RippleGUItester: Change-Aware Exploratory Testing

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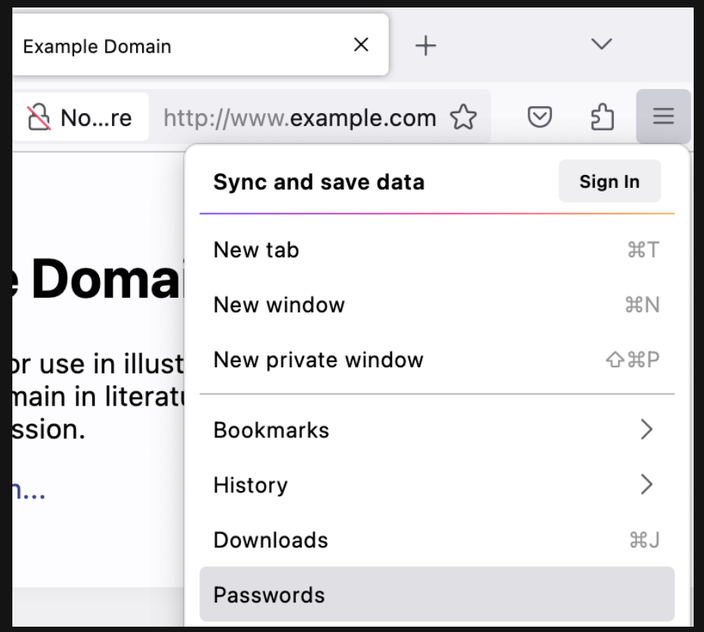
Motivating Example (Firefox)

Issue 1858633: Password page opens with incorrect URL



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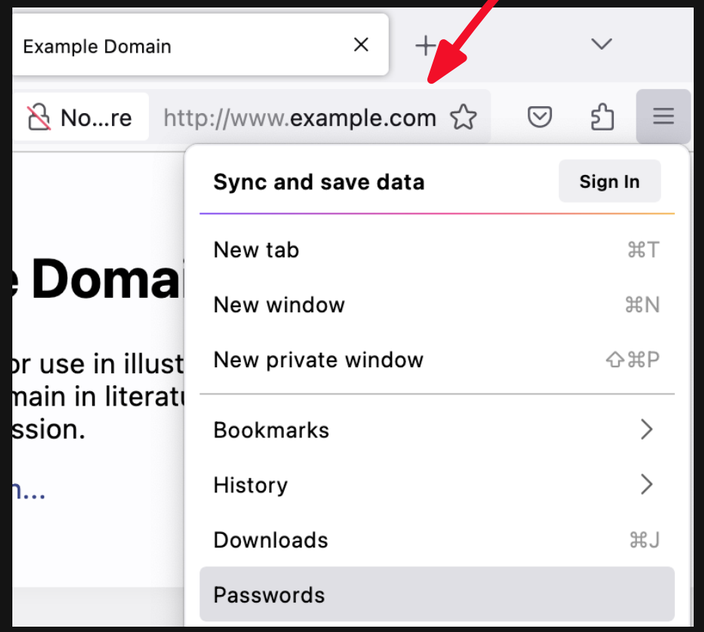

Go to example.com

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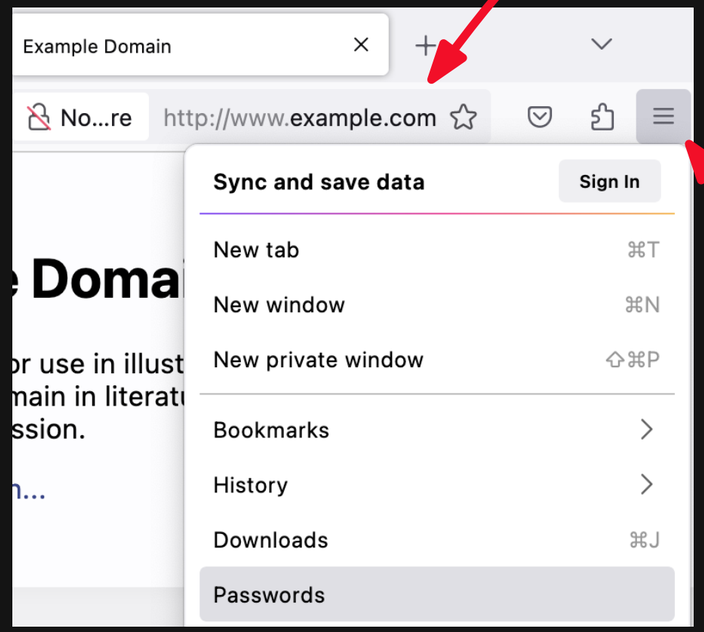

Go to example.com

Click on menu

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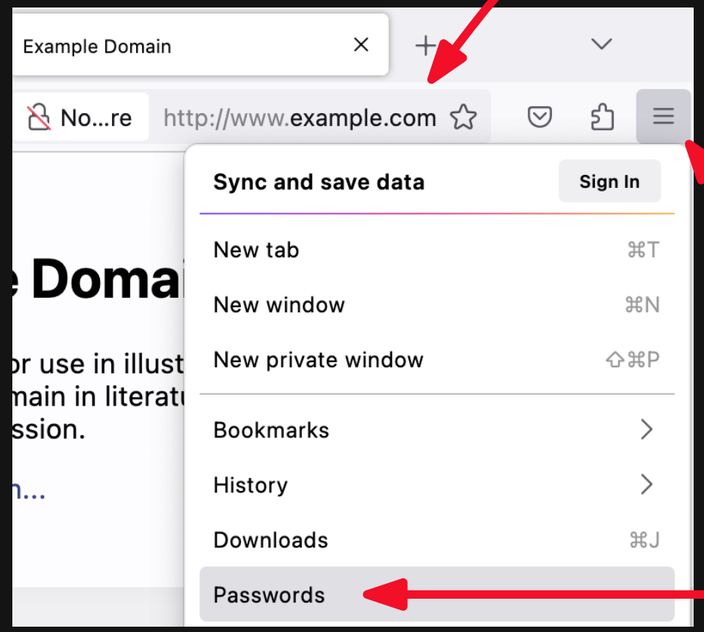

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Click on Passwords

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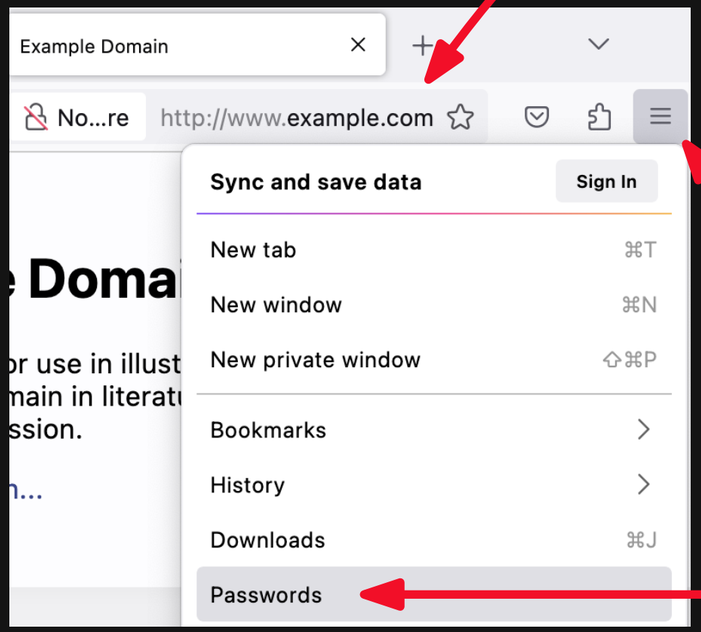

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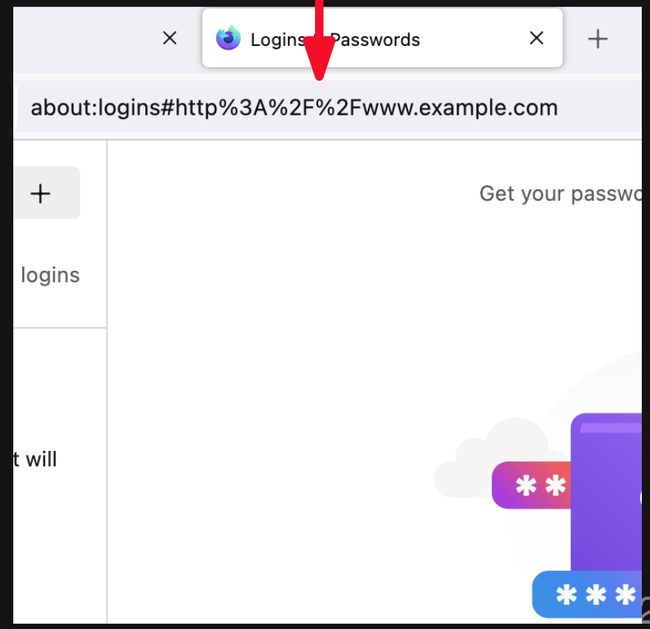

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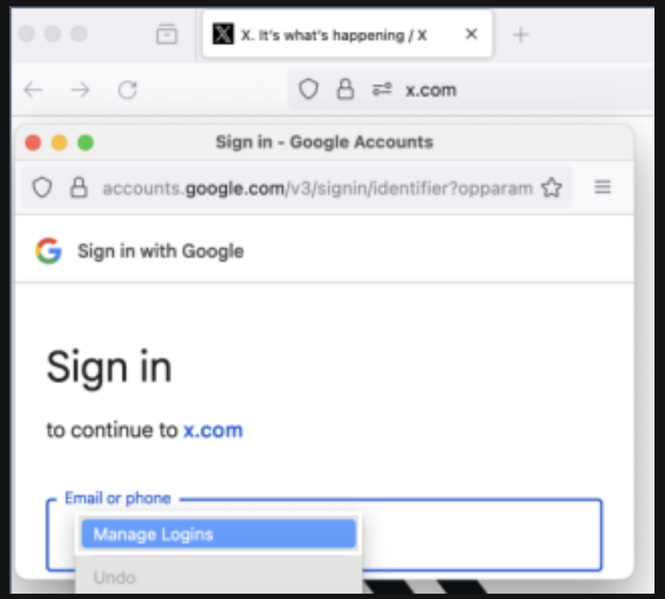

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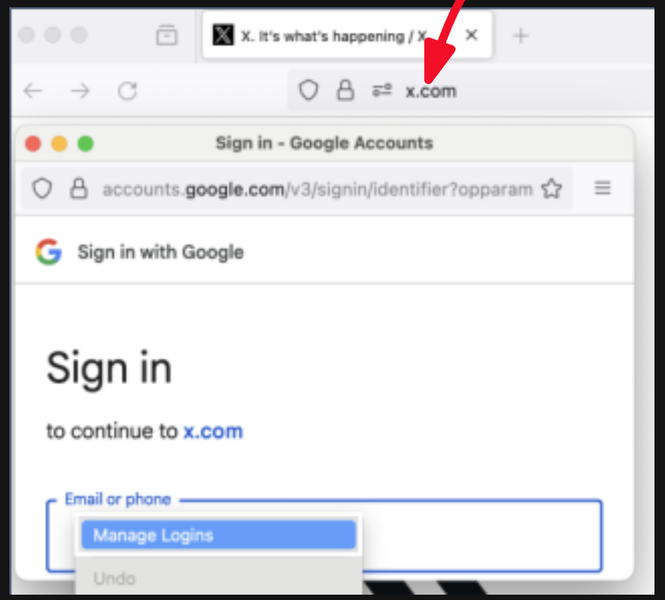

Open site with
pop-up login window

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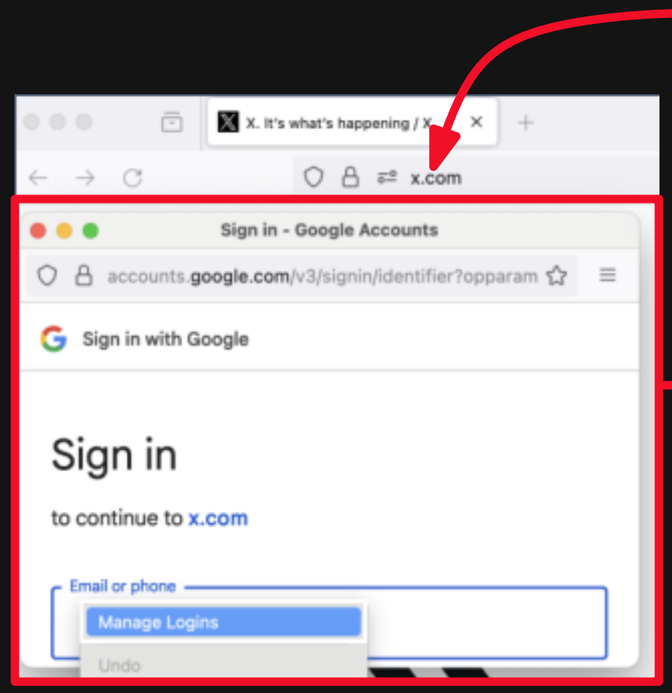

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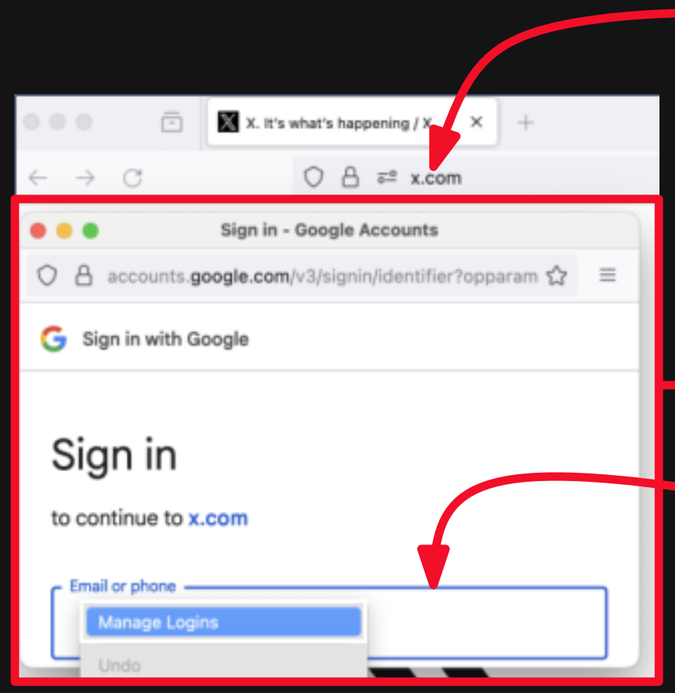

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Right-click input field

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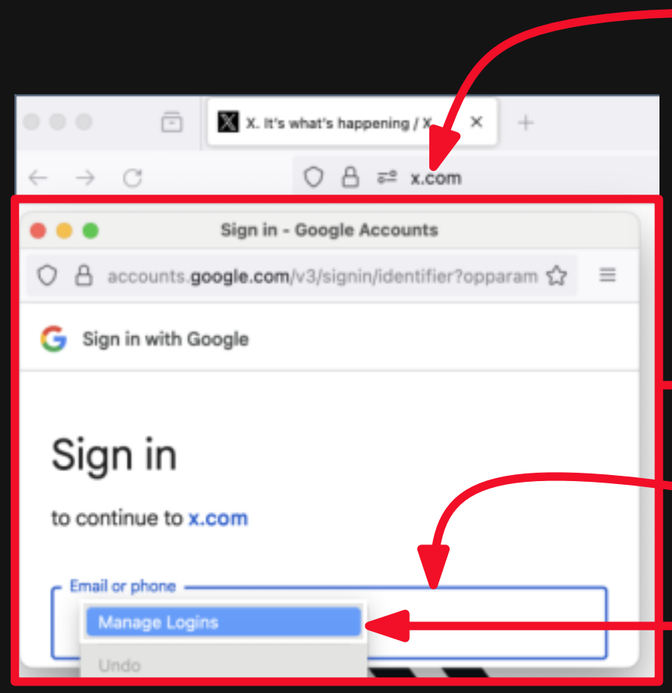

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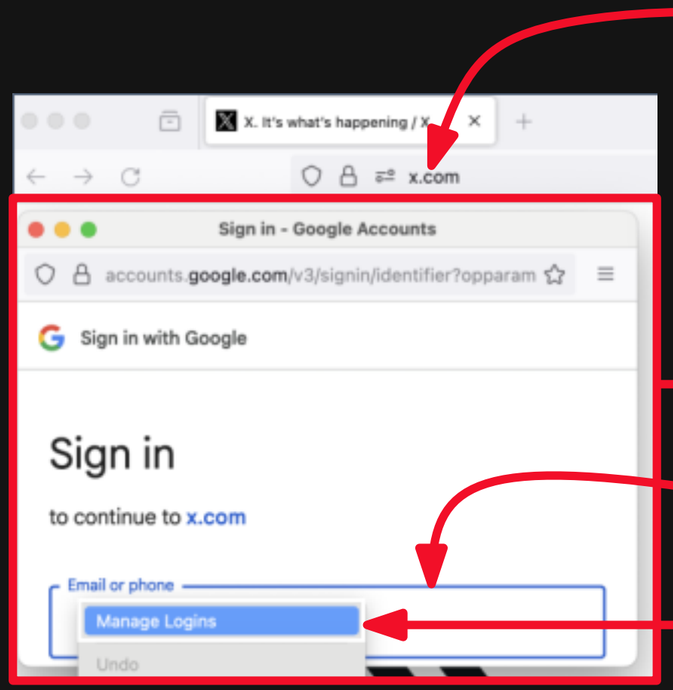

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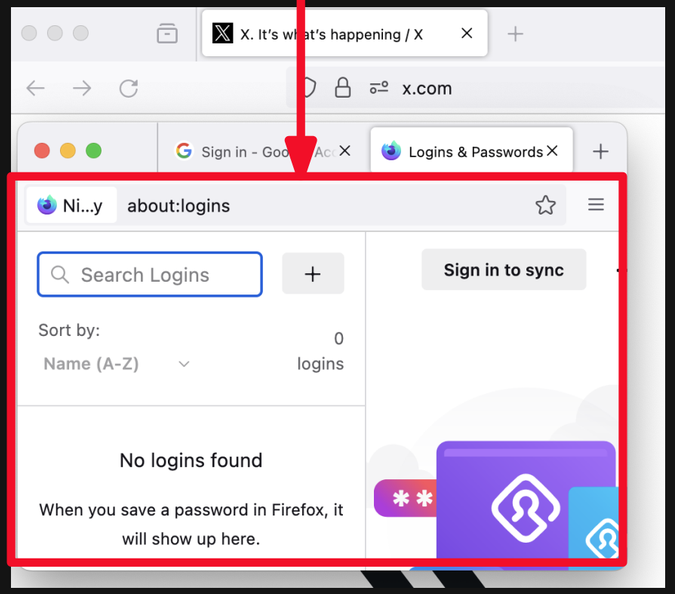
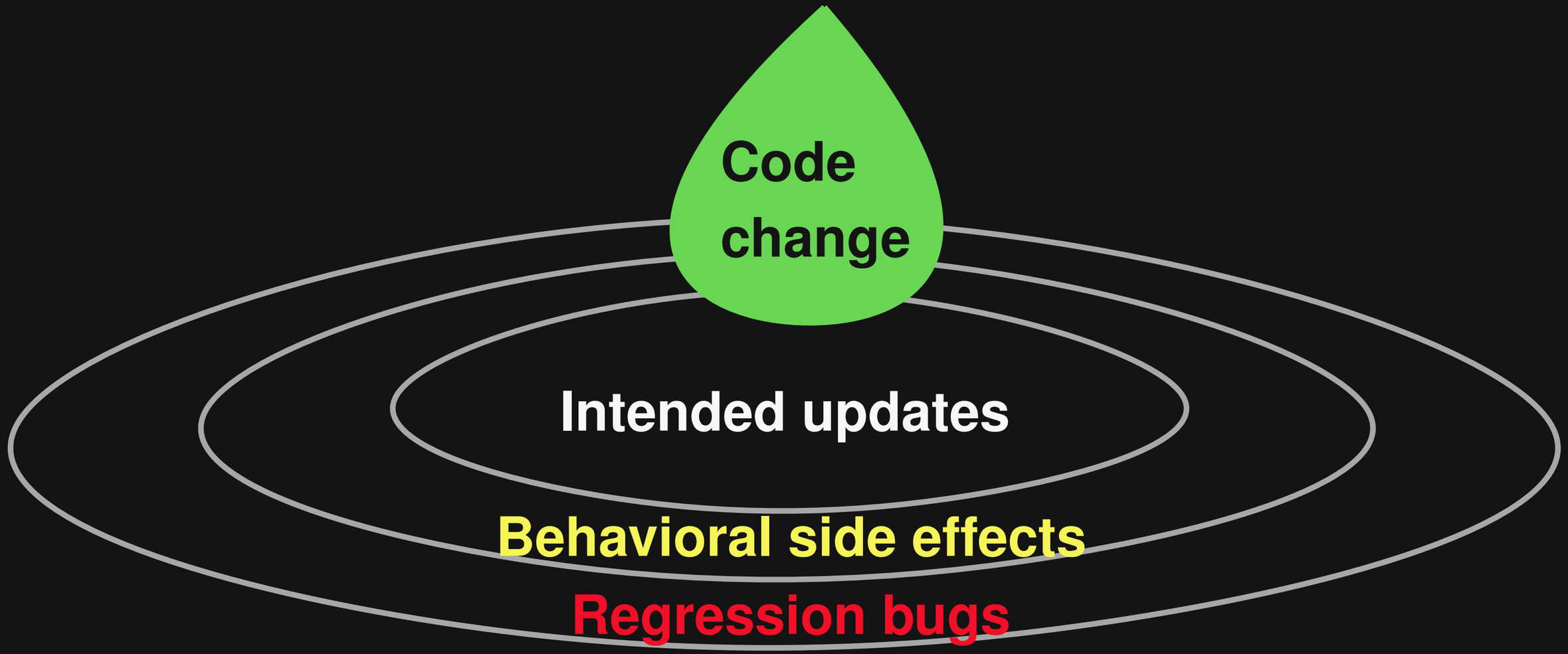


The Ripple Effect of Code Changes



How Often Does This Happen?

97,347 PRs merged into Firefox

Search for issues introduced by these PRs

11,910 PRs (12.2%) of PRs introduced at least one new bug

(Conservative estimate due to missing links and unknown bugs)

Why Is It So Hard?

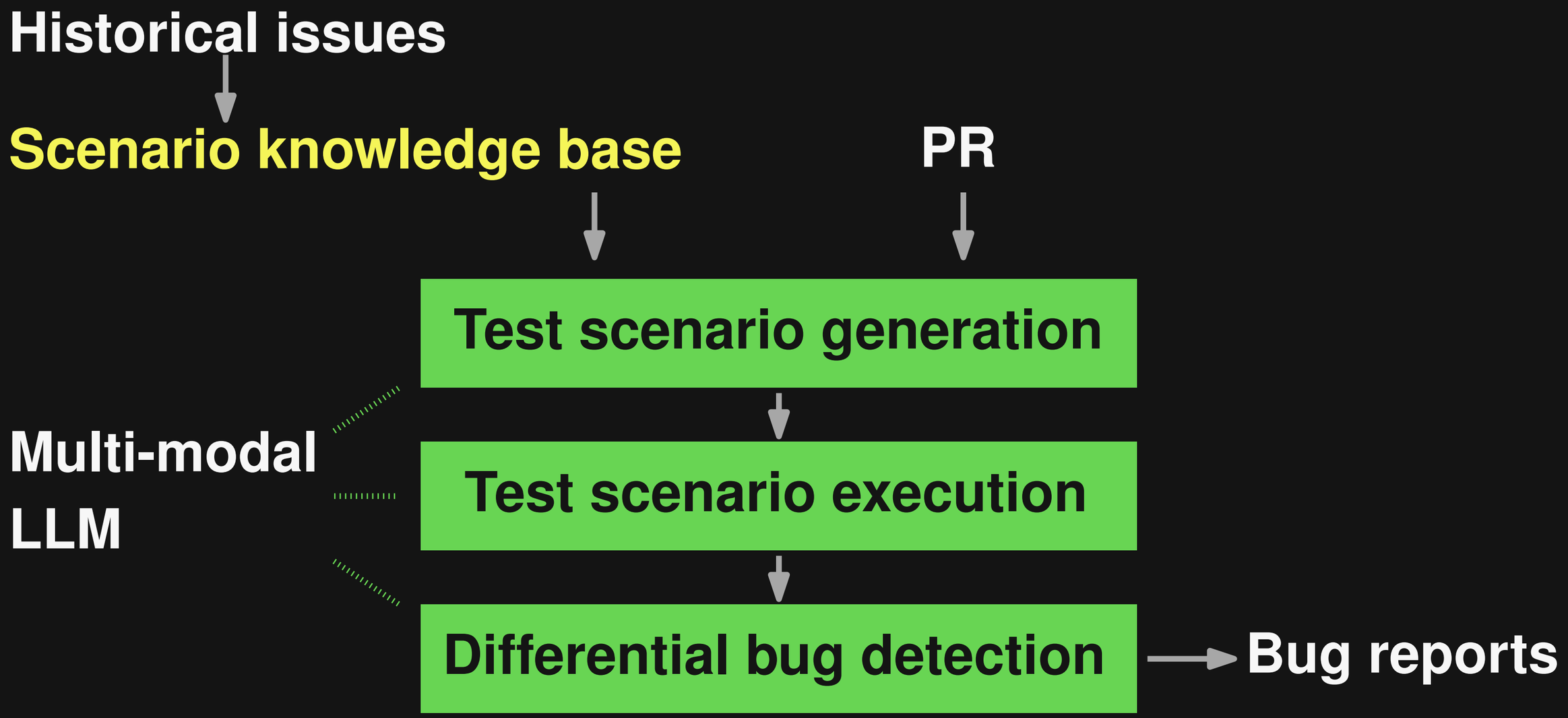
Two reasons:

1) **Challenging trigger steps**

- Specific event sequences
- Specific test data

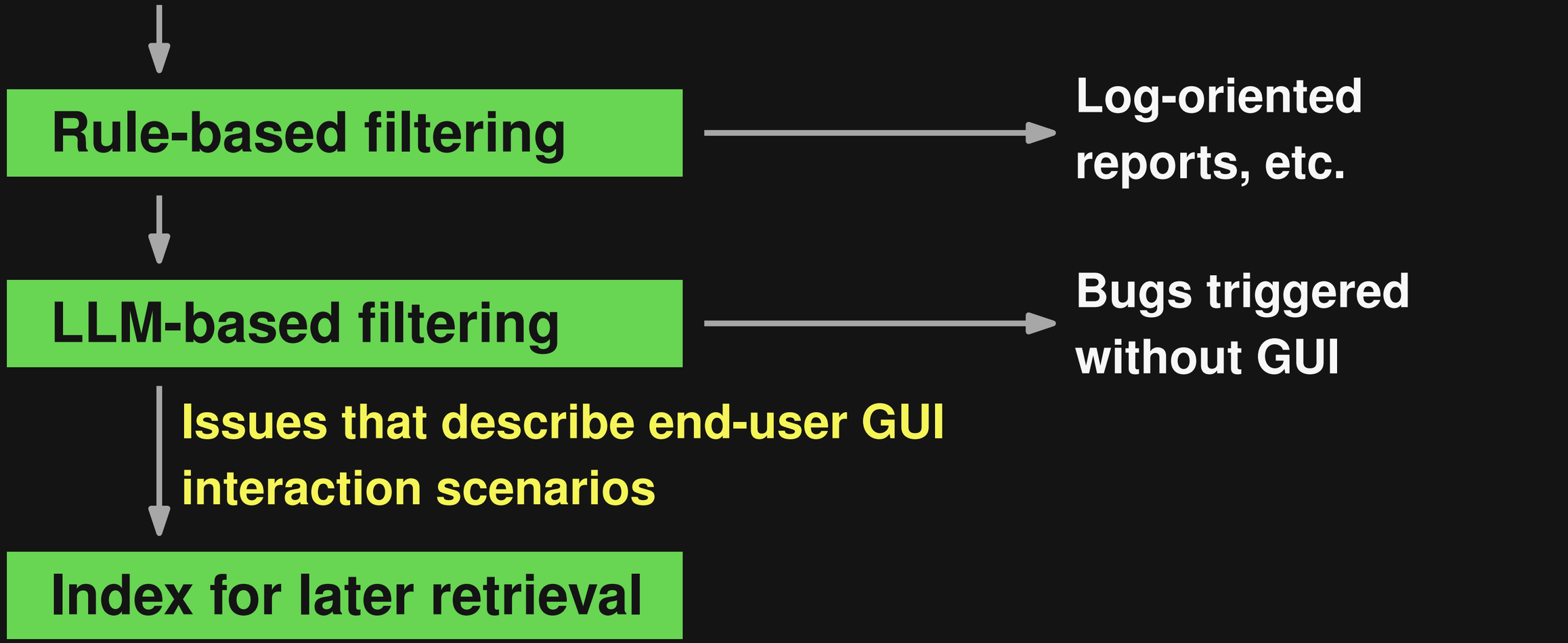
2) **Hard-to-predict oracles**

Overview of RippleGUItester



Scenario Knowledge Base

All issues in project history



Test Scenario Generation

Pipeline of structured LLM queries:

1) Analyze change impact and generate test scenarios
2) Enrich scenarios using retrieved past scenarios
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Example:

- Understands that change affects how Passwords page is opened
- But: Unaware of all entry points to the Passwords page

Test Scenario Generation

Pipeline of structured LLM queries:

1) **Analyze change impact and generate test scenarios**
2) **Enrich scenarios using retrieved past scenarios**
3) **Enhance test data**

Example:

- Finds event sequences that reach Passwords page
- But: Input data remains vague (“from site A, open pop-up window”)

Test Scenario Generation

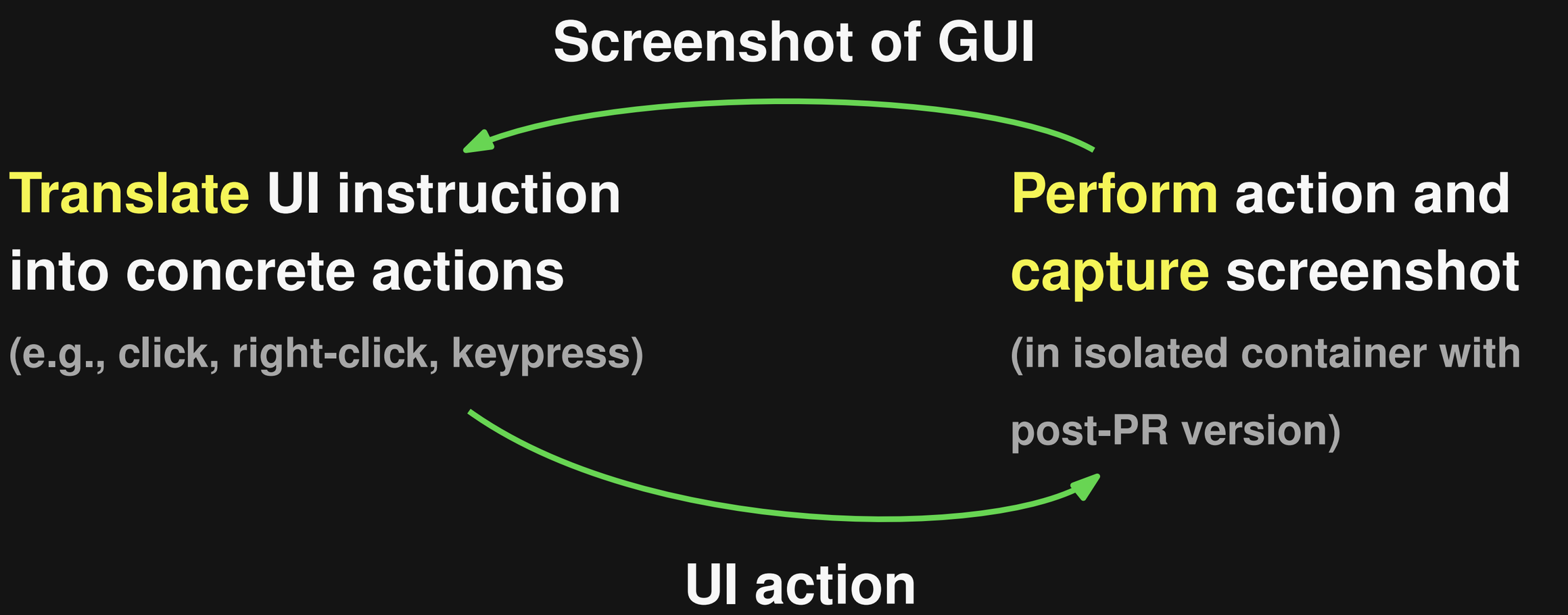
Pipeline of structured LLM queries:

1) **Analyze change impact and generate test scenarios**
2) **Enrich scenarios using retrieved past scenarios**
3) **Enhance test data**

Example:

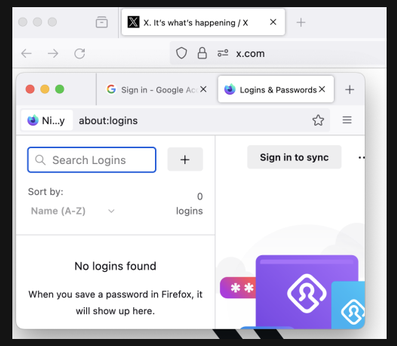
- Instantiates abstract input data requirements
- Generates a script that reliably creates a pop-up

Tests Scenario Execution

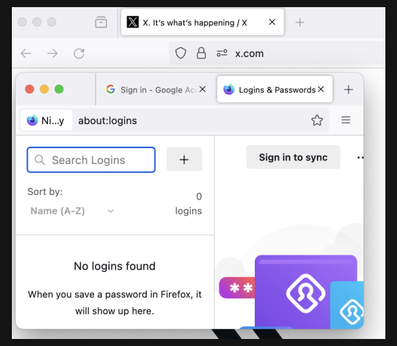


Differential Bug Detection

Pre-PR execution



Post-PR execution



Pixel-based comparison

LLM-based bug detection

LLM-based bug deduplication and filtering

Bug report

Experimental Setup

- **Target projects**
  - Firefox (30 PRs with known regressions)
  - Zettlr (38 recent PRs), Godot (25 recent PRs), JabRef (18 recent PRs)
- **LLMs**
  - GPT-5-nano for filtering historical issues
  - GPT-5.2 for scenario generation and bug detection
  - Claude Opus 4.5 for scenario execution

Bug Detection: Real-World Findings

- 26 previously unknown findings reported to developers
- 18 fixed, 3 confirmed, 5 intended behavior

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Example from Zettlr publication workbench:

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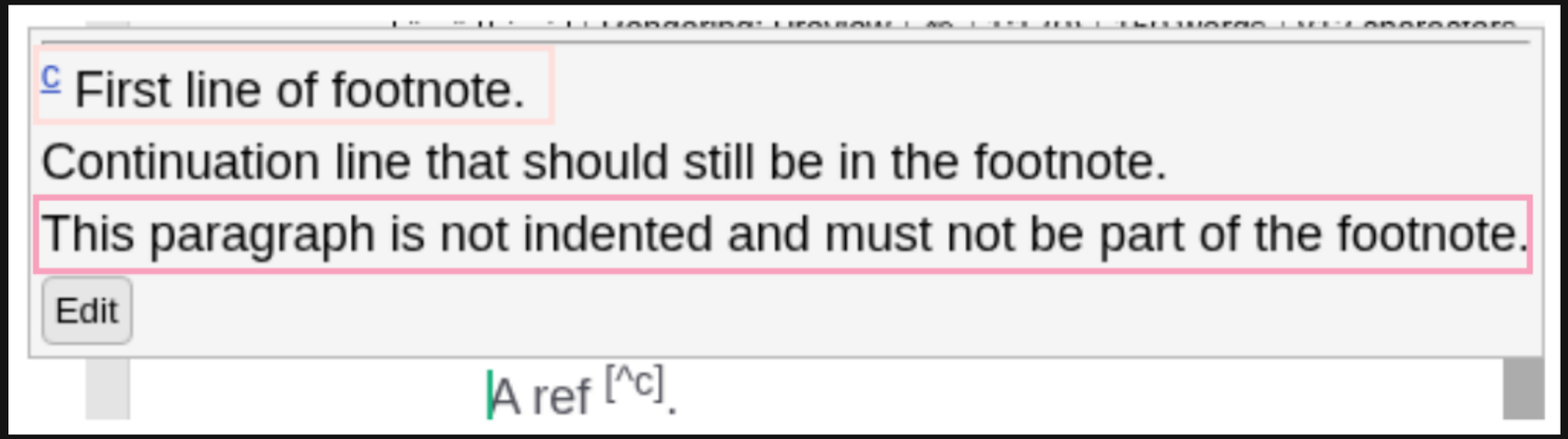

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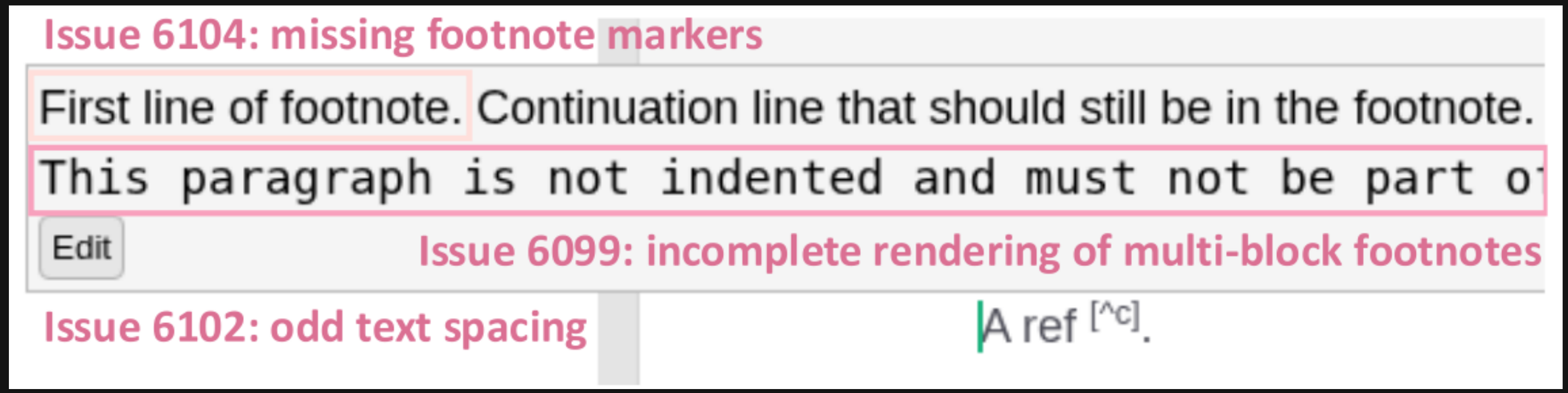

Bug Detection: Precision & Recall

SUT	PR #	Bug #	TP #	FP #	Prec.
Firefox	30	29	52	41	0.559
Zettlr	38	63	67	95	0.414
JabRef	18	15	17	23	0.425
Godot	25	10	10	14	0.417
Total	111	117	146	173	0.458

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On average, a PR introduces more than one new bug!

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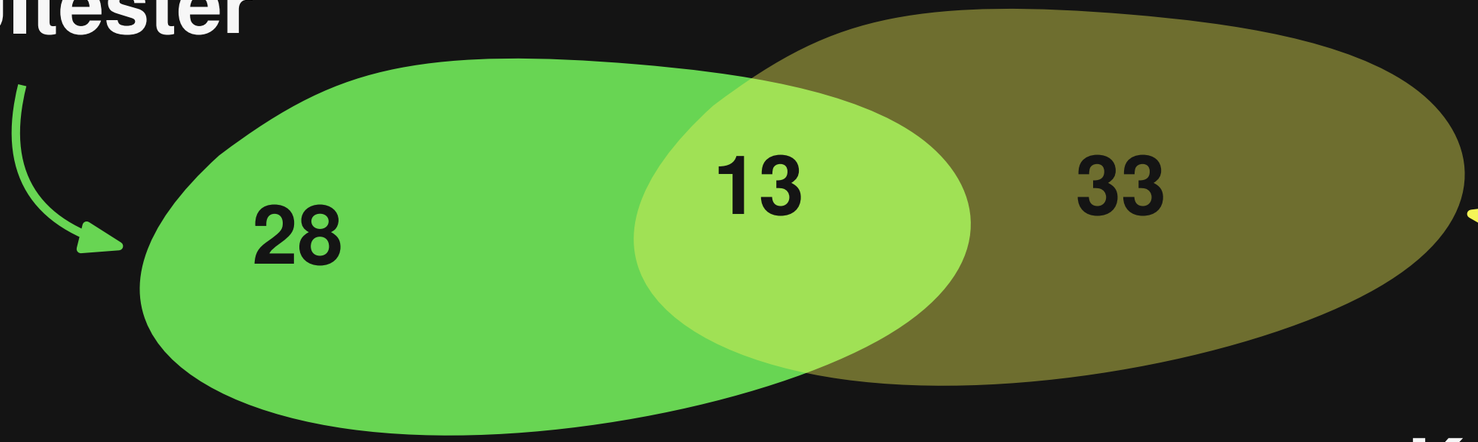
Common reasons for false positives:

- GUI rendering and temporal instability (45%)
- LLM reasoning errors (28%)

Bug Detection: Precision & Recall

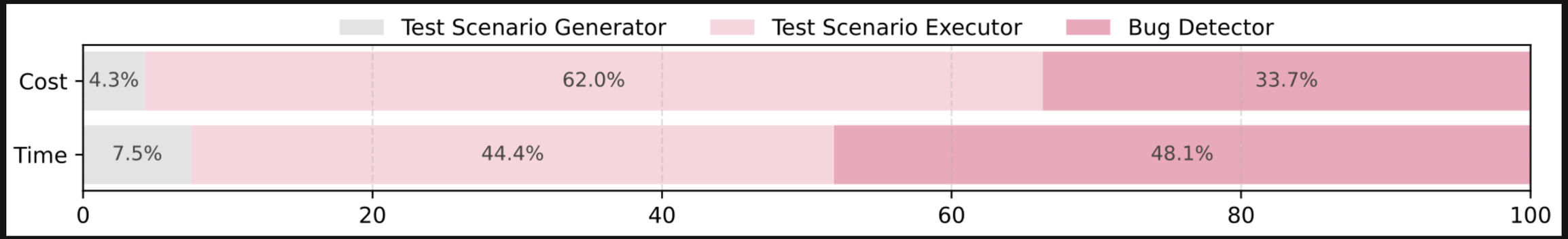
Bugs detected by RippleGUItester



Known bugs in Firefox

Costs and Efficiency

- Scenario knowledge base (**one-time effort**):
  3.22–50.3 hours, USD 0.50–20.82
- **Per-PR costs**:
  54.8 minutes, USD 6.00



Conclusions

- **Code changes have ripple effects**
- **RippleGUItester: Change-aware exploratory testing**
  - GUI-level test scenarios
  - Visual oracle enabled by multi-modal LLMs
- **Envisioned usage:**
  Check changes before or shortly after merging