Monkey See, Monkey Do: Effective Generation of GUI Tests with Inferred Macro Events

Markus Ermuth
Michael Pradel

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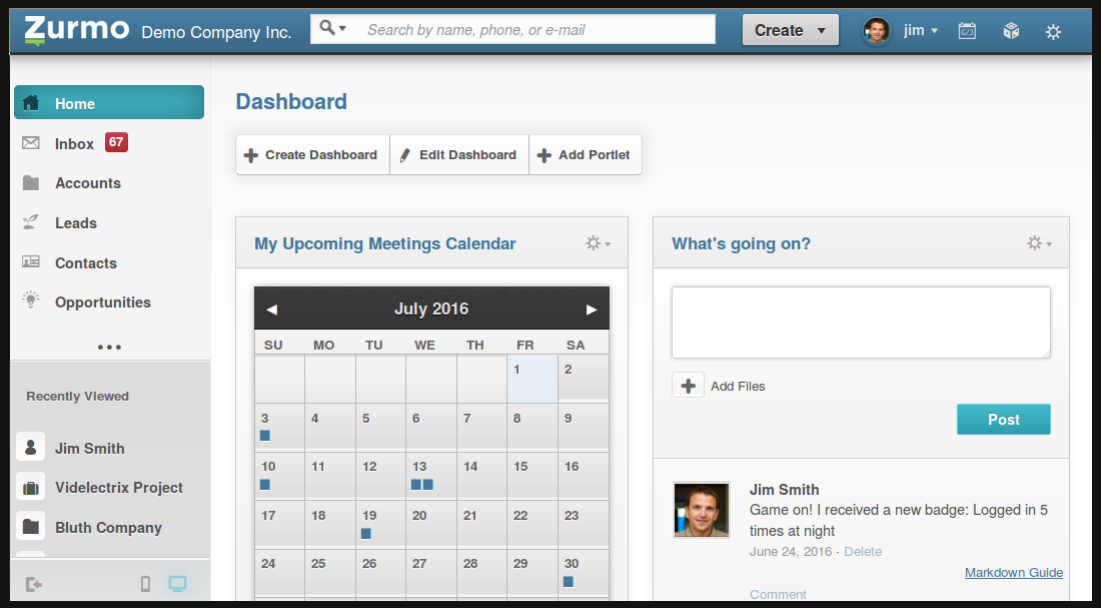
Motivation

How to test complex GUIs?

Manual **Analysis-based** **Random**

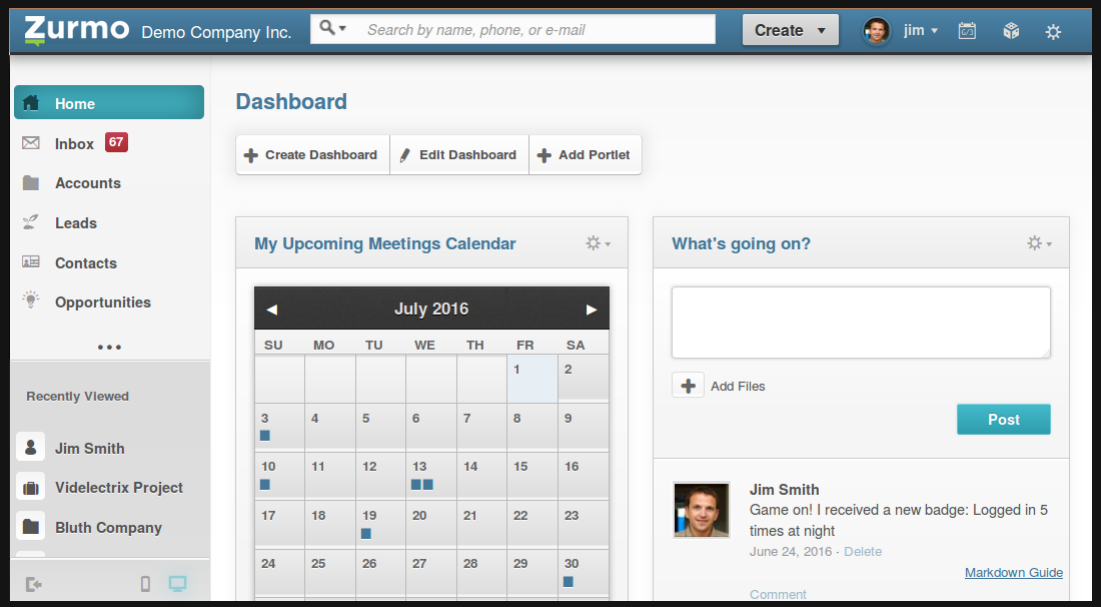


Motivation

How to test complex GUIs?

Manual Analysis-based Random

- **Realistic event sequences**
- **Huge effort**

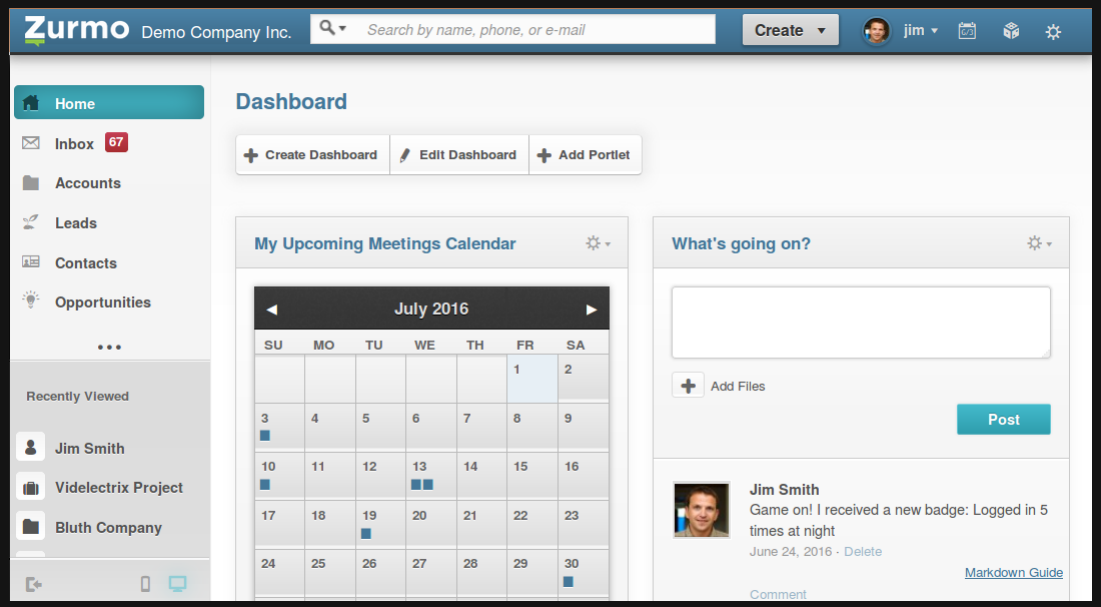


Motivation

How to test complex GUIs?

Manual **Analysis-based** **Random**

- **Automatic**
- **Scalability issues**



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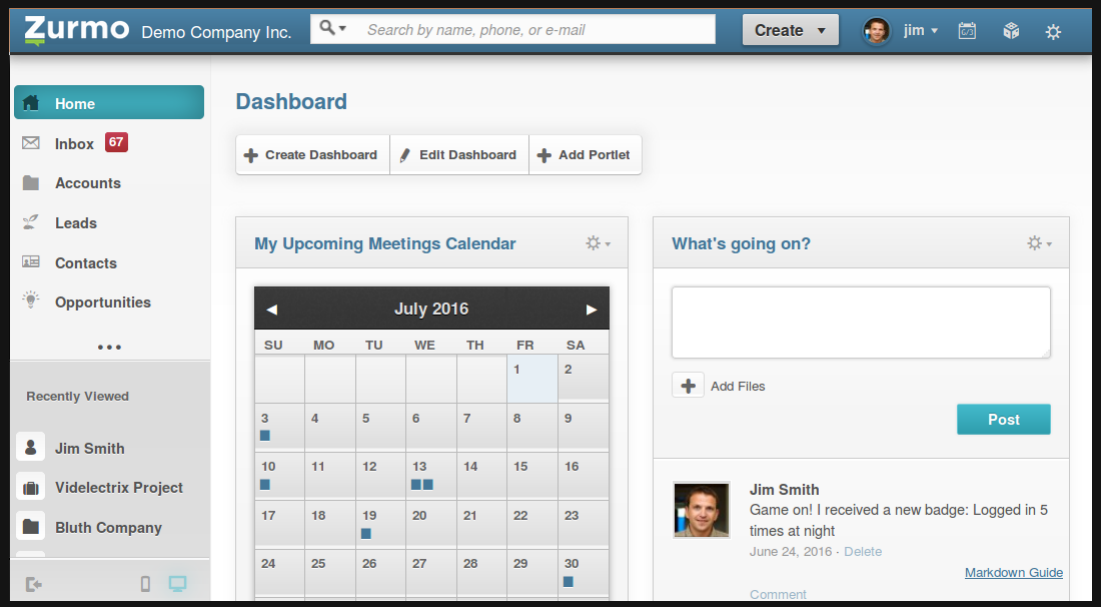
How to test complex GUIs?

Manual **Analysis-based** **Random**

- **Automatic and scalable**
- **Used in practice**



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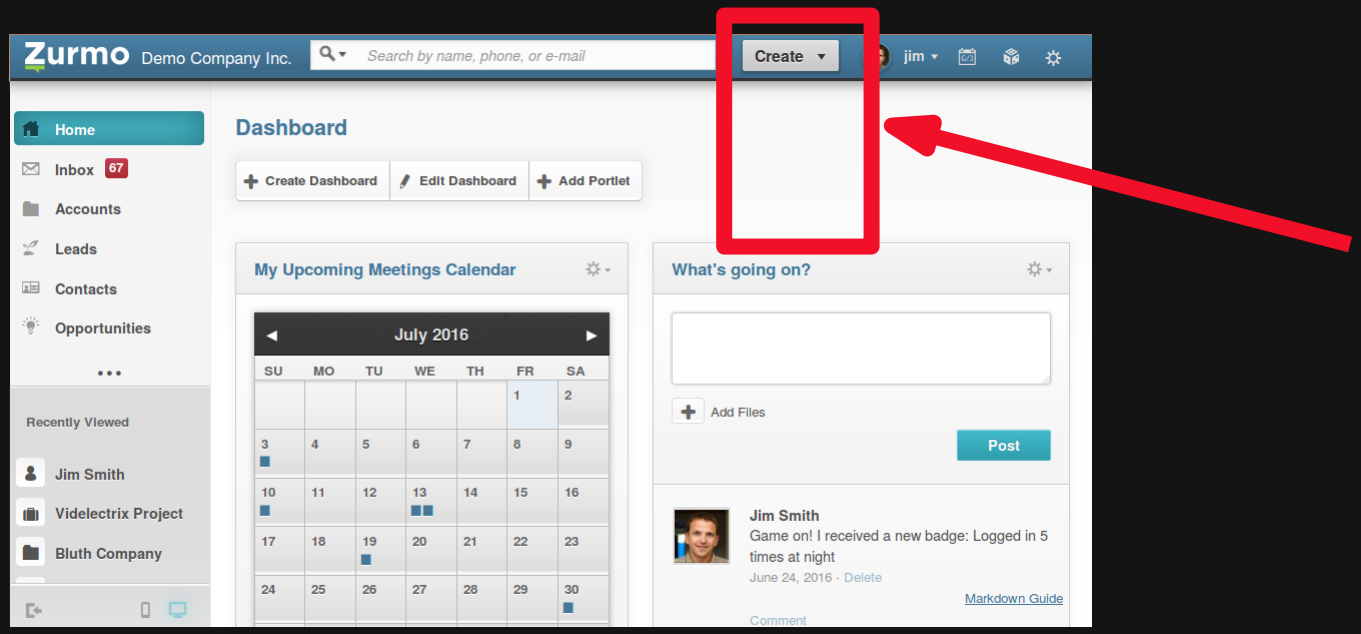


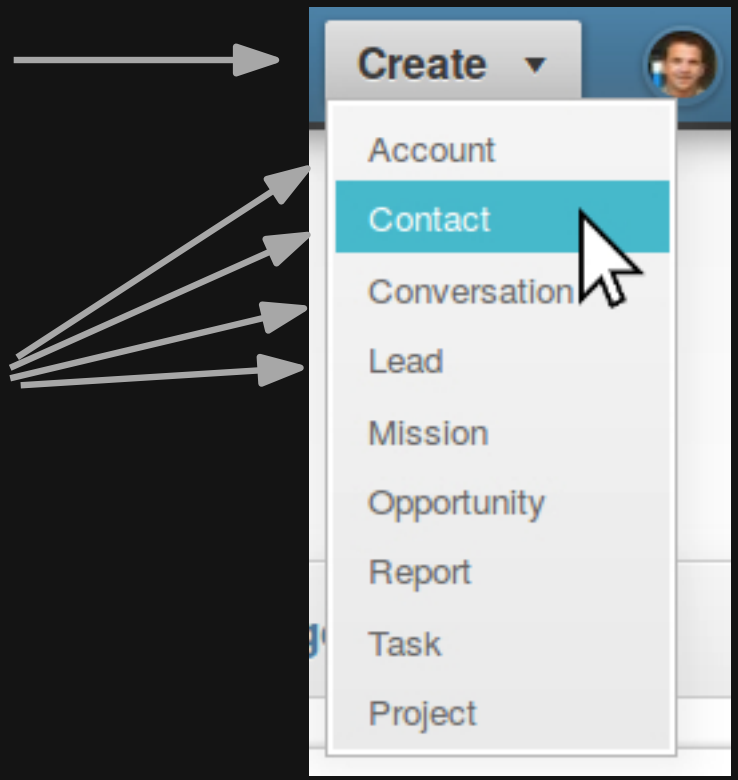
Problem

Header:

- **Mouseover**

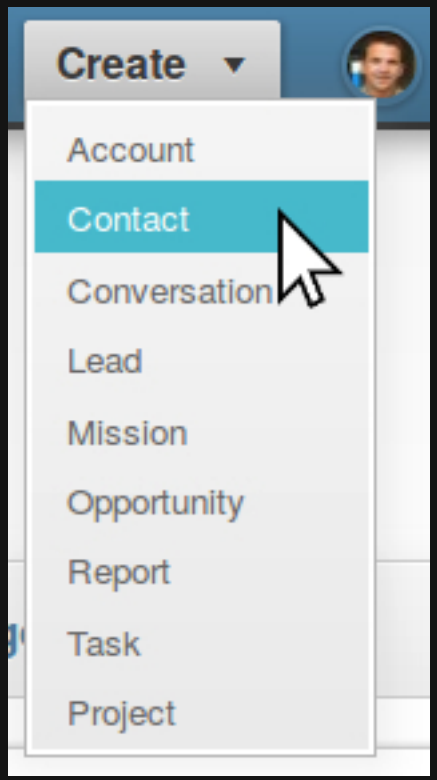
Items:

- **Mouseover**
- **Mouseout**
- **Click**



Problem

- Effective testing requires **complex**, **realistic** sequences of events
- **Probability** to hit them by chance: **Extremely small**



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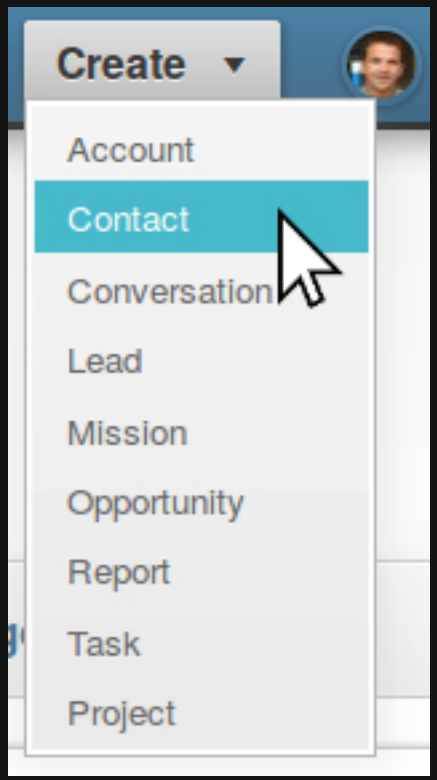


Observation:
UI-level events $\neq$ Logical events

This Talk

Monkey see, monkey do

- **Learn** usage patterns from users
- **Imitate** them during test generation

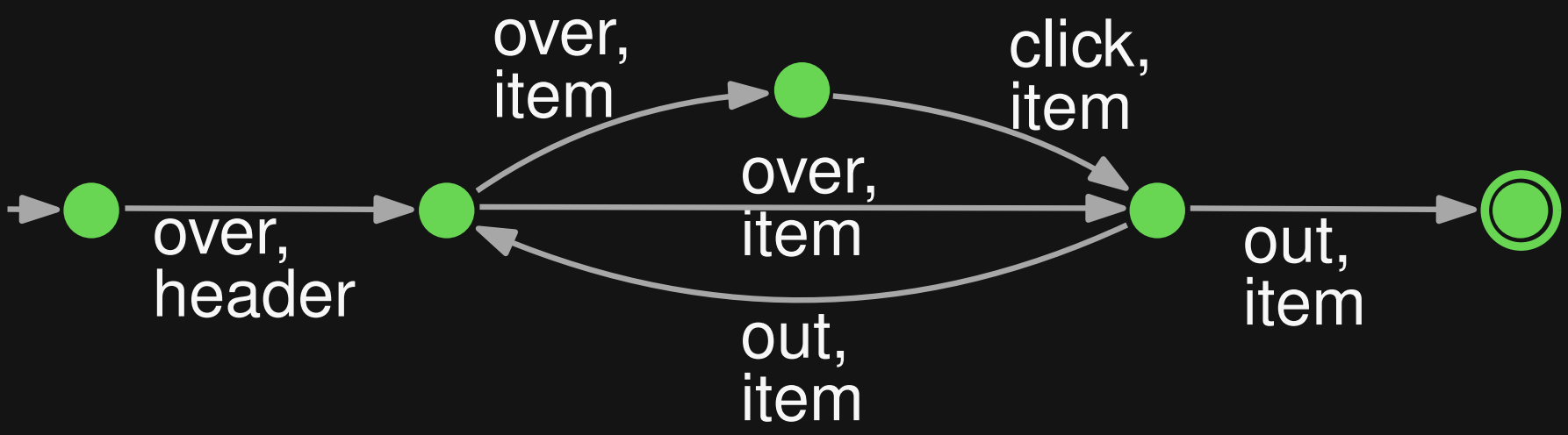
Events vs. Macro Events

Event (implementation level)

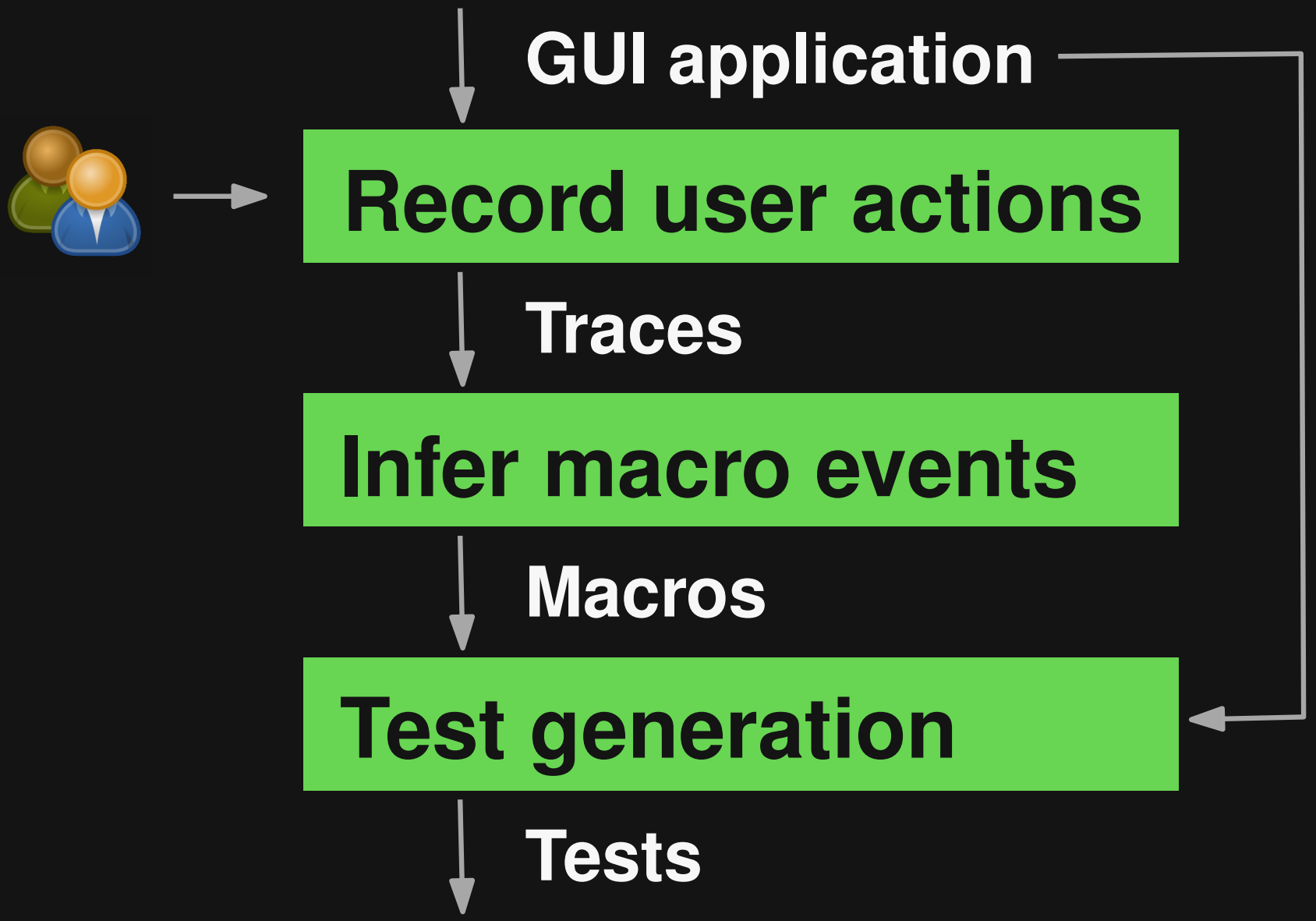
- Type, target

Macro event (logical)

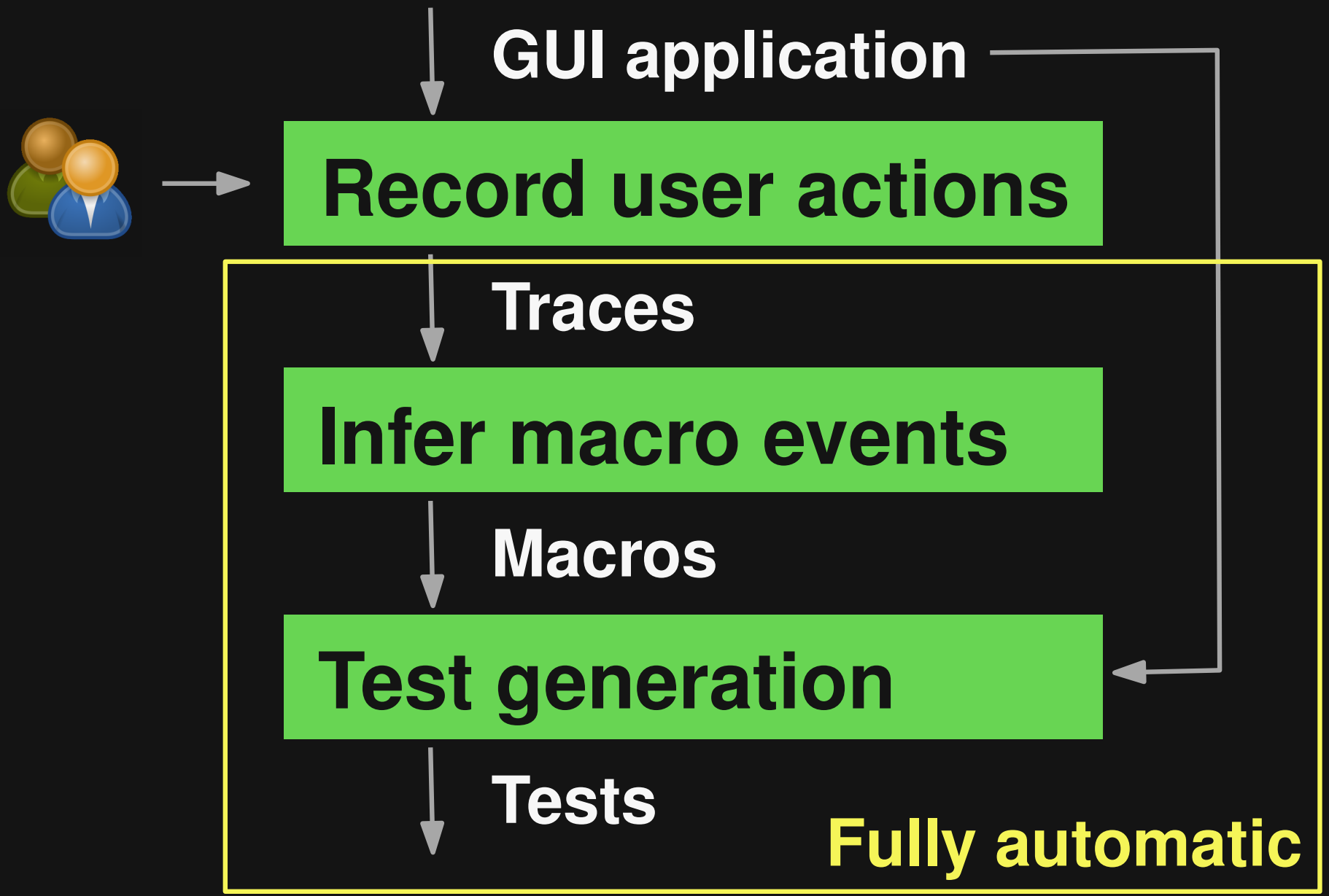
- Finite state machine
- Transitions = abstracted events



Overview

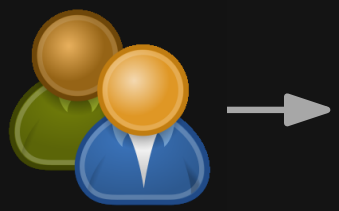

GUI application
Record user actions
Traces
Infer macro events
Macros
Test generation
Tests

Overview


GUI application
Record user actions
Traces
Infer macro events
Macros
Test generation
Tests
Fully automatic

Recording User Actions

Trace: Sequence of events



```
...
over, header
over, item1
click, item1
out, item1
...
```

```
...
over, header
over, item1
out, item1
over, item2
click, item2
out, item2
...
```

etc.

Inference of Macro Events

Inference of Macro Events

Goal: Identify recurring patterns and remove noise

Adapted CloSpan algorithm [Yan et al., 2003]

- **Bounded length of subsequences**
- **Structural relations between events**

Inference of Macro Events

...
over, header
over, item1
click, item1
out, item1
...

...
over, header
over, item1
out, item1
over, item2
click, item2
out, item2
...

Inference of Macro Events

...
over, header
over, item
click, item
out, item
...

...
over, header
over, item
out, item
over, item
click, item
out, item
...

Inference of Macro Events

...
over, header
over, item
click, item
out, item
...

...
over, header
over, item
out, item
over, item
click, item
out, item
...

Inference of Macro Events

Goal: Group related subsequences

Prefix clustering:

- **Same initial event $\rightsquigarrow$ same cluster**

Inference of Macro Events

over, header
over, item
click, item
out, item

over, header
over, item
out, item
over, item
click, item
out, item

Inference of Macro Events

over, header	over, header
over, item	over, item
click, item	out, item
out, item	over, item
	click, item
	out, item

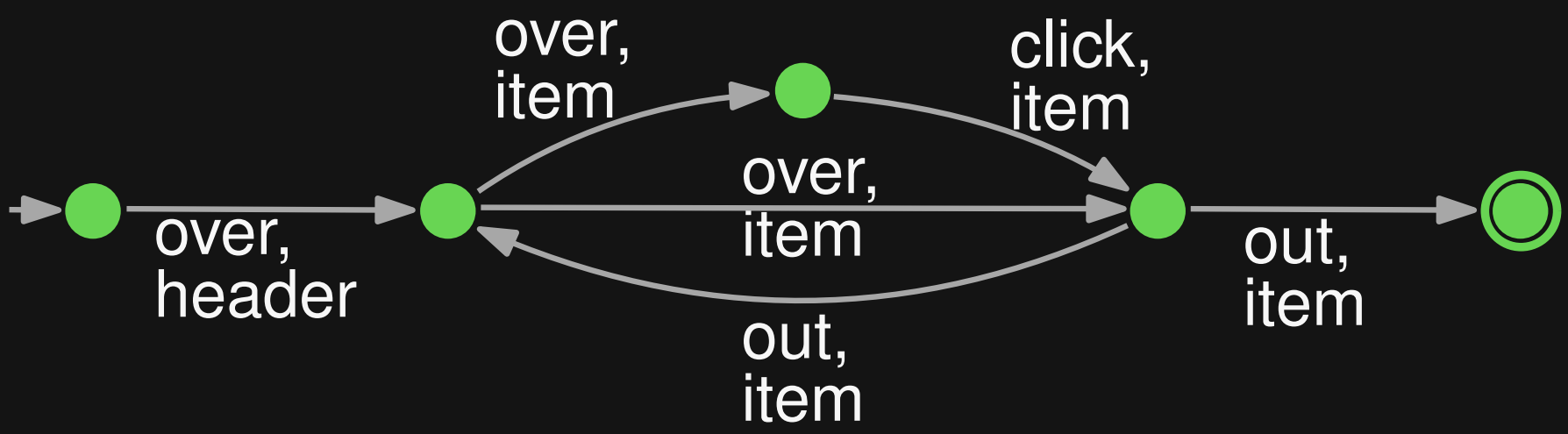
Inference of Macro Events

Goal: Summarize sequences into macros

Adapted k-tails algorithm [Biermann, Feldman, 1972]

- **Optimized state merging**
- **Structural relations between events**

Inference of Macro Events



Test Generation

- Interleave random testing with macro replay
- Pick and replay macros based on available events
- Replay active macro until reaching a final state

More Details in the Paper

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ABSTRACT

Automated testing is an important part of validating the behavior of software with complex graphical user interfaces, such as web, mobile, and desktop applications. Despite recent advances in UI-level test generation, existing approaches often fail to create complex sequences of events that represent realistic user interactions. As a result, these approaches cannot reach particular parts of the application under test, which then remain untested. This paper presents a UI-level test generation approach that exploits execution traces of human users to automatically create complex sequences of events that go beyond the recorded traces. The key idea is to infer so-called macro events, i.e., sequences of low-level UI events that correspond to a single logical step of interaction, such as choosing an item of a drop-down menu or filling and submitting a form. The approach builds upon and adapts well-known data mining techniques, in particular frequent subsequence mining and inference of finite state machines. We implement the approach for client-side web applications and apply it to four real-world applications. Our results

mouse, and filling text into a form. However, the complexity of many GUI applications makes manual UI-level testing difficult. For example, a complex client-side web application may consist of dozens of pages that each provide hundreds of events that a tester may trigger. Because exploring such programs manually is difficult, automated test generation approaches have been proposed [26, 24, 27, 11, 8, 42, 17, 35]. The basic idea is to generate sequences of UI events that achieve high coverage or that trigger a particular kind of problem. Existing approaches include black-box approaches, such as the popular Monkey runner for Android [1], which triggers random UI events, and white-box approaches, which, e.g., symbolically analyze the programs code to find events worth triggering.

Despite recent advances in UI-level test generation, two important challenges remain. First, deeply exploring a program often requires *complex sequences of events*. For example, consider a program that uses a drop-down menu to connect pages to each other. To reach another page, a test generator must move the mouse into the menu, wait until

Implementation

Client-side web applications

Builds on WebAppWalker

- Framework for UI-level testing
- Firefox add-on
- Strategies for selecting events

https://github.com/michaelpradel/WebAppWalker/

Evaluation

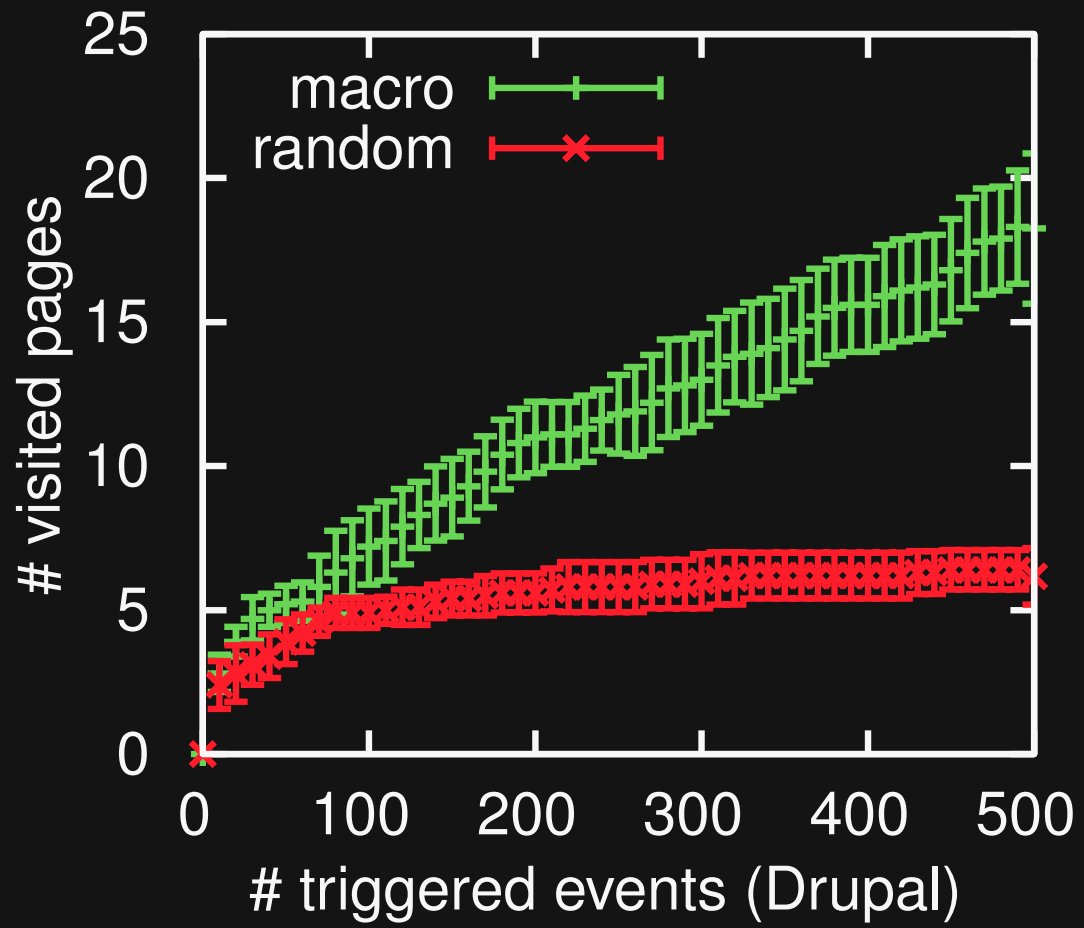
Effectiveness and **efficiency**?

Setup:

- 4 real-world applications
- 16 usage traces
- Comparison with random testing

Visited Pages

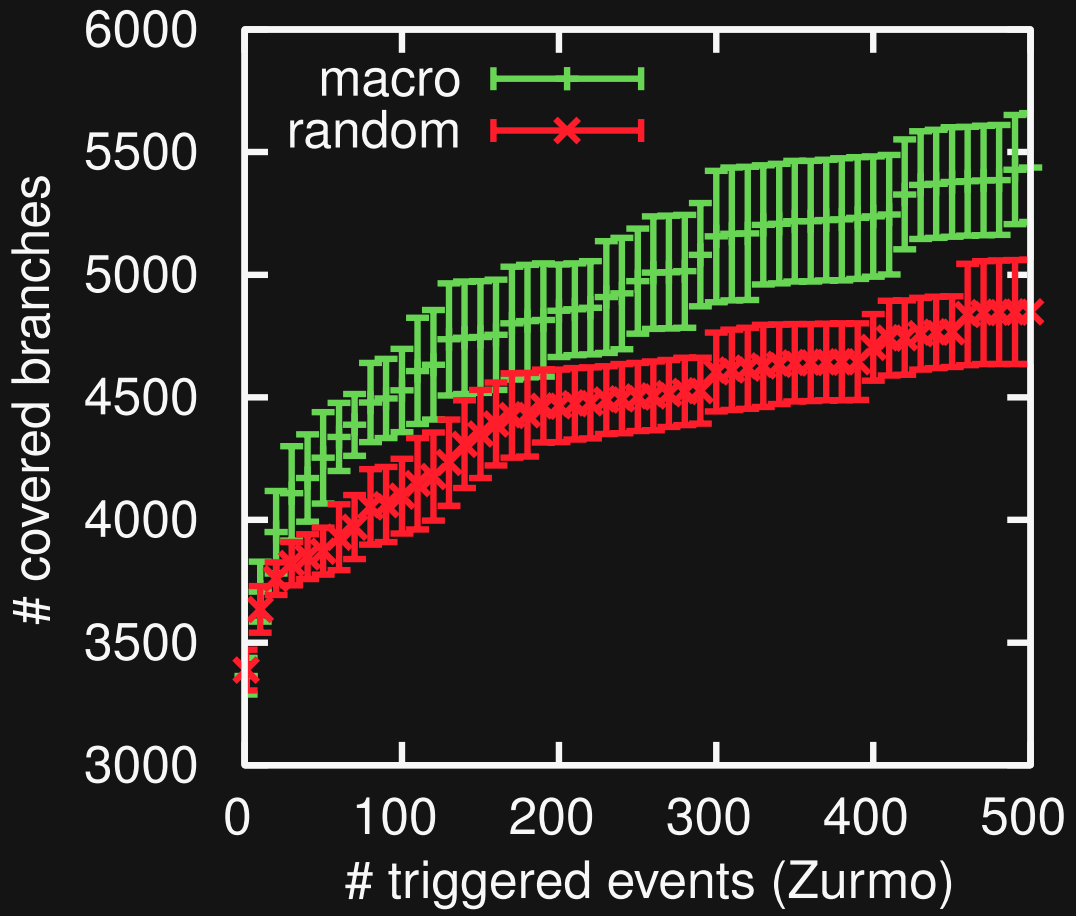
How many pages do the generated tests reach?



Significant improvements for 3/4 applications

Branch Coverage

How many branches do the generated tests cover?



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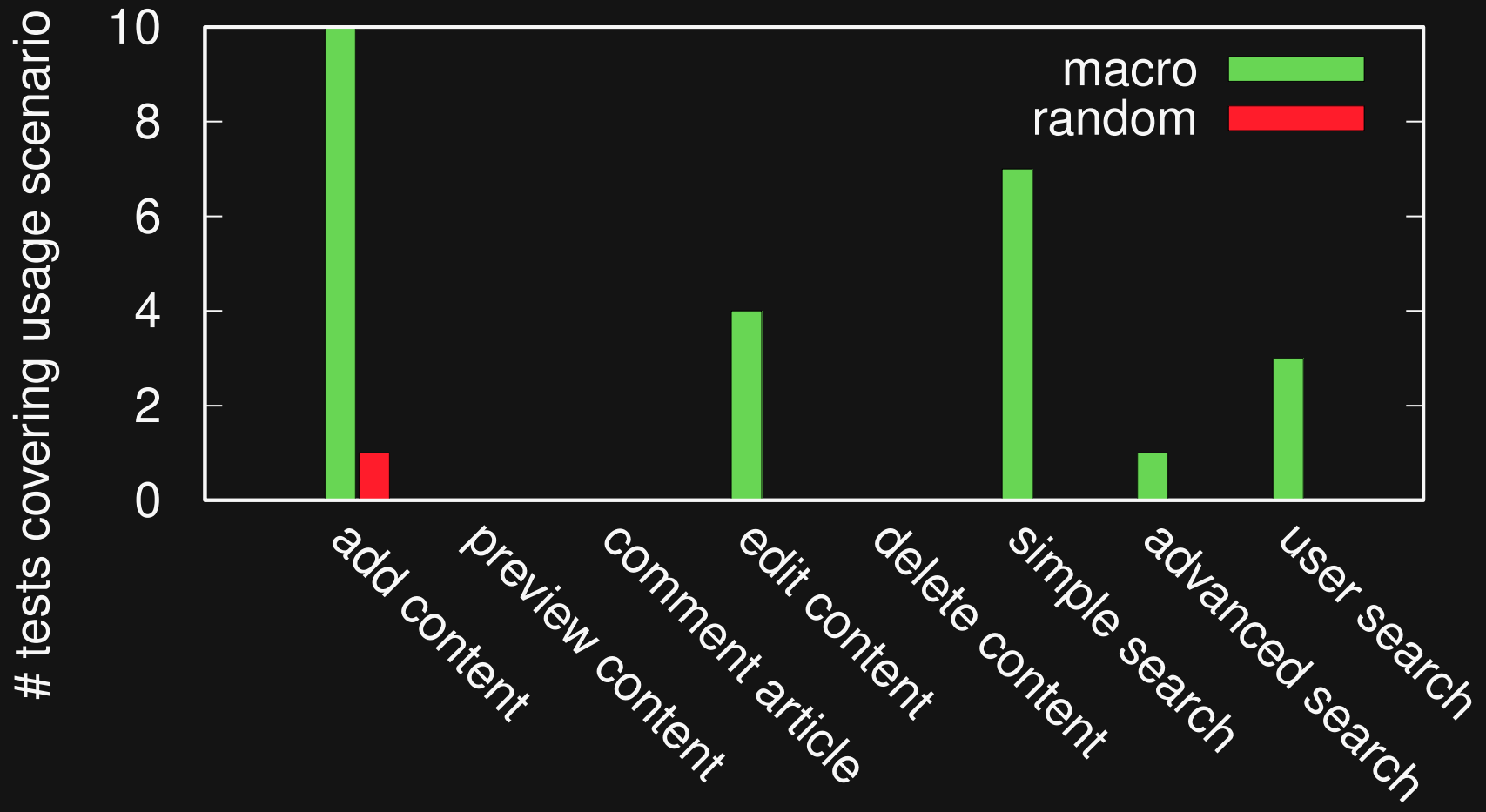
Covered Usage Scenarios

How many usage scenarios do the generated tests cover?



Performance

- Inferring macro events
  - 13 seconds – 85 minutes
  - One-time effort
- Test generation
  - 0.7 – 1.3 seconds per event
  - Only 8% slower than random testing

Future Work

- **Cross-application** macro learning
- Lightweight, **in-production gathering** of traces
- **Scalability** of inference algorithms

Conclusion

- **Macro events:**
  Abstract UI events into logical events
- **Infer and apply macros:**
  More effective GUI testing
- **Human knowledge improves automated testing**

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Thanks!