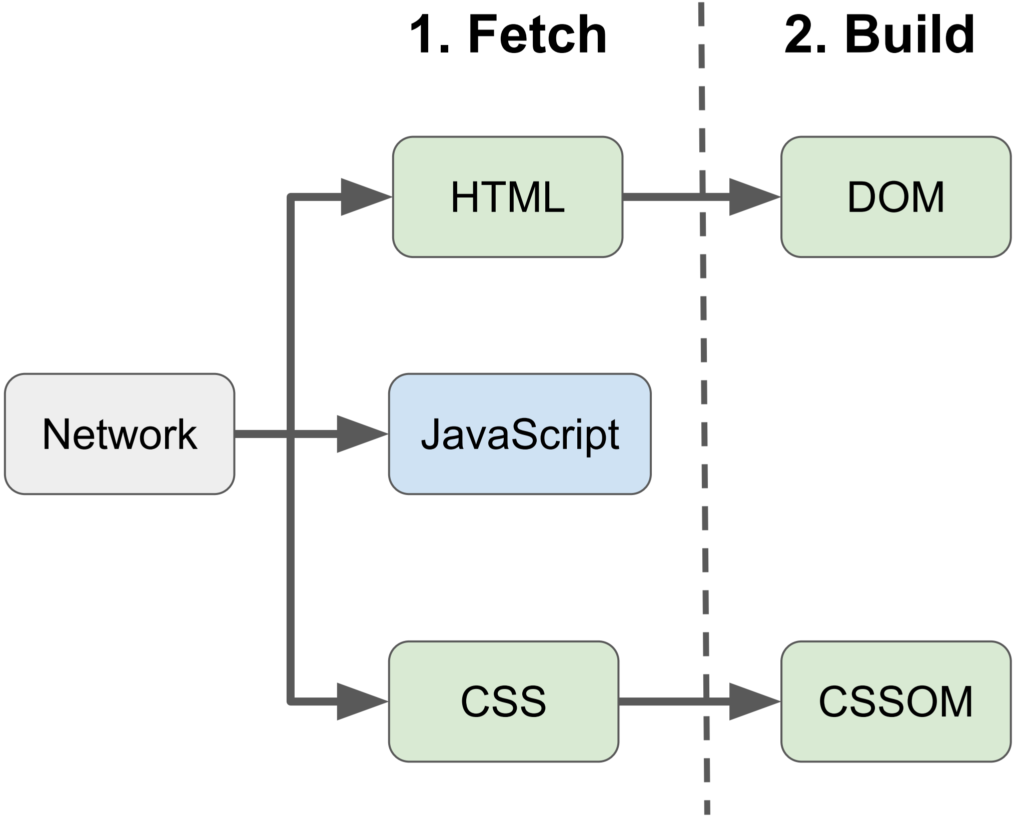
How a browser renders pages

How a browser renders pages

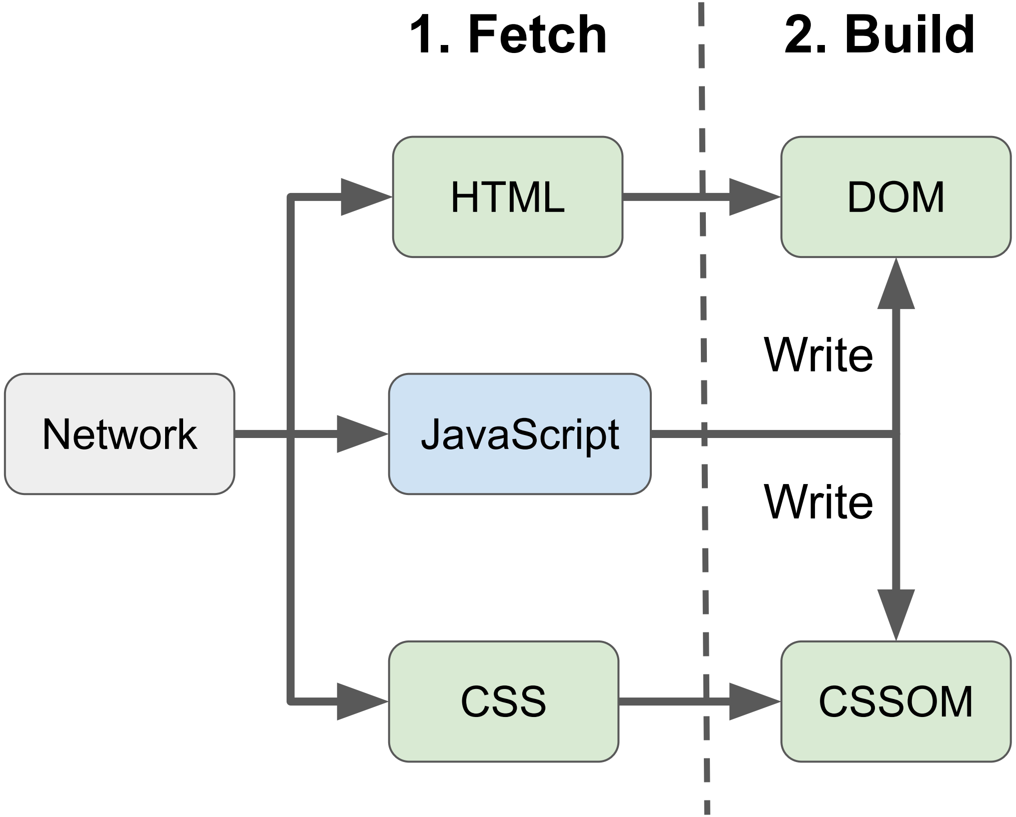
1. Fetch



How a browser renders pages



How a browser renders pages



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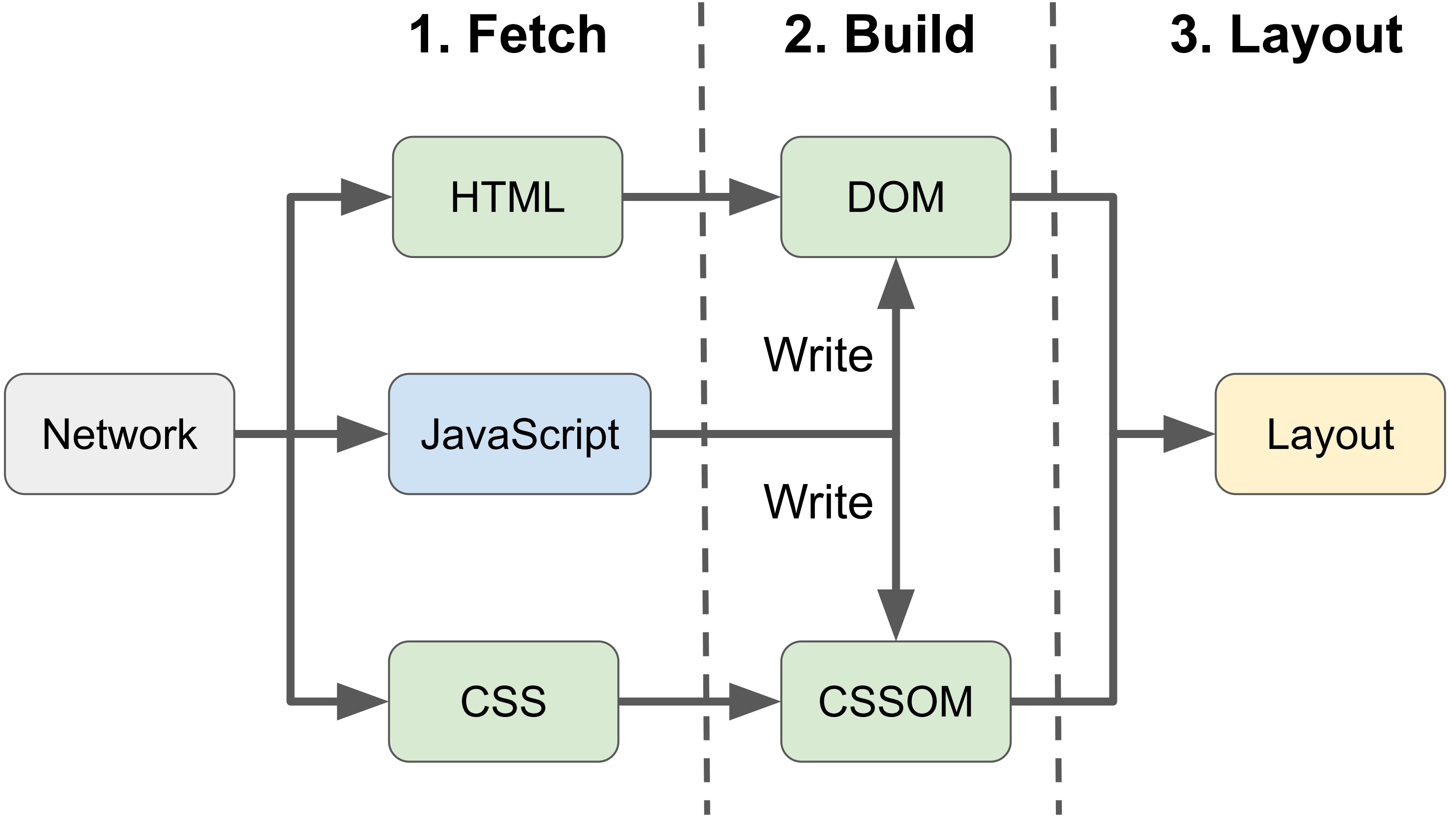

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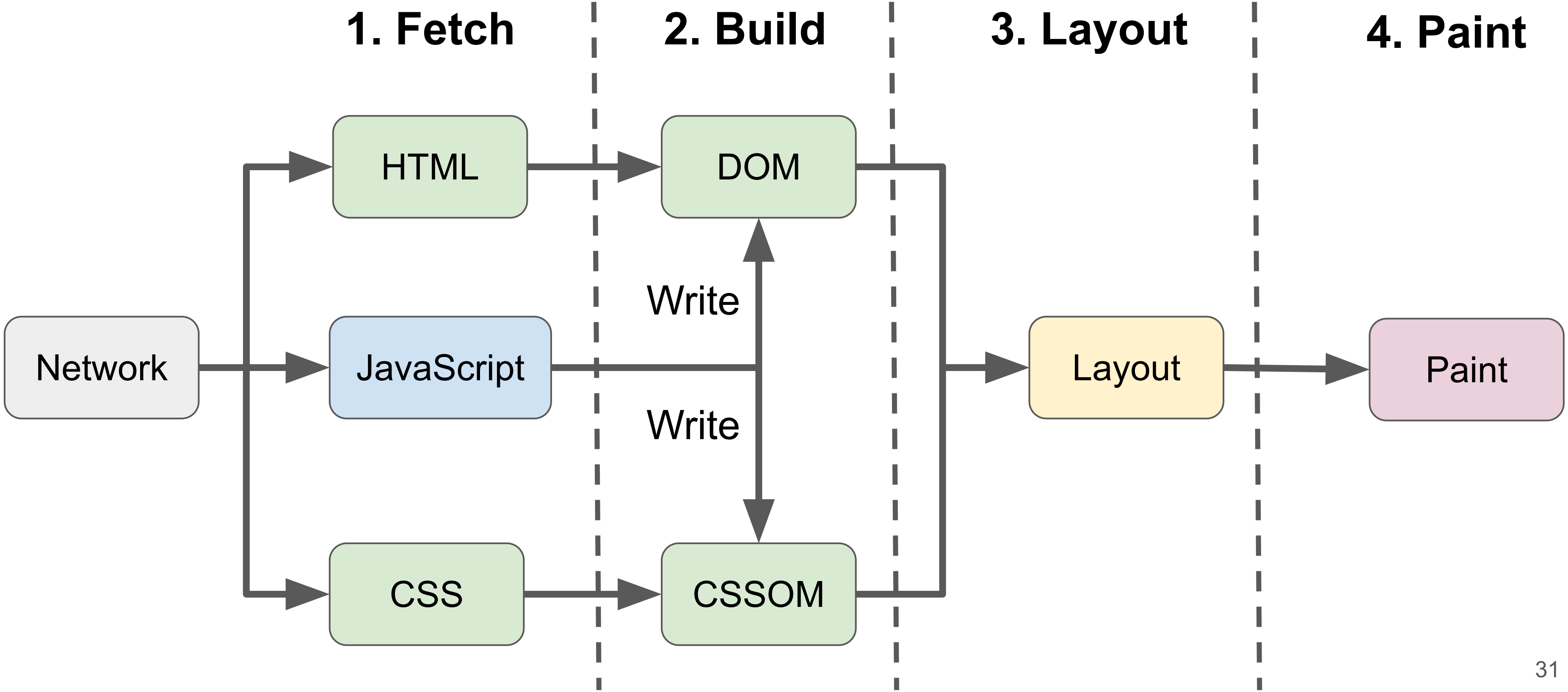

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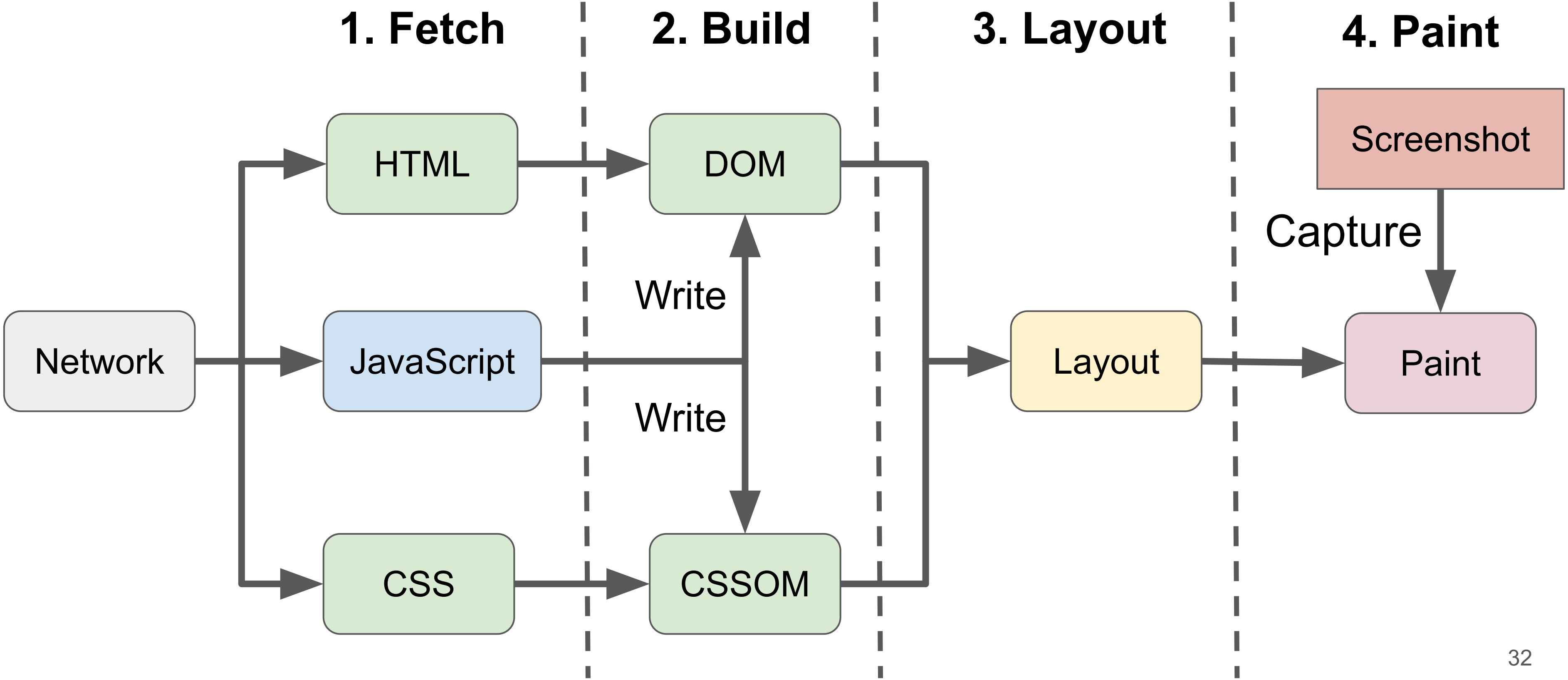

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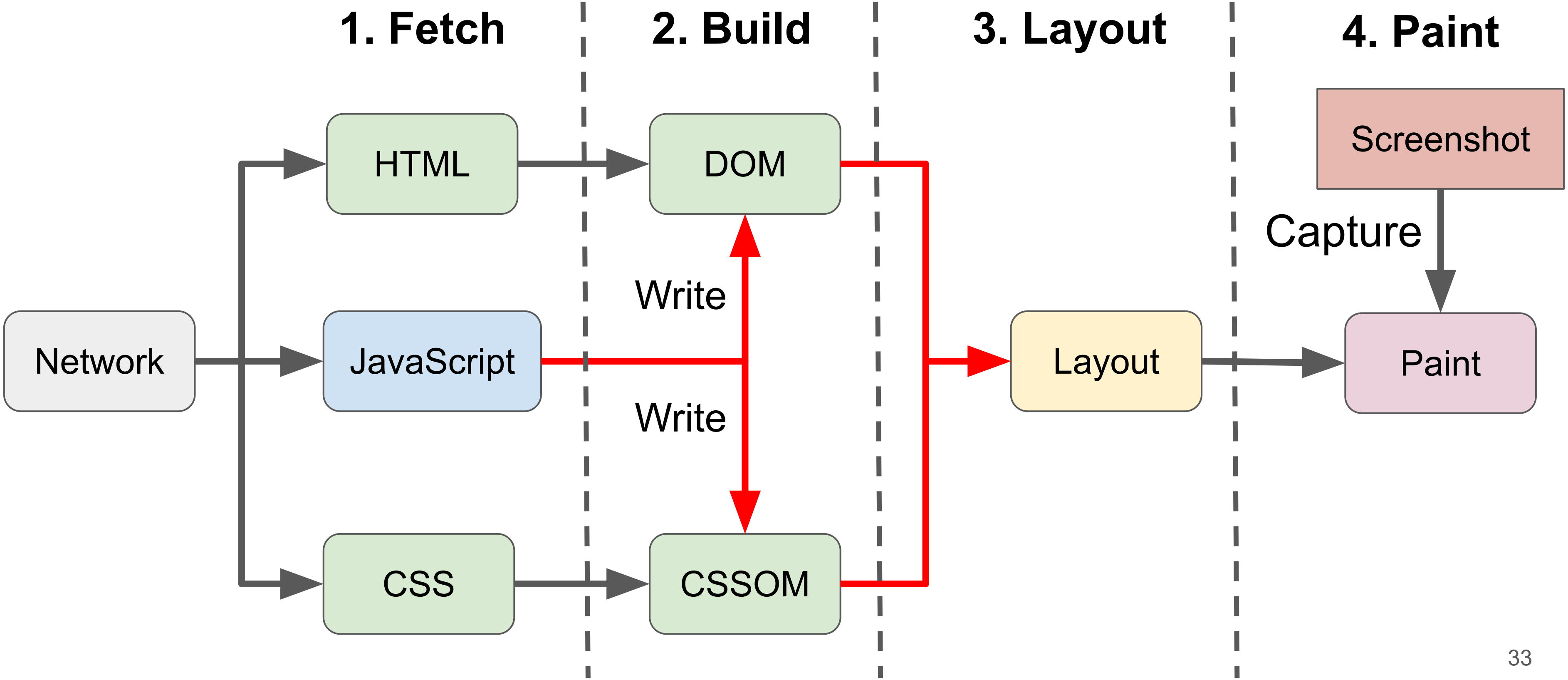
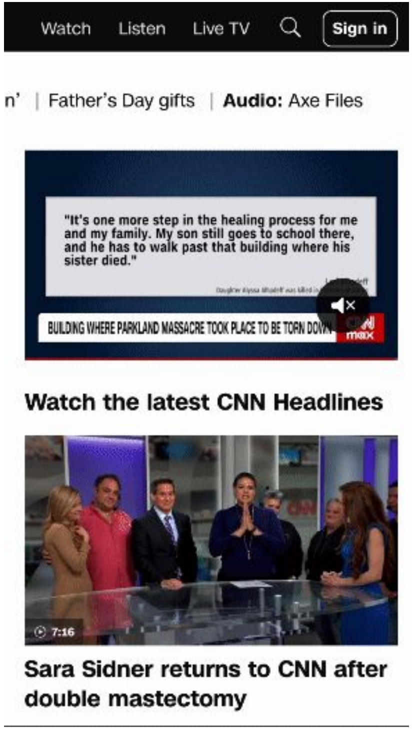


Fidelity violation detection: Match layout tree



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"It's one more step in the healing process for me and my family. My son still goes to school there, and he has to walk past that building where his sister died."

BUILDING WHERE PARKLAND MASSACRE TOOK PLACE TO BE TORN DOWN

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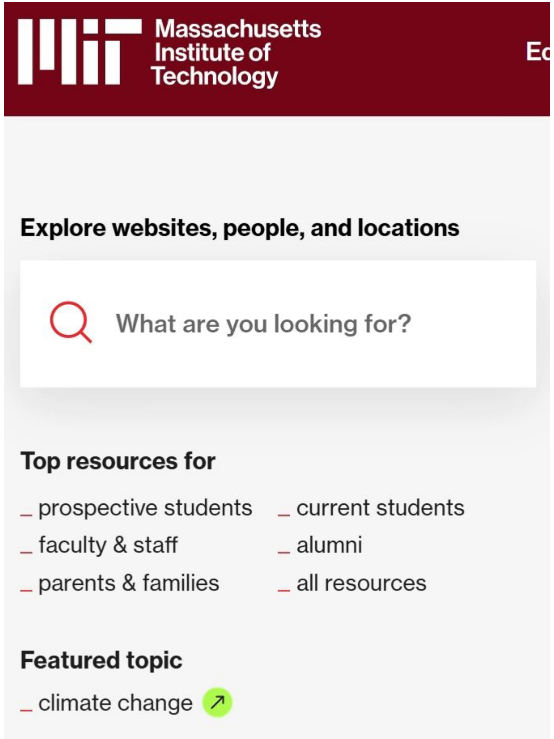
7:16

Sara Sidner returns to CNN after double mastectomy



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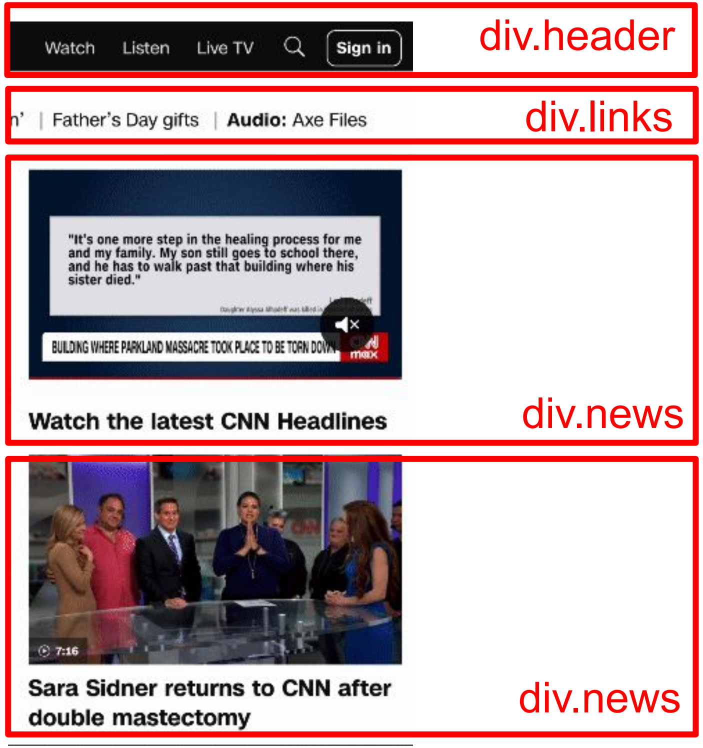
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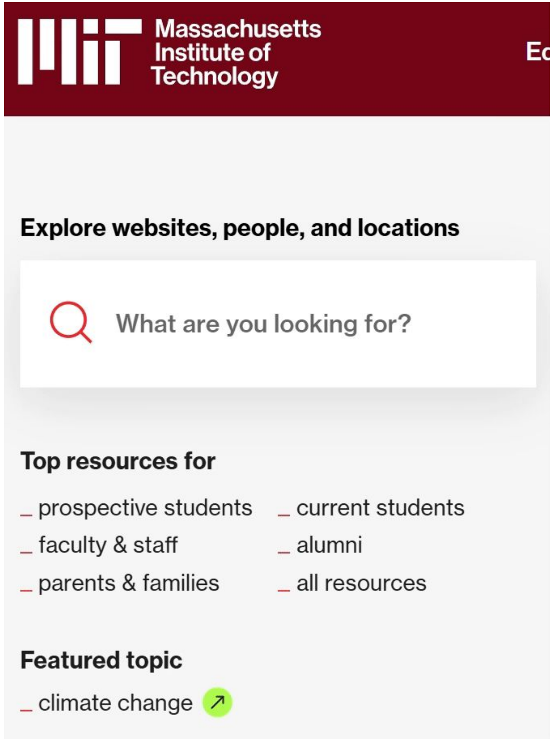

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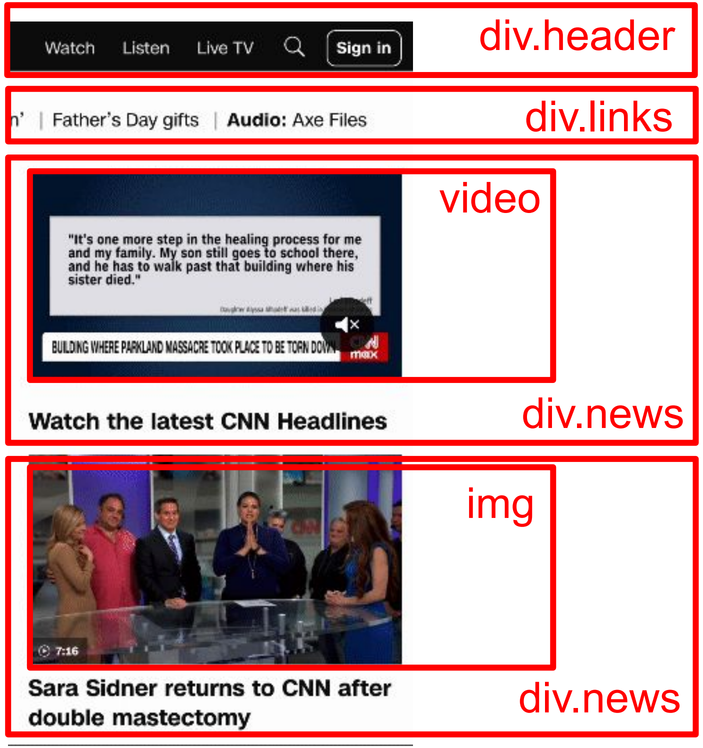

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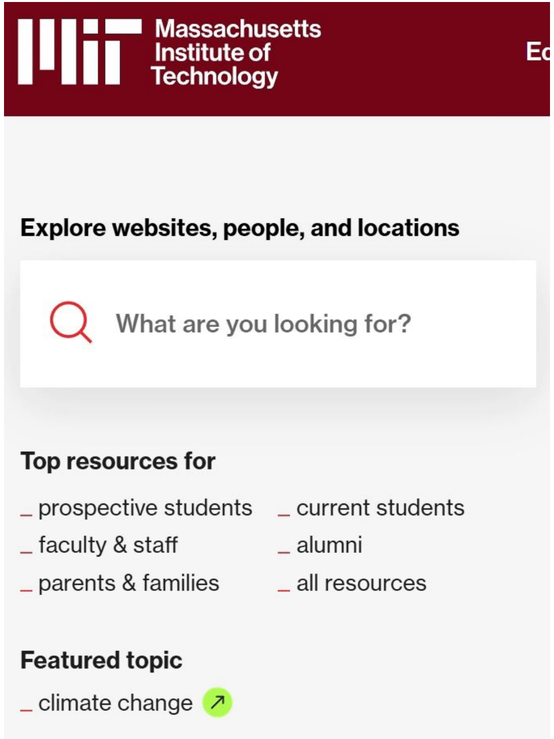
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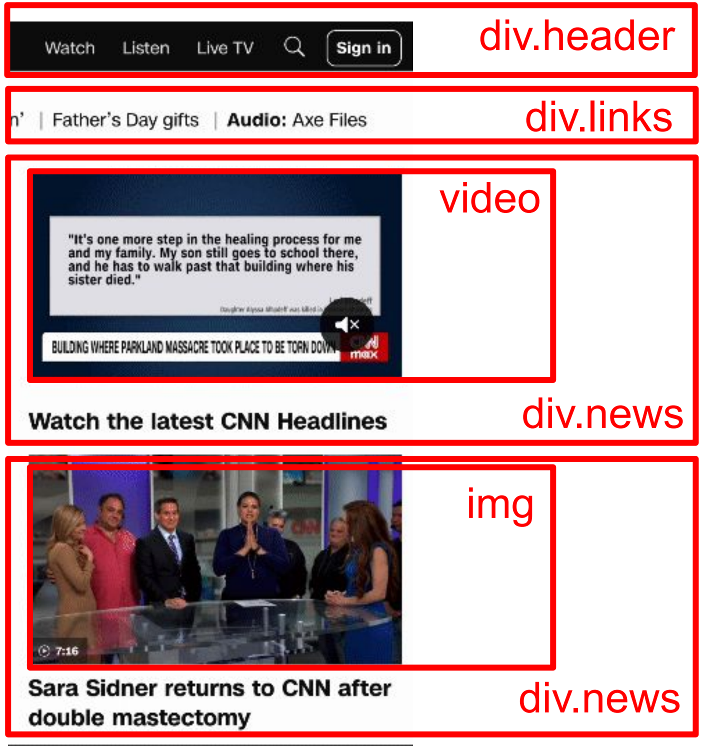
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video
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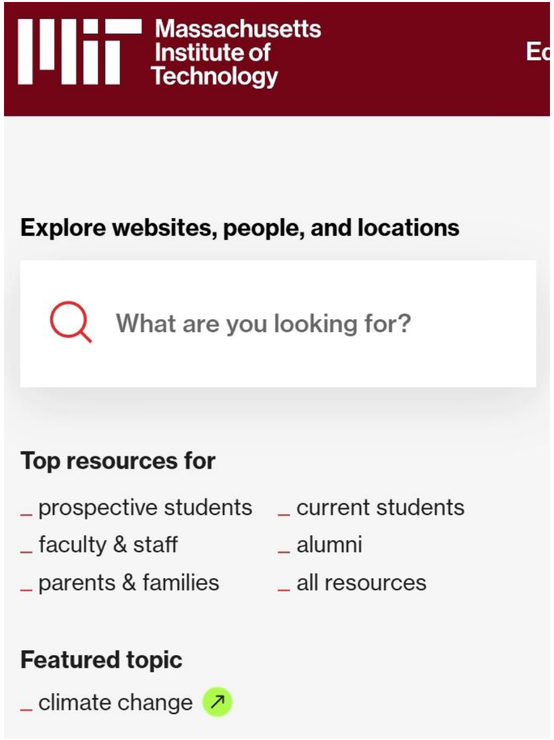
Layout tree unchanged



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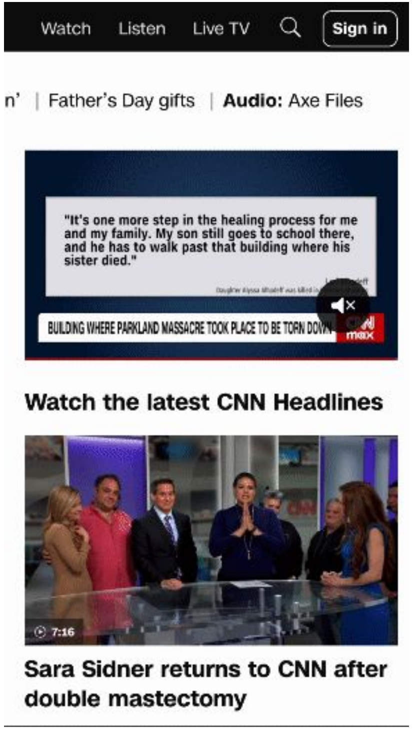

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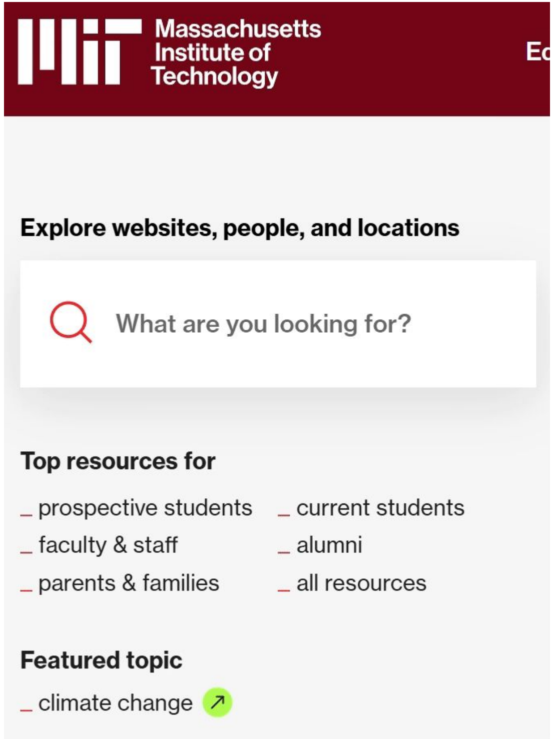

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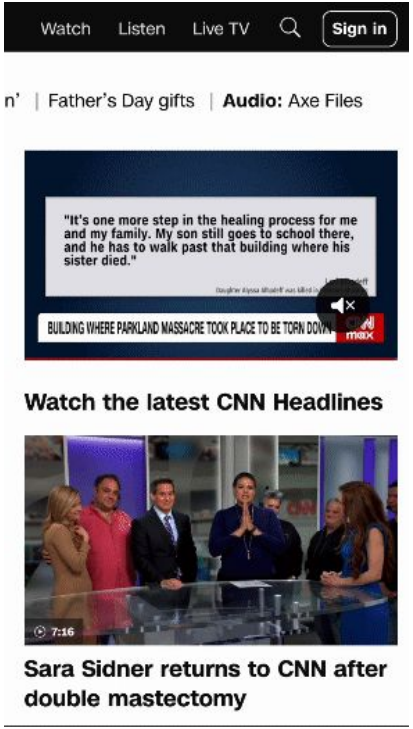
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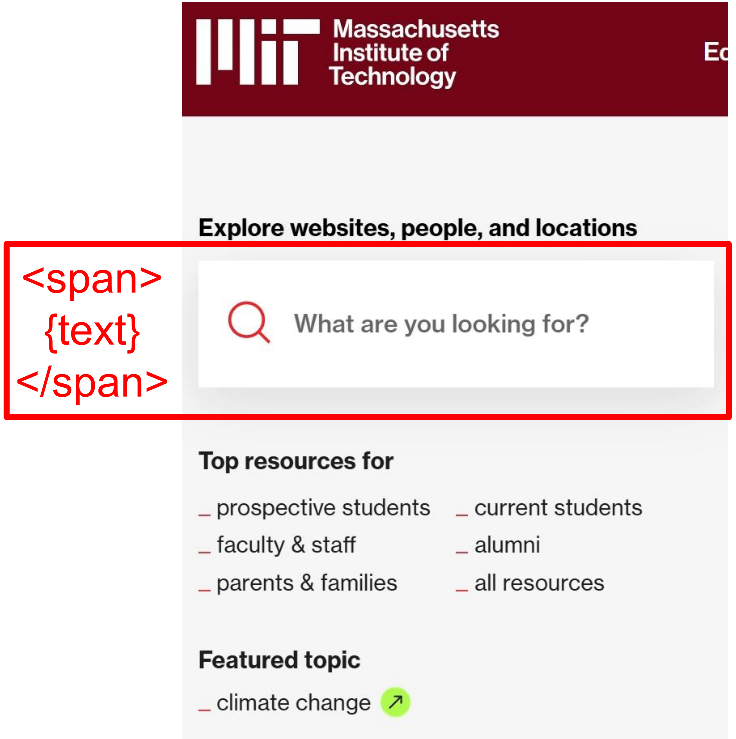
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<span>
{text}
</span>

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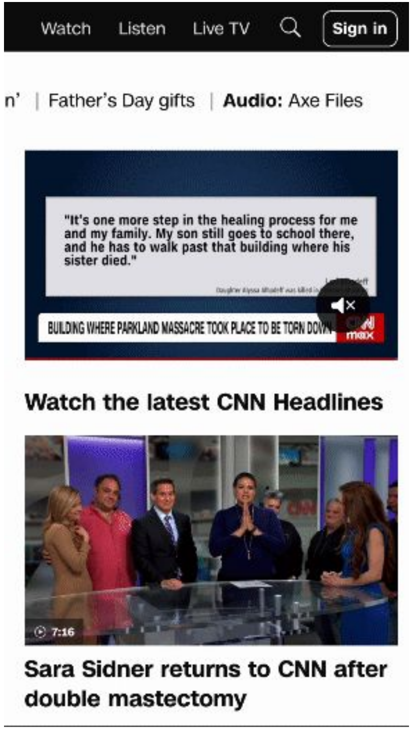
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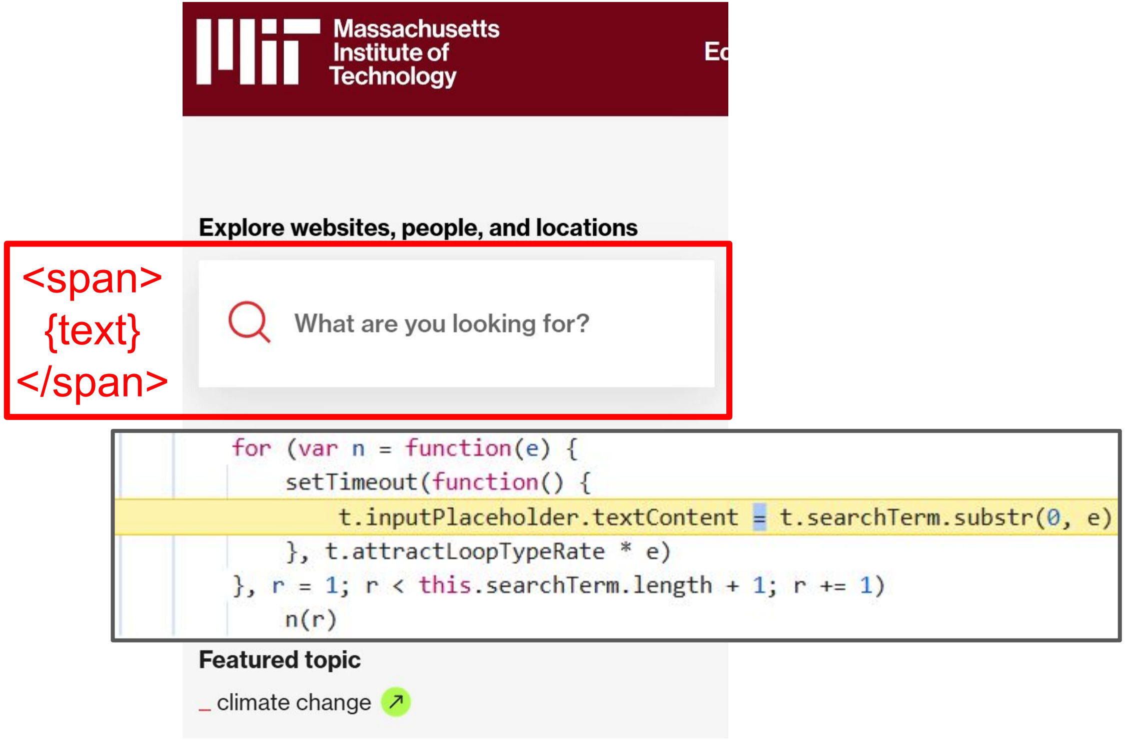
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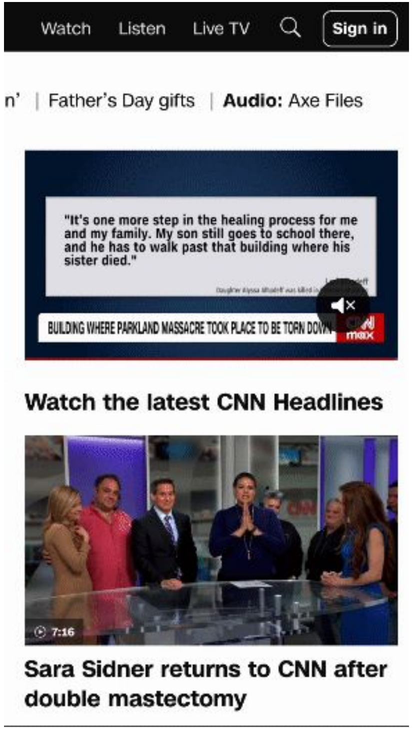
<span>
{text}
</span>

```
for (var n = function(e) {
    setTimeout(function() {
        t.inputPlaceholder.textContent = t.searchTerm.substr(0, e)
    }, t.attractLoopTypeRate * e)
}, r = 1; r < this.searchTerm.length + 1; r += 1)
    n(r)
```

Fidelity violation detection: Match JS writes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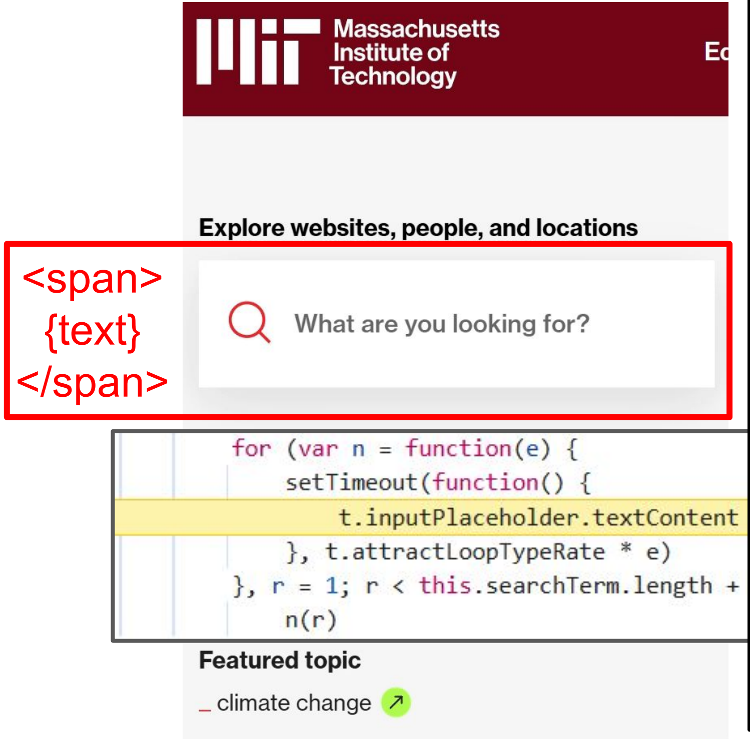
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{text}
</span>
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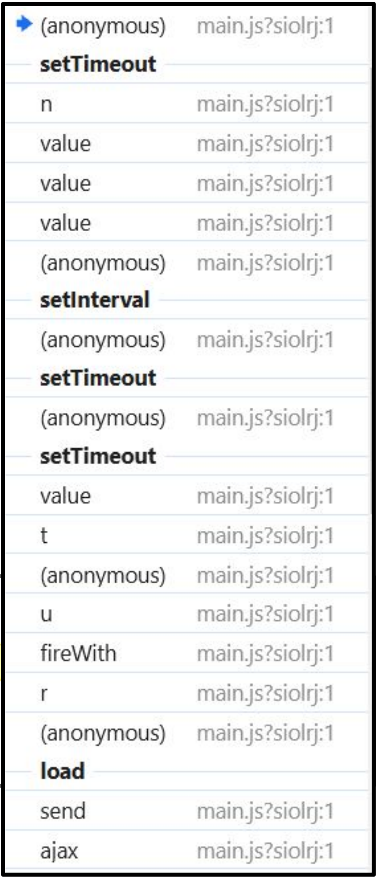
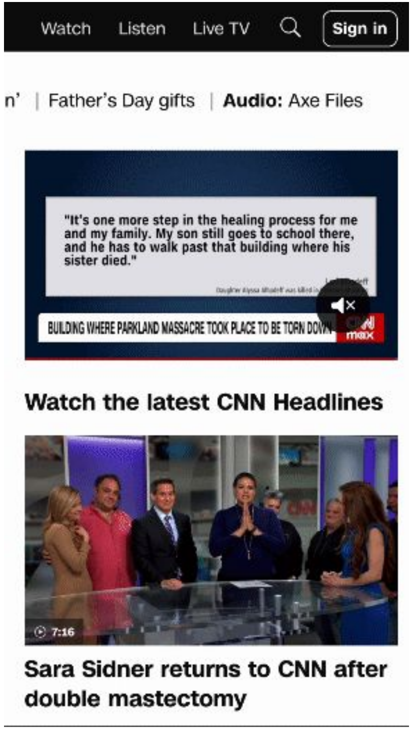
```
for (var n = function(e) {
    setTimeout(function() {
        t.inputPlaceholder.textContent
    }, t.attractLoopTypeRate * e)
}, r = 1; r < this.searchTerm.length +
    n(r)
```



```
(anonymous)   main.js?siolrj:1
setTimeout
n             main.js?siolrj:1
value         main.js?siolrj:1
value         main.js?siolrj:1
value         main.js?siolrj:1
(anonymous)   main.js?siolrj:1
setInterval
(anonymous)   main.js?siolrj:1
setTimeout
(anonymous)   main.js?siolrj:1
setTimeout
value         main.js?siolrj:1
t             main.js?siolrj:1
(anonymous)   main.js?siolrj:1
u             main.js?siolrj:1
fireWith      main.js?siolrj:1
r             main.js?siolrj:1
(anonymous)   main.js?siolrj:1
load
send          main.js?siolrj:1
ajax          main.js?siolrj:1
```

Fidelity violation detection: Match JS writes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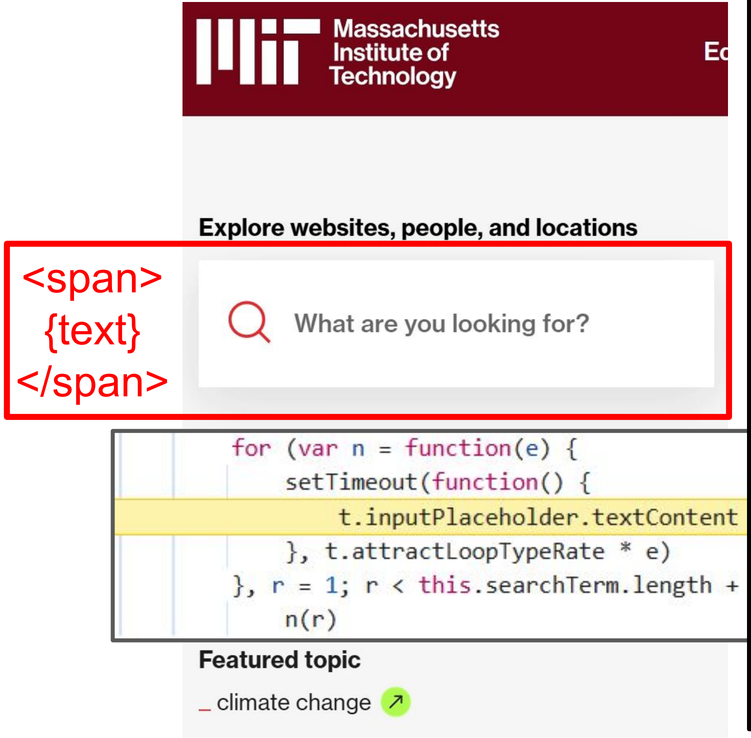
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```

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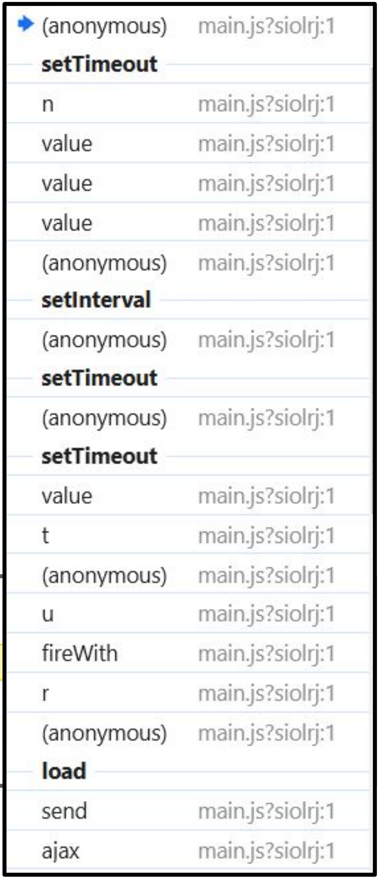
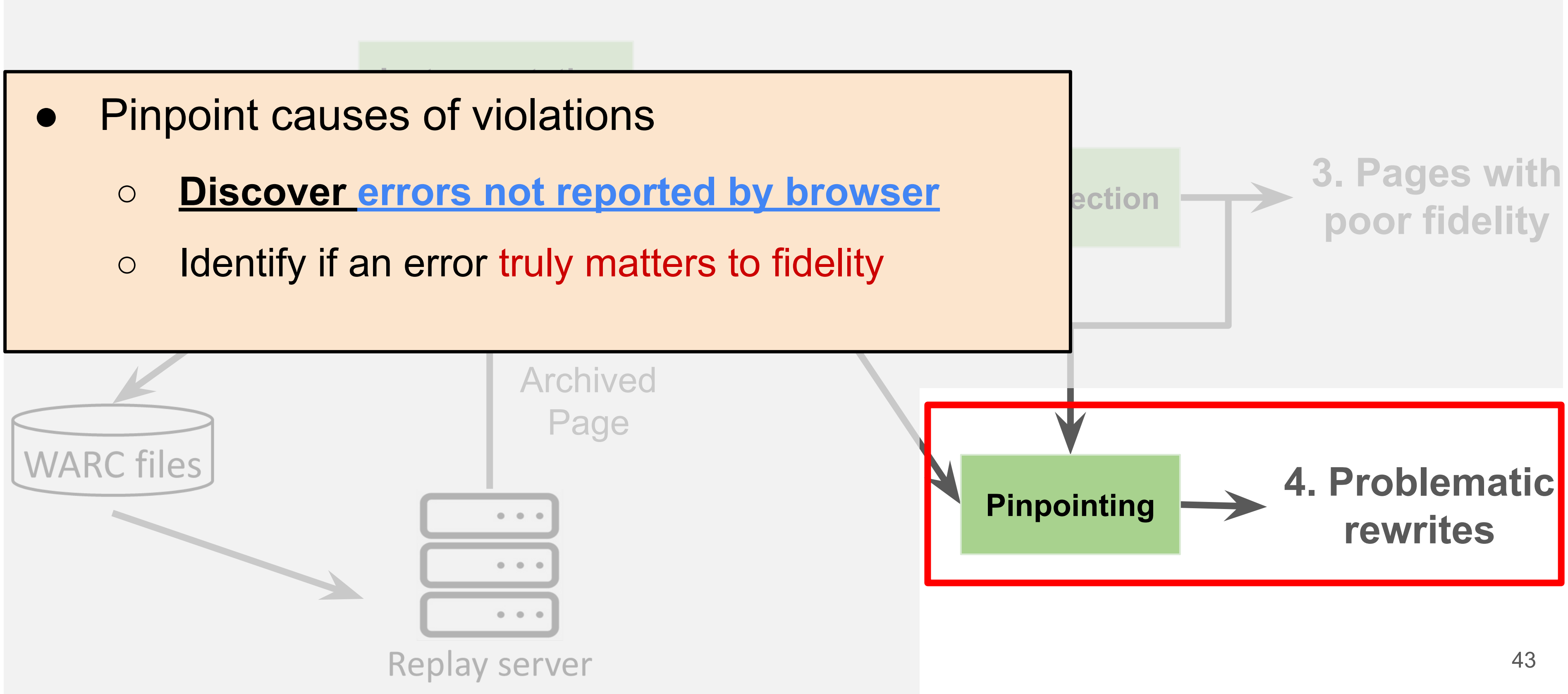


(anonymous)	main.js?siolrj:1
setTimeout	
n	main.js?siolrj:1
value	main.js?siolrj:1
value	main.js?siolrj:1
value	main.js?siolrj:1
(anonymous)	main.js?siolrj:1
setInterval	
(anonymous)	main.js?siolrj:1
setTimeout	
(anonymous)	main.js?siolrj:1
setTimeout	
value	main.js?siolrj:1
t	main.js?siolrj:1
(anonymous)	main.js?siolrj:1
u	main.js?siolrj:1
fireWith	main.js?siolrj:1
r	main.js?siolrj:1
(anonymous)	main.js?siolrj:1
load	
send	main.js?siolrj:1
ajax	main.js?siolrj:1

Associated {JS writes} unchanged

Fidelity violation diagnosis

- Pinpoint causes of violations
  - **Discover errors not reported by browser**
  - Identify if an error truly matters to fidelity



Evaluation

- **Datasets**
  - 80K pages sampled from top 1 million sites, 5 pages per site
  - Pages sampled from End-of-Term and CARTA collections

Evaluation

- **Datasets**
  - 80K pages sampled from top 1 million sites, 5 pages per site
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- **Baselines for detecting fidelity violations**
  - Match screenshots, HTML extracted texts (Browsertrix’s QA)
  - Check if archive has extra errors

FidEx improves accuracy of detecting fidelity violations

	FidEx	Screenshots	More Errors	HTML Text
Positive rate	15.5%	72.6%	43.7%	24.9%

Positive: detected fidelity violation(s)

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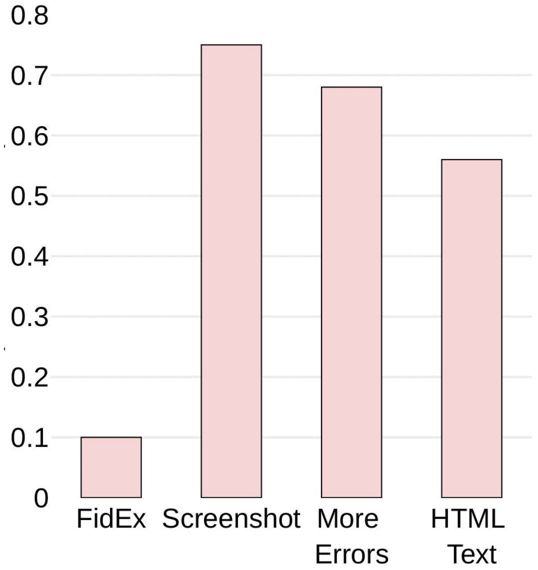
False positives / Positives



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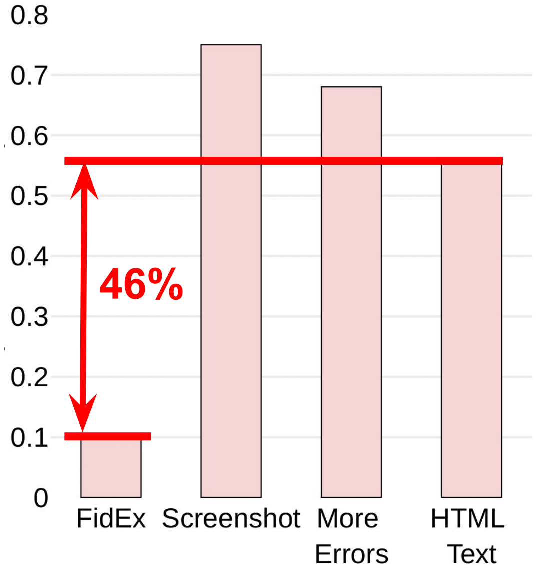

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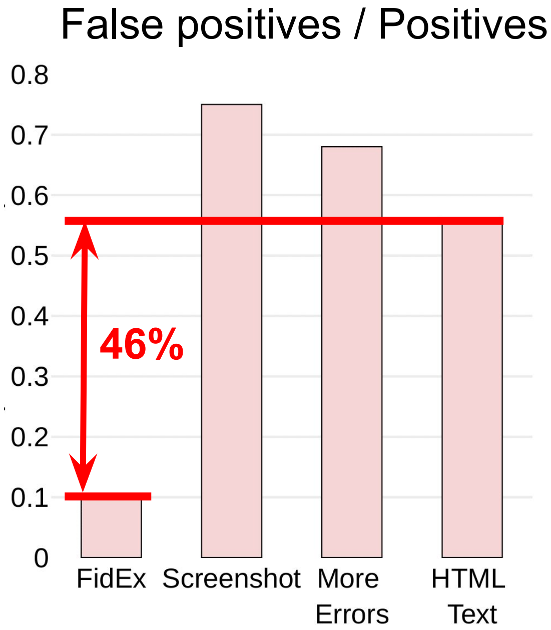

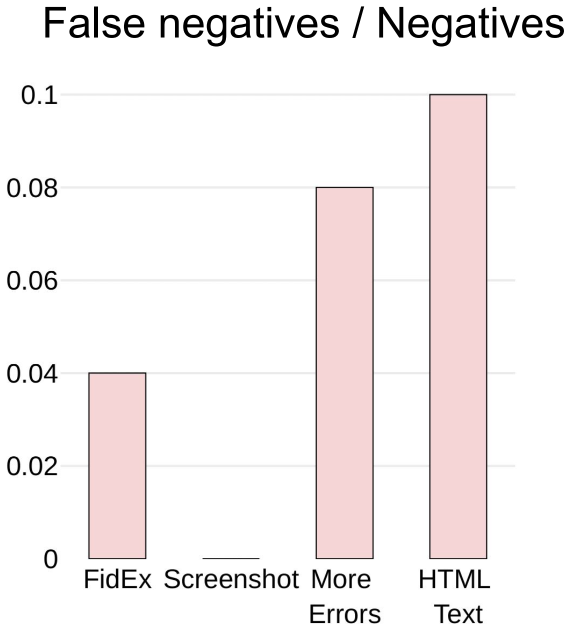

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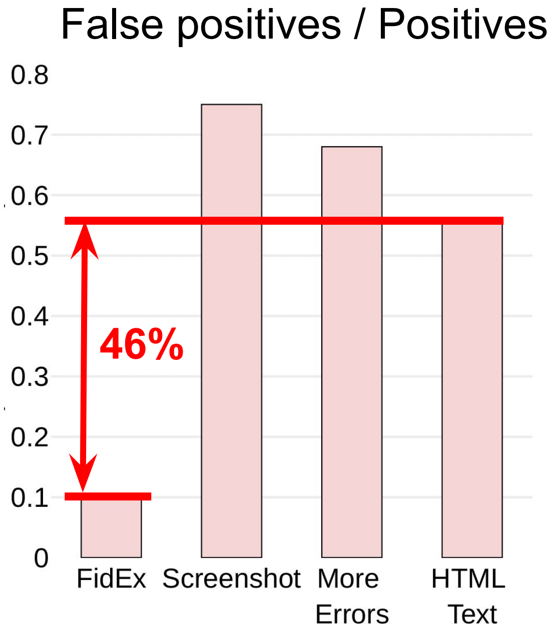
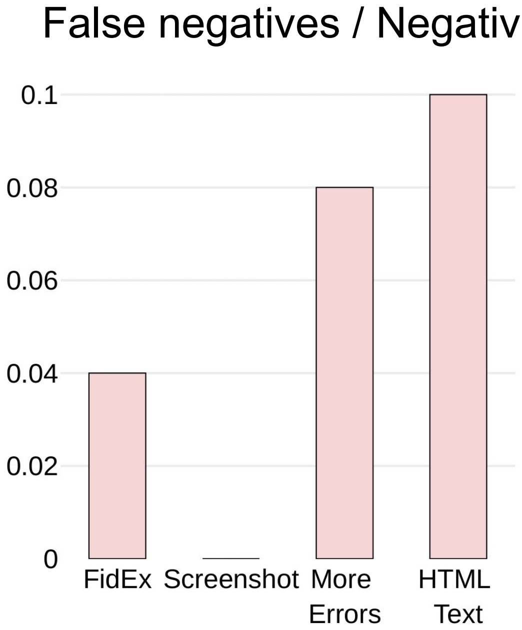
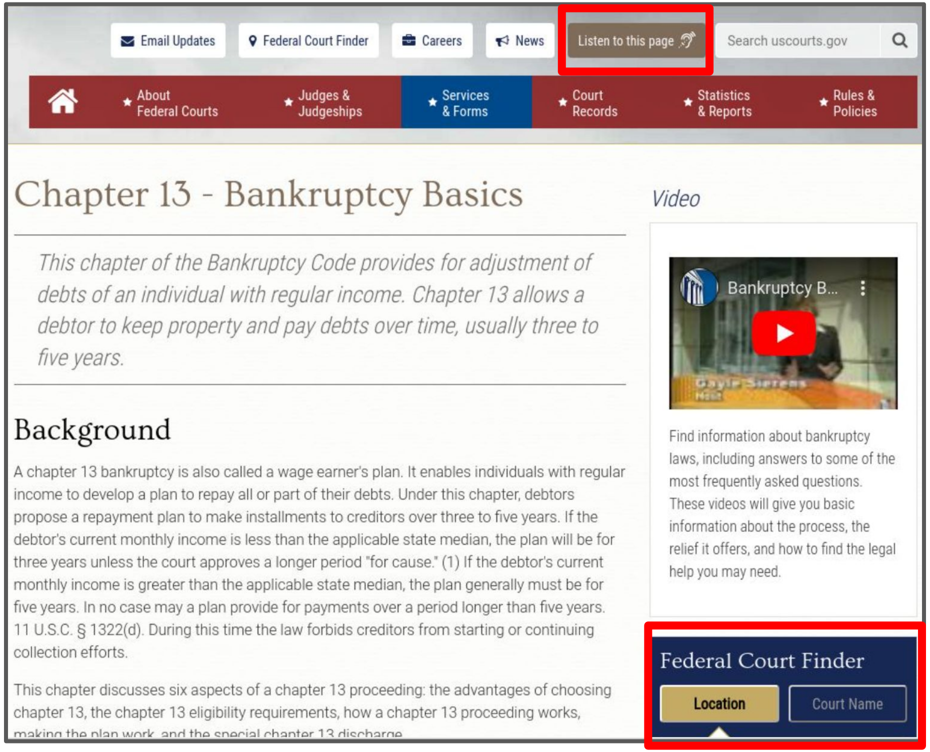




If classify every page as negative, false negative rate will be ~15%

Fidelity Violations Detected by FidEx in EOT

Live web page



Chapter 13 - Bankruptcy Basics

This chapter of the Bankruptcy Code provides for adjustment of debts of an individual with regular income. Chapter 13 allows a debtor to keep property and pay debts over time, usually three to five years.

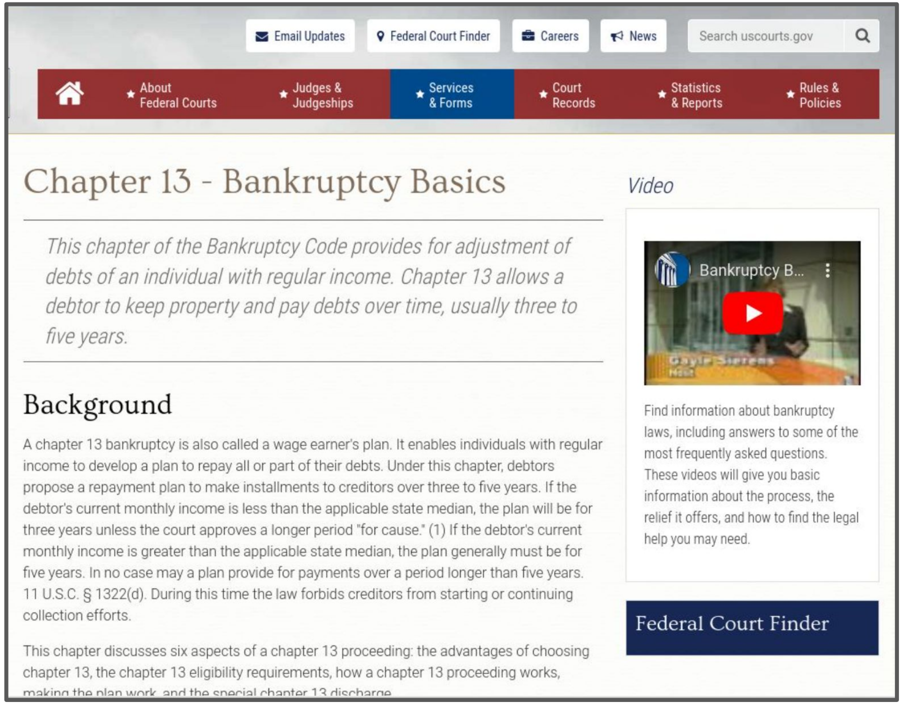
Background

A chapter 13 bankruptcy is also called a wage earner's plan. It enables individuals with regular income to develop a plan to repay all or part of their debts. Under this chapter, debtors propose a repayment plan to make installments to creditors over three to five years. If the debtor's current monthly income is less than the applicable state median, the plan will be for three years unless the court approves a longer period "for cause." (1) If the debtor's current monthly income is greater than the applicable state median, the plan generally must be for five years. In no case may a plan provide for payments over a period longer than five years. 11 U.S.C. § 1322(d). During this time the law forbids creditors from starting or continuing collection efforts.

This chapter discusses six aspects of a chapter 13 proceeding: the advantages of choosing chapter 13, the chapter 13 eligibility requirements, how a chapter 13 proceeding works, making the plan work, and the special chapter 13 discharge

Find information about bankruptcy laws, including answers to some of the most frequently asked questions. These videos will give you basic information about the process, the relief it offers, and how to find the legal help you may need.

Archived copy



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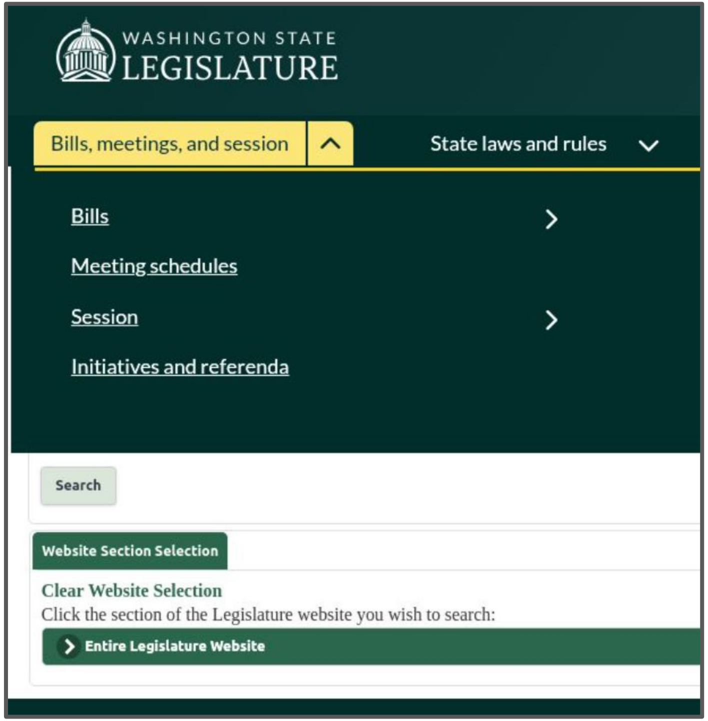
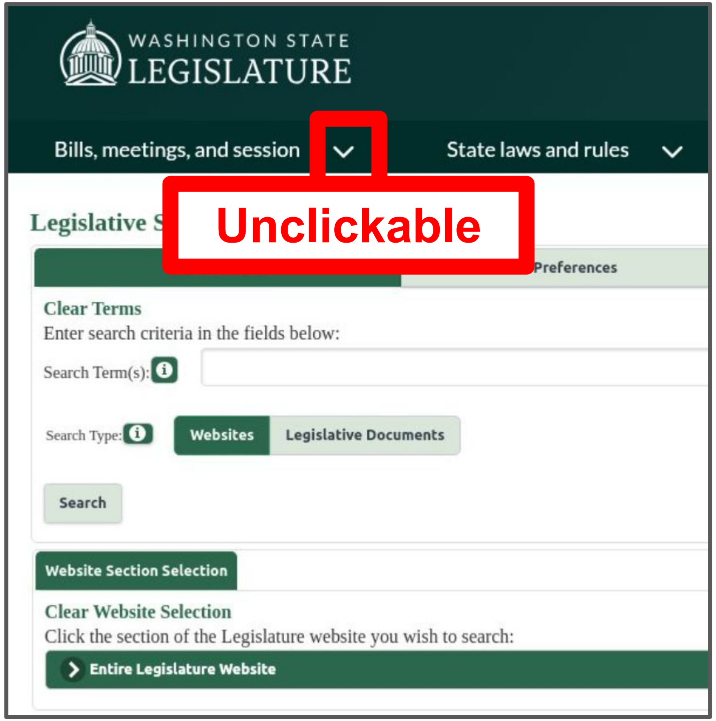


Click the section of the Legislature website you wish to search:

Archived copy



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Click the section of the Legislature website you wish to search:

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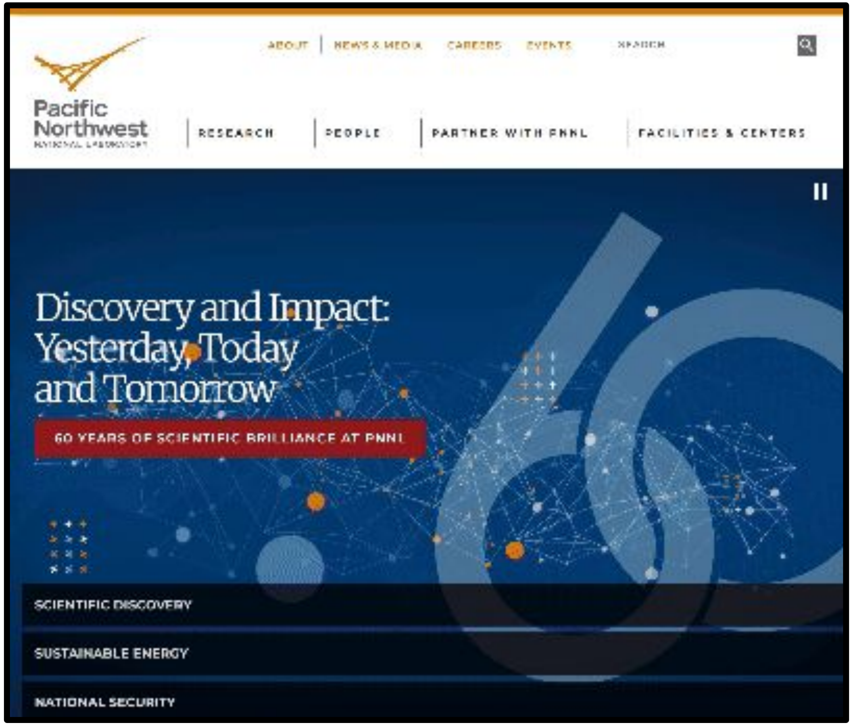
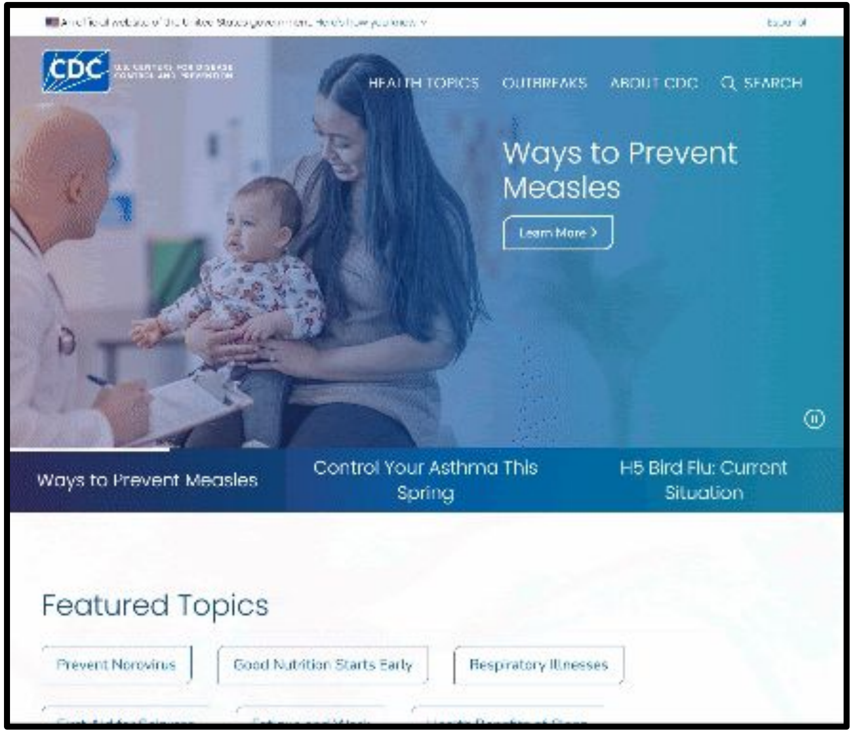


Discovery and Impact: Yesterday, Today and Tomorrow


An official website of the United States government. Here's how you know
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CDC
U.S. CENTERS FOR DISEASE CONTROL AND PREVENTION
HEALTH TOPICS
OUTBREAKS
ABOUT CDC
SEARCH
Learn More
Ways to Prevent Measles
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H5 Bird Flu: Current Situation
Prevent Norovirus
Good Nutrition Starts Early
Respiratory Illnesses

Ways to Prevent Measles

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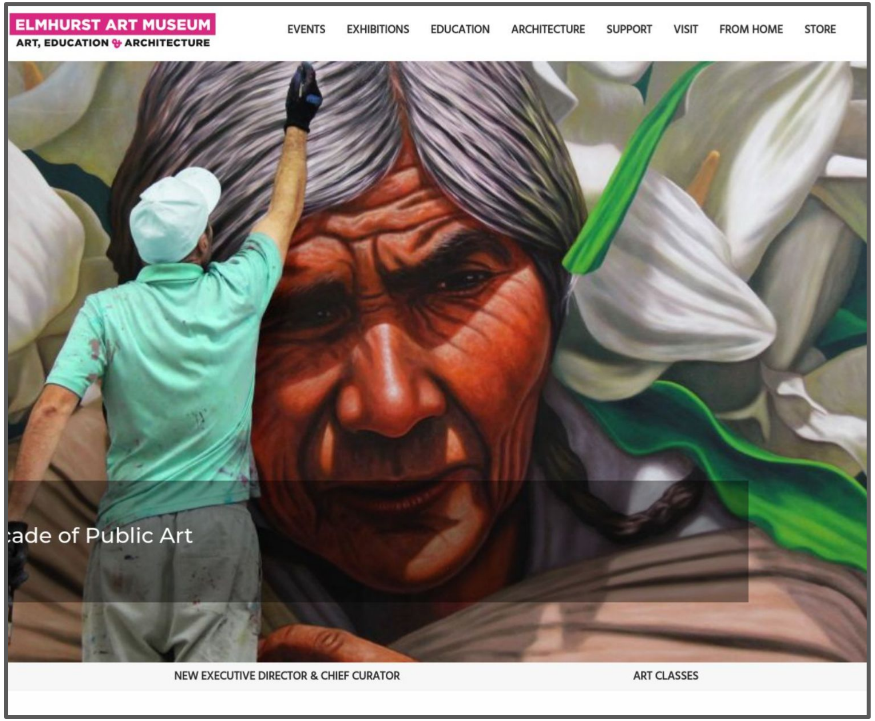

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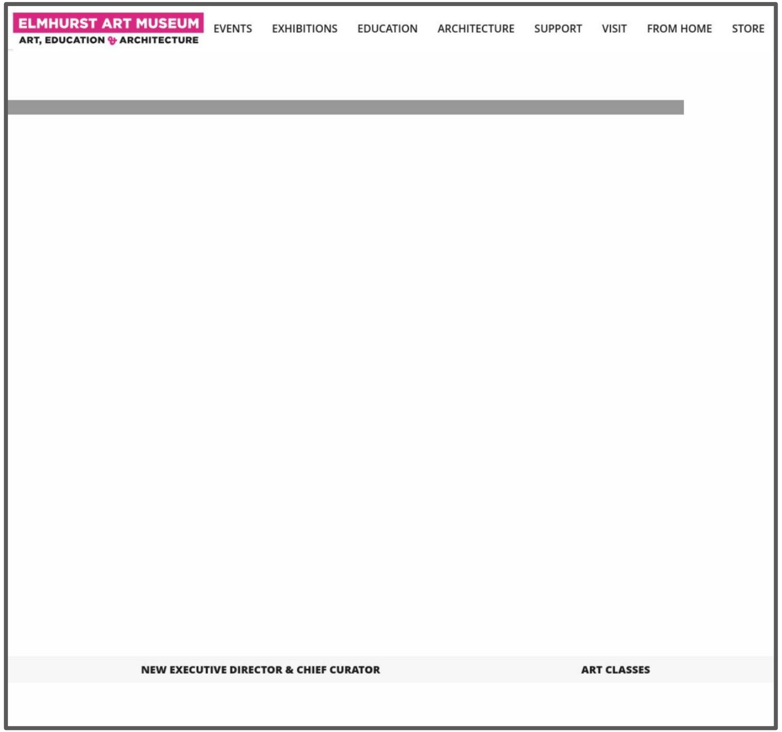
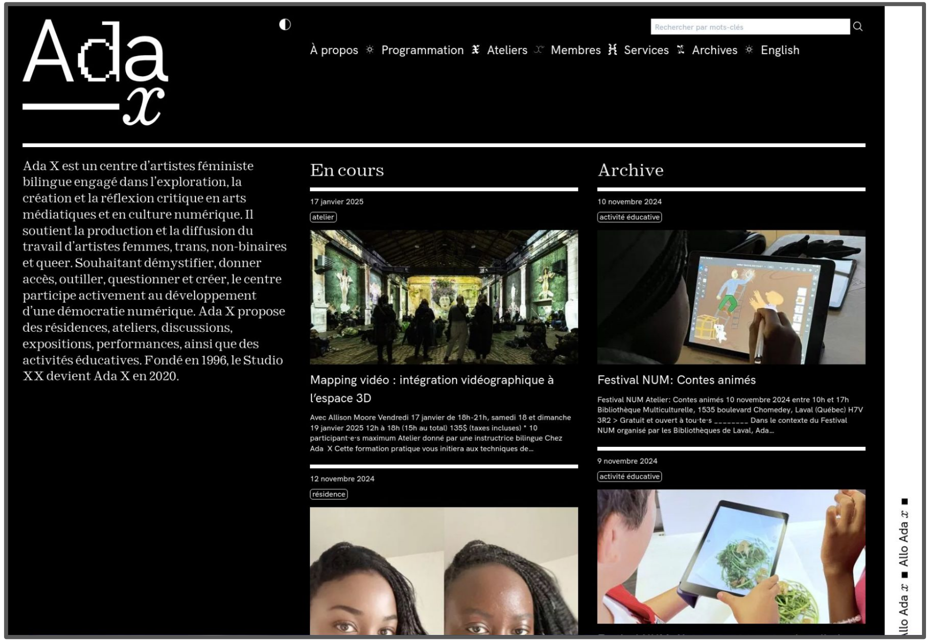


Fidelity Violations Detected by FidEx in CARTA

Live web page



Ada x
◐
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Ada X est un centre d'artistes féministe bilingue engagé dans l'exploration, la création et la réflexion critique en arts médiatiques et en culture numérique. Il soutient la production et la diffusion du travail d'artistes femmes, trans, non-binaires et queer. Souhaitant démystifier, donner accès, outiller, questionner et créer, le centre participe activement au développement d'une démocratie numérique. Ada X propose des résidences, ateliers, discussions, expositions, performances, ainsi que des activités éducatives. Fondé en 1996, le Studio XX devient Ada X en 2020.

En cours

17 janvier 2025

atelier

Mapping vidéo : intégration vidéographique à l'espace 3D

Avec Allison Moore Vendredi 17 janvier de 18h-21h, samedi 18 et dimanche 19 janvier 2025 12h à 18h (15h au total) 135$ (taxes incluses) * 10 participant·e·s maximum Atelier donné par une instructrice bilingue Chez Ada X Cette formation pratique vous initiera aux techniques de...

12 novembre 2024

résidence

Archive

10 novembre 2024

activité éducative

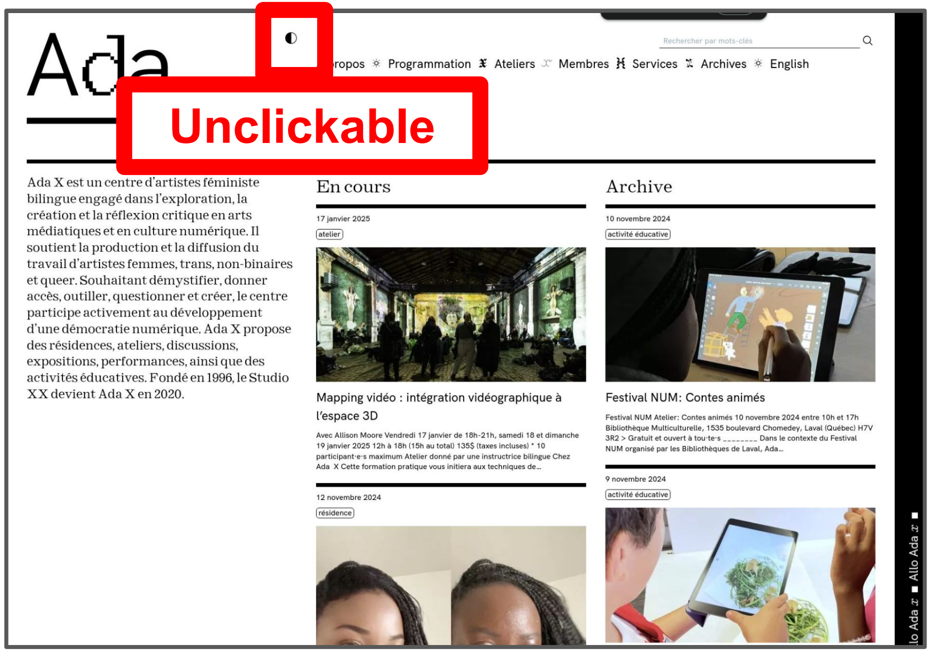
Festival NUM: Contes animés

Festival NUM Atelier: Contes animés 10 novembre 2024 entre 10h et 17h Bibliothèque Multiculturelle, 1535 boulevard Chomedey, Laval (Québec) H7V 3R2 > Gratuit et ouvert à tou·te·s ________ Dans le contexte du Festival NUM organisé par les Bibliothèques de Laval, Ada...

9 novembre 2024

activité éducative

Archived copy



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Ada
◐
Rechercher par mots-clés
ropos ☼ Programmation ⌘ Ateliers ⌘ Membres ⌘ Services ⌘ Archives ☼ English
Allo Ada x ■ Allo Ada x ■

Ada X est un centre d'artistes féministe bilingue engagé dans l'exploration, la création et la réflexion critique en arts médiatiques et en culture numérique. Il soutient la production et la diffusion du travail d'artistes femmes, trans, non-binaires et queer. Souhaitant démystifier, donner accès, outiller, questionner et créer, le centre participe activement au développement d'une démocratie numérique. Ada X propose des résidences, ateliers, discussions, expositions, performances, ainsi que des activités éducatives. Fondé en 1996, le Studio XX devient Ada X en 2020.

En cours

17 janvier 2025

atelier

Mapping vidéo : intégration vidéographique à l'espace 3D

Avec Allison Moore Vendredi 17 janvier de 18h-21h, samedi 18 et dimanche 19 janvier 2025 12h à 18h (15h au total) 135$ (taxes incluses) * 10 participant·e·s maximum Atelier donné par une instructrice bilingue Chez Ada X Cette formation pratique vous initiera aux techniques de...

12 novembre 2024

résidence

Archive

10 novembre 2024

activité éducative

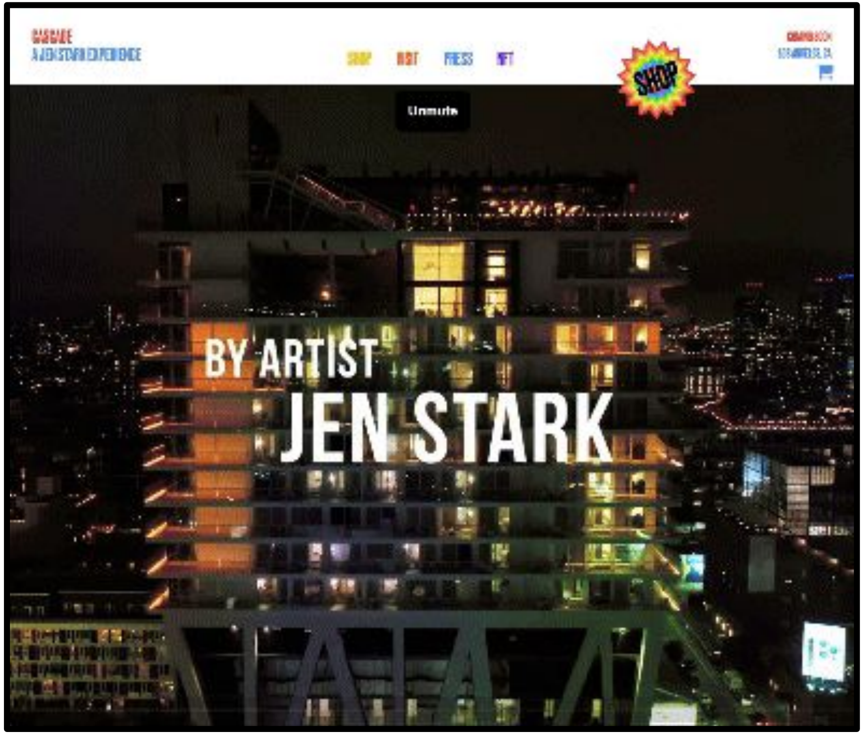
Festival NUM: Contes animés

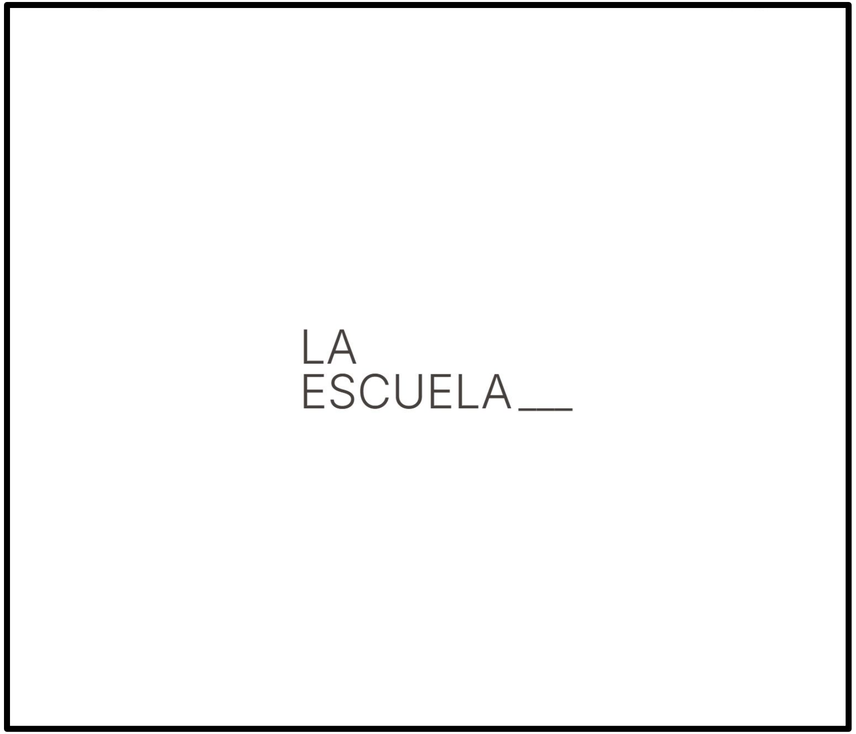
Festival NUM Atelier: Contes animés 10 novembre 2024 entre 10h et 17h Bibliothèque Multiculturelle, 1535 boulevard Chomedey, Laval (Québec) H7V 3R2 > Gratuit et ouvert à tou·te·s ________ Dans le contexte du Festival NUM organisé par les Bibliothèques de Laval, Ada...

9 novembre 2024

activité éducative

False Positives with Screenshot Comparison in CARTA





Summary

- Bugs in JS rewrites → Poor fidelity replay of archived pages

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Detection

- Screenshot comparison leads to false positives
- Instead, compare layout tree and JS writes

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Diagnosis

- Discover errors not reported by browser
- Confirm which errors are worth investigating

Thank you!

Q & A